THE EFFECT OF AIR-GAP / INLET JET WIDTH AND REYNOLDS NUMBER ON INLET DISCHARGE COEFFICIENT FOR CIRCULAR AIR-TURN BARS

By

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Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1998

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 1999

THE EFFECT OF AIR-GAP / INLET JET WIDTH

AND REYNOLDS NUMBER ON INLET

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Thesis Advisor

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Dean of the Graduate College

PREFACE

This study was conducted to provide a preliminary screening of the effect of the flow beneath a rigid stationary web on inlet mass flowrate using the stream function and vorticity approach computed by a FORTRAN program. If there is no web wrapped around a circular air-turn bar, the flow exiting the air-turn bar is similar to the flow through an orifice. The coefficient of discharge will be governed by the coefficient of velocity and coefficient of contraction. The purpose of the study is to determine the effect of air-gap, inlet jet width, and inlet dynamic pressure on the flow between a circular air-turn bar (with air-emitting slots or holes) and the web that causes the inlet mass flowrate to reduce. The test parameters and inlet mass flowrate are normalized to seek the effect of different air-gap/inlet jet width and Reynolds number on inlet discharge coefficient. The effect of viscosity on inlet discharge coefficient is also studied, enable us to determine whether the viscous forces that dominate the airflow in the narrow clearance of the foil-bearing problem applies to the circular air-turn bar. Fundamental knowledge about computational fluid dynamics is sufficient for the reader to understand the theory presented in this paper.

ACKNOWLEDGMENTS

Thanks to God for giving me the strength and wisdom to complete this study.

I wish to express my sincere appreciation to my thesis advisor, Prof. Peter M. Moretti for his intelligent supervision, constructive guidance, inspiration and friendship. My sincere appreciation extends to my other committee members Dr. Young-Bae Chang and Prof. J. Keith Good, whose suggestions, assistance and friendship are also invaluable. I also wish to express my sincere gratitude to the staff of Advanced Technology Research Center Laboratory for their assistance during the study. Moreover, I would like to thank the Web Handling Research Center for providing me with this research opportunity and financial support.

I wish to give my special appreciation to my parents for their precious love, support, and strong encouragement at times of difficulty.

Finally, I would like to thank the faculty and staff of the Department of Mechanical and Aerospace Engineering for their excellent teachings and assistance during my study at Oklahoma State University.

Chee Loon Ng

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ACTUAL FLOW

[P_{dyn} = 5.0 in. of water, b = 4 mm, time step = 1×10^{-6} s]

9. Horizontal Velocity Component for Air-gap, h = 0.20 mm ... 102

10. Horizontal Velocity Component for Air-gap, h = 0.25 mm ... 102

11. Horizontal Velocity Component for Air-gap, h = 0.30 mm ... 102

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21. Horizontal Velocity Component for Air-gap, h = 0.80 mm 104

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23. Horizontal Velocity Component for Air-gap, h = 0.90 mm 105

24. Horizontal Velocity Component for Air-gap, h = 0.95 mm 105

25. Horizontal Velocity Component for Air-gap, h = 1.00 mm 105

26. Horizontal Velocity Component for Air-gap, h = 1.05 mm 105

27. Horizontal Velocity Component for Air-gap, h = 1.10 mm 105

28. Horizontal Velocity Component for Air-gap, h = 1.15 mm 106

29. Horizontal Velocity Component for Air-gap, h = 1.20 mm 106

30. Horizontal Velocity Component for Air-gap, h = 1.25 mm 106

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35. Horizontal Velocity Component for Air-gap, h = 1.50 mm 107

36. Horizontal Velocity Component for Air-gap, h = 1.55 mm 107

37. Horizontal Velocity Component for Air-gap, h = 1.60 mm 107

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39. Horizontal Velocity Component for Air-gap, h = 1.70 mm 108

40. Horizontal Velocity Component for Air-gap, h = 1.75 mm 108

41. Horizontal Velocity Component for Air-gap, h = 1.80 mm 108

42. Horizontal Velocity Component for Air-gap, h = 1.85 mm 108

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45. Horizontal Velocity Component for Air-gap, h = 2.00 mm 109

46. Horizontal Velocity Component for Air-gap, h = 2.10 mm 109

47. Horizontal Velocity Component for Air-gap, h = 2.20 mm 109

48. Horizontal Velocity Component for Air-gap, h = 2.30 mm 110

49. Horizontal Velocity Component for Air-gap, h = 2.40 mm 110

50. Horizontal Velocity Component for Air-gap, h = 2.50 mm 110

51. Horizontal Velocity Component for Air-gap, h = 2.60 mm 110

52. Horizontal Velocity Component for Air-gap, h = 2.70 mm 110

53. Horizontal Velocity Component for Air-gap, h = 2.80 mm 111

54. Horizontal Velocity Component for Air-gap, h = 2.90 mm 111

55. Horizontal Velocity Component for Air-gap, h = 3.00 mm 111

56. Horizontal Velocity Component for Air-gap, h = 3.10 mm 111

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ACTUAL FLOW

[P_{dyn} = 1.0 in. of water, b = 4 mm, time step = 1×10^{-5} s]

58. Horizontal Velocity Component for Air-gap, h = 0.20 mm 112

59. Horizontal Velocity Component for Air-gap, h = 0.40 mm 112

60. Horizontal Velocity Component for Air-gap, h = 0.60 mm 112

61. Horizontal Velocity Component for Air-gap, h = 0.80 mm 112

62. Horizontal Velocity Component for Air-gap, h = 1.00 mm 113

63. Horizontal Velocity Component for Air-gap, h = 1.20 mm 113

64. Horizontal Velocity Component for Air-gap, h = 1.40 mm 113

65. Horizontal Velocity Component for Air-gap, h = 1.60 mm 113

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68. Horizontal Velocity Component for Air-gap, h = 2.20 mm 114

69. Horizontal Velocity Component for Air-gap, h = 2.40 mm 114

70. Horizontal Velocity Component for Air-gap, h = 2.60 mm 114

71. Horizontal Velocity Component for Air-gap, h = 2.80 mm 114

72. Horizontal Velocity Component for Air-gap, h = 3.00 mm 115

73. Horizontal Velocity Component for Air-gap, h = 3.20 mm 115

74. Horizontal Velocity Component for Air-gap, h = 3.40 mm 115

75. Horizontal Velocity Component for Air-gap, h = 3.60 mm 115

ACTUAL FLOW

[P_{dyn} = 0.1 in. of water, b = 4 mm, time step = 1×10^{-5} s]

76. Horizontal Velocity Component for Air-gap, h = 0.20 mm 116

77. Horizontal Velocity Component for Air-gap, h = 0.40 mm 116

78. Horizontal Velocity Component for Air-gap, h = 0.60 mm 116

79. Horizontal Velocity Component for Air-gap, h = 0.80 mm 116

80. Horizontal Velocity Component for Air-gap, h = 1.00 mm 117

81. Horizontal Velocity Component for Air-gap, h = 1.20 mm 117

82. Horizontal Velocity Component for Air-gap, h = 1.40 mm 117

83. Horizontal Velocity Component for Air-gap, h = 1.60 mm 117

84. Horizontal Velocity Component for Air-gap, h = 1.80 mm 117

85. Horizontal Velocity Component for Air-gap, h = 2.00 mm 118

86. Horizontal Velocity Component for Air-gap, h = 2.20 mm 118

87. Horizontal Velocity Component for Air-gap, h = 2.40 mm 118

88. Horizontal Velocity Component for Air-gap, h = 2.60 mm 118

89. Horizontal Velocity Component for Air-gap, h = 2.80 mm 118

90. Horizontal Velocity Component for Air-gap, h = 3.00 mm 119

91. Horizontal Velocity Component for Air-gap, h = 3.20 mm 119

92. Horizontal Velocity Component for Air-gap, h = 3.40 mm 119

93. Horizontal Velocity Component for Air-gap, h = 3.60 mm 119

ACTUAL FLOW

[P_{dyn} = 0.01 in. of water, b = 4 mm, time step = $1x10^{-5}$ s]

94. Horizontal Velocity Component for Air-gap, h = 0.20 mm 120

95. Horizontal Velocity Component for Air-gap, h = 0.40 mm 120

96. Horizontal Velocity Component for Air-gap, h = 0.60 mm 120

97. Horizontal Velocity Component for Air-gap, h = 0.80 mm 120

98. Horizontal Velocity Component for Air-gap, h = 1.00 mm 121

99. Horizontal Velocity Component for Air-gap, h = 1.20 mm 121

100. Horizontal Velocity Component for Air-gap, h = 1.40 mm 121

101. Horizontal Velocity Component for Air-gap, h = 1.60 mm 121

102. Horizontal Velocity Component for Air-gap, h = 1.80 mm 121

103. Horizontal Velocity Component for Air-gap, h = 2.00 mm 122

104. Horizontal Velocity Component for Air-gap, h = 2.20 mm 122

105. Horizontal Velocity Component for Air-gap, h = 2.40 mm 122

106. Horizontal Velocity Component for Air-gap, h = 2.60 mm 122

107. Horizontal Velocity Component for Air-gap, h = 2.80 mm 122

108. Horizontal Velocity Component for Air-gap, h = 3.00 mm 123

109. Horizontal Velocity Component for Air-gap, h = 3.20 mm 123

110. Horizontal Velocity Component for Air-gap, h = 3.40 mm 123

111. Horizontal Velocity Component for Air-gap, h = 3.60 mm 123

FRICTIONLESS FLOW

[P_{dyn} = 5.0 in. of water, b = 4 mm, time step = 1×10^{-6} s]

112. Horizontal Velocity Component for Air-gap, h = 0.20 mm 124

113. Horizontal Velocity Component for Air-gap, h = 0.25 mm 124

114. Horizontal Velocity Component for Air-gap, h = 0.30 mm 124

115. Horizontal Velocity Component for Air-gap, h = 0.35 mm 124

116. Horizontal Velocity Component for Air-gap, h = 0.40 mm 125

117. Horizontal Velocity Component for Air-gap, h = 0.45 mm 125

118. Horizontal Velocity Component for Air-gap, h = 0.50 mm 125

119. Horizontal Velocity Component for Air-gap, h = 0.55 mm 125

120. Horizontal Velocity Component for Air-gap, h = 0.60 mm 125

121. Horizontal Velocity Component for Air-gap, h = 0.65 mm 126

122. Horizontal Velocity Component for Air-gap, h = 0.70 mm 126

123. Horizontal Velocity Component for Air-gap, h = 0.75 mm 126

124. Horizontal Velocity Component for Air-gap, h = 0.80 mm 126

125. Horizontal Velocity Component for Air-gap, h = 0.85 mm 126

126. Horizontal Velocity Component for Air-gap, h = 0.90 mm 127

127. Horizontal Velocity Component for Air-gap, h = 0.95 mm 127

128. Horizontal Velocity Component for Air-gap, h = 1.00 mm 127

129. Horizontal Velocity Component for Air-gap, h = 1.05 mm 127

130. Horizontal Velocity Component for Air-gap, h = 1.10 mm 127

131. Horizontal Velocity Component for Air-gap, h = 1.15 mm 128

132. Horizontal Velocity Component for Air-gap, h = 1.20 mm 128

133. Horizontal Velocity Component for Air-gap, h = 1.25 mm 128

134. Horizontal Velocity Component for Air-gap, h = 1.30 mm 128

135. Horizontal Velocity Component for Air-gap, h = 1.35 mm 128

136. Horizontal Velocity Component for Air-gap, h = 1.40 mm 129

137. Horizontal Velocity Component for Air-gap, h = 1.45 mm 129

138. Horizontal Velocity Component for Air-gap, h = 1.50 mm 129

139. Horizontal Velocity Component for Air-gap, h = 1.55 mm 129

140. Horizontal Velocity Component for Air-gap, h = 1.60 mm 129

141. Horizontal Velocity Component for Air-gap, h = 1.65 mm 130

142. Horizontal Velocity Component for Air-gap, h = 1.70 mm 130

143. Horizontal Velocity Component for Air-gap, h = 1.75 mm 130

144. Horizontal Velocity Component for Air-gap, h = 1.80 mm 130

145. Horizontal Velocity Component for Air-gap, h = 1.85 mm 130

146. Horizontal Velocity Component for Air-gap, h = 1.90 mm 131

147. Horizontal Velocity Component for Air-gap, h = 1.95 mm 131

148. Horizontal Velocity Component for Air-gap, h = 2.00 mm 131

149. Horizontal Velocity Component for Air-gap, h = 2.10 mm 131

150. Horizontal Velocity Component for Air-gap, h = 2.20 mm 131

151. Horizontal Velocity Component for Air-gap, h = 2.30 mm 132

152. Horizontal Velocity Component for Air-gap, h = 2.40 mm 132

153. Horizontal Velocity Component for Air-gap, h = 2.50 mm 132

154. Horizontal Velocity Component for Air-gap, h = 2.60 mm 132

155. Horizontal Velocity Component for Air-gap, h = 2.70 mm 132

156. Horizontal Velocity Component for Air-gap, h = 2.80 mm 133

157. Horizontal Velocity Component for Air-gap, h = 2.90 mm 133

158. Horizontal Velocity Component for Air-gap, h = 3.00 mm 133

159. Horizontal Velocity Component for Air-gap, h = 3.10 mm 133

160. Horizontal Velocity Component for Air-gap, h = 3.20 mm 133

FRICTIONLESS FLOW

[P_{dyn} = 1.0 in. of water, b = 4 mm, time step = 1×10^{-5} s]

161. Horizontal Velocity Component for Air-gap, h = 0.20 mm 134

162. Horizontal Velocity Component for Air-gap, h = 0.40 mm 134

163. Horizontal Velocity Component for Air-gap, h = 0.60 mm 134

164. Horizontal Velocity Component for Air-gap, h = 0.80 mm 134

165. Horizontal Velocity Component for Air-gap, h = 1.00 mm 135

166. Horizontal Velocity Component for Air-gap, h = 1.20 mm 135

167. Horizontal Velocity Component for Air-gap, h = 1.40 mm 135

168. Horizontal Velocity Component for Air-gap, h = 1.60 mm 135

169. Horizontal Velocity Component for Air-gap, h = 1.80 mm 135

170. Horizontal Velocity Component for Air-gap, h = 2.00 mm 136

171. Horizontal Velocity Component for Air-gap, h = 2.20 mm 136

172. Horizontal Velocity Component for Air-gap, h = 2.40 mm 136

173. Horizontal Velocity Component for Air-gap, h = 2.60 mm 136

174. Horizontal Velocity Component for Air-gap, h = 2.80 mm 136

175. Horizontal Velocity Component for Air-gap, h = 3.00 mm 137

176. Horizontal Velocity Component for Air-gap, h = 3.20 mm 137

177. Horizontal Velocity Component for Air-gap, h = 3.40 mm 137

178. Horizontal Velocity Component for Air-gap, h = 3.60 mm 137

FRICTIONLESS FLOW

[P_{dyn} = 0.1 in. of water, b = 4 mm, time step = 1×10^{-5} s]

179. Horizontal Velocity Component for Air-gap, h = 0.20 mm 138

180. Horizontal Velocity Component for Air-gap, h = 0.40 mm 138

181. Horizontal Velocity Component for Air-gap, h = 0.60 mm 138

182. Horizontal Velocity Component for Air-gap, h = 0.80 mm 138

183. Horizontal Velocity Component for Air-gap, h = 1.00 mm 139

184. Horizontal Velocity Component for Air-gap, h = 1.20 mm 139

185. Horizontal Velocity Component for Air-gap, h = 1.40 mm 139

186. Horizontal Velocity Component for Air-gap, h = 1.60 mm 139

187. Horizontal Velocity Component for Air-gap, h = 1.80 mm 139

188. Horizontal Velocity Component for Air-gap, h = 2.00 mm 140

189. Horizontal Velocity Component for Air-gap, h = 2.20 mm 140

190. Horizontal Velocity Component for Air-gap, h = 2.40 mm 140

191. Horizontal Velocity Component for Air-gap, h = 2.60 mm 140

192. Horizontal Velocity Component for Air-gap, h = 2.80 mm 140

193. Horizontal Velocity Component for Air-gap, h = 3.00 mm 141

194. Horizontal Velocity Component for Air-gap, h = 3.20 mm 141

195. Horizontal Velocity Component for Air-gap, h = 3.40 mm 141

196. Horizontal Velocity Component for Air-gap, h = 3.60 mm 141

FRICTIONLESS FLOW

[P_{dyn} = 0.01 in. of water, b = 4 mm, time step = $1 x 10^{-5}$ s]

197. Horizontal Velocity Component for Air-gap, h = 0.20 mm 142

198. Horizontal Velocity Component for Air-gap, h = 0.40 mm 142

199. Horizontal Velocity Component for Air-gap, h = 0.60 mm 142

200. Horizontal Velocity Component for Air-gap, h = 0.80 mm 142

201. Horizontal Velocity Component for Air-gap, h = 1.00 mm 143

202. Horizontal Velocity Component for Air-gap, h = 1.20 mm 143

203. Horizontal Velocity Component for Air-gap, h = 1.40 mm 143

204. Horizontal Velocity Component for Air-gap, h = 1.60 mm 143

205. Horizontal Velocity Component for Air-gap, h = 1.80 mm 143

206. Horizontal Velocity Component for Air-gap, h = 2.00 mm 144

207. Horizontal Velocity Component for Air-gap, h = 2.20 mm 144

208. Horizontal Velocity Component for Air-gap, h = 2.40 mm 144

209. Horizontal Velocity Component for Air-gap, h = 2.60 mm 144

210. Horizontal Velocity Component for Air-gap, h = 2.80 mm 144

211. Horizontal Velocity Component for Air-gap, h = 3.00 mm 145

212. Horizontal Velocity Component for Air-gap, h = 3.20 mm 145

213. Horizontal Velocity Component for Air-gap, h = 3.40 mm 145

214. Horizontal Velocity Component for Air-gap, h = 3.60 mm 145

ACTUAL FLOW

[P_{dyn} = 5.0 in. of water, d = 4 mm, time step = 1×10^{-6} s]

215. Horizontal Velocity Component for Air-gap, h = 0.20 mm 146

216. Horizontal Velocity Component for Air-gap, h = 0.25 mm 146

217. Horizontal Velocity Component for Air-gap, h = 0.30 mm 146

218. Horizontal Velocity Component for Air-gap, h = 0.35 mm 146

219. Horizontal Velocity Component for Air-gap, h = 0.40 mm 147

220. Horizontal Velocity Component for Air-gap, h = 0.45 mm 147

221. Horizontal Velocity Component for Air-gap, h = 0.50 mm 147

222. Horizontal Velocity Component for Air-gap, h = 0.55 mm 147

223. Horizontal Velocity Component for Air-gap, h = 0.60 mm 147

224. Horizontal Velocity Component for Air-gap, h = 0.65 mm 148

225. Horizontal Velocity Component for Air-gap, h = 0.70 mm 148

226. Horizontal Velocity Component for Air-gap, h = 0.75 mm 148

227. Horizontal Velocity Component for Air-gap, h = 0.80 mm 148

228. Horizontal Velocity Component for Air-gap, h = 0.85 mm 148

229. Horizontal Velocity Component for Air-gap, h = 0.90 mm 149

230. Horizontal Velocity Component for Air-gap, h = 0.95 mm 149

231. Horizontal Velocity Component for Air-gap, h = 1.00 mm 149

232. Horizontal Velocity Component for Air-gap, h = 1.05 mm 149

233. Horizontal Velocity Component for Air-gap, h = 1.10 mm 149

234. Horizontal Velocity Component for Air-gap, h = 1.15 mm 150

235. Horizontal Velocity Component for Air-gap, h = 1.20 mm 150

236. Horizontal Velocity Component for Air-gap, h = 1.25 mm 150

237. Horizontal Velocity Component for Air-gap, h = 1.30 mm 150

238. Horizontal Velocity Component for Air-gap, h = 1.35 mm 150

239. Horizontal Velocity Component for Air-gap, h = 1.40 mm 151

240. Horizontal Velocity Component for Air-gap, h = 1.45 mm 151

241. Horizontal Velocity Component for Air-gap, h = 1.50 mm 151

242. Horizontal Velocity Component for Air-gap, h = 1.55 mm 151

243. Horizontal Velocity Component for Air-gap, h = 1.60 mm 151

244. Horizontal Velocity Component for Air-gap, h = 1.65 mm 152

245. Horizontal Velocity Component for Air-gap, h = 1.70 mm 152

246. Horizontal Velocity Component for Air-gap, h = 1.75 mm 152

247. Horizontal Velocity Component for Air-gap, h = 1.80 mm 152

248. Horizontal Velocity Component for Air-gap, h = 1.85 mm 152

249. Horizontal Velocity Component for Air-gap, h = 1.90 mm 153

250. Horizontal Velocity Component for Air-gap, h = 1.95 mm 153

251. Horizontal Velocity Component for Air-gap, h = 2.00 mm 153

ACTUAL FLOW

[$P_{dyn} = 1.0$ in. of water, d = 4 mm, time step = 1×10^{-5} s]

252. Horizontal Velocity Component for Air-gap, h = 0.20 mm 154

253. Horizontal Velocity Component for Air-gap, h = 0.30 mm 154

254. Horizontal Velocity Component for Air-gap, h = 0.40 mm 154

255. Horizontal Velocity Component for Air-gap, h = 0.50 mm 154

256. Horizontal Velocity Component for Air-gap, h = 0.60 mm 155

257. Horizontal Velocity Component for Air-gap, h = 0.70 mm 155

258. Horizontal Velocity Component for Air-gap, h = 0.80 mm 155

259. Horizontal Velocity Component for Air-gap, h = 0.90 mm 155

260. Horizontal Velocity Component for Air-gap, h = 1.00 mm 155

261. Horizontal Velocity Component for Air-gap, h = 1.10 mm 156

262. Horizontal Velocity Component for Air-gap, h = 1.20 mm 156

263. Horizontal Velocity Component for Air-gap, h = 1.30 mm 156

264. Horizontal Velocity Component for Air-gap, h = 1.40 mm 156

265. Horizontal Velocity Component for Air-gap, h = 1.50 mm 156

266. Horizontal Velocity Component for Air-gap, h = 1.60 mm 157

267. Horizontal Velocity Component for Air-gap, h = 1.70 mm 157

268. Horizontal Velocity Component for Air-gap, h = 1.80 mm 157

269. Horizontal Velocity Component for Air-gap, h = 1.90 mm 157

270. Horizontal Velocity Component for Air-gap, h = 2.00 mm 157

ACTUAL FLOW

[P_{dyn} = 0.1 in. of water, d = 4 mm, time step = 1×10^{-5} s]

271. Horizontal Velocity Component for Air-gap, h = 0.20 mm 158

272. Horizontal Velocity Component for Air-gap, h = 0.30 mm 158

273. Horizontal Velocity Component for Air-gap, h = 0.40 mm 158

274. Horizontal Velocity Component for Air-gap, h = 0.50 mm 158

275. Horizontal Velocity Component for Air-gap, h = 0.60 mm 159

276. Horizontal Velocity Component for Air-gap, h = 0.70 mm 159

277. Horizontal Velocity Component for Air-gap, h = 0.80 mm 159

278. Horizontal Velocity Component for Air-gap, h = 0.90 mm 159

279. Horizontal Velocity Component for Air-gap, h = 1.00 mm 159

280. Horizontal Velocity Component for Air-gap, h = 1.10 mm 160

281. Horizontal Velocity Component for Air-gap, h = 1.20 mm 160

282. Horizontal Velocity Component for Air-gap, h = 1.30 mm 160

283. Horizontal Velocity Component for Air-gap, h = 1.40 mm 160

284. Horizontal Velocity Component for Air-gap, h = 1.50 mm 160

285. Horizontal Velocity Component for Air-gap, h = 1.60 mm 161

286. Horizontal Velocity Component for Air-gap, h = 1.70 mm 161

287. Horizontal Velocity Component for Air-gap, h = 1.80 mm 161

288. Horizontal Velocity Component for Air-gap, h = 1.90 mm 161

289. Horizontal Velocity Component for Air-gap, h = 2.00 mm 161

ACTUAL FLOW

$[P_{dyn} = 0.01\text{ in. of water}, d = 4\text{ mm}, \text{time step} = 1\times10^{-5}\text{ s}]$

290. Horizontal Velocity Component for Air-gap, h = 0.20 mm 162

291. Horizontal Velocity Component for Air-gap, h = 0.30 mm 162

292. Horizontal Velocity Component for Air-gap, h = 0.40 mm 162

293. Horizontal Velocity Component for Air-gap, h = 0.50 mm 162

294. Horizontal Velocity Component for Air-gap, h = 0.60 mm 163

295. Horizontal Velocity Component for Air-gap, h = 0.70 mm 163

296. Horizontal Velocity Component for Air-gap, h = 0.80 mm 163

297. Horizontal Velocity Component for Air-gap, h = 0.90 mm 163

298. Horizontal Velocity Component for Air-gap, h = 1.00 mm 163

299. Horizontal Velocity Component for Air-gap, h = 1.10 mm 164

300. Horizontal Velocity Component for Air-gap, h = 1.20 mm 164

301. Horizontal Velocity Component for Air-gap, h = 1.30 mm 164

302. Horizontal Velocity Component for Air-gap, h = 1.40 mm 164

303. Horizontal Velocity Component for Air-gap, h = 1.50 mm 164

304. Horizontal Velocity Component for Air-gap, h = 1.60 mm 165

305. Horizontal Velocity Component for Air-gap, h = 1.70 mm 165

306. Horizontal Velocity Component for Air-gap, h = 1.80 mm 165

307. Horizontal Velocity Component for Air-gap, h = 1.90 mm 165

308. Horizontal Velocity Component for Air-gap, h = 2.00 mm 165

FRICTIONLESS FLOW

[P_{dyn} = 5.0 in. of water, d = 4 mm, time step = $1x10^{-6}$ s]

309. Horizontal Velocity Component for Air-gap, h = 0.20 mm 166

310. Horizontal Velocity Component for Air-gap, h = 0.25 mm 166

311. Horizontal Velocity Component for Air-gap, h = 0.30 mm 166

312. Horizontal Velocity Component for Air-gap, h = 0.35 mm 166

313. Horizontal Velocity Component for Air-gap, h = 0.40 mm 167

314. Horizontal Velocity Component for Air-gap, h = 0.45 mm 167

315. Horizontal Velocity Component for Air-gap, h = 0.50 mm 167

316. Horizontal Velocity Component for Air-gap, h = 0.55 mm 167

317. Horizontal Velocity Component for Air-gap, h = 0.60 mm 167

318. Horizontal Velocity Component for Air-gap, h = 0.65 mm 168

319. Horizontal Velocity Component for Air-gap, h = 0.70 mm 168

320. Horizontal Velocity Component for Air-gap, h = 0.75 mm 168

321. Horizontal Velocity Component for Air-gap, h = 0.80 mm 168

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NOMENCLATURE

A	Minimum cross-sectional area
b	Slot width
d	Hole diameter
EROMM	Criteria for termination check of vorticity iteration
ERPSIM	Criteria for termination check of stream function iteration
g	Gravitational acceleration
h	Air-gap
I	Current cell location in x direction
IMAX	Number of vertical grid lines
IMM1	IMAX – 1
IMP1	IMAX + 1
ISTEPM	Maximum iteration for time step
ITMAX	Maximum iteration for stream function
J	Current cell location in y or r direction
JMAX	Number of horizontal grid lines
JMM1	JMAX – 1
JMP1	JMAX + 1
k	Total drop in inlet mass flowrate due to the flow of air between the air-turn bar and the web. In short, inlet discharge coefficient
$k_{Viscous}$	Drop in inlet mass flowrate due to viscosity. In short, coefficient of

friction

m	Mass flowrate
P_{atm}	Atmospheric pressure
$P_{dynamic}$	Dynamic pressure at the minimum area
P_{static}	Static pressure beneath the web
P_{total}	Total pressure inside circular air-turn bar
R	Radius of air-turn bar
Re	Reynolds number. Slot model: $Re = \rho U_{inlet} b/\mu$ Hole model: $Re = \rho U_{inlet} d/\mu$
r	Radial distance
T	Web tension
t	Time
U	Horizontal velocity component
U_{inlet}	Maximum velocity
U(1, J, 0)	Inlet velocity of slot or hole
u	Horizontal velocity component at any (x, y) location
u_{max}	Maximum velocity at any fixed x location
V	Vertical or radial velocity component
W	Vorticity
$y\|_{1\%}$	Width of the jet at any x location between the air-turn bar and the web
z	Inlet velocity or dynamic pressure of slot or hole (in inches of water)
Δt	Time step

μ	Dynamic viscosity of air
ν	Kinematics viscosity of air
ρ	Density of air
ψ	Stream function

Subscripts

E	East (direction) of current cell
(F)	Frictionless flow
inlet	Variable at inlet
N	North (direction) of current cell
p	Current cell
(R)	Actual flow
S	South (direction) of current cell
W	West (direction) of current cell

Superscript

$'$	Theory section: It symbolized the variable at new time step. Otherwise: It symbolized variable per unit depth.

CHAPTER I

INTRODUCTION

1.1 Background

Webs are thin and flexible materials such as papers, and polymer films that are usually manufactured at high speed in continuous strips. Air-turn bars with air-emitting slots or holes are widely used in web manufacturing whenever a change of web direction is desired. One of the most serious problems that occur in air-turn bar is web flutter that can cause webs to break during high-speed operations. Dynamic instabilities such as bumping, bulging, fluttering, and rocking are commonly observed in circular air-turn bar, placing limits on the speed in which web-handling machinery can be operated. To understand the source of the flutter, it is necessary to determine the pressure and flow between the web and the air-turn bar in both transient and steady state. By studying the effect of different test parameters on inlet mass flowrate, engineers can investigate the mechanics of the web flotation and develop design guidelines for preventing web instability problems. For practical purposes, parametric relationships are usually plotted in dimensionless form to extend their application to larger and smaller circular air-turn bars.

1.2 Research Objectives

This thesis focuses on studying the effect of air-gap, inlet jet width, and inlet dynamic pressure on inlet mass flowrate, by investigating the flow of the air under the web. Traditional study of fluid-web interaction has relied on experiments. Recently, computer modeling has become attractive to research engineers due to its capability of studying modifications of a design rapidly, once the model has been validated by comparison with experiments. To serve the purpose of the study, an analytical and computational model is developed to determine the effect of the test parameters on the flow beneath a rigid stationary web. The inlet mass flowrate is calculated from the computational output after the model achieved steady state. The relationship is normalized to obtain the effect of air-gap/inlet jet width and Reynolds number on inlet discharge coefficient for both actual and frictionless flow. Finally, through this relationship, the effect of viscosity on inlet discharge coefficient is studied.

1.3 Analytical Approach and Computational Model

A single slot and a single hole model are developed to study the effect of air-gap, inlet jet width, and inlet dynamic pressure on the flow under a rigid stationary web. The analytical model uses continuity and Navier-Stroke Equations to solve for the velocity components, stream function ψ, and vorticity W between the web and the air-turn bar. The flow is considered as transient viscous incompressible, with no body forces, in 2-D Cartesian coordinates (for single slot model) and cylindrical coordinates (for single hole model). The partial differential equations are solved using a finite-difference method in a FORTRAN program, and the flow is predicted as a function of both time and position. The fluid region is covered with a rectangular mesh of size Δx and Δy (for single slot model) or Δr (for single hole model) having 9 horizontal grid lines and 8 vertical grid lines. The code is programmed so that the size of Δx and Δy or Δr will automatically expand or contract depending on the jet width and the air-gap. Since the jet is symmetric about the x-axis, it is necessary to compute only the upper half region of the jet and "mirror image it" to obtain the data for the lower half region. Figure 1 shows a simple schematic of the finite-difference method. Figure 2 shows the schematic of a typical point in rectangular grid. Figure 3 shows the schematic of the air-emitting slot. Figure 4 shows the schematic of the air-emitting hole.

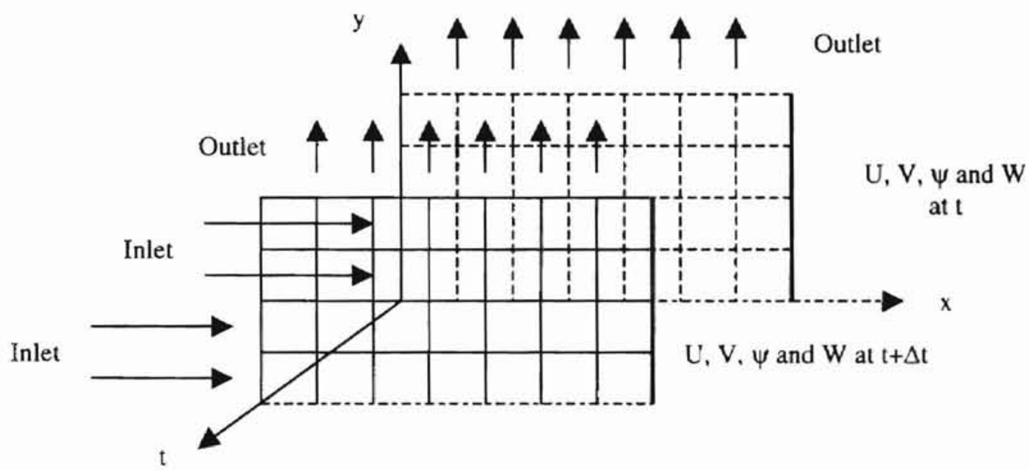


Figure 1. Finite-difference method of the U, V, ψ and W iteration

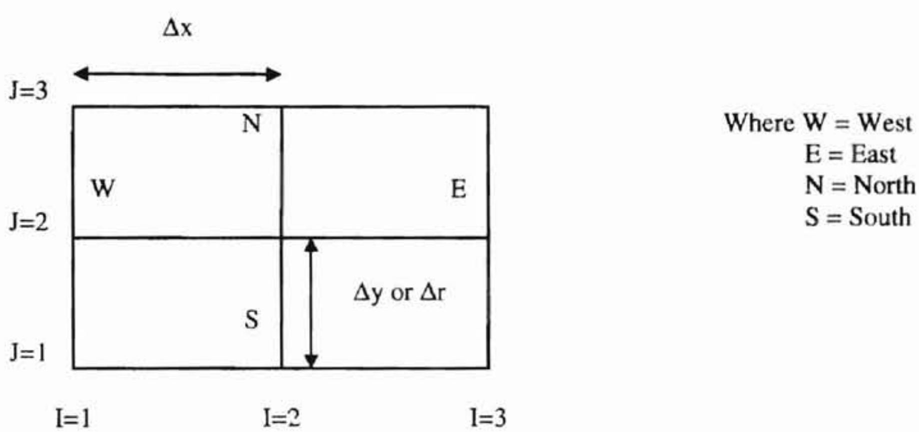


Figure 2. Schematic of a typical point in rectangular grid

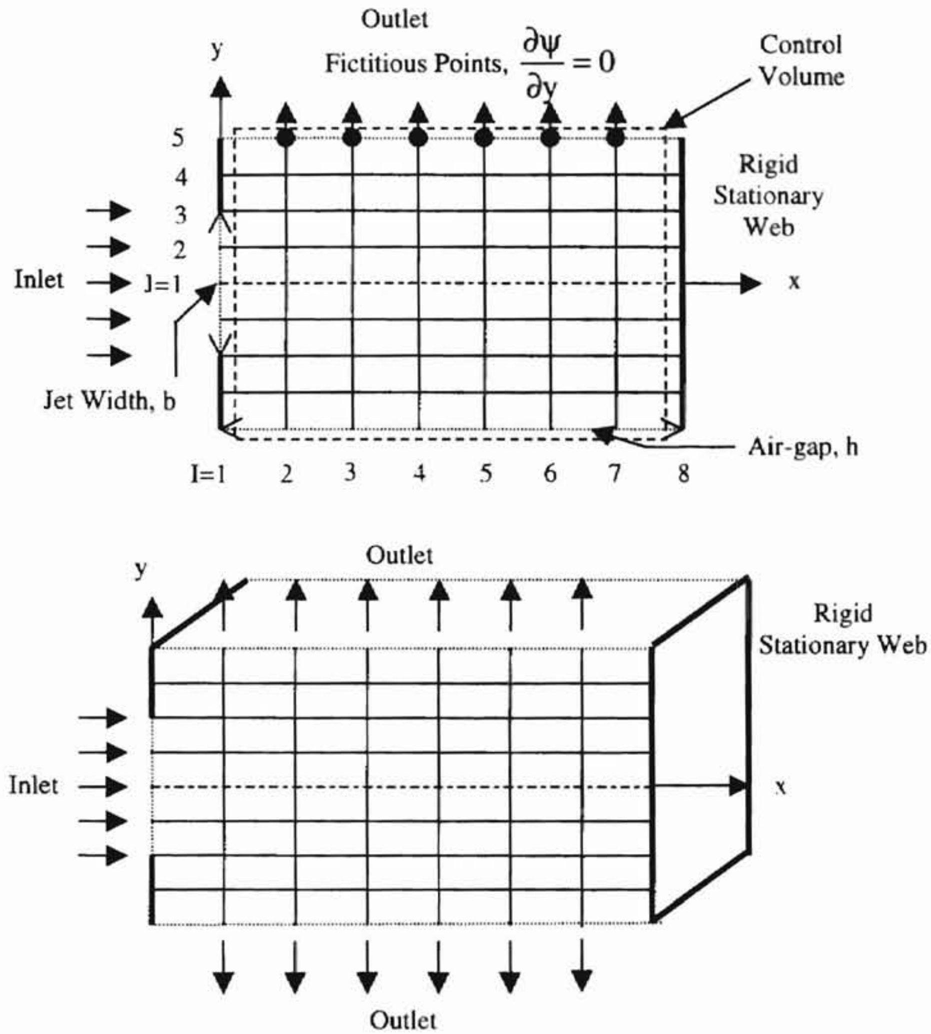
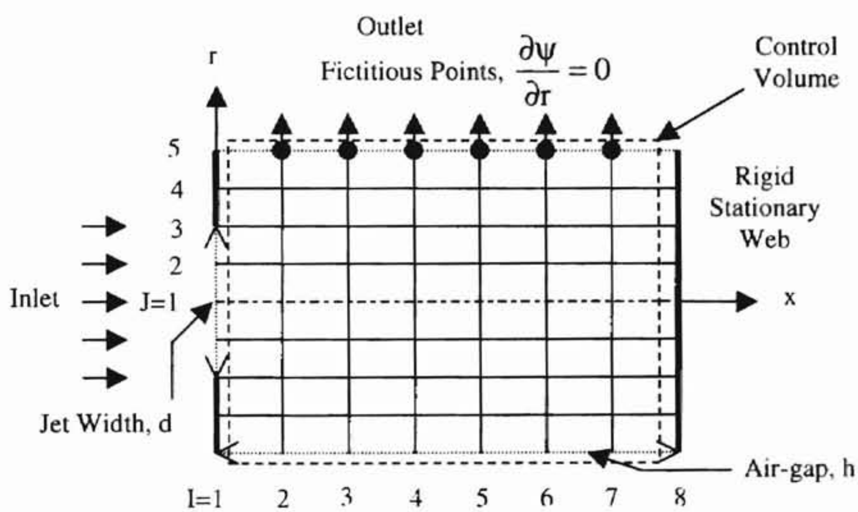


Figure 3. Schematic of the air-emitting slot



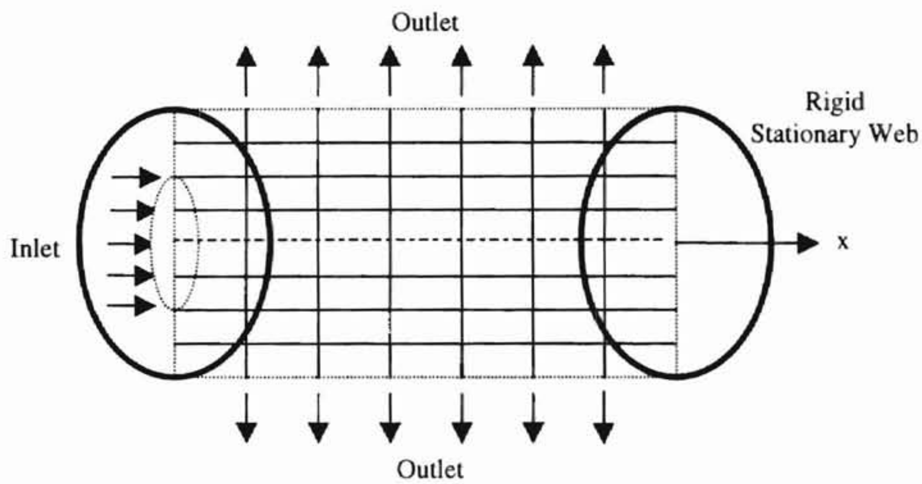


Figure 4. Schematic of the air-emitting hole

1.4 Comparison and Contrast (with FLUENT)

In this thesis, the advantages of using the developed FORTRAN program over FLUENT are:

- A very short computational time is needed to generate the results. Hence, providing the user an efficient way to study the test parameters of many different cases.
- The program does not require the user to do any pre-calculation drawing or setting. The results for different test parameters can be generated by simply entering the desired values.
- Finally, the user has access to intermediate results before the model reaches steady state, providing the user an insight to the transient state of the model.

CHAPTER II

LITERATURE REVIEW

2.1 Segawa (1993)

Segawa analyzed the instability of an elastic plate placed near a rigid wall subjecting to air flows on both sides using traveling-wave theory. It was observed that in the stable region, the critical velocity decreased when the distance between the elastic plate and the rigid wall was reduced.

2.2 Zeelani (1994)

Zeelani performed an experimental study to identify the out-of-plane instability phenomena of a web at circular air-turn bar and determine maps of operating conditions for these instability phenomena. In his study, three types of instability phenomena were observed as shown in figure 5 to figure 7. He also notice that web fluttering increases as spring coefficient increases.

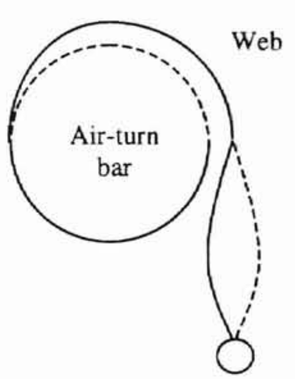


Figure 5. In-phase fluttering

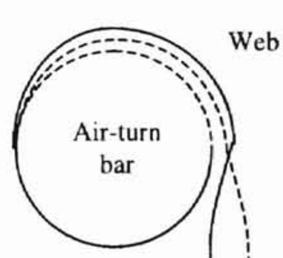


Figure 6. Bumping

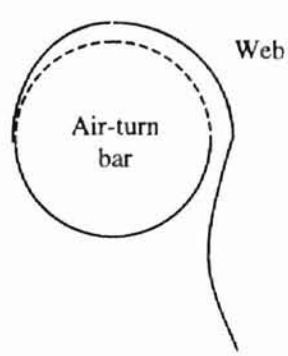


Figure 7. Bulging

2.3 Chen (1996)

Chen investigated the effect of web tension and the length of web on free-span flutter frequency. She observed that the free-span flutter frequency increases as the web tension or the length of web increases. Furthermore, she discovered that the flutter depends strongly on the overwrap angle.

2.4 Zhu (1996)

Zhu focused his study on finding the web buzzing criterion for diverging flow with one radius of curvature and a single type of web material. The buzzing criterion is $2bq/T = 0.23$, where b is jet width, q represents dynamic pressure of the air jet and T denotes web tension. However, the applications of the criterion should be limited to cases with similar test conditions.

2.5 Moretti and Chang (1997)

Moretti and Chang conducted an experimental study to measure the vibration of web supported by air-turn bars for different values of supply pressure of air, web tension and wrap angle. They found that by limiting the required support pressure (T/R), where T represents web tension and R denotes outer radius of the air-turn bar below certain limit, bumping could be avoided. Based on their experiments, bumping instability may not be a problem if the $T/R < 800$ Newton per meter square or 3 inches of water. They also found that high-pitch noise and vibration could be avoided by preventing excessive negative pressure due to the Bernoulli effect near the tangents. This can be done by restricting the flow rate and/or the geometry of the air-turn bar adjusted near the tangents.

Finally, they discovered that if the web tension is nonuniform, the slack edge of the web near the tangents could vibrate at high frequency, resulting in a buzzing sound.

2.6 Chang (1997)

Chang performed a series of experimental study to determine the independent and dependent factors that influence web oscillation. A model representing the slow bumping mode of oscillation was being developed. He found that a nearly constant-pressure air supply leads to a stable (non-bumping) condition. However, a nearly constant mass flow leads to unstable condition.

CHAPTER III

THEORY

3.1 Conceptual and Logical Assumptions

In order to develop an analytical and computational model to study the effect of air-gap, inlet jet width, and inlet dynamic pressure on inlet mass flowrate, the following assumptions are made:

- Transient viscous incompressible (ρ = constant) flow, with no body forces, in 2-D Cartesian coordinates (for slot model) and axisymmetrical ($\partial / \partial\theta = 0$) cylindrical coordinates (for hole model) is assumed.
- Non-swirling (W = 0) flow is assumed in developing the hole model.
- It is assumed that the vertical velocity component of the inlet of the slot (or hole) and the centerline of the jet of air exiting the air-turn bar are zero.
- It is assumed that the horizontal velocity component of the outlets of the jet is zero.
- At steady state, it is assumed that the total pressure inside the circular air-turn bar and the static pressure under the rigid stationary web remained constant.

3.2 The Governing Partial Differential Equations

Presented here are the derivation of partial differential equations that govern the conservation of mass and momentum, in terms of stream function and vorticity variables for developing the FORTRAN program. The conservation of mass and conservation of momentum for 2-D transient incompressible flow (see assumption 1) with constant viscosity and no body forces (leaving out gravity term) in Cartesian (for slot model) and cylindrical (for hole model) coordinates are:

For slot model:

$$\frac{\partial U}{\partial x}+\frac{\partial V}{\partial y}=0 \tag{3.1a}$$

$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+V\frac{\partial U}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu(\frac{\partial^2 U}{\partial x^2}+\frac{\partial^2 U}{\partial y^2}) \tag{3.2a}$$

$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial y}+\nu(\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}) \tag{3.3a}$$

For hole model:

$$\frac{\partial U}{\partial x}+\frac{1}{r}\frac{\partial (rV)}{\partial r}=0 \tag{3.1b}$$

$$\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+V\frac{\partial U}{\partial r}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu[\frac{\partial^2 U}{\partial x^2}+\frac{1}{r}\frac{\partial}{\partial r}(r\frac{\partial U}{\partial r})] \tag{3.2b}$$

$$\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial r}=-\frac{1}{\rho}\frac{\partial p}{\partial r}+\nu\{\frac{\partial^2 V}{\partial x^2}+\frac{\partial}{\partial r}[\frac{1}{r}\frac{\partial}{\partial r}(rV)]\} \tag{3.3b}$$

The two equations relating velocity components U and V to derivatives of ψ are:

For slot model:

$$U=\frac{\partial \psi}{\partial y} \tag{3.4a}$$

$$V=-\frac{\partial \psi}{\partial x} \tag{3.5a}$$

For hole model:

$$U=\frac{1}{r}\frac{\partial \psi}{\partial r} \tag{3.4b}$$

$$V = -\frac{1}{r}\frac{\partial \psi}{\partial x} \tag{3.5b}$$

The equation relating vorticity W to velocity components U and V is:

<u>For slot model:</u>

$$W = \frac{\partial V}{\partial x} - \frac{\partial U}{\partial y} \tag{3.6a}$$

<u>For hole model:</u>

$$W = \frac{\partial V}{\partial x} - \frac{\partial U}{\partial r} \tag{3.6b}$$

Substitution of equations 3.4a (or 3.4b) and 3.5a (or 3.5b) into equation 3.6a (or 3.6b) yields the first equation relating vorticity W to stream function ψ.

<u>For slot model:</u>

$$\boxed{-W = \frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2}} \tag{3.7a}$$

<u>For hole model:</u>

$$\boxed{-rW = \frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial r^2} - \frac{1}{r}\frac{\partial \psi}{\partial r}} \tag{3.7b}$$

The second equation relating vorticity W to stream function ψ can be deduced by cross-differentiating the partial differential equations 3.2a (or 3.2b) and 3.3a (or 3.3b) and subtracted to eliminate p.

<u>For slot model:</u>

Left hand side (L.H.S.) of $\frac{\partial}{\partial x}(3.3a) - \frac{\partial}{\partial y}(3.2a)$ yield

$$\text{L.H.S.} = \frac{\partial}{\partial x}\left(\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y}\right) - \frac{\partial}{\partial y}\left(\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y}\right)$$

$$\text{L.H.S.} = \frac{\partial}{\partial t}\frac{\partial V}{\partial x} + \frac{\partial U}{\partial x}\frac{\partial V}{\partial x} + U\frac{\partial^2 V}{\partial x^2} + \frac{\partial V}{\partial x}\frac{\partial V}{\partial y} + V\frac{\partial^2 V}{\partial x \partial y} -$$
$$\frac{\partial}{\partial t}\frac{\partial U}{\partial y} - \frac{\partial U}{\partial y}\frac{\partial U}{\partial x} - U\frac{\partial^2 U}{\partial x \partial y} - \frac{\partial V}{\partial y}\frac{\partial U}{\partial y} - V\frac{\partial^2 U}{\partial y^2}$$

$$\text{L.H.S.} = \frac{\partial}{\partial t}(\frac{\partial V}{\partial x} - \frac{\partial U}{\partial y}) + \frac{\partial U}{\partial x}\frac{\partial V}{\partial x} + \frac{\partial V}{\partial x}\frac{\partial V}{\partial y} - \frac{\partial U}{\partial y}\frac{\partial U}{\partial x} -$$
$$\frac{\partial V}{\partial y}\frac{\partial U}{\partial y} + U\frac{\partial^2 V}{\partial x^2} - U\frac{\partial^2 U}{\partial x \partial y} + V\frac{\partial^2 V}{\partial x \partial y} - V\frac{\partial^2 U}{\partial y^2}$$

$$\text{L.H.S.} = \frac{\partial}{\partial t}(\frac{\partial V}{\partial x} - \frac{\partial U}{\partial y}) + \frac{\partial V}{\partial x}(\frac{\partial U}{\partial x} + \frac{\partial V}{\partial y}) - \frac{\partial U}{\partial y}(\frac{\partial U}{\partial x} +$$
$$\frac{\partial V}{\partial y}) + U\frac{\partial}{\partial x}(\frac{\partial V}{\partial x} - \frac{\partial U}{\partial y}) + V\frac{\partial}{\partial y}(\frac{\partial V}{\partial x} - \frac{\partial U}{\partial y})$$

Substitute equation 3.1a and equation 3.6a into the above equation yield

$$\text{L.H.S.} = \frac{\partial W}{\partial t} + U\frac{\partial W}{\partial x} + V\frac{\partial W}{\partial y}$$

Multiplying equation 3.1a with vorticity W and add it to the above equation yield

$$\text{L.H.S.} = \frac{\partial W}{\partial t} + U\frac{\partial W}{\partial x} + V\frac{\partial W}{\partial y} + W(\frac{\partial U}{\partial x} + \frac{\partial V}{\partial y})$$

$$\text{L.H.S.} = \frac{\partial W}{\partial t} + \frac{\partial (UW)}{\partial x} + \frac{\partial (VW)}{\partial y}$$

Right hand side (R.H.S.) of $\frac{\partial}{\partial x}(3.3a) - \frac{\partial}{\partial y}(3.2a)$ yield

$$\text{R.H.S.} = \frac{\partial}{\partial x}[-\frac{1}{\rho}\frac{\partial p}{\partial y} + \nu(\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2})] - \frac{\partial}{\partial y}[-\frac{1}{\rho}\frac{\partial p}{\partial x} + \nu(\frac{\partial^2 U}{\partial x^2} + \frac{\partial^2 U}{\partial y^2})]$$

$$\text{R.H.S.} = \nu[(\frac{\partial^2}{\partial x^2}\frac{\partial V}{\partial x} + \frac{\partial}{\partial x}\frac{\partial}{\partial y}\frac{\partial V}{\partial y}) - (\frac{\partial^2}{\partial x^2}\frac{\partial U}{\partial y} + \frac{\partial}{\partial y}\frac{\partial}{\partial y}\frac{\partial U}{\partial y})]$$

$$\text{R.H.S.} = \nu\{\frac{\partial^2}{\partial x^2}(\frac{\partial V}{\partial x} - \frac{\partial U}{\partial y}) + \frac{\partial}{\partial y}[\frac{\partial}{\partial y}(\frac{\partial V}{\partial x} - \frac{\partial U}{\partial y})]\}$$

Substitute equation 3.6a into the above equation yield

$$\text{R.H.S.} = \nu(\frac{\partial^2 W}{\partial x^2} + \frac{\partial^2 W}{\partial y^2})$$

Combining the left hand side and right hand side terms yields

$$\frac{\partial W}{\partial t} + \frac{\partial(UW)}{\partial x} + \frac{\partial(VW)}{\partial y} = \nu(\frac{\partial^2 W}{\partial x^2} + \frac{\partial^2 W}{\partial y^2}) \tag{3.8a}$$

For hole model:

Left hand side (L.H.S.) of $\frac{\partial}{\partial x}(3.3b) - \frac{\partial}{\partial r}(3.2b)$ yield

$$\text{L.H.S.} = \frac{\partial}{\partial x}(\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial r}) - \frac{\partial}{\partial r}(\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial r})$$

$$\text{L.H.S.} = \frac{\partial}{\partial t}\frac{\partial V}{\partial x} + \frac{\partial U}{\partial x}\frac{\partial V}{\partial x} + U\frac{\partial^2 V}{\partial x^2} + \frac{\partial V}{\partial x}\frac{\partial V}{\partial r} + V\frac{\partial^2 V}{\partial x \partial r} - \frac{\partial}{\partial t}\frac{\partial U}{\partial r} - \frac{\partial U}{\partial r}\frac{\partial U}{\partial x} - U\frac{\partial^2 U}{\partial x \partial r} - \frac{\partial V}{\partial r}\frac{\partial U}{\partial r} - V\frac{\partial^2 U}{\partial r^2}$$

$$\text{L.H.S.} = \frac{\partial}{\partial t}(\frac{\partial V}{\partial x} - \frac{\partial U}{\partial r}) + \frac{\partial U}{\partial x}\frac{\partial V}{\partial x} + \frac{\partial V}{\partial x}\frac{\partial V}{\partial r} - \frac{\partial U}{\partial r}\frac{\partial U}{\partial x} - \frac{\partial V}{\partial r}\frac{\partial U}{\partial r} + U\frac{\partial^2 V}{\partial x^2} - U\frac{\partial^2 U}{\partial x \partial r} + V\frac{\partial^2 V}{\partial x \partial r} - V\frac{\partial^2 U}{\partial r^2}$$

$$\text{L.H.S.} = \frac{\partial}{\partial t}(\frac{\partial V}{\partial x} - \frac{\partial U}{\partial r}) + \frac{\partial V}{\partial x}(\frac{\partial U}{\partial x} + \frac{\partial V}{\partial r}) - \frac{\partial U}{\partial r}(\frac{\partial U}{\partial x} + \frac{\partial V}{\partial r}) + U\frac{\partial}{\partial x}(\frac{\partial V}{\partial x} - \frac{\partial U}{\partial r}) + V\frac{\partial}{\partial r}(\frac{\partial V}{\partial x} - \frac{\partial U}{\partial r})$$

From equation 3.1b

$$\frac{\partial U}{\partial x} + \frac{1}{r}\frac{\partial(rV)}{\partial r} = 0 \tag{3.1b}$$

The continuity equation can be rewritten into

$$\frac{\partial U}{\partial x} + \frac{1}{r}(V + r\frac{\partial V}{\partial r}) = 0$$

$$\frac{\partial U}{\partial x}+\frac{\partial V}{\partial r}+\frac{V}{r}=0 \qquad (3.1b')$$

$$\frac{\partial U}{\partial x}+\frac{\partial V}{\partial r}=-\frac{V}{r} \qquad (3.1b'')$$

Substitute equation 3.1b'' and equation 3.6b into the above equation yield

$$L.H.S.=\frac{\partial W}{\partial t}+\frac{\partial V}{\partial x}(-\frac{V}{r})-\frac{\partial U}{\partial r}(-\frac{V}{r})+U\frac{\partial W}{\partial x}+V\frac{\partial W}{\partial r}$$

$$L.H.S.=\frac{\partial W}{\partial t}+U\frac{\partial W}{\partial x}+V\frac{\partial W}{\partial r}-\frac{VW}{r}$$

Multiplying equation 3.1b' with vorticity W and add it to the above equation yield

$$L.H.S.=\frac{\partial W}{\partial t}+U\frac{\partial W}{\partial x}+V\frac{\partial W}{\partial r}-\frac{VW}{r}+W(\frac{\partial U}{\partial x}+\frac{\partial V}{\partial r}+\frac{V}{r})$$

$$L.H.S.=\frac{\partial W}{\partial t}+\frac{\partial (UW)}{\partial x}+\frac{\partial (VW)}{\partial r}$$

Right hand side (R.H.S.) of $\frac{\partial}{\partial x}(3.3b)-\frac{\partial}{\partial r}(3.2b)$ yield

$$R.H.S.=\frac{\partial}{\partial x}\{-\frac{1}{\rho}\frac{\partial p}{\partial r}+\nu[\frac{\partial^2 V}{\partial x^2}+\frac{\partial}{\partial r}(\frac{1}{r}\frac{\partial}{\partial r}rv)]\}-$$
$$\frac{\partial}{\partial r}\{-\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu[\frac{\partial^2 U}{\partial x^2}+\frac{1}{r}\frac{\partial}{\partial r}(r\frac{\partial U}{\partial r})]\}$$

$$R.H.S.=\nu[\frac{\partial^2}{\partial x^2}\frac{\partial V}{\partial x}+\frac{\partial}{\partial r}(\frac{1}{r}\frac{\partial}{\partial r}r\frac{\partial V}{\partial x})-\frac{\partial^2}{\partial x^2}\frac{\partial U}{\partial r}-\frac{\partial}{\partial r}\frac{1}{r}\frac{\partial}{\partial r}(r\frac{\partial U}{\partial r})]$$

$$R.H.S.=\nu[\frac{\partial^2}{\partial x^2}(\frac{\partial V}{\partial x}-\frac{\partial U}{\partial r})+\frac{\partial}{\partial r}\frac{1}{r}\frac{\partial}{\partial r}r(\frac{\partial V}{\partial x}-\frac{\partial U}{\partial r})]$$

Substitute equation 3.6b into the above equation yield

$$R.H.S.=\nu[\frac{\partial^2 W}{\partial x^2}+\frac{\partial}{\partial r}\frac{1}{r}\frac{\partial}{\partial r}(rW)]$$

Combining the left hand side and right hand side yield

$$\frac{\partial W}{\partial t}+\frac{\partial(UW)}{\partial x}+\frac{\partial(VW)}{\partial r}=\nu[\frac{\partial^2 W}{\partial x^2}+\frac{\partial}{\partial r}\frac{1}{r}\frac{\partial}{\partial r}(rW)]$$

$$\frac{\partial W}{\partial t}+\frac{\partial(UW)}{\partial x}+\frac{\partial(VW)}{\partial r}=\nu(\frac{\partial^2 W}{\partial x^2}+\frac{\partial^2 W}{\partial r^2}+\frac{1}{r}\frac{\partial W}{\partial r}-\frac{W}{r^2}) \tag{3.8b}$$

The second equation relating vorticity W to stream function ψ can be obtained by substituting equation 3.4a or 3.4b and 3.5a or 3.5b into equation 3.8a or 3.8b.

For slot model:

$$\boxed{\frac{\partial W}{\partial t}+\frac{\partial\psi}{\partial y}\frac{\partial W}{\partial x}-\frac{\partial\psi}{\partial x}\frac{\partial W}{\partial y}=\nu(\frac{\partial^2 W}{\partial x^2}+\frac{\partial^2 W}{\partial y^2})} \tag{3.9a}$$

For hole model:

$$\boxed{\frac{\partial W}{\partial t}+\frac{1}{r}(\frac{\partial\psi}{\partial r}\frac{\partial W}{\partial x}-\frac{\partial\psi}{\partial x}\frac{\partial W}{\partial r}+\frac{W}{r}\frac{\partial\psi}{\partial x})=\nu(\frac{\partial^2 W}{\partial x^2}+\frac{\partial^2 W}{\partial r^2}+\frac{1}{r}\frac{\partial W}{\partial r}-\frac{W}{r^2})} \tag{3.9b}$$

Having the two partial differential equations at hand, the next step is to determine the finite difference equations from the partial differential equations.

3.3 The Finite Difference Equations

A finite difference solution procedure is used, in which the governing partial differential equations are replaced by a set of algebraic finite difference equations using either centered differences or upwind (also known as forward and backward) differences for the convection terms and centered differences for the diffusion terms. The W-step marching equation at internal points can be obtained from the partial differential equations 3.8a or 3.8b.

For slot model:

$$\frac{\partial W}{\partial t}+\frac{\partial(UW)}{\partial x}+\frac{\partial(VW)}{\partial y}=\nu(\frac{\partial^2 W}{\partial x^2}+\frac{\partial^2 W}{\partial y^2}) \tag{3.8a}$$

For hole model:

$$\frac{\partial W}{\partial t}+\frac{\partial(UW)}{\partial x}+\frac{\partial(VW)}{\partial r}=\nu(\frac{\partial^2 W}{\partial x^2}+\frac{\partial^2 W}{\partial r^2}+\frac{1}{r}\frac{\partial W}{\partial r}-\frac{W}{r^2}) \tag{3.8b}$$

Equation 3.8a or 3.8b can be rearranged to yield

For slot model:

$$\frac{\partial W}{\partial t}=-\frac{\partial(UW)}{\partial x}-\frac{\partial(VW)}{\partial y}+\nu(\frac{\partial^2 W}{\partial x^2}+\frac{\partial^2 W}{\partial y^2})$$

$$\frac{W_p' - W_p}{\Delta t}=a+b+c+d$$

or

$$W_p' = W_p + \Delta t(a+b+c+d) \tag{3.10a}$$

Where $a=-\frac{\partial}{\partial x}(UW)_p$, $b=-\frac{\partial}{\partial y}(VW)_p$ ← Use appropriate approximation

$$\frac{\partial}{\partial x}(UW)\Big|_p = [(UW)_E-(UW)_W]/(2\Delta x) \quad \leftarrow \text{ Centered, } U_p=0$$
$$= [(UW)_p - (UW)_W]/\Delta x \quad \leftarrow \text{ Upwind, } U_p>0$$
$$= [(UW)_E - (UW)_p]/\Delta x \quad \leftarrow \text{ Upwind, } U_p<0$$

The similar equations apply to $\frac{\partial}{\partial y}(VW)\Big|_p$ by replacing U with V, E with N, W with S and Δx with Δy. Note that U and V are calculated from ψ.

$$c=\nu[W_E-2W_p+W_W]/(\Delta x)^2,\ d=\nu[W_N-2W_p+W_S]/(\Delta y)^2$$

For hole model:

$$\frac{\partial W}{\partial t}=-\frac{\partial(UW)}{\partial x}-\frac{\partial(VW)}{\partial r}+\nu(\frac{\partial^2 W}{\partial x^2}+\frac{\partial^2 W}{\partial r^2}+\frac{1}{r}\frac{\partial W}{\partial r}-\frac{W}{r^2})$$

$$\frac{W_p' - W_p}{\Delta t}=a+b+c+d+e+f$$

or

$$\boxed{W_p' = W_p + \Delta t(a+b+c+d+e+f)} \tag{3.10b}$$

Where $a = -\frac{\partial}{\partial x}(UW)_p$, $b = -\frac{\partial}{\partial r}(VW)_p$ ← Use appropriate approximation

$$\frac{\partial}{\partial x}(UW)\Big|_p = [(UW)_E - (UW)_W]/(2\Delta x) \quad \leftarrow \text{ Centered, } U_p = 0$$
$$= [(UW)_p - (UW)_W]/\Delta x \quad \leftarrow \text{ Upwind, } U_p > 0$$
$$= [(UW)_E - (UW)_p]/\Delta x \quad \leftarrow \text{ Upwind, } U_p < 0$$

The similar equations apply to $\frac{\partial}{\partial r}(VW)\Big|_p$ by replacing U with V, E with N, W with S, and Δx with Δr. Note that U and V are calculated from ψ.

$$c = \nu[W_E - 2W_p + W_W]/(\Delta x)^2,\ d = \nu[W_N - 2W_p + W_S]/(\Delta r)^2,$$

$$e = \nu\frac{W_N - W_S}{2r_p\Delta r} \text{ and } f = \frac{W_p}{r_p^{\ 2}}$$

The ψ iteration equation can be obtained from the partial differential equations 3.7a or 3.7b.

<u>For slot model:</u>

$$-W = \frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} \tag{3.7a}$$

$$-W_p' = \frac{\psi_E - 2\psi_p + \psi_W}{(\Delta x)^2} + \frac{\psi_N - 2\psi_p + \psi_W}{(\Delta y)^2}$$

$$\boxed{\psi_p = [\frac{\psi_E}{(\Delta x)^2} + \frac{\psi_W}{(\Delta x)^2} + \frac{\psi_N}{(\Delta y)^2} + \frac{\psi_S}{(\Delta y)^2} + W_p']/[\frac{2}{(\Delta x)^2} + \frac{2}{(\Delta y)^2}]} \tag{3.11a}$$

<u>For hole model:</u>

$$-rW = \frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial r^2} - \frac{1}{r}\frac{\partial\psi}{\partial r} \tag{3.7b}$$

$$-rW_p' = \frac{\psi_E - 2\psi_p + \psi_W}{(\Delta x)^2} + \frac{\psi_N - 2\psi_p + \psi_S}{(\Delta r)^2} - \frac{1}{r}\frac{\psi_N - \psi_S}{2\Delta r}$$

$$\boxed{\begin{aligned}\psi_p = {} & [\frac{\psi_E}{(\Delta x)^2} + \frac{\psi_W}{(\Delta x)^2} + \frac{\psi_N}{(\Delta r)^2} + \frac{\psi_S}{(\Delta r)^2} + \frac{\psi_S - \psi_N}{2r\Delta r} + rW_p']/ \\ & [\frac{2}{(\Delta x)^2} + \frac{2}{(\Delta r)^2}]\end{aligned}} \qquad (3.11b)$$

Having the finite difference equations of vorticity and stream function at hand, the next step is to develop the methodology for solving the finite difference equations using a FORTRAN program.

CHAPTER IV

METHOD

4.1 Introduction

The inlet mass flowrate is a function of density, horizontal inlet velocity and cross-sectional area. The minimum cross-sectional area per unit depth of the slot model is 2h (if $h/b \leq 0.5$) or b (if $h/b \geq 0.5$), and the minimum cross-sectional area of the hole model is πhd (if $h/d \leq 0.25$) or $\pi d^2/4$ (if $h/d \geq 0.25$). If an incompressible and inviscid model is assumed, the mass flowrate depends solely on the minimum cross-sectional area and the maximum velocity.

At steady state, the total pressure inside a circular air-turn bar and the static pressure beneath the web each remained constant (assumption 5 in theory). The dynamic pressure at the minimum area is obtained by subtracting the static pressure from the total pressure:

$$P_{dynamic} = P_{total} - P_{static} \tag{4.12}$$

where $P_{static} = P_{atm} + (T - \mu U_{web}^{2})/R$. Since the total pressure and static pressure are constant, the calculated dynamic pressure is constant. For an incompressible model (assumption 1 in theory), the dynamic pressure at the minimum area is also equal to velocity pressure:

$$P_{dynamic} = P_{velocity} = \frac{1}{2}\rho U_{inlet}^{2} \tag{4.13}$$

which results in a constant maximum velocity (U_{inlet}).

The effect of h/b or h/d on $m_{inlet}/\rho U_{inlet} = \rho U_{inlet} A_{inlet} / \rho U_{inlet} = A_{inlet}$ is shown in Figure 8 and Figure 9; frictionless flows (with free-slip boundary condition) and real flows (with no-slip boundary condition) should be below those curves, and asymptotic to them for very large or very small h/b or h/d.

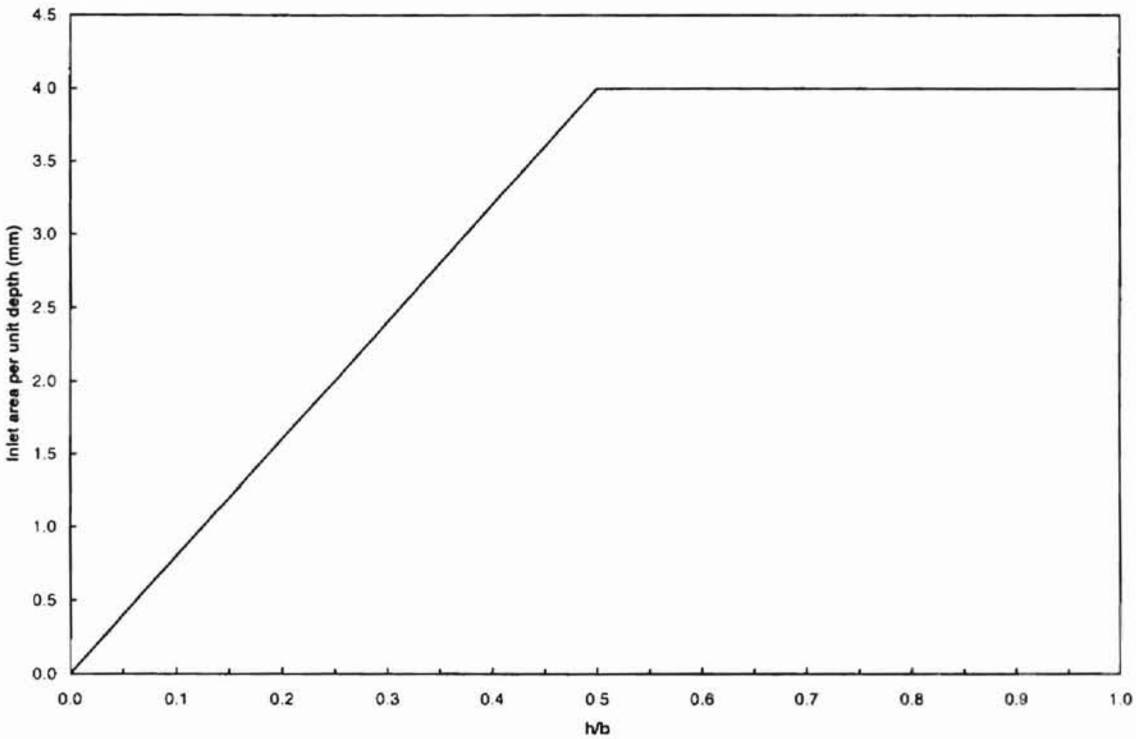


Figure 8. The effect of h/b on inlet area per unit depth (slot model)

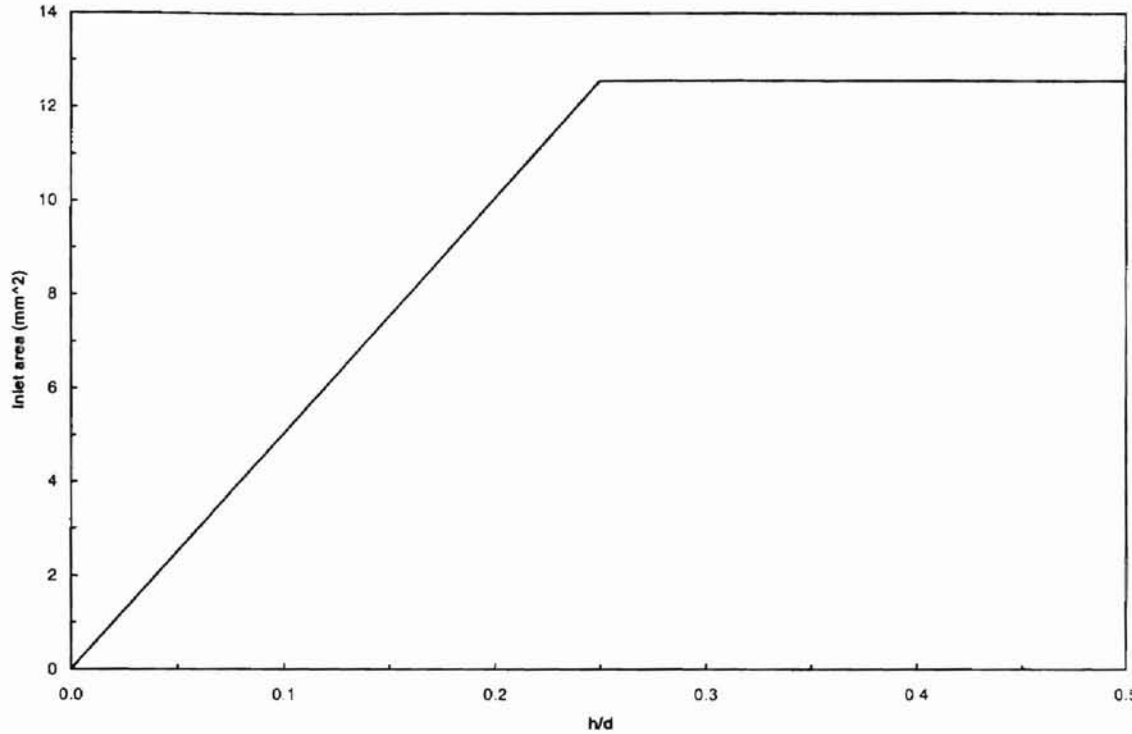


Figure 9. The effect of h/d on inlet area (hole model)

4.2 Programming Methodology

Stream function and vorticity approach is used to seek the effect of the flow between the web and air-turn bar on horizontal inlet velocity. First, the preliminaries and initial boundary conditions are entered. With those values at hand, the vorticity W(x, y or r, t) of the next time step is calculated. Having the calculated vorticity at a certain time step, we can proceed by calculating the stream function $\psi(x, y \text{ or } r, t)$ using the Gauss-Seidel iteration. Finally, the horizontal velocity component U(x, y or r, t) and vertical velocity component V(x, y or r, t) are calculated. The iteration is carried out until the desired time is reached or steady state convergence is achieved. If we assumed that the inlet consists of only horizontal velocity component (assumption 3 in theory), the stream function $\psi(1, 1, t)$ and $\psi(1, 2, t)$ of the final steady state solution are equal to $\psi(2, 1, t)$

and $\psi(2, 2, t)$. This implies that the horizontal inlet velocity U(1, 1, t) of the final steady state solution is equal to U(1, 2, t).

The ψ - W methodology for transient state can be summarized as follow:

- Start: Input preliminaries
- Layout finite difference mesh
- Set initial conditions at t = 0
- Calculate: new $t = t + \Delta t$

  new W at internal points
- Iterate for new ψ at all points using new W at internal points
- Calculate new U and V from ψ
- Calculate new boundary values of W using ψ values at internal points
- Desired time reached or steady state convergence
- Stop: Print output

4.3 Initial Boundary Conditions

At t = 0, the flow is estimated as 1-D ideal parallel flow solution. The initial stream function, vorticity, and velocity component (U and V) are set to zero at internal points except for an initial inlet velocity (U_{inlet}) in m/s. The program will compute the initial inlet velocity from the dynamic (or velocity) pressure input by the user. The horizontal inlet velocity can be determined after the solution converged or achieved steady state. For the actual flow model, the surface of the circular air-turn bar and the rigid stationary web are considered as no-slip boundary. For the frictionless flow model, the kinematic viscosity is set to zero (to eliminate the viscous terms in the governing finite difference equations). In addition, the surface of the air-turn bar and the web are considered as free-slip boundary. The following summarized the initial boundary conditions (at t = 0) between the air-turn bar and the web.

- The horizontal velocity component, U(x, y or r, t):

  $P_{dynamic} = \rho gz(\text{in. of } H_2 0)$; z (in. of water) is entered by user

  $U(1, J, 0) = \sqrt{\frac{2P_{dynamic}}{\rho}}$; J = 1 to 3

  U(I, J, 0) = 0 for everywhere else

- The vertical velocity component, V(x, y or r, t)

  V(I, J, 0) = 0 for everywhere else

- The stream function, ψ(x, y or r ,t)

  At inlet:

  For slot model:

  Since $U(x, r, t) = \frac{\partial \psi}{\partial y}$

  ψ(1, J, 0) = U(1, J, 0)y(J); J = 1 to 3

  For hole model:

  Since $U(x, r, t) = \frac{1}{r}\frac{\partial \psi}{\partial r}$

  $\psi(1, J, 0) = U(1, J, 0)\frac{r(J)^2}{2}$; J = 1 to 3

  At outlet:

  Zero gradient at outlet. Using fictitious point technique (mirror condition)

  ψ(I, JMAX+1, t) = ψ(I, JMAX-1, t); I = 2 to IMM1

At east wall:

$\psi(IMAX, J, 0) = \psi(1, 1, 0)$; J = 1 to JMAX

At west wall:

$\psi(1, J, 0) = \psi(1, 3, 0)$; J = 4 to 5

$\psi(I, J, 0) = 0$ for everywhere else

- The vorticity, W(x, y, t)

At outlet:

Zero gradient at outlet using fictitious point technique (mirror condition)

W(I, JMAX+1, t) = W(I, JMAX-1, t); I = 2 to IMM1

W(I, J, 0) = 0 for everywhere else

CHAPTER V

PROGRAM DESCRIPTION

5.1 Program Outline

The FORTRAN program used in solving U, V, ψ and W between the circular air-turn bar (with air-emitting slot or air-emitting hole) and the rigid stationary web are shown in appendix A. Basically, the programs can be divided into 11 chapters. The tasks carried out in each chapter are described below.

5.1.0 Chapter 0---- Preliminaries

- Set the dimension of the arrays of slot or hole inlet (Y or R), vorticity (OM), stream function (PSI), horizontal velocity component (U) and vertical velocity component (V).
- Set the maximum iteration of stream function (ITMAX) and time step (ISTEPM).
- Print preamble statement.
- Read in vertical grid (IMAX), horizontal grid (JMAX), time step (DELT), initial dynamic pressure of the air-emitting slot or air-emitting hole (PP), air-gap (AG), slot width or hole diameter (SW or HD), kinematic viscosity (NU), density (RHO), stream function (ERPSIM) and vorticity (EROMM) convergence criteria.
- Set IMM1 = IMAX-1, IMP1 = IMAX+1, JMM1 = JMAX-1 and JMP1 = JMAX+1 for easy usage in later chapters.

- Calculate initial inlet velocity of slot or hole.

5.1.1 Chapter 1---- Store Data in File

- Store the output data in a file named SLOTVAR (slot model) or HOLEVAR (hole model).
- Calculate Y(J) (slot model) or R(J) (hole model) to be used in calculating the initial stream function in Chapter 2.

5.1.2 Chapter 2---- Set Inlet Boundary Conditions

- Set the initial boundary conditions at inlet.

5.1.3 Chapter 3---- Set West Wall Boundary Conditions

- Set the initial boundary conditions for west wall.

5.1.4 Chapter 4---- Set East Wall Boundary Condition and Initialization of the Internal Points

- Set the initial boundary conditions for the rigid stationary web and initialize internal points.

5.1.5 Chapter 5---- Begin Time Step

- Begin the time iteration from 1 to 9990 starting from DELT to 9990xDELT with an increment of DELT. However, the computer program will terminate if steady state convergence is achieved.
- Set the initial sum of vorticity error (EROM = 0.0).

5.1.6 Chapter 6---- Calculation of Boundary Values of Vorticity (along East wall and West wall)

- The first DO loop calculate W_p along East wall for J = 1 to JMAX using the expression

<u>For slot model:</u>

$$W_p = \frac{2}{(\Delta x)^2}(\psi_p - \psi_W)$$

<u>For hole model:</u>

$$W_p = \frac{2}{R(J)(\Delta x)^2}(\psi_p - \psi_W)$$

- The second DO loop calculate W_p along West wall for J = 3 to JMAX using the Expression

<u>For slot model:</u>

$$W_p = \frac{2}{(\Delta x)^2}(\psi_p - \psi_E)$$

<u>For hole model:</u>

$$W_p = \frac{2}{R(J)(\Delta x)^2}(\psi_p - \psi_E)$$

5.1.7 Chapter 7---- Set Zero Gradient at North Boundary for ψ, W and V

- The DO loop set zero gradient at North boundary for ψ, W and V using fictitious points techniques.

5.1.8 Chapter 8---- Calculate Vorticity at New Time Step (at internal points and North boundary points)

- In this chapter, IF THEN ELSE statements are used to calculate a, b, c and d (for slot model) and a, b, c, d, e and f (for hole model) from equation 3.10a or 3.10b using either centered differences for the diffusion terms and upwind differences for the convection terms. Having a, b, c and d (for slot model) and a, b, c, d, e and f (for hole model) at hand, W-step marching equation at internal points can be determined.

- The residual of vorticity is calculated at node (I, J) = (3, 3).

5.1.9 Chapter 9---- Begin Iteration for ψ

- The iteration for ψ is calculated from equation 3.11a or 3.11b.
- The residual of ψ is calculated in node (I, J) = (3, 3)
- Termination check for ψ iteration.

5.1.10 Chapter 10---- Calculate U and V

- Using a DO loop, the horizontal velocity component U(I, 1, t) is calculated by using equation 3.4a or 3.4b for I = 2 to IMM1.
- Using a DO loop, the horizontal velocity component U(I, J, t) is calculated from equation 3.4a or 3.4b for I = 2 to IMM1 and J = 2 to JMAX.
- Using a DO loop, the vertical velocity component V(I, J, t) is calculated from equation 3.5a or 3.5b for I = 2 to IMM1 and J = 2 to JMAX.
- ψ(3, 3), W(3, 3), U(3, 3), V(3, 3), PSIRES, OMERES at the nodal point (3, 3) is printed to visualize convergence.
- Carry out intermediate printing of U, V, ψ and W before the desired time is reached or steady state convergence is achieved.

5.1.11 Chapter 11---- Termination Check for Vorticity: Steady State Convergence

- Termination check for vorticity.

- In case of no convergence is achieved at the maximum time step, write a statement and shown the maximum time.
- Printing steady state solution.

CHAPTER VI

RESULTS

6.1 Introduction

Although the solutions for transient state are developed, the major concern of this study is to determine the effect of the flow between the air-turn bar and the web on inlet mass flowrate at steady state. Then, the effect of air-gap/inlet jet width and Reynolds number on inlet discharge coefficient can be determined by normalizing the test parameters and the inlet mass flowrate. The desired task can be achieved by setting the stream function $\psi(1, 1, t)$ and $\psi(1, 2, t)$ of the final steady state solution equal to $\psi(2, 1, t)$ and $\psi(2, 2, t)$ as described in section 4.2. Hence, enable us to set the horizontal inlet velocity $U(1, 1, t)$ equal to $U(2, 1, t)$.

6.2 Computational Results

The sample output solutions of the FORTRAN programs for the slot model and the hole model undergoes actual flow and frictionless flow are shown in appendix B. To reduce the use of paper, only the first intermediate solution and the final steady state solution are printed. A typical convergence solution of one case can take over 100 to 200 pages. Instead, a 3.5" diskette containing a sample solution of one arbitrary case of the slot model and the hole model undergoes actual flow is submitted with this thesis. Notice that the stream function is zero for the output solution of the hole model. This is because only four decimal places are printed. Since we are not interested in plotting the stream function, the truncation has no negative effect on the output results. It is worth while to mention that for certain air-gap, the solution may not achieve steady state at the maximum time step because the vorticity will not converge (see final solution of appendix B.1.3). For those cases, the vorticity is made to converge up to one decimal place so that U and V can be made to converge up to four decimal places. Usually, stream function will converge for all cases.

The converged solutions of the horizontal velocity component of the flow between the air-turn bar and the web are tabulated in Table 9 to Table 402 in appendix D. Notice that the dimensionless test parameters air-gap/inlet jet width can be varied by changing either air-gap or inlet jet width. In this study, air-gap has been arbitrarily varied to perform the desired task.

6.3 Research Findings

Using the fact that U(1, 1, t) is equal to U(1, 2, t), the inlet mass flowrate of the slot model and the hole model of actual flow and frictionless flow for the converged solutions can be determined from Table 9 to Table 402 in appendix D. The effect of h/b on $\dot{m}_{inlet(F)} / \rho U_{inlet} = U_{inlet(F)} A_{inlet}' / U_{inlet}$, $\dot{m}_{inlet(R)} / \rho U_{inlet} = U_{inlet(R)} A_{inlet}' / U_{inlet}$, inlet discharge coefficient (k) and coefficient of friction ($k_{Viscous}$) for different Reynolds numbers are shown in Table 1 to Table 4 in appendix C. The inlet discharge coefficient (k) of the slot model is obtained by dividing $U_{inlet(R)} A_{inlet}' / U_{inlet}$ with A_{inlet}'. The coefficient of friction ($k_{Viscous}$) is obtained by dividing $U_{inlet(R)} A_{inlet}' / U_{inlet(F)}$ by A_{inlet}'.

The effect of h/d on $m_{inlet(F)}/\rho U_{inlet} = U_{inlet(F)} A_{inlet} / U_{inlet}$, $m_{inlet(R)}/\rho U_{inlet} = U_{inlet(R)} A_{inlet} / U_{inlet}$, inlet discharge coefficient (k) and coefficient of friction ($k_{Viscous}$) for different Reynolds numbers are shown in Table 5 to Table 8 in appendix C. The inlet discharge coefficient (k) of the hole model is obtained by dividing $U_{inlet(R)} A_{inlet} / U_{inlet}$ by A_{inlet}. The coefficient of friction ($k_{Viscous}$) is obtained by dividing $U_{inlet(R)} A_{inlet} / U_{inlet(F)}$ by A_{inlet}.

Figure 10 to Figure 13 show the effect of h/b on volumetric flowrate per unit depth/initial horizontal inlet velocity ($U_{inlet(F\,or\,R)} A_{inlet} / U_{inlet}$) for Re = 405, 181, 57 and 18.

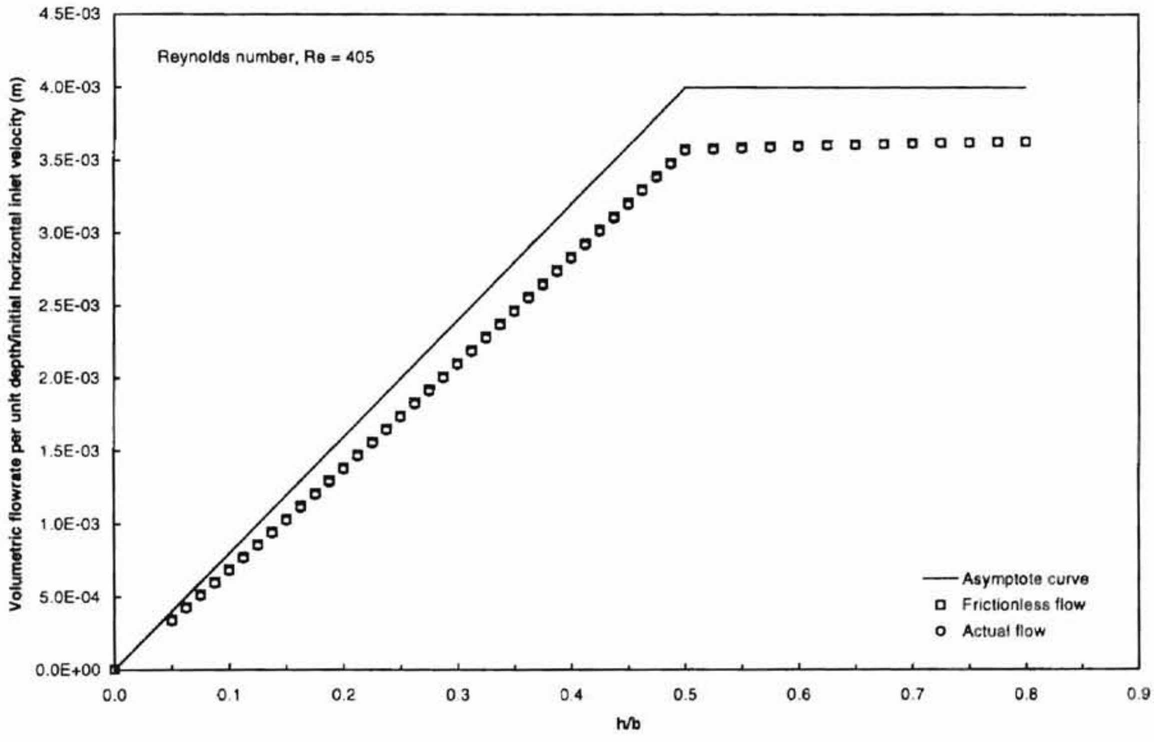


Figure 10. The effect of h/b on volumetric flowrate per unit depth/initial horizontal inlet velocity ($U_{inlet(F\,or\,R)} A_{inlet} / U_{inlet}$) for Re = 405 (slot model)

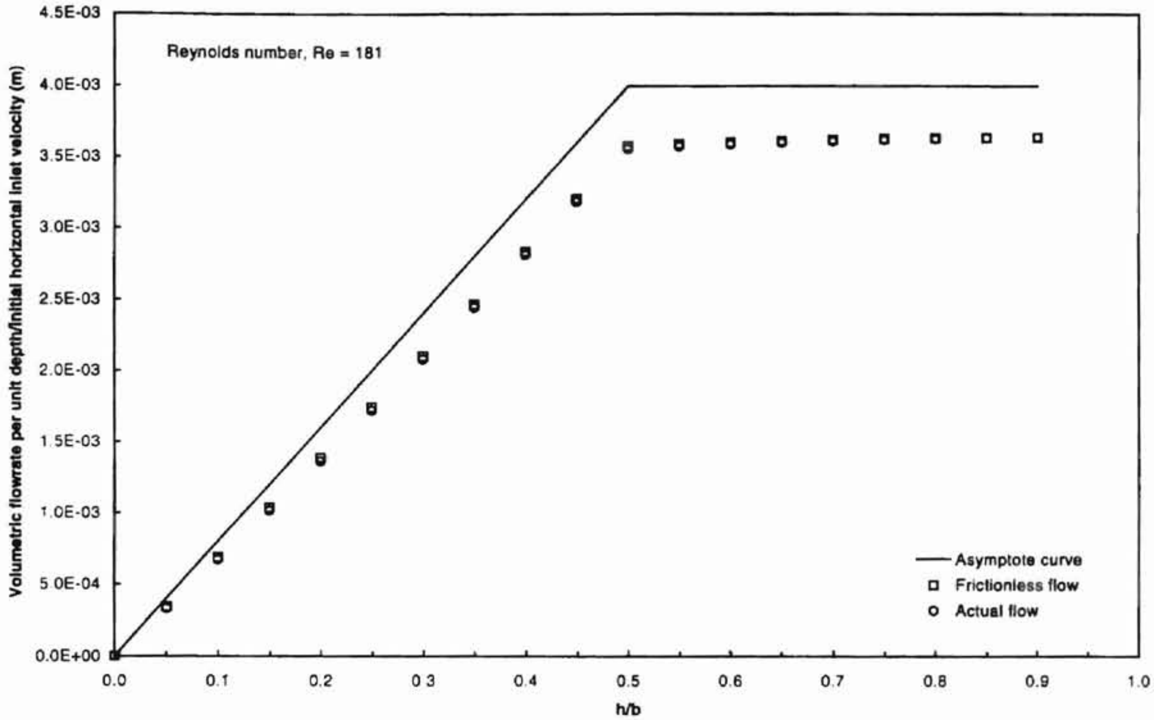


Figure 11. The effect of h/b on volumetric flowrate per unit depth/initial horizontal inlet velocity ($U_{inlet\ (F\ or\ R)}A_{inlet} / U_{inlet}$) for Re = 181 (slot model)

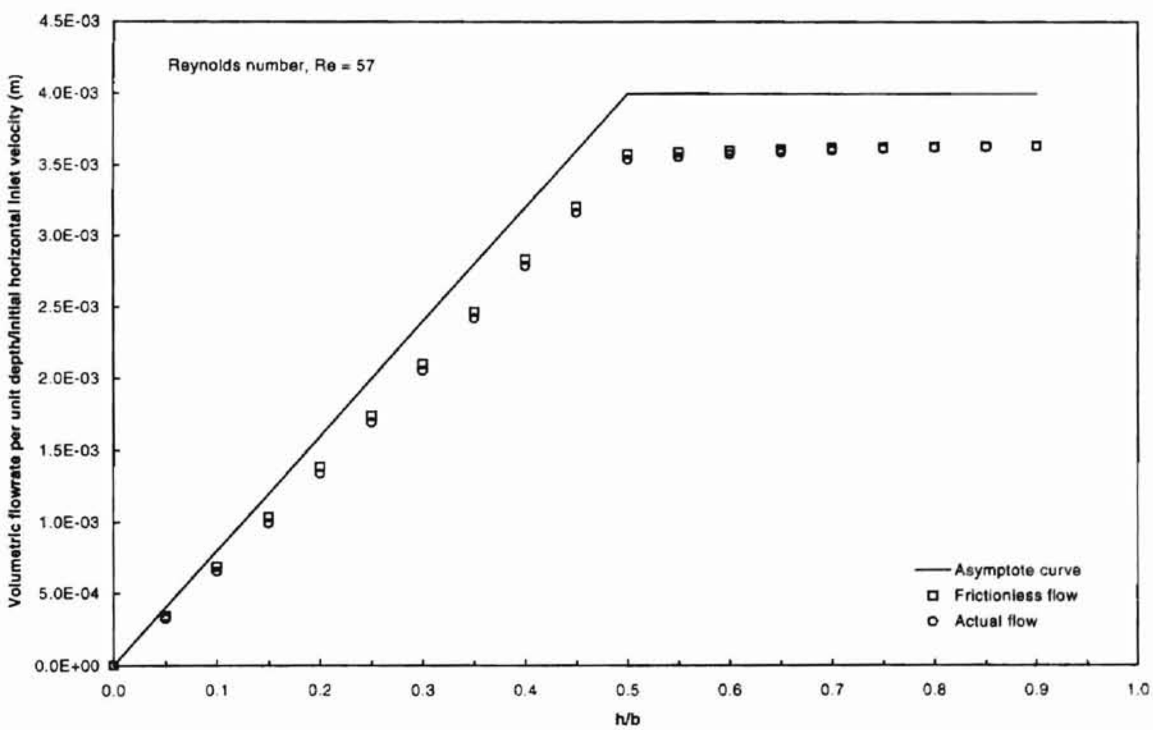


Figure 12. The effect of h/b on volumetric flowrate per unit depth/initial horizontal inlet velocity ($U_{inlet\ (F\ or\ R)}A_{inlet} / U_{inlet}$) for Re = 57 (slot model)

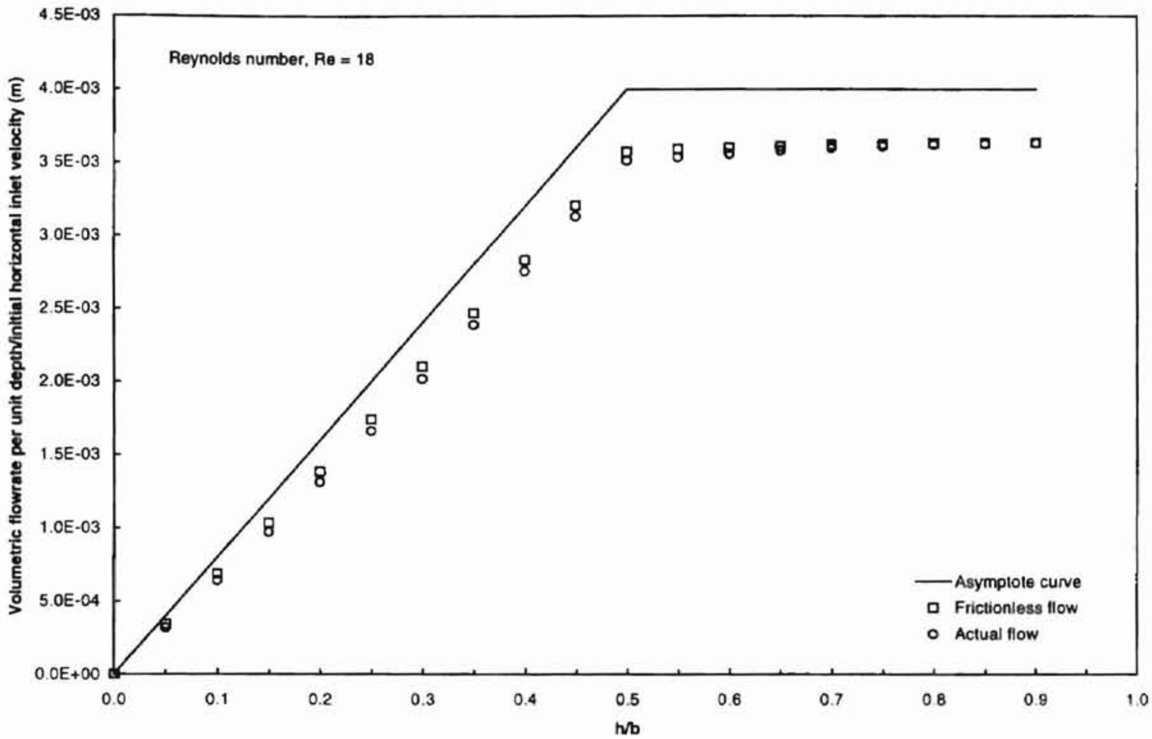


Figure 13. The effect of h/b on volumetric flowrate per unit depth/initial horizontal inlet velocity ($U_{inlet\,(F\,or\,R)}A_{inlet}' / U_{inlet}$) for Re = 18 (slot model)

With reference to Figure 10 to Figure 13, as h/b increases from 0 to 0.5, $U_{inlet\,(F\,or\,R)}A_{inlet}' / U_{inlet}$ of frictionless flow and actual flow diverges from the asymptote curve with an increasing rate. At this portion of the curve, viscosity becomes increasingly significant. After h/b = 0.5, $U_{inlet\,(F\,or\,R)}A_{inlet}' / U_{inlet}$ of frictionless flow and actual flow begins to approach the asymptote curve with a slow increasing rate. Viscosity is not very significant at this portion of the curve. Notice that the effect of viscosity becomes more significant as the Reynolds number decreases.

Figure 14 to Figure 17 show the effect of h/d on volumetric flowrate/initial horizontal inlet velocity ($U_{inlet\,(F\,or\,R)}A_{inlet} / U_{inlet}$) for Reynolds number, Re = 405, 181, 57 and 18.

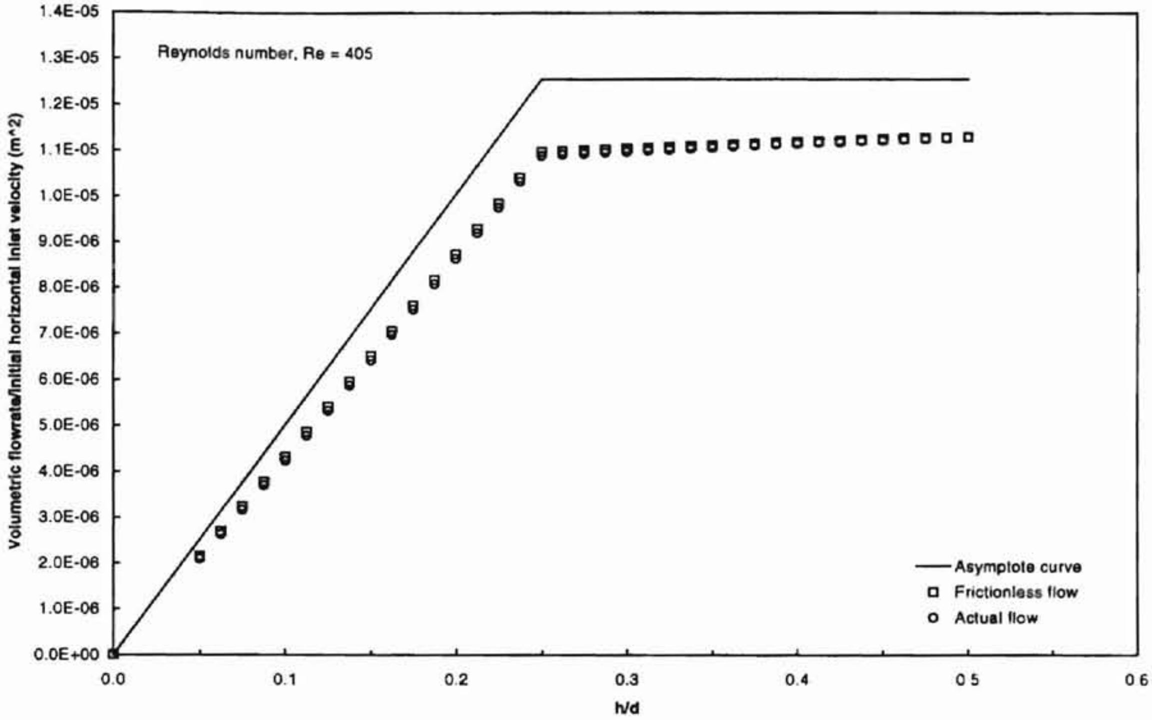


Figure 14. The effect of h/d on volumetric flowrate/initial horizontal inlet velocity ($U_{inlet\,(F\,or\,R)}A_{inlet} / U_{inlet}$) for Re = 405 (hole model)

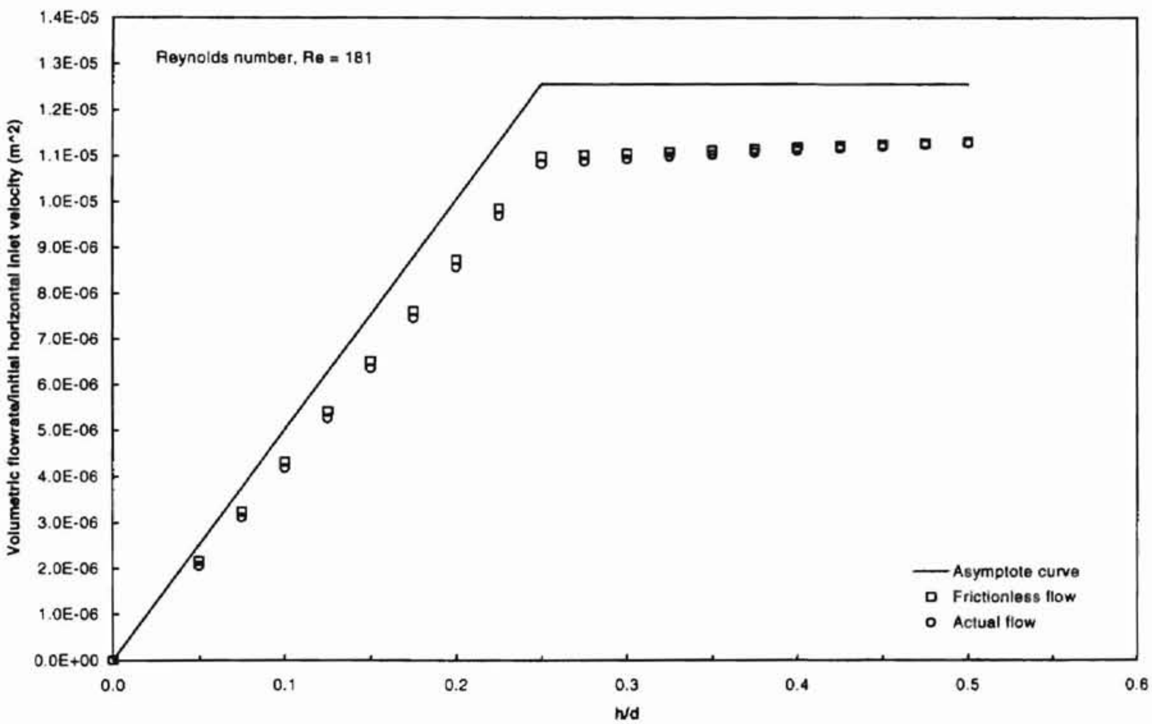


Figure 15. The effect of h/d on volumetric flowrate/initial horizontal inlet velocity ($U_{inlet\,(F\,or\,R)}A_{inlet} / U_{inlet}$) for Re = 181 (hole model)

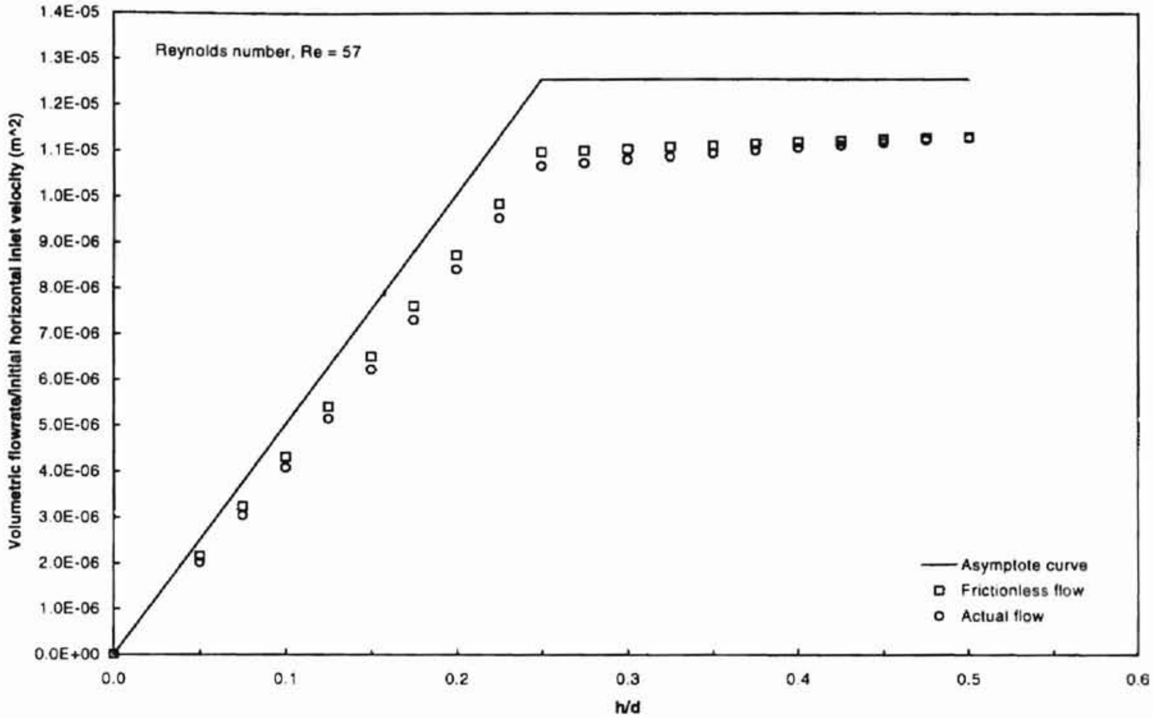


Figure 16. The effect of h/d on volumetric flowrate/initial horizontal inlet velocity ($U_{inlet\ (F\ or\ R)} A_{inlet} / U_{inlet}$) for Re = 57 (hole model)

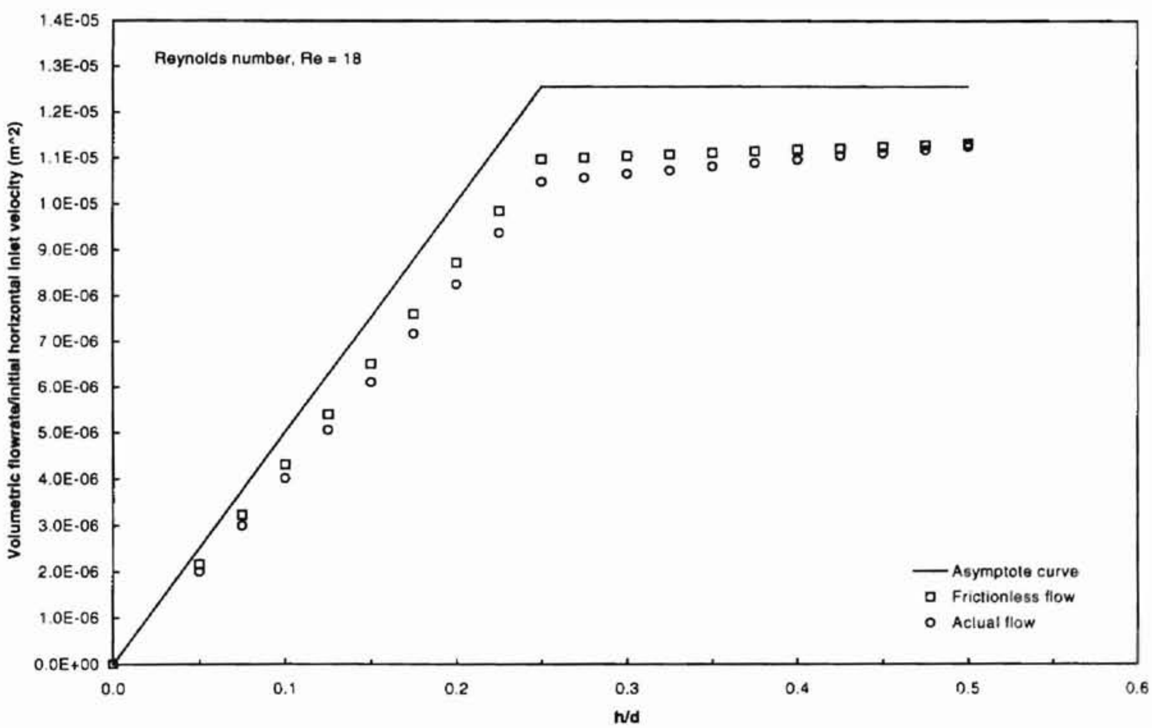


Figure 17. The effect of h/d on volumetric flowrate/initial horizontal inlet velocity ($U_{inlet\ (F\ or\ R)} A_{inlet} / U_{inlet}$) for Re = 18 (hole model)

With reference to Figure 14 to Figure 17, as h/d increases from 0 to 0.25, $U_{inlet\,(F\,or\,R)}A_{inlet}\,/\,U_{inlet}$ of frictionless flow and actual flow diverges from the asymptote curve with an increasing rate. At this portion of the curve, viscosity becomes increasingly significant. After h/d = 0.25, $U_{inlet\,(F\,or\,R)}A_{inlet}\,/\,U_{inlet}$ of frictionless flow and actual flow begins to approach the asymptote curve with a slow increasing rate. Viscosity is not very significant at this portion of the curve. Notice that the effect of viscosity becomes more significant as the Reynolds number decreases.

Figure 18 to Figure 21 show the effect of h/b on inlet discharge coefficient (k) for Reynolds number, Re = 405, 181, 57 and 18. With reference to Figure 18 to Figure 20, as h/b increases, the inlet discharge coefficient increases with a decreasing rate. With reference to Figure 21, when h/b < 0.25, the inlet discharge coefficient increases with an increasing rate. After that, the inlet discharge coefficient increases with a decreasing rate.

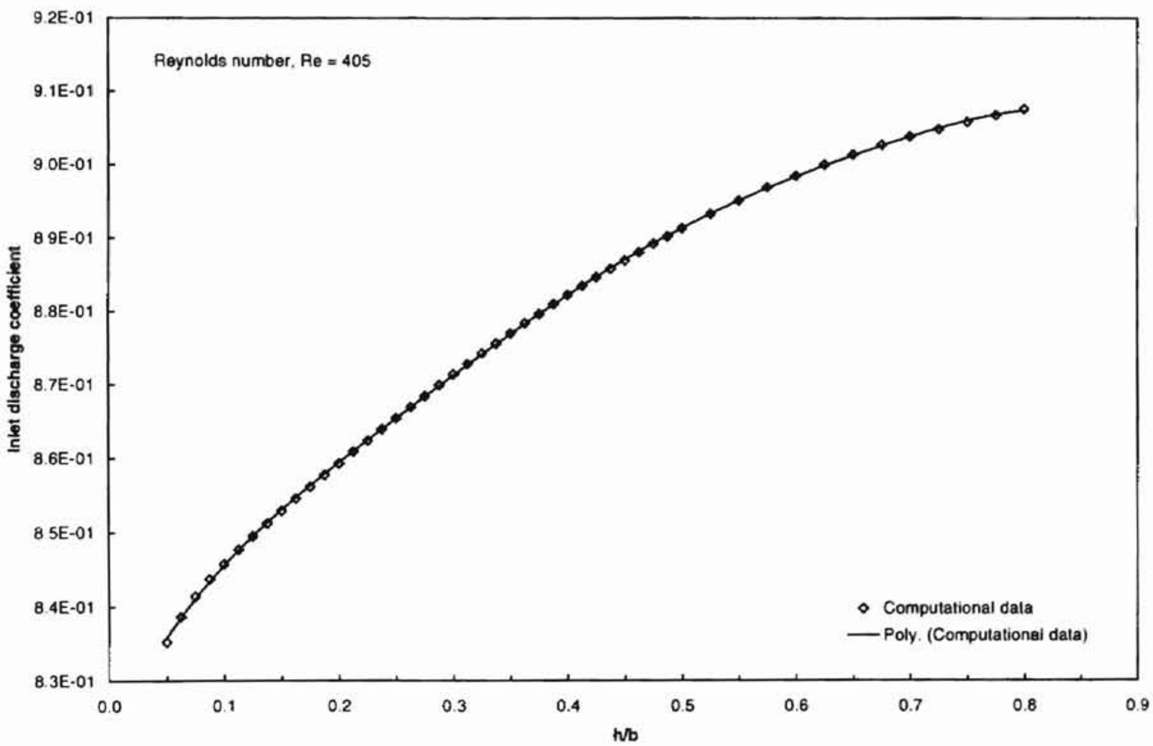


Figure 18. The effect of h/b on k for Re = 405 (slot model)

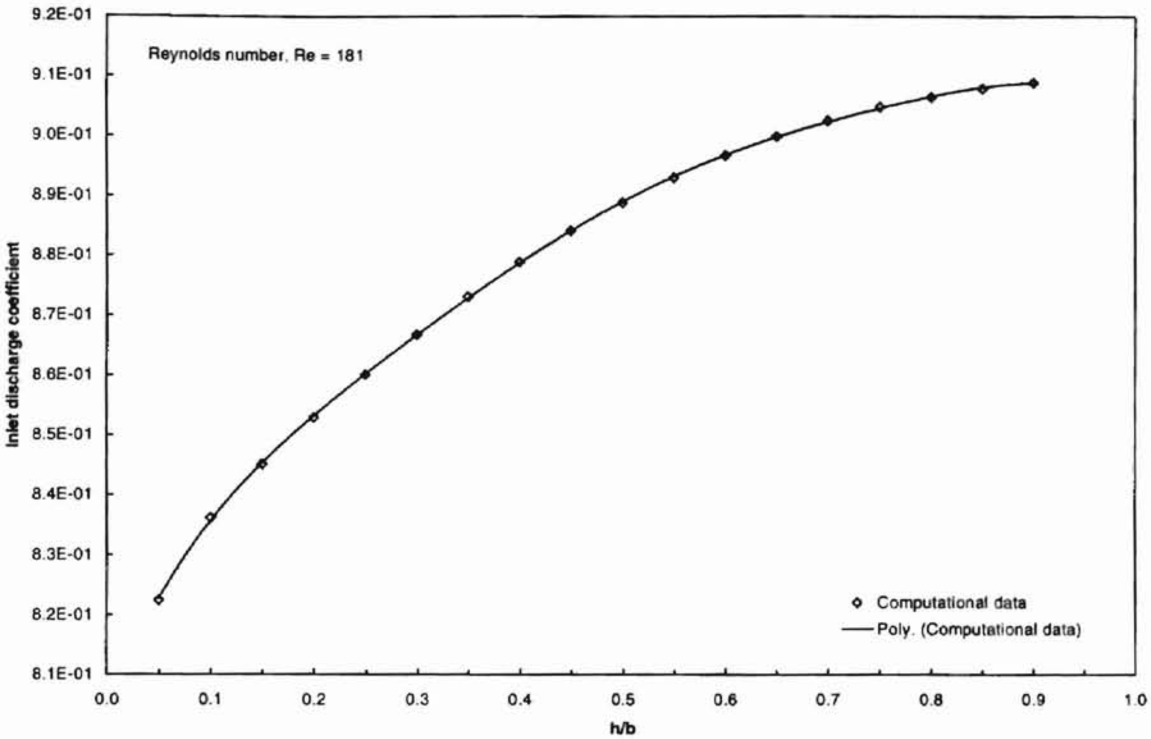


Figure 19. The effect of h/b on k for Re = 181 (slot model)

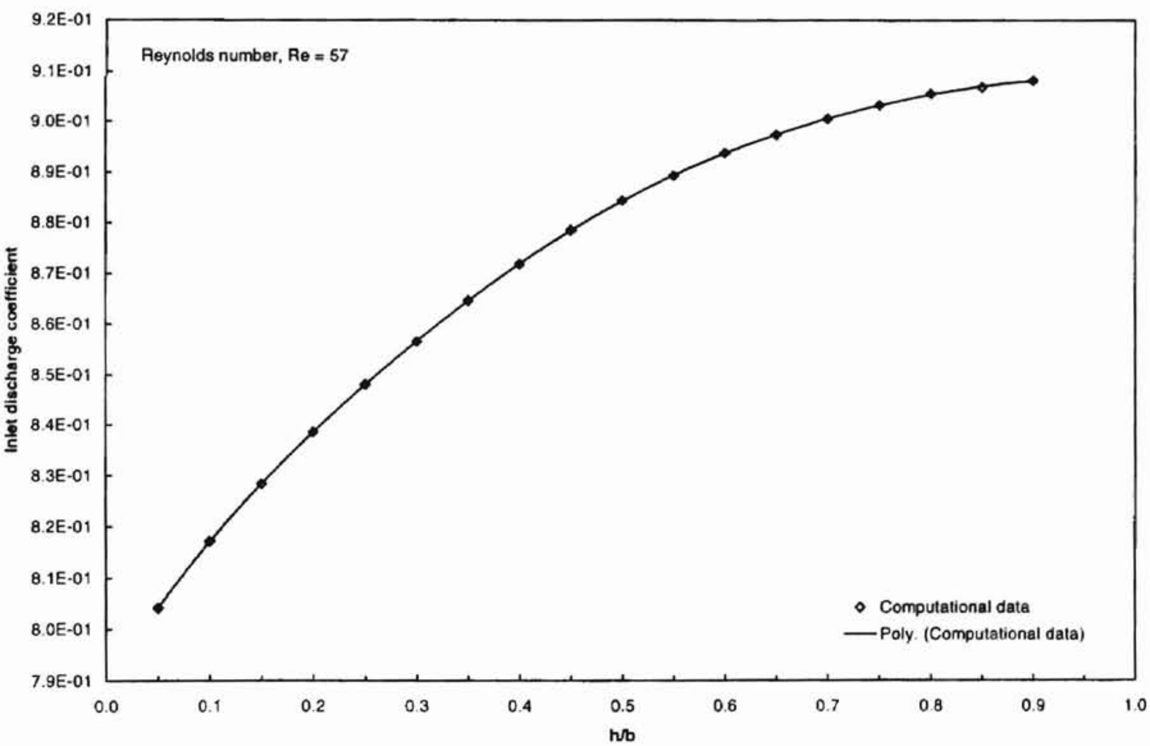


Figure 20. The effect of h/b on k for Re = 57 (slot model)

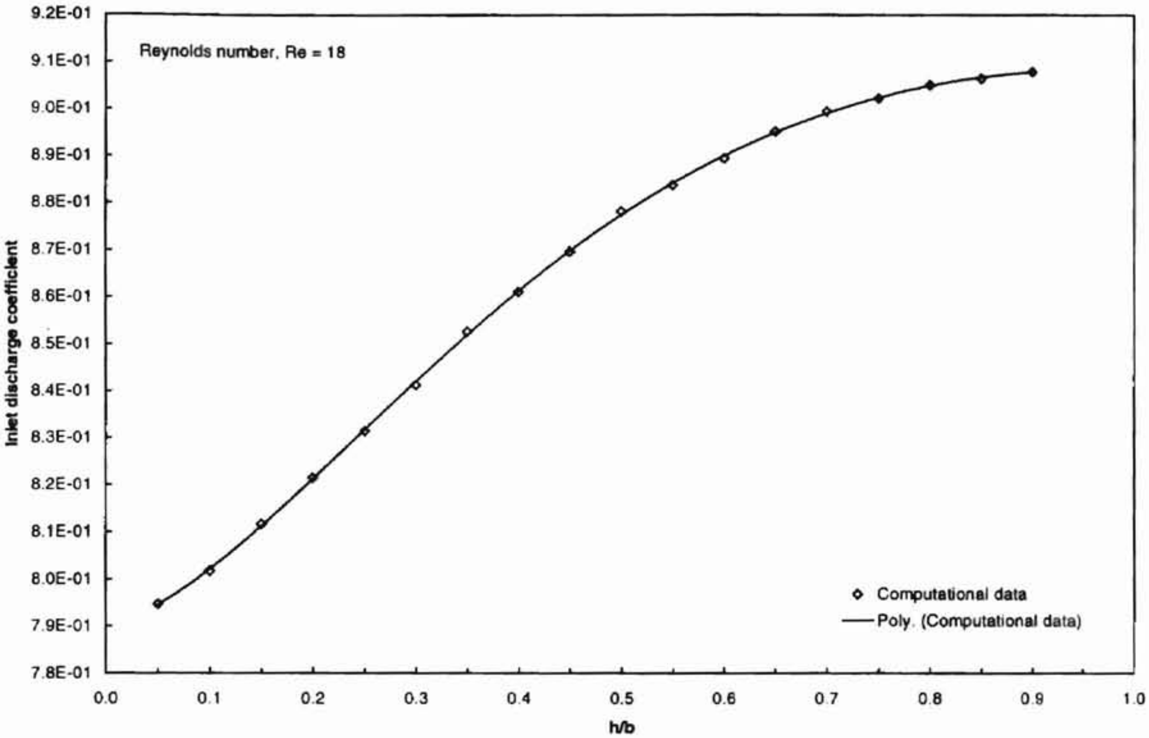


Figure 21. The effect of h/b on k for Re = 18 (slot model)

Figure 22 to Figure 25 show the effect of h/d on inlet discharge coefficient (k) for Reynolds number, Re = 405, 181, 57 and 18. With reference to Figure 22 and Figure 23, at the beginning of the curve, the inlet discharge coefficient increases with a decreasing rate as h/d increases. At the middle of the curve, the inlet discharge coefficient increases linearly with h/d. At the end of the curve, the inlet discharge coefficient increases with a slow decreasing rate. With reference to Figure 24, the inlet discharge coefficient increases linearly with h/d. At the end of the curve, the inlet discharge coefficient increases with a slow decreasing rate. With reference to Figure 25, when h/d < 0.25, the inlet discharge coefficient increases with an increasing rate. After that, the inlet discharge coefficient increases linearly with h/d. At the last two points of the curve, it looks like the inlet discharge coefficient starts to increases with a slow decreasing rate.

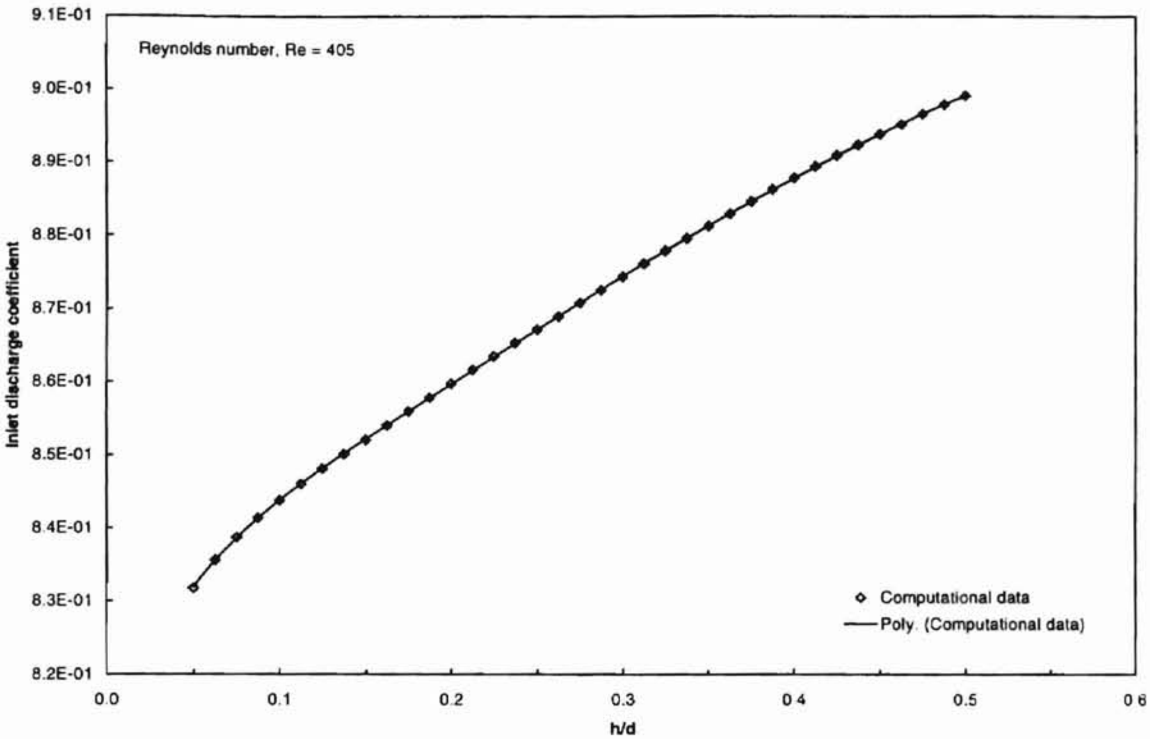


Figure 22. The effect of h/d on k for Re = 405 (hole model)

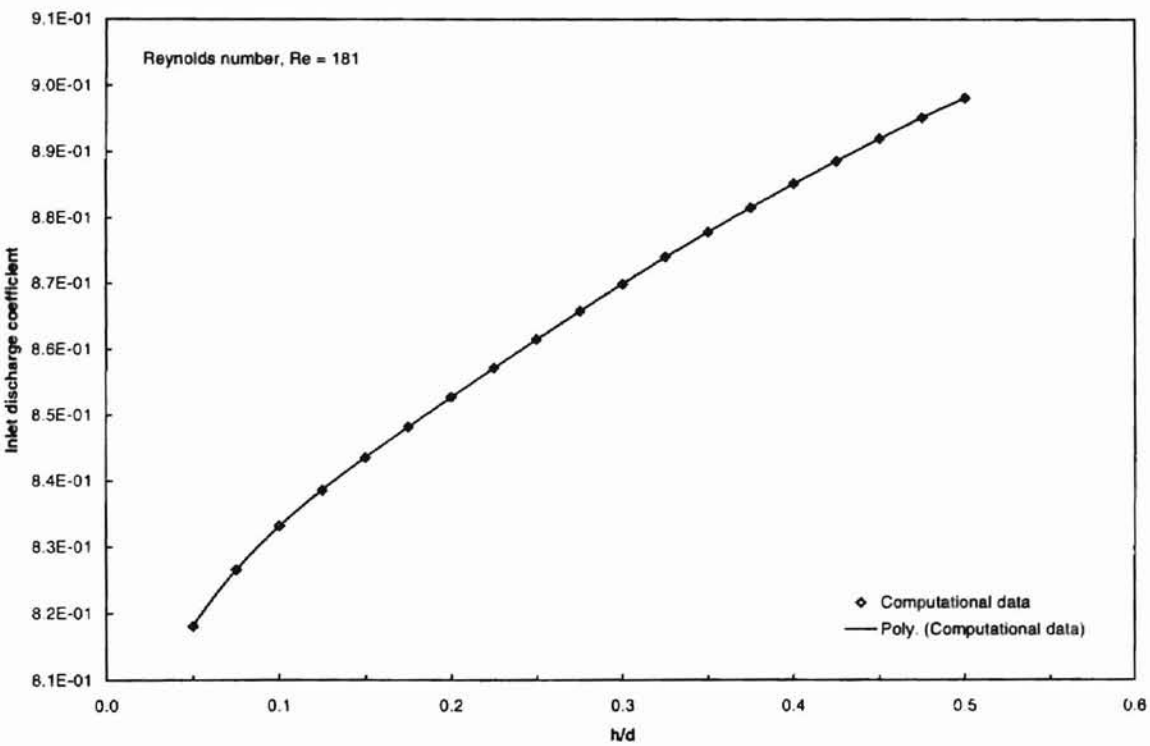


Figure 23. The effect of h/d on k for Re = 181 (hole model)

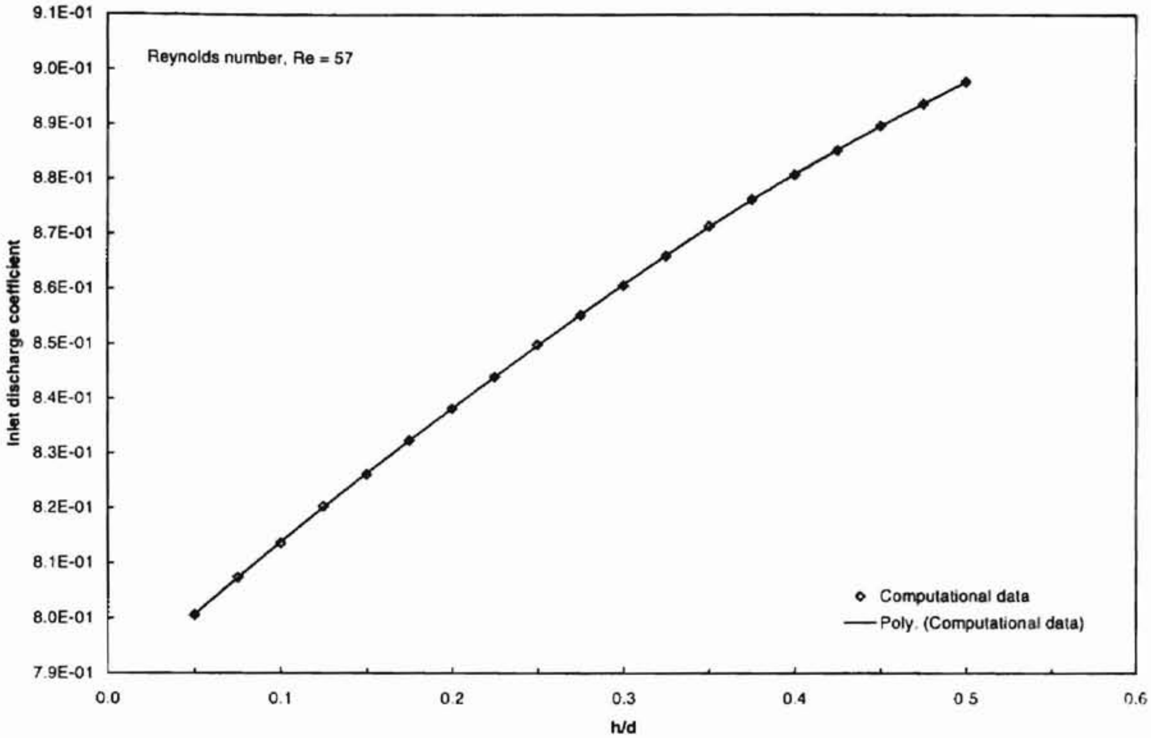


Figure 24. The effect of h/d on k for Re = 57 (hole model)

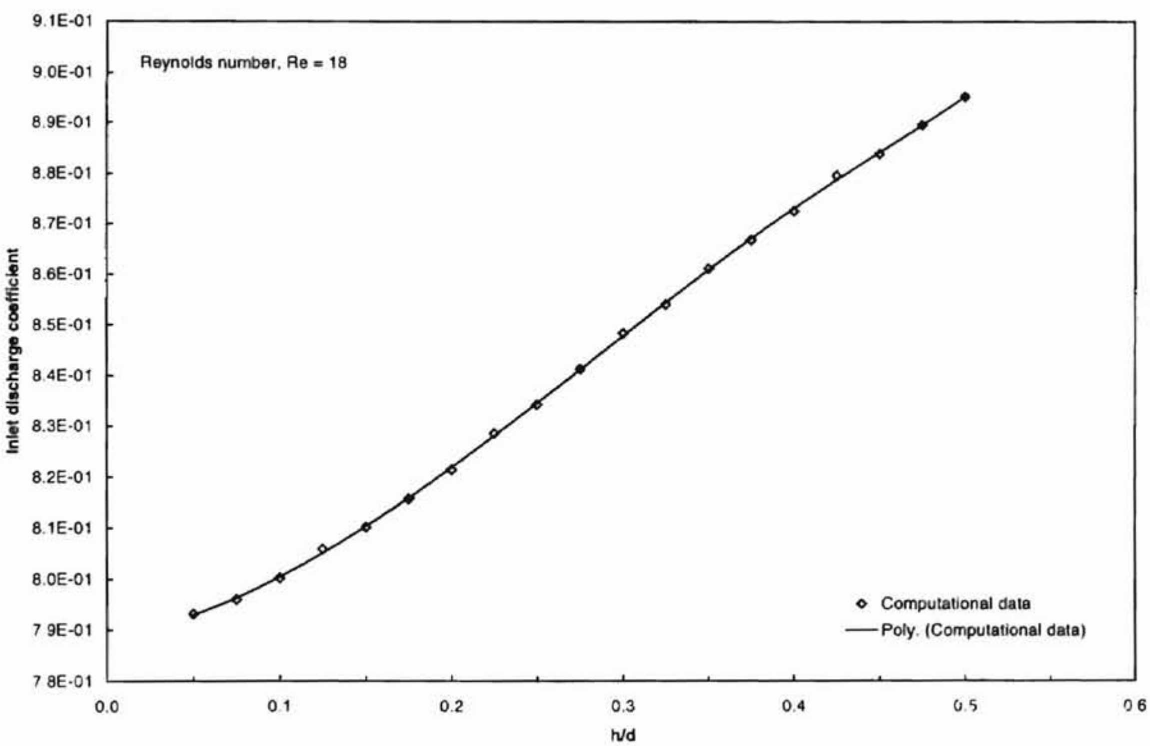


Figure 25. The effect of h/d on k for Re = 18 (hole model)

Figure 26 to Figure 29 show the effect of h/b on coefficient of friction ($k_{Viscous}$) for Reynolds number, Re = 405, 181, 57 and 18. With reference to Figure 26 to Figure 29, at the beginning of the curve, the coefficient of friction increases almost linearly with h/b. Notice that the gradient of the curve decreases (becomes less steep) as Reynolds number decreases. Later on, the coefficient of friction increases with a decreasing rate. The occurrence of the transition of the trend depends on the Reynolds number. The smaller the Reynolds number, the slower the transition of trend occurs.

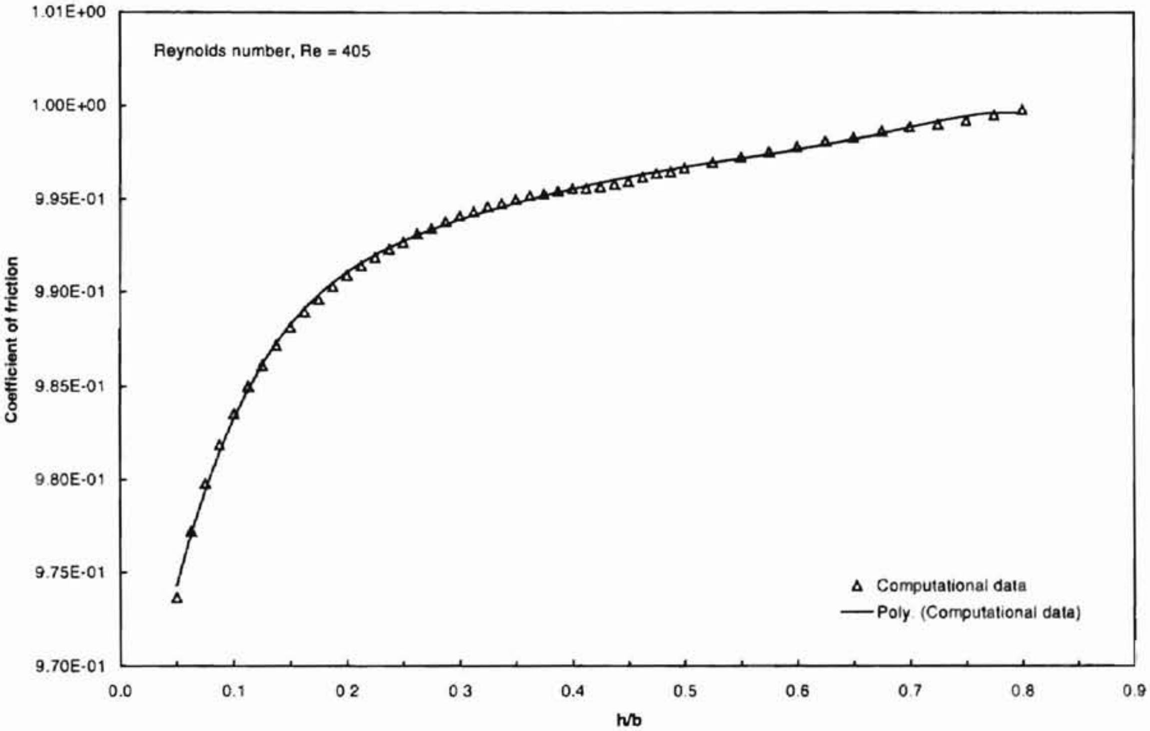


Figure 26. The effect of h/b on $k_{Viscous}$ for Re = 405 (slot model)

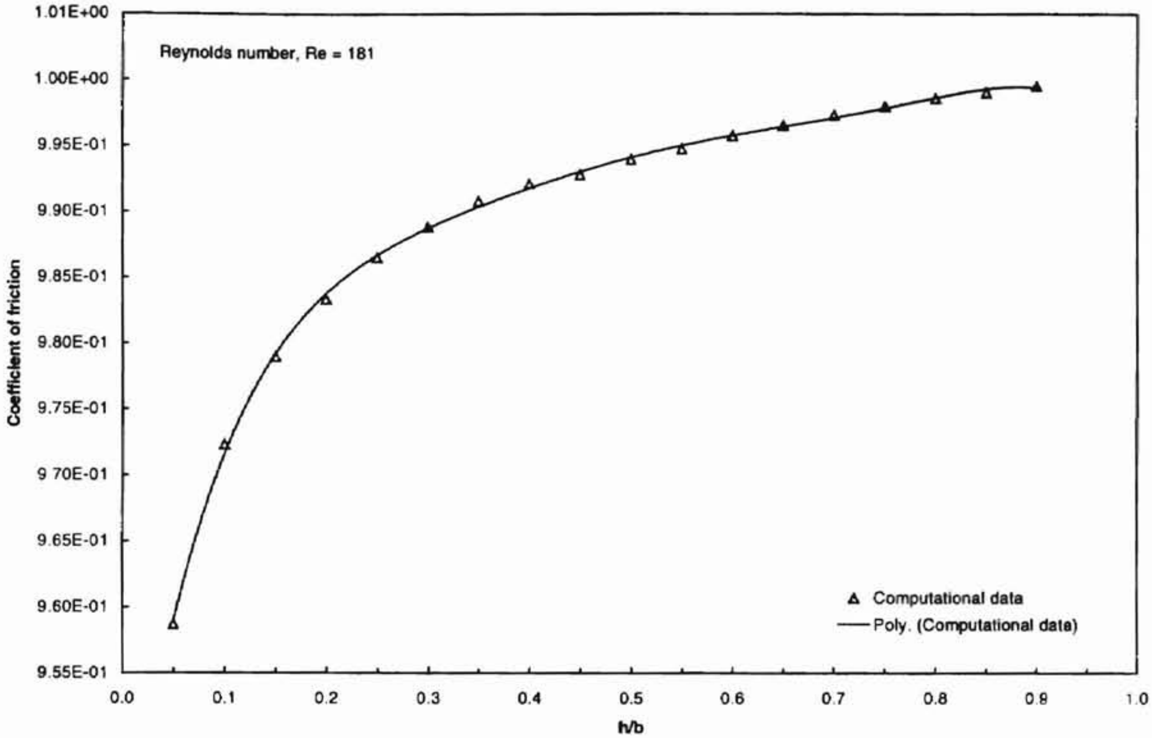


Figure 27. The effect of h/b on $k_{Viscous}$ for Re = 181 (slot model)

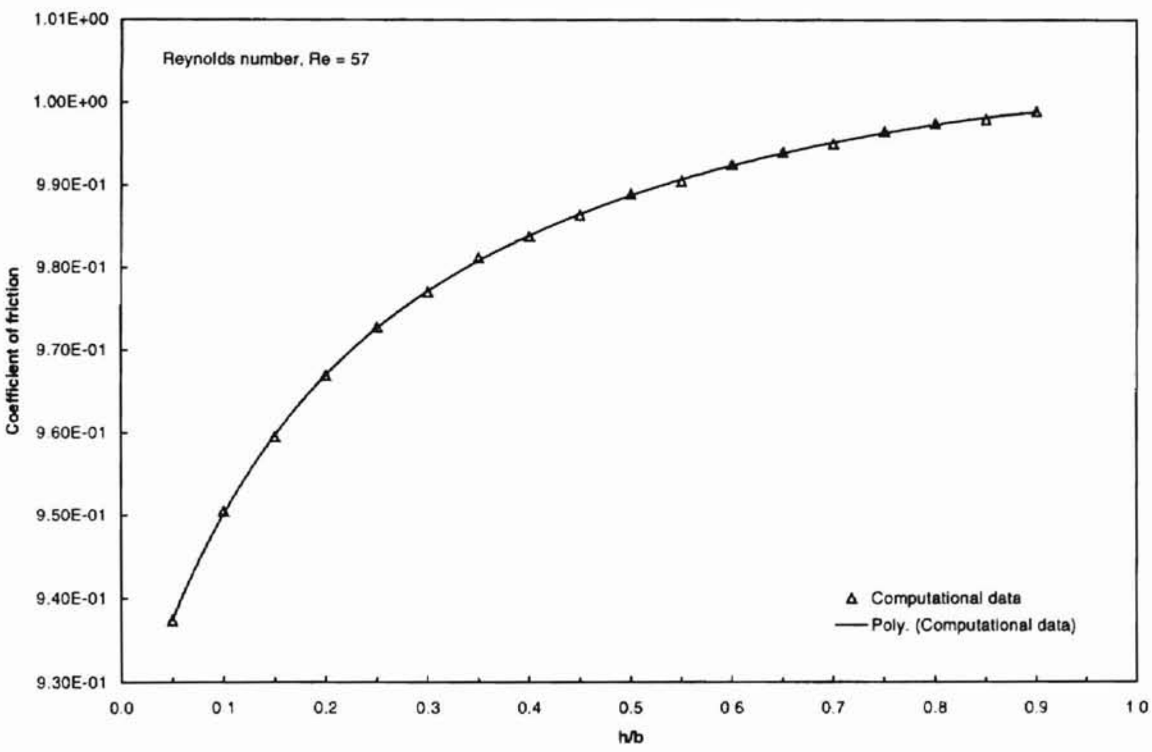


Figure 28. The effect of h/b on $k_{Viscous}$ for Re = 57 (slot model)

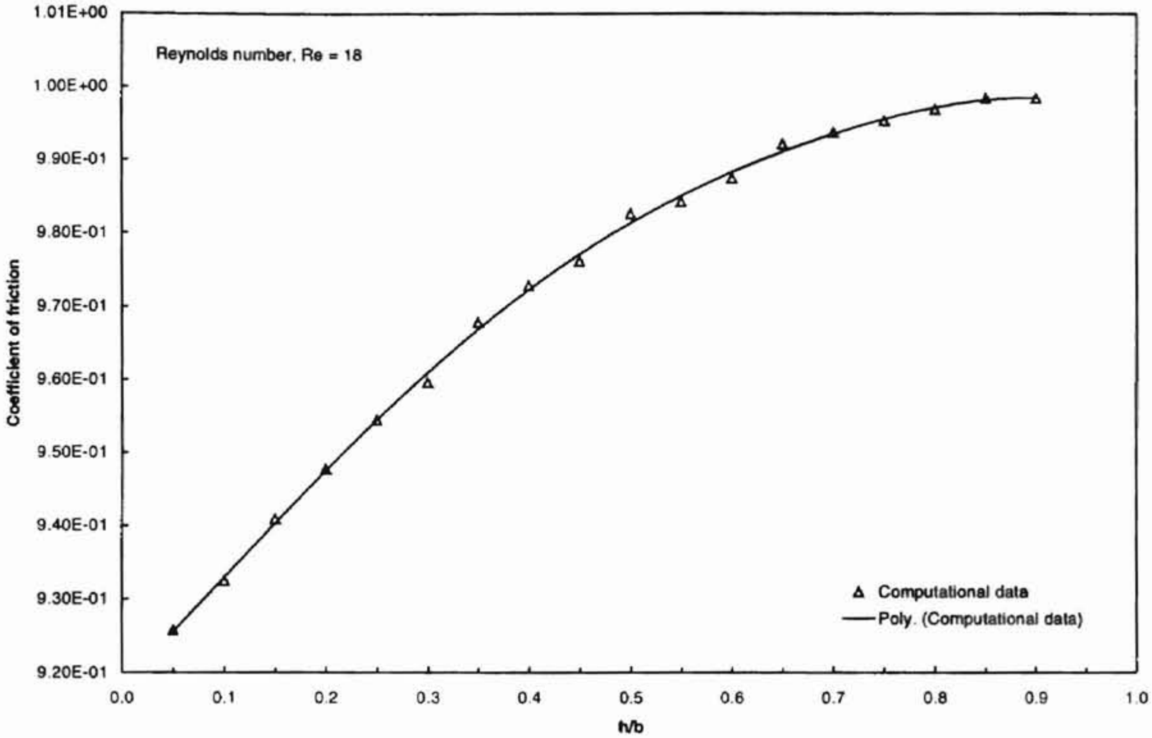


Figure 29. The effect of h/b on $k_{Viscous}$ for Re = 18 (slot model)

Figure 30 to Figure 33 show the effect of h/d on coefficient of friction ($k_{Viscous}$) for Reynolds number, Re = 405, 181, 57 and 18. With reference to Figure 30 to Figure 32, at the beginning of the curve, the coefficient of friction increases almost linearly with h/d. Notice that the gradient at the beginning of Figure 30 to Figure 33 decreases (becomes less steep) as Reynolds number decreases. Later on, the coefficient of friction increases with a decreasing rate. The occurrence of the transition of the trend depends on the Reynolds number. The smaller the Reynolds number, the slower the transition of trend occurs. With reference to Figure 33, it looks like the coefficient of friction increases linearly with h/d.

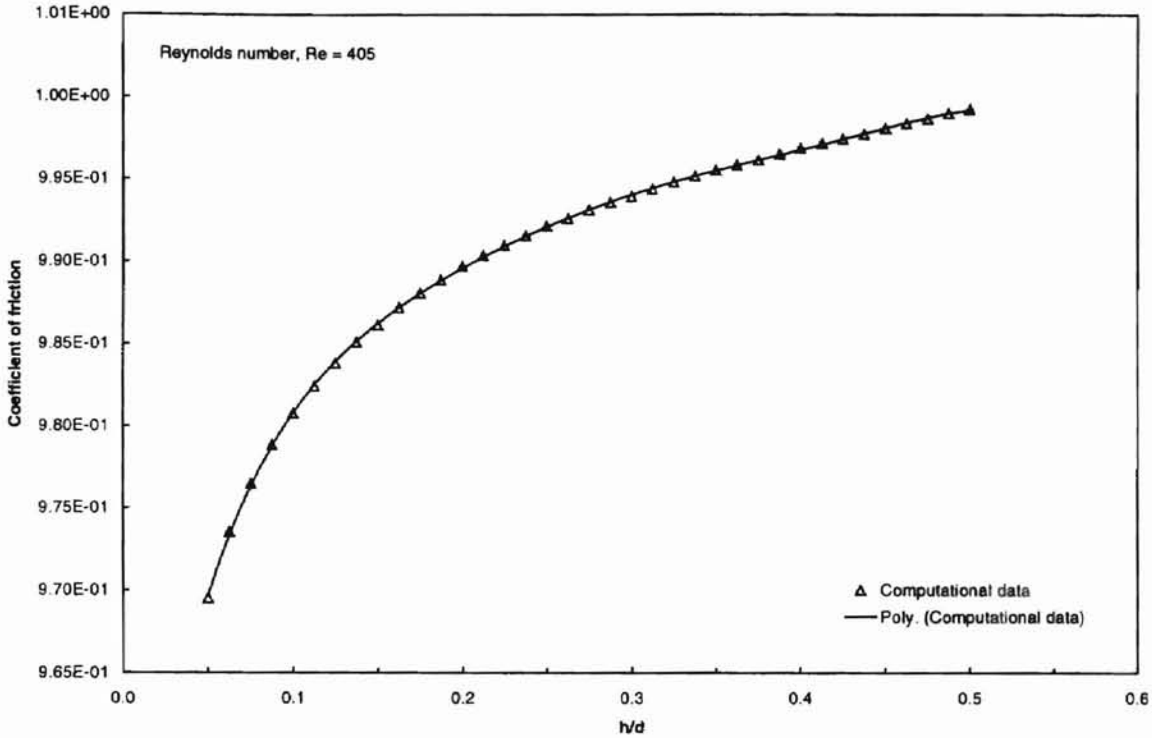


Figure 30. The effect of h/d on $k_{Viscous}$ for Re = 405 (hole model)

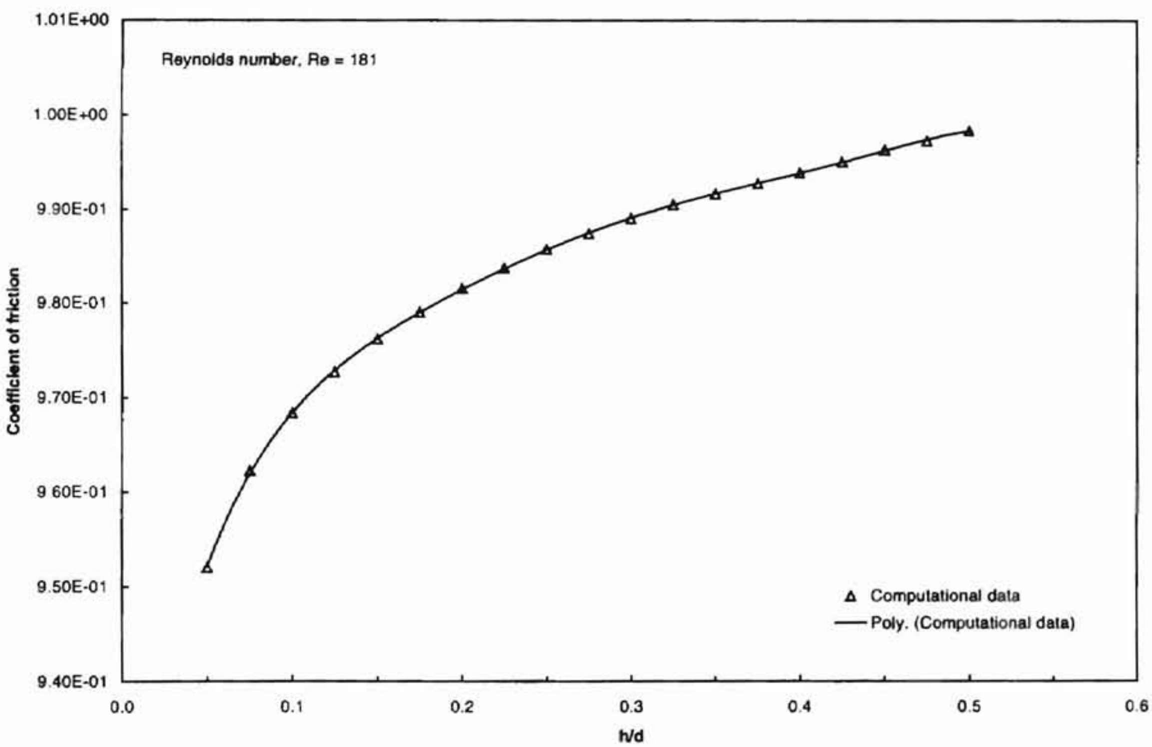


Figure 31. The effect of h/d on $k_{Viscous}$ for Re = 181 (hole model)

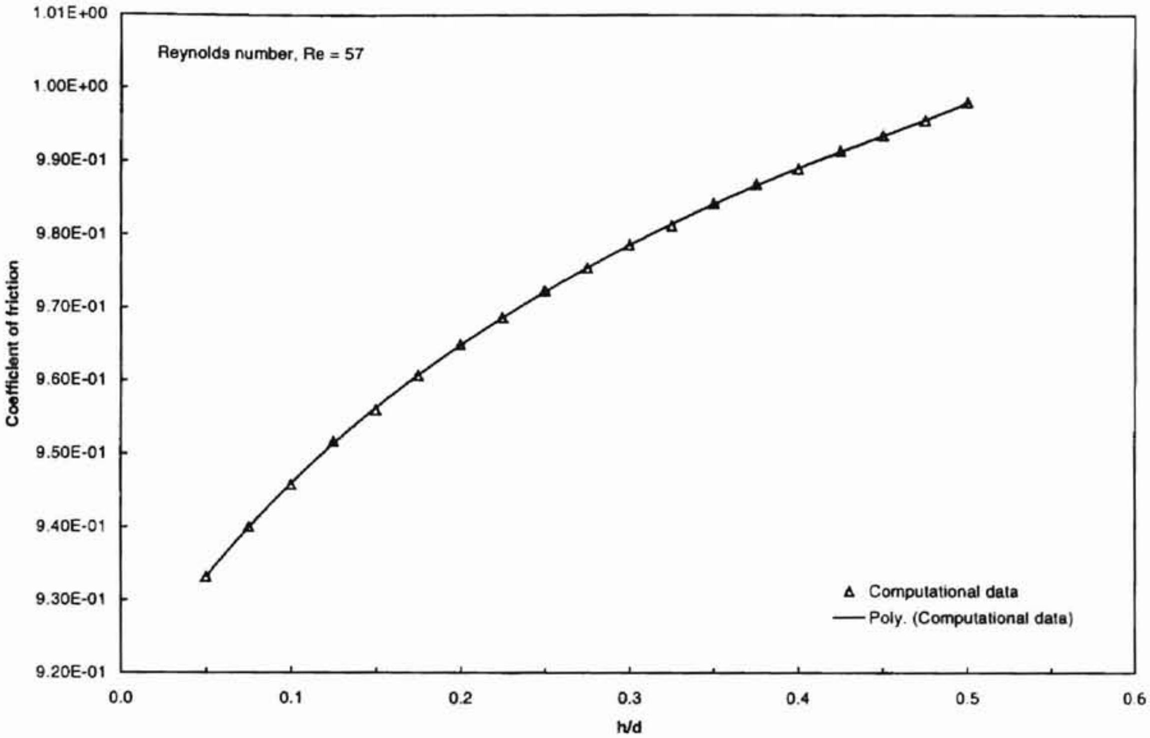


Figure 32. The effect of h/d on $k_{Viscous}$ for Re = 57 (hole model)

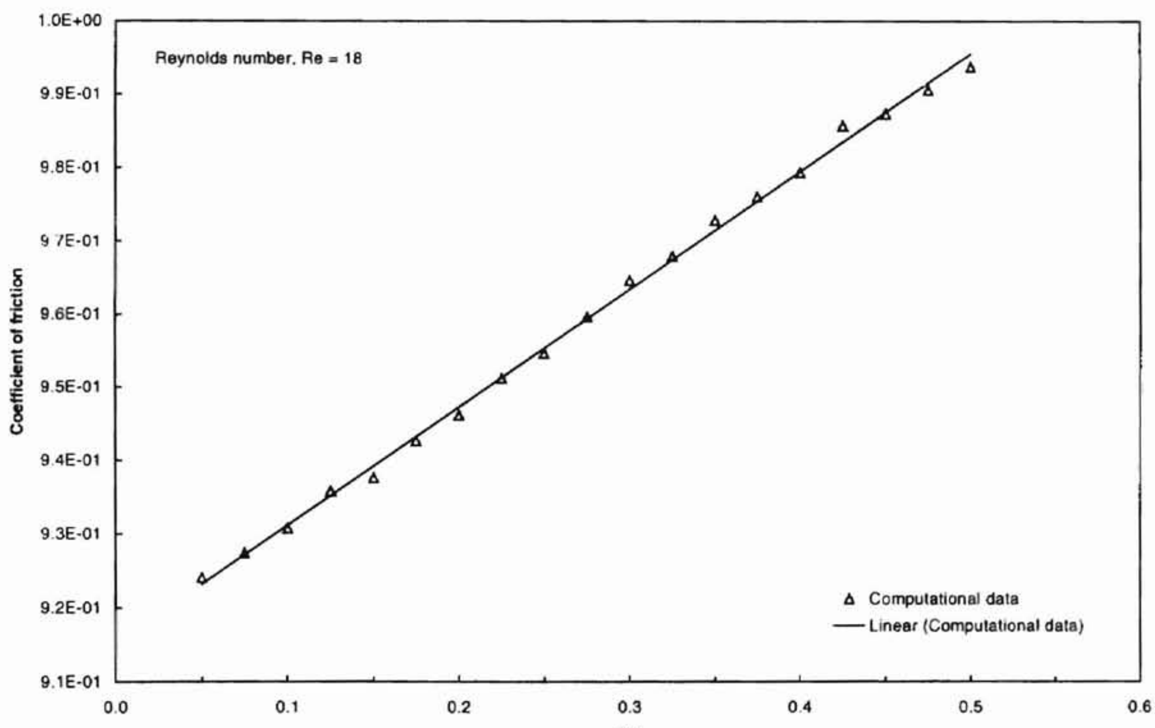


Figure 33. The effect of h/d on $k_{Viscous}$ for Re = 18 (hole model)

6.4 Analysis of Research Findings

Linear and sixth-order polynomial curve fitting were performed on the computational data in Figure 18 to Figure 33. The main purpose of performing the curve fitting is to obtain the basic equation that govern the effect of h/b or h/d on inlet discharge coefficient and coefficient of friction for different Reynolds number. In my opinion, the linear and sixth-order polynomial curve fits closely to the computational data. The following equations govern the effect of h/b on inlet discharge coefficient of the slot model for four different Reynolds numbers.

For Reynolds number, Re = 405:

$$k = -3.2163(\frac{h}{b})^6 + 8.9829(\frac{h}{b})^5 - 9.8431(\frac{h}{b})^4 + 5.3246(\frac{h}{b})^3 - 1.5479(\frac{h}{b})^2 + 0.3522(\frac{h}{b}) + 0.8214 \qquad (6.14)$$

For Reynolds number, Re = 181:

$$k = -2.2191(\frac{h}{b})^6 + 6.9764(\frac{h}{b})^5 - 8.6145(\frac{h}{b})^4 + 5.2921(\frac{h}{b})^3 - 1.7856(\frac{h}{b})^2 + 0.4499(\frac{h}{b}) + 0.8040 \qquad (6.15)$$

For Reynolds number, Re = 57:

$$k = -0.7237(\frac{h}{b})^6 + 2.2668(\frac{h}{b})^5 - 2.7531(\frac{h}{b})^4 + 1.6625(\frac{h}{b})^3 - 0.6683(\frac{h}{b})^2 + 0.3343(\frac{h}{b}) + 0.7890 \qquad (6.16)$$

For Reynolds number, Re = 18:

$$k = 0.0438(\frac{h}{b})^6 - 0.4582(\frac{h}{b})^5 + 1.2413(\frac{h}{b})^4 - 1.4680(\frac{h}{b})^3 + 0.6883(\frac{h}{b})^2 + 0.0711(\frac{h}{b}) + 0.7894 \qquad (6.17)$$

The following equations govern the effect of h/d on inlet discharge coefficient of the hole model for four different Reynolds numbers.

For Reynolds number, Re = 405:

$$k = -34.9298(\frac{h}{d})^6 + 65.8011(\frac{h}{d})^5 - 49.9757(\frac{h}{d})^4 + 19.3976(\frac{h}{d})^3 - 4.0740(\frac{h}{d})^2 + 0.5909(\frac{h}{d}) + 0.8105 \quad (6.18)$$

For Reynolds number, Re = 181:

$$k = -40.7144(\frac{h}{d})^6 + 77.4764(\frac{h}{d})^5 - 59.3839(\frac{h}{d})^4 + 2.3143(\frac{h}{d})^3 - 5.0057(\frac{h}{d})^2 + 0.7416(\frac{h}{d}) + 0.7910 \quad (6.19)$$

For Reynolds number, Re = 57:

$$k = 12.1590(\frac{h}{d})^6 - 18.4412(\frac{h}{d})^5 + 10.4472(\frac{h}{d})^4 - 2.7781(\frac{h}{d})^3 + 0.2487(\frac{h}{d})^2 + 0.2578(\frac{h}{d}) + 0.7874 \quad (6.20)$$

For Reynolds number, Re = 18:

$$k = 2.9968(\frac{h}{d})^6 - 31.4952(\frac{h}{d})^5 + 17.6508(\frac{h}{d})^4 - 5.7471(\frac{h}{d})^3 + 1.4308(\frac{h}{d})^2 + 0.0069(\frac{h}{d}) + 0.7897 \quad (6.21)$$

The following equations govern the effect of h/b coefficient of friction of the slot model for four different Reynolds numbers.

For Reynolds number, Re = 405:

$$k_{Viscous} = -2.9194(\frac{h}{b})^6 + 8.4104(\frac{h}{b})^5 - 9.8373(\frac{h}{b})^4 + 6.0268(\frac{h}{b})^3 - 2.0742(\frac{h}{b})^2 + 0.4017(\frac{h}{b}) + 0.9587 \quad (6.22)$$

For Reynolds number, Re = 181:

$$k_{Viscous} = -2.1597(\frac{h}{b})^6 + 7.0195(\frac{h}{b})^5 - 9.2150(\frac{h}{b})^4 + 6.2878(\frac{h}{b})^3 - 2.3952(\frac{h}{b})^2 + 0.5179(\frac{h}{b}) + 0.9383 \quad (6.23)$$

For Reynolds number, Re = 57:

$$k_{Viscous} = -0.4640(\frac{h}{b})^6 + 1.7183(\frac{h}{b})^5 - 2.6653(\frac{h}{b})^4 + 2.2610(\frac{h}{b})^3 - 1.1659(\frac{h}{b})^2 + 0.3949(\frac{h}{b}) + 0.9203 \quad (6.24)$$

For Reynolds number, Re = 18:

$$k_{Viscous} = -0.1859(\frac{h}{b})^6 + 0.2746(\frac{h}{b})^5 + 0.0885(\frac{h}{b})^4 - 0.3390(\frac{h}{b})^3 + 0.1014(\frac{h}{b})^2 + 0.1372(\frac{h}{b}) + 0.9186 \quad (6.25)$$

The following equations govern the effect of h/d on coefficient of friction of the hole model for four different Reynolds numbers.

For Reynolds number, Re = 405:

$$k_{Viscous} = -43.6642(\frac{h}{d})^6 + 81.1845(\frac{h}{d})^5 - 61.1171(\frac{h}{d})^4 + 24.0571(\frac{h}{d})^3 - 5.3634(\frac{h}{d})^2 + 0.7055(\frac{h}{d}) + 0.9452 \quad (6.26)$$

For Reynolds number, Re = 181:

$$k_{Viscous} = -81.3785(\frac{h}{d})^6 + 150.0931(\frac{h}{d})^5 - 111.1597(\frac{h}{d})^4 + 42.4890(\frac{h}{d})^3 - 9.0291(\frac{h}{d})^2 + 1.1180(\frac{h}{d}) + 0.9141 \quad (6.27)$$

For Reynolds number, Re = 57:

$$k_{Viscous} = 5.7780(\frac{h}{d})^6 - 6.3170(\frac{h}{d})^5 + 1.2951(\frac{h}{d})^4 + 1.0958(\frac{h}{d})^3 - 0.8421(\frac{h}{d})^2 + 0.3612(\frac{h}{d}) + 0.9197 \qquad (6.28)$$

For Reynolds number, Re = 18:

$$k_{Viscous} = 0.1608(\frac{h}{d}) + 0.9152 \qquad (6.29)$$

To clearly demonstrate the effect of Reynolds number on k and $k_{Viscous}$, Figure 18 to Figure 33 are plotted together into four figures as shown in Figure 34 to Figure 37. Detail discussions of the effect of the test parameters on inlet discharge coefficient and coefficient of friction will be included in the next chapter.

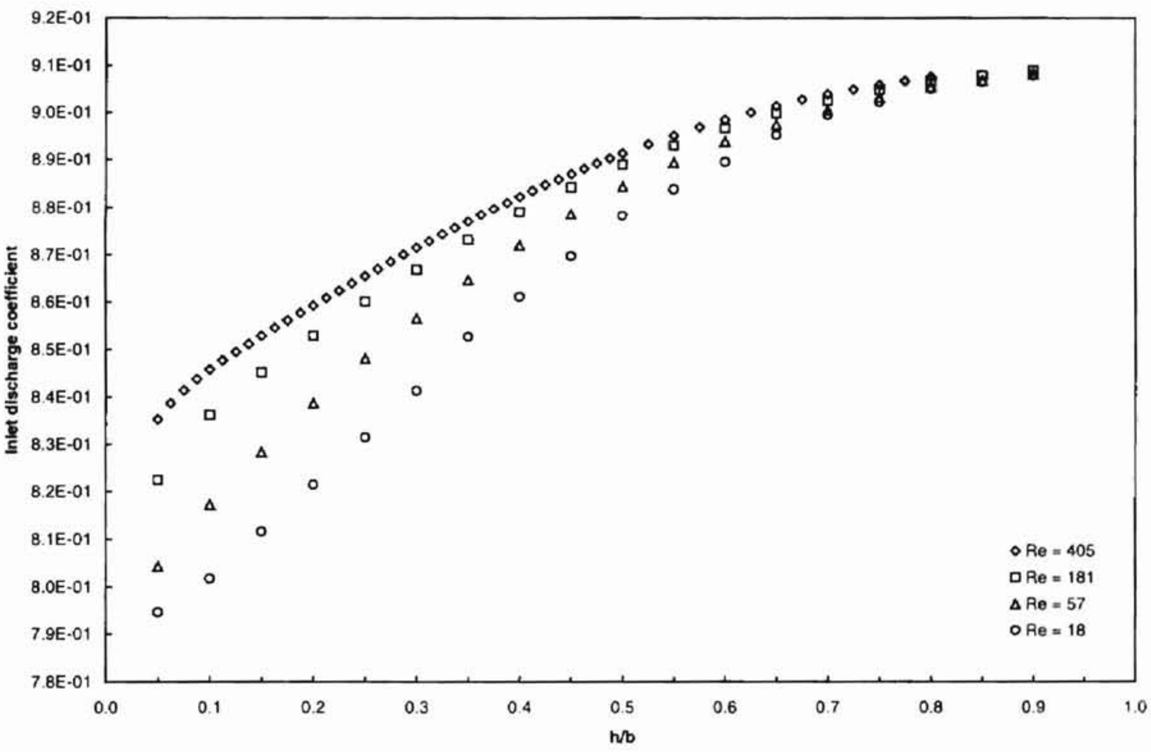


Figure 34. The effect of h/b on k for different Reynolds numbers (slot model)

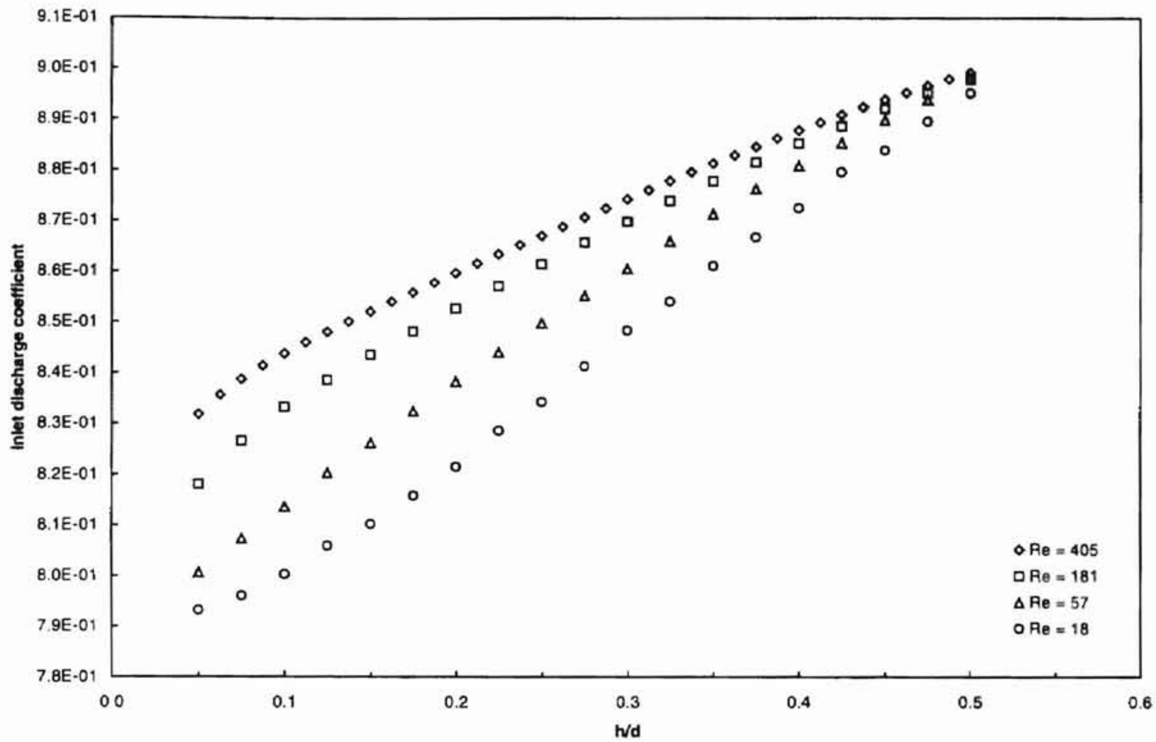


Figure 35. The effect of h/d on k for different Reynolds numbers (hole model)

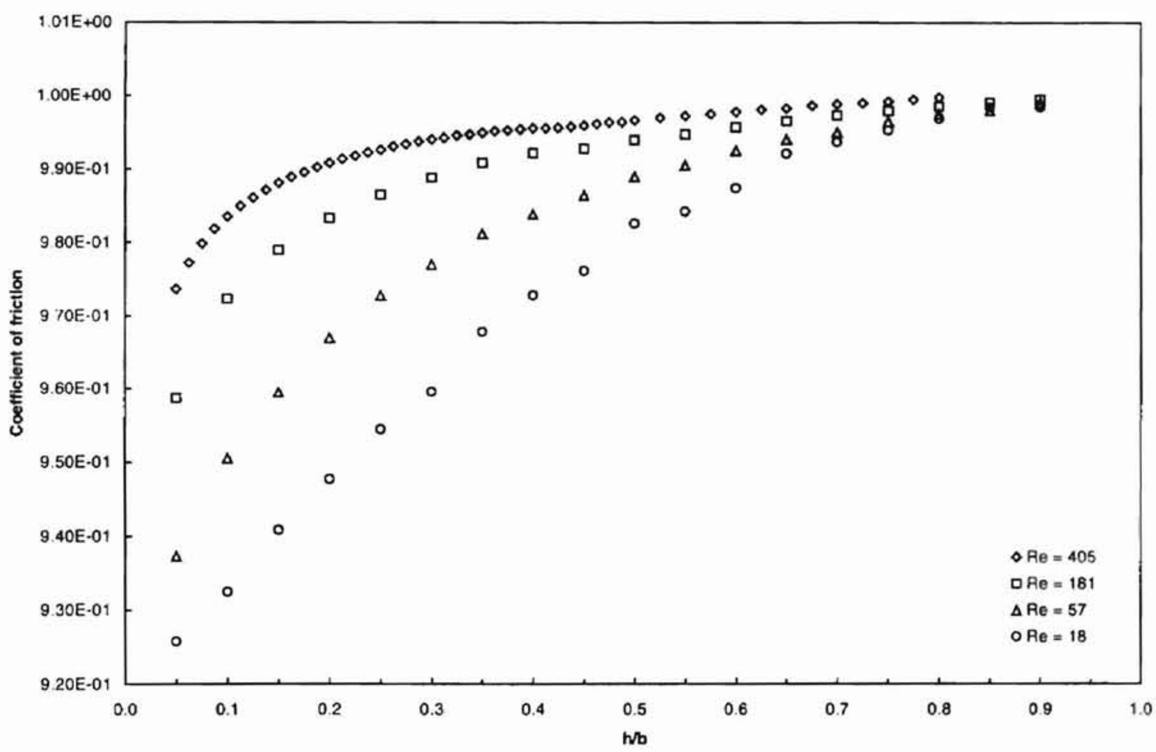


Figure 36. The effect of h/b on $k_{Viscous}$ for different Reynolds number (slot model)

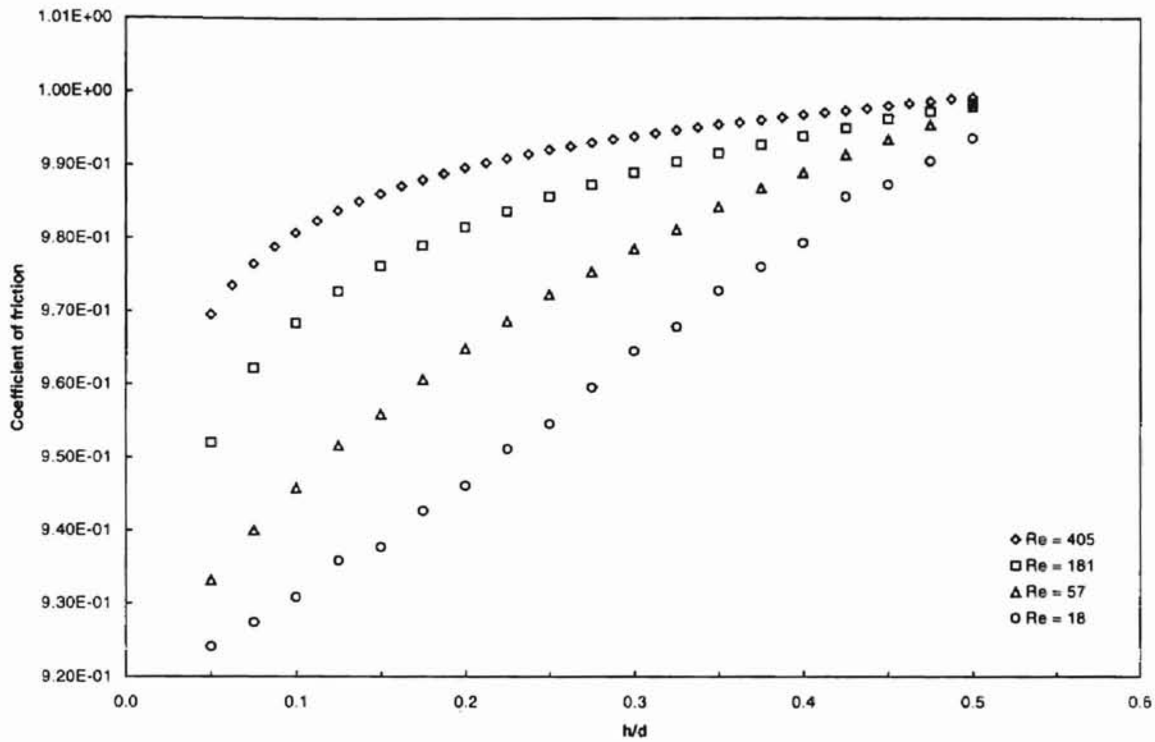


Figure 37. The effect of h/d on $k_{Viscous}$ for different Reynolds numbers (hole model)

6.5 Research Findings Summary

In short, the transient solutions of the effect of air-gap, inlet jet width, and initial inlet dynamic pressure on the flow beneath a rigid stationary web have been generated via a FORTRAN program. The horizontal velocity components of the converged solutions are tabulated in appendix D. The horizontal inlet velocity of the converged solution for both frictionless flow and actual flow are tabulated in appendix C. The effect of air-gap/inlet jet width and Reynolds number on $U_{inlet\,(F\,or\,R)}A_{inlet}\,/\,U_{inlet}$ (for slot model) or $U_{inlet\,(F\,or\,R)}A_{inlet}\,/\,U_{inlet}$ (for hole model), inlet discharge coefficient (k) and coefficient of friction ($k_{Viscous}$) are also tabulated in appendix C. The effect of h/b or h/d on $U_{inlet\,(F\,or\,R)}A_{inlet}\,/\,U_{inlet}$ or $U_{inlet\,(F\,or\,R)}A_{inlet}\,/\,U_{inlet}$ for different Reynolds numbers are plotted. The effect of h/b or h/d on k and $k_{Viscous}$ for different Reynolds numbers are plotted and curve fitted. The equations that govern the effect of h/b or h/d on k and $k_{Viscous}$ are obtained. Discussion of the results will be included in the next chapter.

CHAPTER VII

DISCUSSION

7.1 Inputs

In this thesis, we are interested in the flow where air-gap is less than inlet jet width or air-gap/inlet jet width < 1. For a given air-gap, the computational solution may not achieve steady state at the maximum time step because the vorticity will not converge. The number of iterations and the time step chosen to generate the desired computational results are good (that is, the vorticity converges to one decimal place, so that U and V can be made to converge to four decimal places) for the range of test parameters that lies in the region of interest. The fluid region is covered with a 9 by 8 rectangular mesh. This is the minimum number of mesh points that allows us to compute horizontal inlet velocity of the converged solution correctly (using the fact U(1, 1, t) is equal to U(1, 2, t)) and still maintain a short computational time. The code has been written to conduct study for different horizontal and vertical odd-number grids. If a different horizontal grid and vertical grid are used, the user may need to find the correct time step and also change the print statement. If more than 90 grid lines are used, the user should check the dimension of the arrays to make sure that the arrays are able to support the chosen grid lines. One can choose a different stream function (ERPSIM) and vorticity (EROMM) for more accuracy. However, longer time is needed for the solution to converge.

7.2 Discussion of Research Findings

Presented here are some discussions that may help the reader to better understand the research findings. In addition, these discussions may be useful to anyone who wishes to extend the existing program for some other applications.

7.2.1 Flow Separation and Vortex

With reference to appendix D, in actual flow, flow separation occurs near to the outlet when air-gap is very much smaller than the inlet jet width. As air-gap increases, flow separation begins to vanish, starting from left to right. In other words, as air-gap increases, the vortex at the outlet diminishes, starting from the surface of the air-turn bar to the rigid stationary web. Note that the vortex diminishes as the solutions converge. This can be seen from the sample solutions in the 3.5" diskette supplied with this thesis. If one goal is to eliminate these vortexes, a smaller Δx and Δy or Δr should be used which will help us to locate the smaller vortex. In frictionless flow, no flow separation is observed. It is worth while to mention that the converged solutions of the horizontal velocity component in appendix D also provide the reader a possible way to estimate the mass flowrate (at centerline) and dynamic pressure between the air-turn bar and the web. For instance, we can define the width of the jet at any x locations between the air-turn bar and the web as twice the distance y where $u = 0.01u_{max}$:

$$\text{Width of the jet} = 2y\Big|_{1\%} \tag{7.30}$$

Having the width of the jet, horizontal velocity component and density at that particular x locations, enable us to determine the mass flowrate.

7.2.2 Effect of Test Parameters on Frictionless Flow and Actual Flow

With reference to appendix C, in frictionless flow, Reynolds number has no effect (or in some case, little effect) on $U_{inlet(F)}A_{inlet}'/U_{inlet}$ or $U_{inlet(F)}A_{inlet}/U_{inlet}$. In actual flow, Reynolds number causes $U_{inlet(R)}A_{inlet}'/U_{inlet}$ or $U_{inlet(R)}A_{inlet}/U_{inlet}$ to reduce. However, Reynolds number becomes less significant when h/b or h/d is large. With reference to appendix C, in frictionless flow, $U_{inlet(F)}A_{inlet}'/U_{inlet}$ or $U_{inlet(F)}A_{inlet}/U_{inlet}$ increases with a decreasing rate as h/b or h/d increases. The same phenomenon is observed for actual flow.

With reference to Figure 10 to Figure 17, relatively speaking, it looks like viscosity is more significant in the hole model than the slot model. However, this may due to the fact that the magnitude of $U_{inlet(F or R)}A_{inlet}'/U_{inlet}$ is larger than $U_{inlet(F or R)}A_{inlet}/U_{inlet}$. Discussions concerning Figure 10 to Figure 17 have been presented in the result section.

With reference to Figure 34, when h/b is small, the effect of h/b on k depends strongly on Reynolds number. Reynolds number becomes less significant when h/b is large. Despite of the fact that the curves in Figure 35 have different trends, the same phenomenon is observed. With reference to Figure 36, when h/b is small, the effect of h/b on $k_{Viscous}$ depends strongly on Reynolds number. Reynolds number becomes less significant when h/b is large. It is obvious from Figure 36 that the effect of viscosity is significant when h/b is small. Despite of the fact that the curves in Figure 37 have slightly different trends, the same phenomenon is observed. Linear and polynomial curve fits equations relating air-gap/inlet jet width to k and $k_{Viscous}$ for different Reynolds numbers have been presented in the result section. Discussions concerning Figure 18 to Figure 33 have been presented in the Result section.

7.3 Grid Size

The program has been run using finer grids (129 by 8) for the largest and smallest air-gap used in this thesis. For the slot model, this results in a maximum change of 0.18% for the smallest air-gap (h = 0.2 mm), and a maximum drop of 11.76% for the largest air-gap (h = 3.6 mm). For the hole model, a maximum change of 0.38% is observed for the smallest air-gap (h = 0.2 mm) and a maximum drop of 7.85% for the largest air-gap (h = 2 mm). This information is intended to provide a basic guideline for those who wish to improve the computational results by doing grid refinement.

7.4 Control Volume for Fluid Regions

A simulation has been performed using maximum number of horizontal grid lines (240 by 15) available in FLUENT and triple the size of the control volume. The result generated using FLUENT is compared with the computational result of the FORTRAN program as shown in Figure 38. For slot model, a percent difference of 10.79% is observed. Figure 39 shows the velocity vectors at inlet generated using FLUENT. Figure 40 shows the velocity vectors for 1/4 of the fluid regions included in the simulation. This information is intended to provide a basic guideline for those who wish to improve the computational results by extending the control volume of the fluid regions and doing a grid refinement.

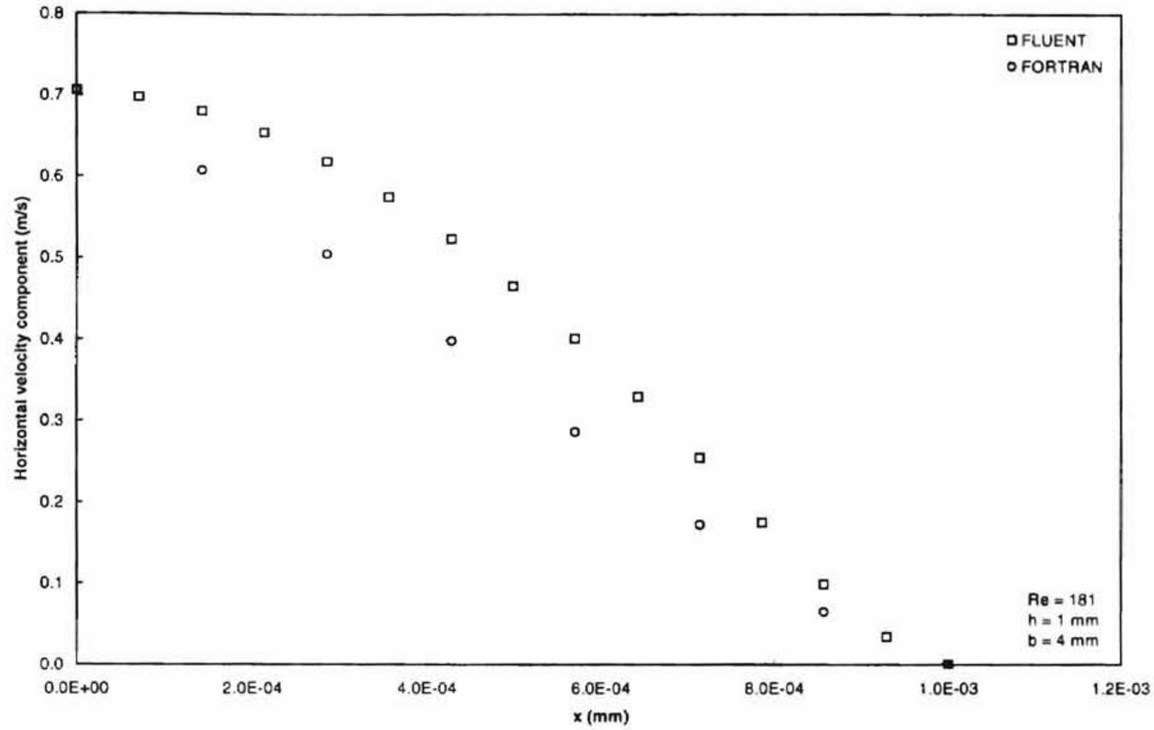


Figure 38. The effect of x distance on horizontal velocity component at centerline of jet

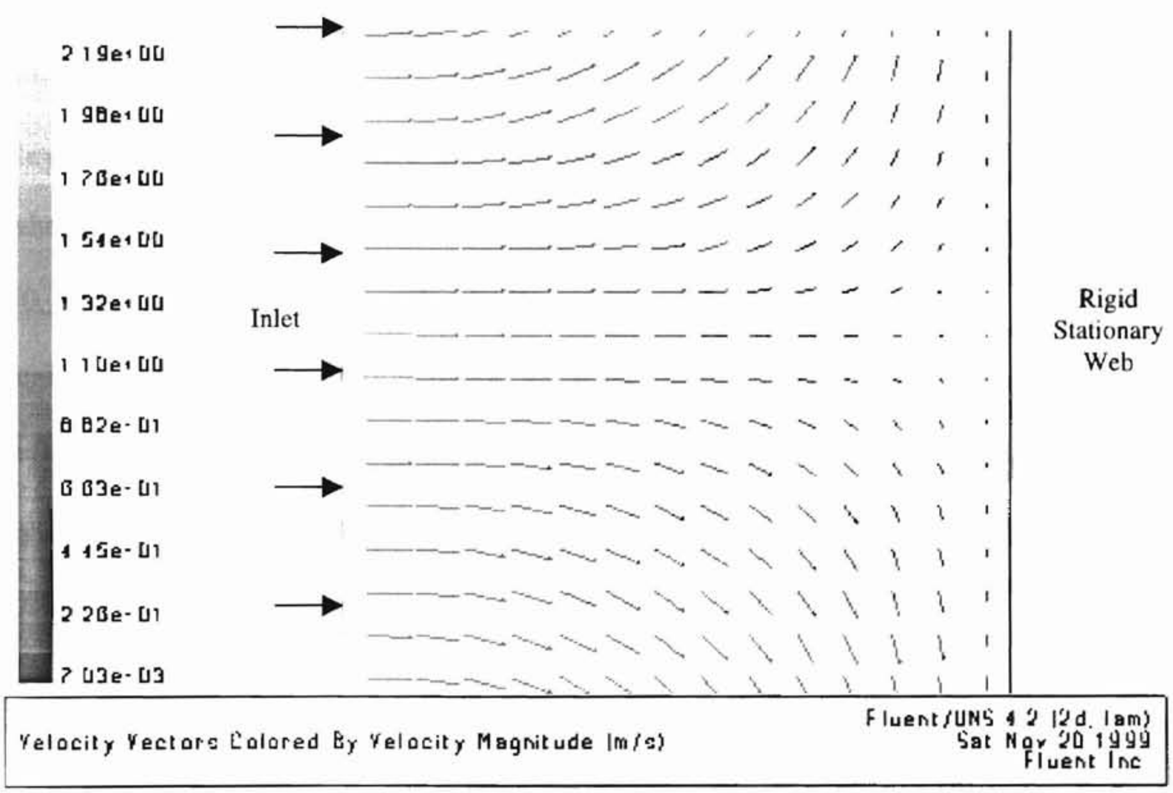


Figure 39. Velocity vectors at inlet

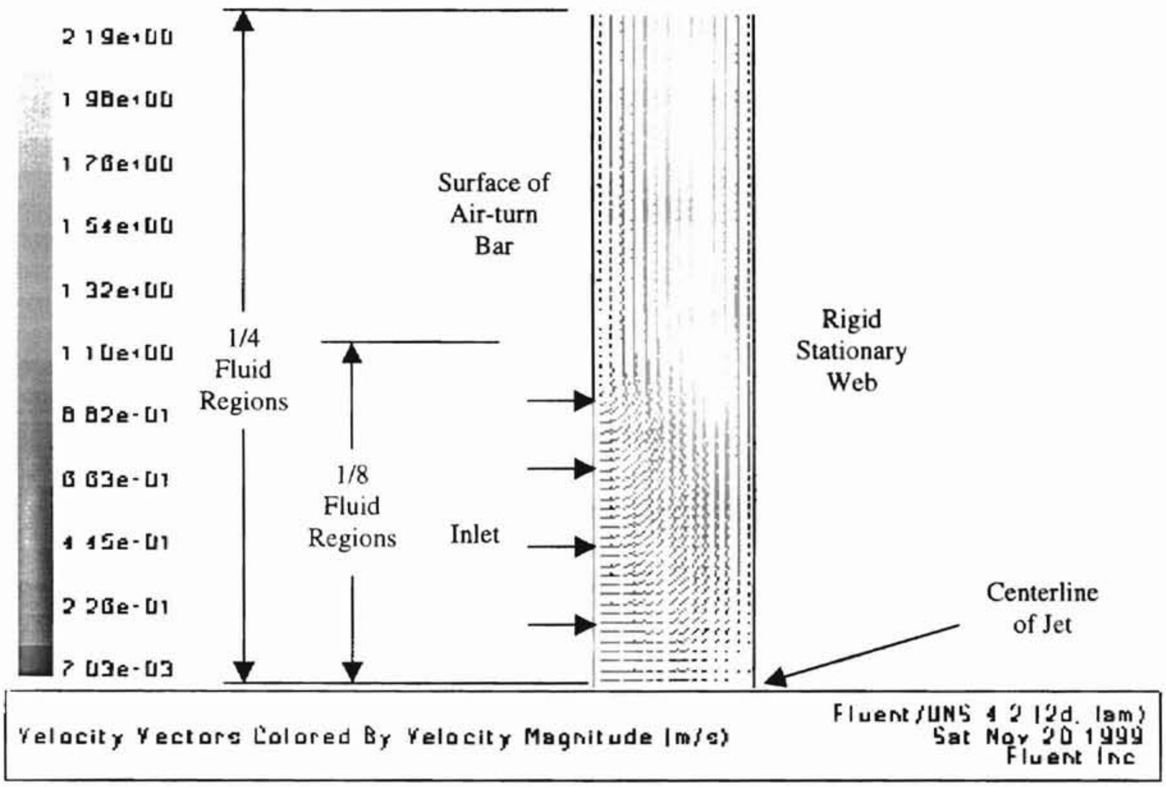


Figure 40. Velocity vectors for 1/4 of the fluid regions

7.5 Verification of Assumption

The most questionable assumption in developing the computational model is whether the vertical velocity component of the outlet of the jet is indeed zero. In Figure 40, it appears that the horizontal velocity component is zero except for the 1/8 of the fluid region nearest to the centerline of the jet, if the maximum horizontal grid is used. Grid refinement may have a larger benefit than extending the control volume, but it is appropriate both to extend the control volume of the fluid region and also to refine the grids.

CHAPTER VIII

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

8.1 Summary

We have conducted a study to provide a preliminary screening of the effect of the flow beneath a rigid stationary web on the inlet mass flowrate using an analytical approach computed by a FORTRAN program. The analytical model uses continuity and Navier-Stroke Equations to solve for the velocity components, stream function, and vorticity between the air-turn bar and the web in 2-D Cartesian (for slot model) and axisymmetric cylindrical coordinates (for hole model). Then, the test parameters and the inlet mass flowrate are normalized to seek the effects of air-gap/inlet jet width and Reynolds number on the inlet discharge coefficient. To do so, the transient solutions of the effect of air-gap, inlet jet width, and inlet dynamic pressure on the flow (velocity components, stream function and vorticity) between the air-turn bar and the web are obtained via the FORTRAN program. Using the fact that U(1, 1, t) is equal to U(1, 2, t), the horizontal inlet velocity of the converged solutions are determined, which enable us to calculate the inlet mass flowrate. Finally, the test parameters and inlet mass flowrate are normalized to seek the effect of air-gap/inlet jet width and Reynolds numbers on inlet discharge coefficient (k). The effect of air-gap/inlet jet width and Reynolds number coefficient of friction ($k_{Viscous}$) is also studied, providing us a useful way to determine whether the viscous forces that dominate the airflow in the narrow clearance of the foil-bearing problem applies to the circular air-turn bar. Discussions of the FORTRAN program and research findings are included in results section and discussion section.

8.2 Conclusions

A wide range of test parameters relating the effect of air-gap/inlet jet width and Reynolds numbers on inlet discharge coefficient (k) and coefficient of friction ($k_{Viscous}$) were tested. From this study, the following conclusions can be made:

- The inlet mass flowrate, the inlet discharge coefficient, and the coefficient of friction are functions of air-gap/inlet jet width ratio and Reynolds number.
- In actual flow, flow separation occurs near the outlet when the air-gap is very much smaller than the inlet jet width. As the air-gap increases, flow separation begins to vanish, starting from left to right. In other words, as the air-gap increases, the vortex at the outlet diminishes, starting from the surface of the air-turn bar to the rigid stationary web.
- In actual flow, Reynolds number causes $m_{inlet(R)}/\rho U_{inlet} = U_{inlet(R)} A_{inlet} / U_{inlet}$ to reduce. However, Reynolds number becomes less significant when h/b or h/d are large.
- When $h/b \leq 0.5$ or $h/d \leq 0.25$, $m_{inlet(R)}/\rho U_{inlet} = U_{inlet(R)} A_{inlet} / U_{inlet}$ diverges from the asymptote curve with an increasing rate. In this portion of the curve, viscosity is significant. When $h/b > 0.5$ or $h/d > 0.25$, $m_{inlet(R)}/\rho U_{inlet} = U_{inlet(R)} A_{inlet} / U_{inlet}$ begins to approach the asymptote curve with a slow increasing rate. Viscosity is not

very important in this portion of curve. In general, viscosity becomes more significant when Reynolds number is low.

- Relatively speaking, it looks like viscosity is more significant in the hole model than the slot model. However, this may due to the fact that the magnitude of $U_{inlet(F\ or\ R)}A_{inlet}{}'/U_{inlet}$ is larger than $U_{inlet(F\ or\ R)}A_{inlet}/U_{inlet}$.
- When h/b or h/d is small, the effect of h/b or h/d on inlet discharge coefficient (k) depends strongly on Reynolds number. Reynolds number becomes less significant when h/b or h/d are large.
- When h/b or h/d are small, the effect of h/b or h/d on coefficient of friction ($k_{Viscous}$) depends strongly on Reynolds number. Reynolds number becomes less significant when h/b or h/d are large.
- The effect of viscosity on the inlet discharge coefficient is significant when h/b or h/d is small.
- Linear and sixth-order polynomial curve fits equations relating air-gap/inlet jet width to k and $k_{Viscous}$ for different Reynolds numbers have been obtained (see result section).

8.3 Limits and Applications

This study was conducted to provide a preliminary screening of the effect of the flying height of a web on the mass flowrate from a perforated turning bar using a computer simulation of the airflow. The dimensionless parameters k and $k_{Viscous}$ do not include the pressure drop within the hole itself, but do include the flow effects from the hole to the web that cause the mass flowrate from a perforated turning bar to be reduced.

It is recommended to carry out the changes suggested in section 8.4 to include the pressure drop within the hole.

8.4 Recommendations for Future Study

It is recommended that future study should focus on improving the computational results by including the following changes:

- Run the program using finer grid size to eliminate the percent error discussed in section 7.3. It is crucial to use a finer grid (of no less than 100 by 100) if one objective is to study the flow separation around the slot or hole.
- Extend the control volume of the fluid region so that the effect of viscosity can be study thoroughly.
- For frictionless flow, predict the vorticity at the surface of the air-turn bar and the rigid stationary web by including the effect of the free-slip velocity (chapter 6 in computer codes) using the expression:

  For slot model:

$$W_p = \frac{2(\Psi_p - \Psi_{E \text{ or } W} + \Delta x V(I,J))}{(\Delta x)^2}$$

  For hole model:

$$W_p = \frac{2(\Psi_p - \Psi_{E \text{ or } W} + \Delta x V(I,J))}{(\Delta x)^2 R(J)}$$

- Extend the existing computer codes from a stationary web to a moving web. The effect of web speed on inlet discharge coefficient should be studied by holding the current test parameters constant.

Finally, it is recommended to design an experiment to validate the computational results.

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APPENDIX A: COMPUTER CODES

A.1 FORTRAN Programs of the Slot Model

A.1.1 Actual flow

A.1.2 Frictionless flow

A.2 FORTRAN Programs of the Hole Model

A.2.1 Actual flow

A.2.2 Frictionless flow

APPENDIX A.1.1

FORTRAN PROGRAM OF THE SLOT MODEL THAT UNDERGOES ACTUAL FLOW

```
C CHAPTER 0---- PRELIMINARIES
      REAL NU, PP, P, UU, SW, AG, RHO, ZZ
      INTEGER ZZZ, Z

C SETTING THE DIMENSION OF THE ARRAYS
      DIMENSION Y(100),OM(100,100),U(100,100),V(100,100),PSI(100,100)

C SETTING THE MAXIMUM ITERATION OF STREAM FUNCTION AND TIME STEP
      DATA ITMAX, ISTEPM/ 999, 9990/

C PREAMBLE PRINT STATEMENTS
      WRITE (*,*) "******************************************************"
      WRITE (*,*) "*                                                    *"
      WRITE (*,*) "*   THE EFFECT OF AIR-GAP, INLET SLOT WIDTH AND      *"
      WRITE (*,*) "*    INLET DYNAMIC PRESSURE ON THE FLOW BETWEEN      *"
      WRITE (*,*) "*       THE CIRCULAR AIR-TURN BAR (WITH AIR-         *"
      WRITE (*,*) "*           EMITTING SLOT) AND THE RIGID             *"
      WRITE (*,*) "*                  STATIONARY WEB                    *"
      WRITE (*,*) "*                                                    *"
      WRITE (*,*) "*              WRITTEN BY: CHEE LOON NG              *"
      WRITE (*,*) "*     THESIS ADVISOR: PROF. PETER M. MORETTI         *"
      WRITE (*,*) "*                                                    *"
      WRITE (*,*) "*  THIS COMPUTER PROGRAM CALCULATES THE HORIZONTAL  *"
      WRITE (*,*) "*  AND VERTICAL VELOCITY COMPONENTS, STREAM FUNC-    *"
      WRITE (*,*) "*  TION AND VORTICITY BETWEEN THE AIR-TURN BAR       *"
      WRITE (*,*) "*  WITH AIR-EMITTING SLOT AND THE WEB IN 2-D CAR-    *"
      WRITE (*,*) "*  TESIAN COORDINATES.  THE FLOW IS MODELED AS       *"
      WRITE (*,*) "*  TRANSIENT VISCOUS INCOMPRESSIBLE WITH NO BODY     *"
      WRITE (*,*) "*  FORCE.  THE SURFACE OF THE AIR-TURN BAR AND THE  *"
      WRITE (*,*) "*  WEB IS CONSIDERED AS NO-SLIP BOUNDARY.  IT IS     *"
      WRITE (*,*) "*  ASSUMED THAT THE CENTERLINE AND INLET CONSISTS    *"
      WRITE (*,*) "*  OF ONLY HORIZONTAL VELOCITY COMPONENT. IT IS      *"
      WRITE (*,*) "*  ASSUMED THAT THE OUTLET CONSISTS OF ONLY VERTI-  *"
      WRITE (*,*) "*  CAL VELOCITY COMPONENT.                           *"
      WRITE (*,*) "*                                                    *"
      WRITE (*,*) "******************************************************"

C READ IN NUMBER OF VERTICAL GRID
      WRITE(*,*) "PLEASE ENTER THE NUMBER OF VERTICAL GRID"
      WRITE(*,*) "(MAXIMUM 8)"
      READ(*,*) IMAX

C READ IN NUMBER OF HORIZONTAL GRID
      WRITE(*,*) "PLEASE ENTER THE NUMBER OF HORIZONTAL GRID"
```

```
      WRITE(*,*) "(IN ODD NUMBER)"
      READ(*,*) JMAX

C READ IN TIME STEP
      WRITE(*,*) "PLEASE ENTER THE TIME STEP"
      WRITE (*,*) "DEFAULT SUGGESTION: 0.000001"
      READ(*,*) DELT

C READ IN INITAL DYNAMIC PRESSURE OF THE AIR-EMITTING SLOT
      WRITE(*,*) "PLEASE ENTER THE INITIAL DYNAMIC PRESSURE OF THE"
      WRITE(*,*) "AIR-EMITTING SLOT (INCHES OF WATER)"
      READ(*,*) PP

C READ IN AIR-GAP
      WRITE(*,*) "PLEASE ENTER THE AIR-GAP"
      WRITE(*,*) "(IN MM)"
      READ(*,*) AG
      DELX = (AG/1000)/(IMAX-1)

C READ IN SLOT WIDTH
      WRITE(*,*) "PLEASE ENTER SLOT WIDTH"
      WRITE(*,*) "(IN MM)"
      READ(*,*) SW
      DELY = ((SW/1000)/(JMAX-1))

C READ IN KINEMATIC VISCOSITY AND DENSITY
      WRITE (*,*) "PLEASE ENTER THE KINEMATIC VISCOSITY AND"
      WRITE (*,*) "DENSITY OF AIR"
      WRITE (*,*) "AT STANDARD ATMOSHERIC PRESSURE AND TEMPERATURE-->"
      WRITE (*,*) "KINEMATIC VISCOSITY = 1.56E-5, DENSITY = 1.184"
      READ (*,*) NU, RHO

C READ IN ERPSIM AND EROMM
      WRITE (*,*) "PLEASE ENTER THE STREAM FUNCTION (ERPSIM) AND"
      WRITE (*,*) "VORTICITY (EROMM) CONVERGENCE CRITERIA"
      WRITE (*,*) "DEFAULT SUGGESTION: ERPSIM = 0.00001"
      WRITE (*,*) "DEFAULT SUGGESTION: EROMM = 0.00025"
      READ (*,*) ERPSIM, EROMM

      DELXSQ = DELX**2
      DELYSQ = DELY**2
      IMM1 = IMAX - 1
      IMP1 = IMAX + 1
      JMM1 = JMAX - 1
      JMP1 = JMAX + 1

C CALCULATE INITIAL INLET VELOCITY OF SLOT
      P = (PP*0.3048/12)*9.807*RHO
      UU = ((2*P)/RHO)**0.5

C CHAPTER 1---- STORE DATA IN FILE
      OPEN(6,FILE='SLOTVAR.DAT')
      WRITE(6,2000)
      Y(1) = 0.
      DO 100 J = 2, JMAX
  100 Y(J) = Y(J-1) + DELY
```

```
C CHAPTER 2---- SET INLET BOUNDARY CONDITIONS
      ZZ = JMM1/4
      Z = JMAX - 2*ZZ
      DO 200 J = 1, Z
      U(1,J) = UU
      V(1,J) = 0.
      OM(1,J) = 0.
  200 PSI(1,J) = U(1,J)*Y(J)

C CHAPTER 3---- SET WEST WALL BOUNDARY CONDITIONS
      ZZZ = Z + 1
      DO 300 J = ZZZ, JMAX
      U(1,J) = 0.
      V(1,J) = 0.
  300 PSI(1,J) = PSI(1,Z)

C CHAPTER 4---- SET EAST WALL BOUNDARY CONDITION AND INITIALIZATION OF
C               INTERNAL POINTS
      DO 401 I = 2, IMM1
        DO 400 J =  1, JMAX
        U(I,J) = 0.
        V(I,J) = 0.
        OM(I,J) = 0.
  400   PSI(I,J) = 0.
      PSI(IMAX,J) = 0.

      U(IMAX,J) = 0.
  401 V(IMAX,J) = 0.

C CHAPTER 5---- BEGIN TIME STEP
      DO 500 ISTEP = 1, ISTEPM
      TIME = ISTEP*DELT
      EROM = 0.

C CHAPTER 6---- CALCULATION BOUNDARY VALUES OF VORTICITY
C               (ALONG EAST WALL AND WEST WALL)
      ZZ = JMM1/4
      Z = JMAX - 2*ZZ
      DO 600 J = 1, JMAX
  600 OM(IMAX,J) = 2.*(PSI(IMAX,J) - PSI(IMM1,J))/DELXSQ
      DO 601 J = Z, JMAX
  601 OM(1,J) = 2.*(PSI(1,J) - PSI(2,J))/DELXSQ

C CHAPTER 7---- SET ZERO GRADIENT AT NORTH BOUNDARY FOR PSI, OM, AND V
      DO 700 I = 2, IMM1
      PSI(I,JMP1) = PSI(I,JMM1)
      OM(I,JMP1) = OM(I,JMM1)
  700 V(I,JMP1) = V(I,JMM1)

C CHAPTER 8---- CALCULATE VORTICITY AT NEW TIME STEP
C               (AT INTERNAL POINTS AND NORTH BOUNDARY POINTS)
      DO 800 I = 2, IMM1
      DO 800 J = 2, JMAX
      OMPRV = OM(I,J)

C SELECTION OF APPROPRIATE CONVECTIVE UPDATE FORMULA
      IF (U(I,J).EQ.0.) THEN
```

```
      A = -(U(I+1,J)*OM(I+1,J) - U(I-1,J)*OM(I-1,J))/(2.*DELX)
      ELSE IF(U(I,J).GT.0.) THEN
      A = -(U(I,J)*OM(I,J) - U(I-1,J)*OM(I-1,J))/DELX
      ELSE
      A = -(U(I+1,J)*OM(I+1,J) - U(I,J)*OM(I,J))/DELX
      ENDIF
      IF (V(I,J).EQ.0.) THEN
      B = -(V(I,J+1)*OM(I,J+1) - V(I,J-1)*OM(I,J-1))/(2.*DELY)
      ELSE IF(V(I,J).GT.0.) THEN
      B = -(V(I,J)*OM(I,J) - V(I,J-1)*OM(I,J-1))/DELY
      ELSE
      B = -(V(I,J+1)*OM(I,J+1) - V(I,J)*OM(I,J))/DELY
      ENDIF

      C = NU*(OM(I+1,J) - 2.*OM(I,J) + OM(I-1,J))/DELXSQ
      D = NU*(OM(I,J+1) - 2.*OM(I,J) + OM(I,J-1))/DELYSQ

      OM(I,J) = OM(I,J) + DELT*(A + B + C + D)

C CALCULATION OF RESIDUAL OF OMEGA AT THE NODE(I,J)=(Z,Z)
      ZZ = JMM1/4
      Z = JMAX - 2*ZZ
      IF ((I.EQ.Z).AND.(J.EQ.Z)) THEN
      OMRES = -(OM(I,J) - OMPRV)/DELT*(A + B + C + D)
      ENDIF
  800 EROM = EROM + ABS(OMPRV - OM(I,J))

C CHAPTER 9---- BEGIN ITERATION FOR PSI
      DO 901 IT = 1,ITMAX
      ERPSI = 0.
      DENOM = 2./DELXSQ + 2./DELYSQ
      DO 900 I = 2, IMM1
      DO 900 J = 2, JMAX
      PSIPRV = PSI(I,J)

      PSI(I,J) = (PSI(I,J+1)/DELYSQ+PSI(I,J-1)/DELYSQ+PSI(I+1,J)/DELXSQ
     ++PSI(I-1,J)/DELXSQ+OM(I,J))/DENOM

C CALCULATION OF RESIDUAL OF PSI AT THE NODE (I,J) = (Z,Z)
      ZZ = JMM1/4
      Z = JMAX - 2*ZZ
      IF((I.EQ.Z).AND.(J.EQ.Z)) THEN
      PSIRES = -PSI(I,J)*DENOM+(PSI(I+1,J)+PSI(I-1,J))/DELXSQ+
     +(PSI(I,J+1)+PSI(I,J-1))/DELYSQ+OM(I,J)
      ENDIF
  900 ERPSI = ERPSI + ABS(PSIPRV - PSI(I,J))

C TERMINATION CHECK FOR PSI ITERATION
      IF (ERPSI.LE.ERPSIM) GO TO 1000
  901 CONTINUE

C CHAPTER 10---- CALCULATE U AND V
 1000 DO 1001 I = 2, IMM1
      U(I,1) = (PSI(I,2) - PSI(I,1))/DELY
      DO 1001 J = 2, JMAX
      V(I,J) = -(PSI(I+1,J) - PSI(I-1,J))/(2.*DELX)
 1001 U(I,J) = (PSI(I,J+1) - PSI(I,J-1))/(2.*DELY)
```

```
C PRINT PSI(Z,Z),OM(Z,Z),U(Z,Z),V(Z,Z),PSIRES,OMRES AT THIS
C NODAL POINT(Z,Z)
 2000 FORMAT(/////,7X,'TIME',6X,'PSI(3,3)',4X,'OM(3,3)',6X,
     +'U(3,3)',6X,'V(3,3)'7X,'PSIRES',9X,'OMRES',/)
      WRITE(6,2001) TIME,PSI(Z,Z),OM(Z,Z),U(Z,Z),V(Z,Z),PSIRES,OMRES
 2001 FORMAT(5X,F7.6,4F12.4,2E15.5)

C INTERMEDIATE PRINTING
      IF (ISTEP.EQ.(ISTEP/20*20)) THEN
      WRITE(6,2002) TIME
 2002 FORMAT(1H1,///,1X,'***** INTERMEDIATE SOLUTION *****',/,
     +              10X,'TIME = ',F7.6,/)
      WRITE(6,2003) (I,I=1,8)
 2003 FORMAT(///,T45,'U-VELOCITY (M/S) ' ,//,T53,'I',/,
     + '     J',3X,9(5X,I5)/)
      DO 2004 K = 1, JMAX
      J = JMAX - K + 1
 2004 WRITE(6,2011) J,(U(I,J),I=1,IMAX)
      WRITE(6,2005) (I,I=1,8)
 2005 FORMAT(///,T45,'V-VELOCITY (M/S) ',//,T53,'I',/,
     + '     J',3X,9(5X,I5)/)
      DO 2006 K = 1, JMAX
      J = JMAX -K + 1
 2006 WRITE(6,2011) J,(V(I,J),I=1,IMAX)
      WRITE(6,2007) (I,I=1,8)
 2007 FORMAT(///,T46,'VORTICITY (1/S)',//,T53,'I',/,
     + '     J',3X,9(5X,I5)/)
      DO 2008 K = 1, JMAX
      J = JMAX - K + 1
 2008 WRITE(6,2011) J, (OM(I,J),I=1,IMAX)
      WRITE(6,2009) (I,I=1,8)
 2009 FORMAT(///,T43,'STREAM FUNCTION (M**3/S)',//,T53,'I',/,
     + '     J', 3X,9(5X,I5)/)
      DO 2010 K = 1, JMAX
      J = JMAX - K + 1
 2010 WRITE(6,2011) J,(PSI(I,J),I=1,IMAX)
 2011 FORMAT(I5,5X,9F10.4)
      WRITE(6,2012)
 2012 FORMAT(1H1)
      WRITE(6,2000)
      ENDIF

C CHAPTER 11---- TERMINATION CHECK FOR W : STEADY STATE CONVERGENCE
      IF(EROM.LE.EROMM) GO TO 3000
  500 CONTINUE

C IN CASE OF NO CONVERGENCE IS ACHIEVED AT THE MAXIMUM TIME STEP
      WRITE(6,2013) TIME
 2013 FORMAT(1H1,///,1X,'***** THE STEADY-STATE CRITERIA IS NOT',
     + ' ACHIEVED AT THE MAXIMUM TIME STEP *****',/,
     + 7X,'MAXIMUM TIME = ',F7.6,////)

C PRINT STEADY STATE SOLUTION
 3000 WRITE(6,3001) TIME
 3001 FORMAT(1H1,////,5X,'TIME = ',F7.6)
      WRITE(6,3002) (I,I=1,8)
```

```
3002 FORMAT(///,T45,'U-VELOCITY (M/S)',//,T53,'I',/,
    + '     J',3X,9(5X,I5)/)
     DO 3003 K = 1, JMAX
     J = JMAX - K + 1
3003 WRITE(6,2011) J,(U(I,J),I=1,IMAX)
     WRITE(6,3004) (I,I=1,8)
3004 FORMAT(///,T45,'V-VELOCITY (M/S)',//,T53,'I',/,
    + '     J',3X,9(5X,I5)/)
     DO 3005 K = 1, JMAX
     J = JMAX - K + 1
3005 WRITE(6,2011) J,(V(I,J),I=1,IMAX)
     WRITE(6,3006) (I,I=1,8)
3006 FORMAT(///,T46,'VORTICITY (1/S)',//,T53,'I',/,
    + '     J',3X,9(5X,I5)/)
     DO 3007 K = 1, JMAX
     J = JMAX - K + 1
3007 WRITE(6,2011) J,(OM(I,J),I=1,IMAX)
     WRITE(6,3008) (I,I=1,8)
3008 FORMAT(///,T43,'STREAM FUNCTION (M**3/S)',//,T53,'I',/,
    + '     J',3X,9(5X,I5)/)
     DO 3009 K = 1, JMAX
     J = JMAX - K + 1
3009 WRITE(6,2011) J,(PSI(I,J),I=1,IMAX)

     STOP
     END
```

APPENDIX A.1.2

FORTRAN PROGRAM OF THE SLOT MODEL THAT UNDERGOES FRICTIONLESS FLOW

In order to convert the computer code from actual flow to frictionless flow, the following modifications are made to the FORTRAN program in appendix A.1.1:

- The user must set the kinematic viscosity, NU = 0 in the input statement. This will eliminate the viscosity terms from the governing finite difference equations.
- The surface of the air-turn bar and the rigid stationary web are changed from no-slip boundary to free-slip boundary by performing the following modifications.

```
C CHAPTER 3---- SET WEST WALL BOUNDARY CONDITIONS
      ZZZ = Z + 1
      DO 300 J = ZZZ, JMAX
      U(1,J) = 0.
      V(1,J) = V(2,J)
 300  PSI(1,J) = PSI(1,Z)

C CHAPTER 4---- SET EAST WALL BOUNDARY CONDITION AND INITIALIZATION
C               OF INTERNAL POINTS
      DO 401 I = 2, IMM1
      DO 400 J =  1, JMAX
      U(I,J) = 0.
      V(I,J) = 0.
      OM(I,J) = 0.
 400  PSI(I,J) = 0.
      PSI(IMAX,J) = 0.

      U(IMAX,J) =0.
 401  V(IMAX,J) = V(IMM1,J)

C CHAPTER 7---- SET ZERO GRADIENT AT EAST BOUNDARY FOR PSI, OM, AND U
      DO 700 I = 2, IMM1
      PSI(I,JMP1) = PSI(I,JMM1)
      OM(I,JMP1) = OM(I,JMM1)
 700  V(I,JMP1) = V(I,JMM1)
      DO 701 J = 4, JMAX
 701  V(1,J) = V(2,J)
      DO 702 J = 1, JMAX
 702  V(IMAX,J) = V(IMM1,J)
```

APPENDIX A.2.1

FORTRAN PROGRAM OF THE HOLE MODEL THAT UNDERGOES ACTUAL FLOW

```
C CHAPTER 0---- PRELIMINARIES
      REAL NU, PP, P, UU, HD, AG, RHO, ZZ
      INTEGER ZZZ, Z

C SETTING THE DIMENSION OF THE ARRAYS
      DIMENSION R(100),OM(100,100),U(100,100),V(100,100),PSI(100,100)

C SETTING THE MAXIMUM ITERATION OF STREAM FUNCTION AND TIME STEP
      DATA ITMAX, ISTEPM/ 999, 9990/

C PREAMBLE PRINT STATEMENTS
      WRITE (*,*) "*****************************************************"
      WRITE (*,*) "*                                                   *"
      WRITE (*,*) "*  THE EFFECT OF AIR-GAP, INLET HOLE DIAMETER AND   *"
      WRITE (*,*) "*    INLET DYNAMIC PRESSURE ON THE FLOW BETWEEN     *"
      WRITE (*,*) "*       THE CIRCULAR AIR-TURN BAR (WITH AIR-        *"
      WRITE (*,*) "*           EMITTING HOLE) AND THE RIGID            *"
      WRITE (*,*) "*                  STATIONARY WEB                   *"
      WRITE (*,*) "*                                                   *"
      WRITE (*,*) "*             WRITTEN BY: CHEE LOON NG              *"
      WRITE (*,*) "*     THESIS ADVISOR: PROF. PETER M. MORETTI        *"
      WRITE (*,*) "*                                                   *"
      WRITE (*,*) "*  THIS COMPUTER PROGRAM CALCULATES THE HORIZONTAL *"
      WRITE (*,*) "*  AND VERTICAL VELOCITY COMPONENTS, STREAM FUNC-   *"
      WRITE (*,*) "*  TION AND VORTICITY BETWEEN THE AIR-TURN BAR      *"
      WRITE (*,*) "*  WITH AIR-EMITTING HOLE AND THE WEB IN 2-D CY-    *"
      WRITE (*,*) "*  LINDRICAL COORDINATES.  THE FLOW IS MODELED AS   *"
      WRITE (*,*) "*  TRANSIENT VISCOUS INCOMPRESSIBLE WITH NO BODY    *"
      WRITE (*,*) "*  FORCE.  THE SURFACE OF THE AIR-TURN BAR AND THE *"
      WRITE (*,*) "*  WEB IS CONSIDERED AS NO-SLIP BOUNDARY.  IT IS    *"
      WRITE (*,*) "*  ASSUMED THAT THE CENTERLINE AND INLET CONSISTS   *"
      WRITE (*,*) "*  OF ONLY HORIZONTAL VELOCITY COMPONENT. IT IS     *"
      WRITE (*,*) "*  ASSUMED THAT THE OUTLET CONSISTS OF ONLY VERTI-  *"
      WRITE (*,*) "*  CAL VELOCITY COMPONENT.                          *"
      WRITE (*,*) "*                                                   *"
      WRITE (*,*) "*****************************************************"

C READ IN NUMBER OF VERTICAL GRID
      WRITE(*,*) "PLEASE ENTER THE NUMBER OF VERTICAL GRID"
      WRITE(*,*) "(MAXIMUM 8)"
      READ(*,*) IMAX

C READ IN NUMBER OF HORIZONTAL GRID
      WRITE(*,*) "PLEASE ENTER THE NUMBER OF HORIZONTAL GRID"
```

```
      WRITE(*,*) "(IN ODD NUMBER)"
      READ(*,*) JMAX

C READ IN TIME STEP
      WRITE(*,*) "PLEASE ENTER THE TIME STEP"
      WRITE (*,*) "DEFAULT SUGGESTION: 0.000001"
      READ(*,*) DELT

C READ IN INITAL DYNAMIC PRESSURE OF THE AIR-EMITTING HOLE
      WRITE(*,*) "PLEASE ENTER THE INITIAL DYNAMIC PRESSURE OF THE"
      WRITE(*,*) "AIR-EMITTING HOLE (INCHES OF WATER)"
      READ(*,*) PP

C READ IN AIR-GAP
      WRITE(*,*) "PLEASE ENTER THE AIR-GAP"
      WRITE(*,*) "(IN MM)"
      READ(*,*) AG
      DELX = (AG/1000)/(IMAX-1)

C READ IN HOLE DIAMETER
      WRITE(*,*) "PLEASE ENTER THE HOLE DIAMETER"
      WRITE(*,*) "(IN MM)"
      READ(*,*) HD
      DELR = ((HD/1000)/(JMAX-1))

C READ IN KINEMATIC VISCOSITY AND DENSITY
      WRITE (*,*) "PLEASE ENTER THE KINEMATIC VISCOSITY AND"
      WRITE (*,*) "DENSITY OF AIR"
      WRITE (*,*) "AT STANDARD ATMOSHERIC PRESSURE AND TEMPERATURE-->"
      WRITE (*,*) "KINEMATIC VISCOSITY = 1.56E-5, DENSITY = 1.184"
      READ (*,*) NU, RHO

C READ IN STREAM FUNCTION (ERPSIM) AND VORTICITY (EROMM) CRITERIA
      WRITE (*,*) "PLEASE ENTER THE STREAM FUNCTION (ERPSIM) AND"
      WRITE (*,*) "VORTICITY (EROMM) CONVERGENCE CRITERIA"
      WRITE (*,*) "DEFAULT SUGGESTION: ERPSIM = 0.00001"
      WRITE (*,*) "DEFAULT SUGGESTION: EROMM = 0.00025"
      READ (*,*) ERPSIM, EROMM

      DELXSQ = DELX**2
      DELRSQ = DELR**2
      IMM1 = IMAX - 1
      IMP1 = IMAX + 1
      JMM1 = JMAX - 1
      JMP1 = JMAX + 1

C CALCULATE INITIAL INLET VELOCITY OF HOLE
      P = (PP*0.3048/12)*9.807*RHO
      UU = (2*P/RHO)**0.5

C CHAPTER 1---- STORE DATA IN FILE
      OPEN(6,FILE='HOLEVAR.DAT')
      WRITE(6,2000)
      R(1) = 0.
      DO 100 J = 2, JMAX
  100 R(J) = R(J-1) + DELR
```

```
C CHAPTER 2---- SET INLET BOUNDARY CONDITIONS
      ZZ = JMM1/4
      Z = JMAX - 2*ZZ
      DO 200 J = 1, Z
      U(1,J) = UU
      V(1,J) = 0.
      OM(1,J) = 0.
  200 PSI(1,J) = U(1,J)*((R(J)**2)/2)

C CHAPTER 3---- SET WEST WALL BOUNDARY CONDITIONS
      ZZZ = Z + 1
      DO 300 J = ZZZ, JMAX
      U(1,J) = 0.
      V(1,J) = 0.
  300 PSI(1,J) = PSI(1,Z)

C CHAPTER 4---- SET EAST WALL BOUNDARY CONDITION AND INITIALIZATION OF
C           INTERNAL POINTS
      DO 401 I = 2, IMM1
        DO 400 J =  1, JMAX
        U(I,J) = 0.
        V(I,J) = 0.
        OM(I,J) = 0.
  400   PSI(I,J) = 0.
      PSI(IMAX,J) = 0.

      U(IMAX,J) = 0.
  401 V(IMAX,J) = 0.

C CHAPTER 5---- BEGIN TIME STEP
      DO 500 ISTEP = 1, ISTEPM
      TIME = ISTEP*DELT
      EROM = 0.

C CHAPTER 6---- CALCULATION BOUNDARY VALUES OF VORTICITY
C            (ALONG EAST WALL AND WEST WALL)
      ZZ = JMM1/4
      Z = JMAX - 2*ZZ
      OM(IMAX,1) = 0.
      DO 600 J = 2, JMAX
  600 OM(IMAX,J) = 2.*(PSI(IMAX,J) - PSI(IMM1,J))/(R(J)*DELXSQ)
      DO 601 J = Z, JMAX
  601 OM(1,J) = 2.*(PSI(1,J) - PSI(2,J))/(R(J)*DELXSQ)

C CHAPTER 7---- SET ZERO GRADIENT AT EAST BOUNDARY FOR PSI, OM, AND U
      DO 700 I = 2, IMM1
      PSI(I,JMP1) = PSI(I,JMM1)
      OM(I,JMP1) = OM(I,JMM1)
  700 V(I,JMP1) = V(I,JMM1)

C CHAPTER 8---- CALCULATE VORTICITY AT NEW TIME STEP
C            (AT INTERNAL POINTS AND NORTH BOUNDARY POINTS)
      DO 800 I = 2, IMM1
      DO 800 J = 2, JMAX
      OMPRV = OM(I,J)

C SELECTION OF APPROPRIATE CONVECTIVE UPDATE FORMULA
```

```
      IF (U(I,J).EQ.0.) THEN
      A = -(U(I+1,J)*OM(I+1,J) - U(I-1,J)*OM(I-1,J))/(2.*DELX)
      ELSE IF(U(I,J).GT.0.) THEN
      A = -(U(I,J)*OM(I,J) - U(I-1,J)*OM(I-1,J))/DELX
      ELSE
      A = -(U(I+1,J)*OM(I+1,J) - U(I,J)*OM(I,J))/DELX
      ENDIF
      IF (V(I,J).EQ.0.) THEN
      B = -(V(I,J+1)*OM(I,J+1) - V(I,J-1)*OM(I,J-1))/(2.*DELR)
      ELSE IF(V(I,J).GT.0.) THEN
      B = -(V(I,J)*OM(I,J) - V(I,J-1)*OM(I,J-1))/DELR
      ELSE
      B = -(V(I,J+1)*OM(I,J+1) - V(I,J)*OM(I,J))/DELR
      ENDIF

      C = NU*(OM(I+1,J) - 2.*OM(I,J) + OM(I-1,J))/DELXSQ
      D = NU*(OM(I,J+1) - 2.*OM(I,J) + OM(I,J-1))/DELRSQ
      E = NU*(OM(I,J+1) - OM(I,J-1))/(DELR*R(J)*2)
      F = NU*(-OM(I,J)/(R(J)**2))

      OM(I,J) = OM(I,J) + DELT*(A + B + C + D + E + F)

C CALCULATION OF RESIDUAL OF OMEGA AT THE NODE(I,J)=(Z,Z)
      ZZ = JMM1/4
      Z = JMAX - 2*ZZ
      IF ((I.EQ.Z).AND.(J.EQ.Z)) THEN
      OMRES = -(OM(I,J) - OMPRV)/DELT*(A + B + C + D + E + F)
      ENDIF
  800 EROM = EROM + ABS(OMPRV - OM(I,J))

C CHAPTER 9---- BEGIN ITERATION FOR PSI
      DO 901 IT = 1,ITMAX
      ERPSI = 0.
      DENOM = 2./DELXSQ + 2./DELRSQ
      DO 900 I = 2, IMM1
      DO 900 J = 2, JMAX
      PSIPRV = PSI(I,J)
      P = 1/DELRSQ - 1/(2*R(J)*DELR)
      Q = 1/DELRSQ + 1/(2*R(J)*DELR)

      PSI(I,J) = (PSI(I,J+1)*P+PSI(I,J-1)*Q+R(J)*OM(I,J)+(PSI(I+1,J)
     ++PSI(I-1,J))/DELXSQ)/DENOM

C CALCULATION OF RESIDUAL OF PSI AT THE NODE (I,J) = (Z,Z)
      ZZ = JMM1/4
      Z = JMAX - 2*ZZ
      IF((I.EQ.Z).AND.(J.EQ.Z)) THEN
      PSIRES = -PSI(I,J)*DENOM+(PSI(I+1,J)+PSI(I-1,J))/DELXSQ+
     +PSI(I,J+1)*P+PSI(I,J-1)*Q+R(J)*OM(I,J)
      ENDIF
  900 ERPSI = ERPSI + ABS(PSIPRV - PSI(I,J))

C TERMINATION CHECK FOR PSI ITERATION
       IF (ERPSI.LE.ERPSIM) GO TO 1000
  901 CONTINUE

C CHAPTER 10---- CALCULATE U AND V
```

```
 1000 DO 1001 I = 2, IMM1
      U(I,1) = 2.*(PSI(I,2) - PSI(I,1))/DELRSQ
      DO 1001 J = 2, JMAX
      V(I,J) = -(PSI(I+1,J) - PSI(I-1,J))/(2.*R(J)*DELX)
 1001 U(I,J) = (PSI(I,J+1) - PSI(I,J-1))/(2.*R(J)*DELR)

C PRINT PSI(Z,Z),OM(Z,Z),U(Z,Z),V(Z,Z),PSIRES,OMRES AT THIS
C NODAL POINT(Z,Z)
 2000 FORMAT(/////,7X,'TIME',6X,'PSI(3,3)',4X,'OM(3,3)',6X,
     +'U(3,3)',6X,'V(3,3)'7X,'PSIRES',9X,'OMRES',/)
      WRITE(6,2001) TIME,PSI(Z,Z),OM(Z,Z),U(Z,Z),V(Z,Z),PSIRES,OMRES
 2001 FORMAT(5X,F7.6,4F12.4,2E15.5)

C INTERMEDIATE PRINTING
      IF (ISTEP.EQ.(ISTEP/20*20)) THEN
      WRITE(6,2002) TIME
 2002 FORMAT(1H1,///,1X,'***** INTERMEDIATE SOLUTION *****',/,
     +             10X,'TIME = ',F7.6,/)
      WRITE(6,2003) (I,I=1,IMAX)
 2003 FORMAT(///,T45,'U-VELOCITY (M/S) ' ,//,T53,'I',/,
     + '     J',3X,9(5X,I5)/)
      DO 2004 K = 1, JMAX
      J = JMAX - K + 1
 2004 WRITE(6,2011) J,(U(I,J),I=1,IMAX)
      WRITE(6,2005) (I,I=1,IMAX)
 2005 FORMAT(///,T45,'V-VELOCITY (M/S) ',//,T53,'I',/,
     + '     J',3X,9(5X,I5)/)
      DO 2006 K = 1, JMAX
      J = JMAX -K + 1
 2006 WRITE(6,2011) J,(V(I,J),I=1,IMAX)
      WRITE(6,2007) (I,I=1,IMAX)
 2007 FORMAT(///,T46,'VORTICITY (1/S)',//,T53,'I',/,
     + '     J',3X,9(5X,I5)/)
      DO 2008 K = 1, JMAX
      J = JMAX - K + 1
 2008 WRITE(6,2011) J, (OM(I,J),I=1,IMAX)
      WRITE(6,2009) (I,I=1,IMAX)
 2009 FORMAT(///,T43,'STREAM FUNCTION (M**3/S)',//,T53,'I',/,
     + '     J', 3X,9(5X,I5)/)
      DO 2010 K = 1, JMAX
      J = JMAX - K + 1
 2010 WRITE(6,2011) J,(PSI(I,J),I=1,IMAX)
 2011 FORMAT(I5,5X,9F10.4)
      WRITE(6,2012)
 2012 FORMAT(1H1)
      WRITE(6,2000)
      ENDIF

C CHAPTER 11---- TERMINATION CHECK FOR W : STEADY STATE CONVERGENCE
      IF(EROM.LE.EROMM) GO TO 3000
  500 CONTINUE

C IN CASE OF NO CONVERGENCE IS ACHIEVED AT THE MAXIMUM TIME STEP
      WRITE(6,2013) TIME
 2013 FORMAT(1H1,///,1X,'***** THE STEADY-STATE CRITERIA IS NOT',
     + ' ACHIEVED AT THE MAXIMUM TIME STEP *****',/,
     + 7X,'MAXIMUM TIME = ',F7.6,////)
```

```
C PRINT STEADY STATE SOLUTION
 3000 WRITE(6,3001) TIME
 3001 FORMAT(1H1,////,5X,'TIME = ',F7.6)
      WRITE(6,3002) (I,I=1,IMAX)
 3002 FORMAT(///,T45,'U-VELOCITY (M/S)',//,T53,'I',/,
     + '      J',3X,9(5X,I5)/)
      DO 3003 K = 1, JMAX
      J = JMAX - K + 1
 3003 WRITE(6,2011) J,(U(I,J),I=1,IMAX)
      WRITE(6,3004) (I,I=1,IMAX)
 3004 FORMAT(///,T45,'V-VELOCITY (M/S)',//,T53,'I',/,
     + '      J',3X,9(5X,I5)/)
      DO 3005 K = 1, JMAX
      J = JMAX - K + 1
 3005 WRITE(6,2011) J,(V(I,J),I=1,IMAX)
      WRITE(6,3006) (I,I=1,IMAX)
 3006 FORMAT(///,T46,'VORTICITY (1/S)',//,T53,'I',/,
     + '      J',3X,9(5X,I5)/)
      DO 3007 K = 1, JMAX
      J = JMAX - K + 1
 3007 WRITE(6,2011) J,(OM(I,J),I=1,IMAX)
      WRITE(6,3008) (I,I=1,IMAX)
 3008 FORMAT(///,T43,'STREAM FUNCTION (M**3/S)',//,T53,'I',/,
     + '      J',3X,9(5X,I5)/)
      DO 3009 K = 1, JMAX
      J = JMAX - K + 1
 3009 WRITE(6,2011) J,(PSI(I,J),I=1,IMAX)

      STOP
      END
```

APPENDIX A.2.2

FORTRAN PROGRAM OF THE HOLE MODEL THAT UNDERGOES FRICTIONLESS FLOW

In order to convert the computer code from actual flow to frictionless flow, the following modifications are made to the FORTRAN program in appendix A.2.1:

- The user must set the kinematic viscosity, NU = 0 in the input statement. This will eliminate the viscosity terms from the governing finite difference equations.
- The surface of the air-turn bar and the rigid stationary web are changed from no-slip boundary to free-slip boundary by performing the following modifications.

```
C CHAPTER 3---- SET WEST WALL BOUNDARY CONDITIONS
     ZZZ = Z + 1
     DO 300 J = ZZZ, JMAX
     U(1,J) = 0.
     V(1,J) = V(2,J)
 300 PSI(1,J) = PSI(1,Z)

C CHAPTER 4---- SET EAST WALL BOUNDARY CONDITION AND INITIALIZATION
C               OF INTERNAL POINTS
     DO 401 I = 2, IMM1
     DO 400 J =  1, JMAX
     U(I,J) = 0.
     V(I,J) = 0.
     OM(I,J) = 0.
 400 PSI(I,J) = 0.
     PSI(IMAX,J) = 0.

     U(IMAX,J) =0.
 401 V(IMAX,J) = V(IMM1,J)

C CHAPTER 7---- SET ZERO GRADIENT AT EAST BOUNDARY FOR PSI, OM, AND U
     DO 700 I = 2, IMM1
     PSI(I,JMP1) = PSI(I,JMM1)
     OM(I,JMP1) = OM(I,JMM1)
 700 V(I,JMP1) = V(I,JMM1)
     DO 701 J = 4, JMAX
 701 V(1,J) = V(2,J)
     DO 702 J = 1, JMAX
 702 V(IMAX,J) = V(IMM1,J)
```

APPENDIX B: SAMPLE SOLUTIONS

B.1 Output Solutions of the Slot Model

- B.1.1 Preamble of computer code and user inputs
- B.1.2 Actual flow solutions
- B.1.3 Frictionless flow solutions

B.2 Output Solutions of the Hole Model

- B.2.1 Preamble of computer code and user inputs
- B.2.2 Actual flow solutions
- B.2.3 Frictionless flow solutions

APPENDIX B.1.1

PREAMBLE OF COMPUTER CODE AND USER INPUTS OF SLOT MODEL

```
***************************************************
*                                                 *
*   THE EFFECT OF AIR-GAP, INLET SLOT WIDTH AND   *
*    INLET DYNAMIC PRESSURE ON THE FLOW BETWEEN   *
*       THE CIRCULAR AIR-TURN BAR (WITH AIR-      *
*           EMITTING SLOT) AND THE RIGID          *
*                  STATIONARY WEB                 *
*                                                 *
*             WRITTEN BY: CHEE LOON NG            *
*     THESIS ADVISOR: PROF. PETER M. MORETTI      *
*                                                 *
*  THIS COMPUTER PROGRAM CALCULATES THE HORIZONTAL *
*  AND VERTICAL VELOCITY COMPONENTS, STREAM FUNC-  *
*  TION AND VORTICITY BETWEEN THE AIR-TURN BAR     *
*  WITH AIR-EMITTING SLOT AND THE WEB IN 2-D CAR-  *
*  TESIAN COORDINATES.  THE FLOW IS MODELED AS     *
*  TRANSIENT VISCOUS INCOMPRESSIBLE WITH NO BODY   *
*  FORCE.  THE SURFACE OF THE AIR-TURN BAR AND THE *
*  WEB IS CONSIDERED AS NO-SLIP BOUNDARY.  IT IS   *
*  ASSUMED THAT THE CENTERLINE AND INLET CONSISTS  *
*  OF ONLY HORIZONTAL VELOCITY COMPONENT. IT IS    *
*  ASSUMED THAT THE OUTLET CONSISTS OF ONLY VERTI- *
*  CAL VELOCITY COMPONENT.                         *
*                                                 *
***************************************************

PLEASE ENTER THE NUMBER OF VERTICAL GRID
(MAXIMUM 8)
8

PLEASE ENTER THE NUMBER OF HORIZONTAL GRID
(IN ODD NUMBER)
5

PLEASE ENTER THE TIME STEP
DEFAULT SUGGESTION: 0.00001
0.00001

PLEASE ENTER THE INITIAL DYNAMIC PRESSURE OF THE
AIR-EMITTING SLOT (INCHES OF WATER)
1

PLEASE ENTER THE AIR-GAP
```

```
(IN MM)
2.4

PLEASE ENTER SLOT WIDTH
(IN MM)
4

PLEASE ENTER THE KINEMATIC VISCOSITY AND
DENSITY OF AIR
AT STANDARD ATMOSHERIC PRESSURE AND TEMPERATURE-->
KINEMATIC VISCOSITY = 1.56E-5, DENSITY = 1.184
1.56E-5
1.184

PLEASE ENTER THE STREAM FUNCTION (ERPSIM) AND
VORTICITY (EROMM) CONVERGENCE CRITERIA
DEFAULT SUGGESTION: ERPSIM = 0.00001
DEFAULT SUGGESTION: EROMM = 0.00025
0.00001
0.00025
```

[Note: In addition to the modifications described in appendix A.1.2, the user must enter zero for kinematic viscosity when generating output solution for frictionless flow.]

APPENDIX B.1.2

OUTPUT SOLUTION OF THE SLOT MODEL THAT UNDERGOES ACTUAL FLOW

First intermediate solution:

TIME	PSI(3,3)	OM(3,3)	U(3,3)	V(3,3)	PSIRES	OMRES
000010	.0009	.3704	.2209	.6921	.22165E-03	-.13719E+10
.000020	.0009	4.0290	.2479	.6835	-.52267E-03	-.13385E+12
.000030	.0009	8.7494	.2500	.6877	.21322E-03	-.22282E+12
.000040	.0009	14.3033	.2508	.6929	.48674E-03	-.30846E+12
.000050	.0009	20.6271	.2514	.6978	.20179E-03	-.39991E+12
.000060	.0009	27.6660	.2519	.7025	.42864E-03	-.49545E+12
.000070	.0009	35.3679	.2523	.7070	.29095E-03	-.59319E+12
.000080	.0009	43.6838	.2526	.7113	-.54199E-03	-.69154E+12
.000090	.0009	52.5692	2530	.7153	.14124E-03	-.78950E+12
.000100	.0009	61.9796	.2534	.7191	.38070E-03	-.88557E+12
.000110	.0009	71.8748	.2538	.7225	-.21472E-03	-.97915E+12
.000120	.0009	82.2150	.2541	.7259	.46302E-03	-.10692E+13
.000130	.0009	92.9635	.2545	.7289	.21552E-03	-.11553E+13
.000140	.0009	104.0851	.2549	.7318	-.49760E-03	-.12369E+13
.000150	.0009	115.5465	.2553	.7346	-.12582E-04	-.13136E+13
.000160	.0010	127.3172	2557	.7370	-.45655E-03	-.13855E+13
.000170	.0010	139.3669	.2561	.7394	-.46010E-03	-.14520E+13
.000180	.0010	151.6665	.2565	.7416	.25004E-03	-.15128E+13
.000190	.0010	164.1904	.2569	.7437	.40395E-03	-.15685E+13
.000200	.0010	176.9133	.2574	.7456	-.39842E-03	-.16187E+13

***** INTERMEDIATE SOLUTION *****
TIME = .000200

U-VELOCITY (M/S)

J \ I	1	2	3	4	5	6	7	8
5	.0000	-.0008	-.0008	-.0006	-.0004	-.0002	.0000	.0000
4	.0000	-.0106	.0206	.0362	.0370	.0285	.0149	.0000
3	.7058	.3112	.2574	.2040	.1516	.0998	.0486	.0000
2	.7058	.6194	.4837	.3638	.2602	.1671	.0803	.0000
1	.7058	.6003	.4906	.3829	.2801	.1823	.0882	.0000

V-VELOCITY (M/S)

J \ I	1	2	3	4	5	6	7	8
5	.0000	.5880	6091	.6040	.5964	.5890	5704	.0000
4	.0000	.5926	.6298	.6155	.5964	.5803	5570	.0000
3	.0000	6480	7456	.6519	.5738	.5246	4874	.0000
2	.0000	.3139	.3170	.3069	.2926	.2800	2658	.0000
1	.0000	0000	0000	.0000	.0000	.0000	0000	.0000

VORTICITY (1/S)

J \ I	1	2	3	4	5	6	7	8
5	3313.3130	125.2122	2.5856	.0483	-.0058	-.9163	-78.4578	-3240.7830
4	3240.5860	237.9163	13.9324	.6778	.0173	-.8890	-75.8645	-3153.6840

3	3003.6120	1505.7690	176.9133	12.1088	.5230	-.7161	-63.4082	-2728.5040
2	.0000	2.4224	.5337	.0566	.0006	-.4023	-34.9982	-1498.9600
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

STREAM FUNCTION (M**3/S)

J \ I	1	2	3	4	5	6	7	8
5	.0014	.0012	.0010	.0008	.0006	.0004	.0002	.0000
4	.0014	.0012	.0010	.0008	.0006	.0004	.0002	.0000
3	.0014	.0012	.0010	.0007	.0005	.0003	.0002	.0000
2	.0007	.0006	.0005	.0004	.0003	.0002	.0001	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Final steady state solution:

TIME	PSI(3,3)	OM(3,3)	U(3,3)	V(3,3)	PSIRES	OMRES
.021610	.0012	983.0952	3899	.5272	61732E-03	.00000E+00
.021620	.0012	983.0952	.3899	.5272	.61732E-03	.00000E+00
.021630	.0012	983.0952	.3899	.5272	.61732E-03	.00000E+00
.021640	.0012	983.0953	.3899	.5272	.56194E-03	-.19079E+02
.021650	.0012	983.0953	.3899	.5272	.56194E-03	.00000E+00
.021660	.0012	983.0953	3899	.5272	.56194E-03	.00000E+00

TIME = .021660

U-VELOCITY (M/S)

J \ I	1	2	3	4	5	6	7	8
5	0000	0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0324	.0678	.0775	0641	.0352	.0035	.0000
3	7058	.3982	.3899	.3396	.2616	.1674	.0691	.0000
2	7058	.6744	.5979	.4937	.3724	.2412	.1072	.0000
1	.7058	.6329	.5491	.4518	.3421	.2223	.0980	.0000

V-VELOCITY (M/S)

J \ I	1	2	3	4	5	6	7	8
5	.0000	.1170	.3956	6685	.8598	.9502	.8062	.0000
4	.0000	.1208	.4349	.6760	.8369	.9173	.8124	.0000
3	.0000	.3149	.5272	6575	.7364	.7736	.7035	.0000
2	.0000	.2286	.2641	3019	.3347	.3559	.3242	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

VORTICITY (1/S)

J \ I	1	2	3	4	5	6	7	8
5	-34.1786	685.8697	913.1068	706.8647	447.3144	86.5475	-965.1032	-3767.1630
4	-298.6544	1099.1870	959.5134	709.4213	474.5796	186.2019	-682.5842	-4019.8320
3	1067.9420	1404.6870	983.0953	682.1884	452.6281	231.5779	-360.5792	-3648.3320
2	0000	9.6846	16.7608	22.2495	24.5639	1.0486	-242.1370	-1667.5650
1	0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

STREAM FUNCTION (M**3/S)

J \ I	1	2	3	4	5	6	7	8
5	.0014	.0014	.0013	.0011	.0009	.0006	.0002	.0000
4	.0014	.0014	.0013	.0011	0009	.0006	.0002	.0000
3	.0014	.0013	.0012	.0010	0007	.0005	.0002	.0000
2	.0007	.0006	.0005	.0005	0003	.0002	.0001	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

APPENDIX B.1.3

OUTPUT SOLUTION OF THE SLOT MODEL THAT UNDERGOES FRICTIONLESS FLOW

First intermediate solution:

TIME	PSI(3,3)	OM(3,3)	U(3,3)	V(3,3)	PSIRES	OMRES
.000010	.0009	.0000	.2200	.6903	-.52886E-03	.00000E+00
.000020	.0009	2.8471	.2467	6814	.40544E-03	-.81059E+11
.000030	.0009	6.6022	.2487	.6853	-.35931E-03	-.14101E+12
.000040	.0009	11.0698	.2494	6903	.36584E-03	-.19959E+12
.000050	.0009	16.2011	.2498	6951	-.15644E-03	-.26330E+12
.000060	.0009	21.9544	.2502	.6997	-.73522E-04	-.33101E+12
.000070	.0009	28.2903	.2505	.7040	.27961E-03	-.40143E+12
.000080	.0009	35.1712	.2507	.7082	.49822E-04	-.47348E+12
.000090	.0009	42.5635	.2510	.7122	-.45520E-03	-.54646E+12
.000100	.0009	50.4324	2512	.7159	-.28800E-03	-.61919E+12
.000110	.0009	58.7473	.2515	.7194	.39636E-03	-.69137E+12
.000120	.0009	67.4767	.2517	.7227	-.39152E-03	-.76202E+12
.000130	0009	76.5926	.2520	.7258	.25413E-03	-.83101E+12
.000140	.0009	86.0667	.2523	.7288	-.14195E-03	-.89759E+12
.000150	.0009	95.8734	.2526	.7315	.13299E-03	-.96170E+12
.000160	.0009	105.9869	.2529	.7341	.39469E-03	-.10228E+13
.000170	.0010	116.3838	.2532	.7367	.30138E-03	-.10810E+13
.000180	.0010	127.0418	.2535	.7389	.23602E-03	-.11359E+13
000190	.0010	137.9387	.2538	.7410	-.18669E-04	-.11874E+13
000200	.0010	149.0535	.2542	.7431	.43277E-03	-.12354E+13

***** INTERMEDIATE SOLUTION *****
TIME = .000200

U-VELOCITY (M/S)

J \ I	1	2	3	4	5	6	7	8
5	.0000	-.0006	-.0007	-.0006	-.0004	-.0003	-.0001	.0000
4	.0000	-.0136	.0194	.0356	.0367	.0286	.0154	.0000
3	.7058	.3066	.2542	.2021	.1509	.1002	.0500	.0000
2	.7058	.6172	.4811	.3624	.2600	.1682	.0827	.0000
1	.7058	.5997	.4900	.3828	.2808	.1840	.0910	.0000

V-VELOCITY (M/S)

J \ I	1	2	3	4	5	6	7	8
5	.5997	.5988	.5997	.5945	.5868	.5793	.5740	.5734
4	.6047	.6028	.6211	.6063	.5872	5710	.5606	.5597
3	.0000	.6554	7431	.6449	.5664	5172	.4906	.4893
2	.0000	.3148	.3163	.3050	.2899	2768	.2683	.2678
1	.0000	.0000	0000	.0000	.0000	0000	.0000	.0000

VORTICITY (1/S)

J \ I	1	2	3	4	5	6	7	8
5	3486.2500	6.2850	.3288	.0112	.0003	.0000	.0000	-3334.2620
4	3402.2350	124.8545	8.6244	.3688	.0105	.0002	.0000	-3244.5700
3	3079.7830	1473.1770	149.0535	8.5480	.3011	.0065	.0001	-2805.7470
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	-1545.0750

1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

STREAM FUNCTION (M**3/S)

	I							
J	1	2	3	4	5	6	7	8
5	.0014	.0012	.0010	.0008	.0006	.0004	.0002	.0000
4	0014	.0012	.0010	.0008	.0006	.0004	.0002	.0000
3	0014	.0012	.0010	.0007	.0005	.0003	.0002	.0000
2	.0007	.0006	.0005	.0004	.0003	.0002	.0001	.0000
1	0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

Final solution:

TIME	PSI(3,3)	OM(3,3)	U(3,3)	V(3,3)	PSIRES	OMRES
.099810	.0012	930.8461	4281	.4814	-.70454E-03	-.14687E+03
.099820	.0012	930.8468	.4281	.4814	-.86787E-03	-.55023E+04
.099830	.0012	930.8462	4281	.4814	-.81044E-03	-.38700E+04
.099840	.0012	930.8463	.4281	.4814	.87272E-03	-.15259E+03
.099850	.0012	930.8473	.4281	.4814	-.10862E-02	-.96191E+04
.099860	.0012	930.8469	4281	.4814	.55216E-03	-.17477E+04
.099870	.0012	930.8472	4281	.4814	-.26155E-03	-.10138E+04
.099880	0012	930.8461	.4281	.4814	-.45271E-03	-.10943E+05
.099890	.0012	930.8458	.4281	.4814	-.41834E-03	-.84877E+03
.099900	.0012	930.8464	.4281	.4814	.28660E-03	-.37060E+04

***** THE STEADY-STATE CRITERIA IS NOT ACHIEVED AT THE MAXIMUM TIME STEP *****
MAXIMUM TIME = .099900

TIME = .099900

U-VELOCITY (M/S)

	I							
J	1	2	3	4	5	6	7	8
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	0000	.0387	.1061	.1146	.1020	.0753	.0398	.0000
3	7058	.4396	.4281	.3796	.3047	.2125	.1095	.0000
2	7058	.6778	.6088	.5127	.3984	.2722	.1385	.0000
1	7058	6356	.5554	.4627	.3583	.2444	.1239	.0000

V-VELOCITY (M/S)

	I							
J	1	2	3	4	5	6	7	8
5	-.0265	-.0265	.2599	.6257	.8161	.9393	1.0136	1.0136
4	.0000	-.0001	.4272	.6475	.8057	9113	.9761	.9761
3	.0000	.2829	.4814	.6137	.7014	7581	.7940	.7940
2	.0000	.2193	.2521	.2875	.3185	.3418	.3564	.3564
1	.0000	.0000	.0000	.0000	.0000	0000	.0000	.0000

VORTICITY (1/S)

	I							
J	1	2	3	4	5	6	7	8
5	-361.1706	42.8886	1500.6570	735.2098	507.7537	328.5068	183.7713	-6068.7410
4	-1753.3790	1995.9840	914.0797	710.4277	514.3085	338.6117	190.8211	-5832.9940
3	954.9142	1256.1670	930.8464	675.4636	470.2229	303.3175	168.8600	-4713.2980
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	-2107.9620
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

STREAM FUNCTION (M**3/S)

	I							
J	1	2	3	4	5	6	7	8
5	.0014	.0014	.0014	.0013	.0010	.0007	.0004	.0000
4	.0014	.0015	.0014	.0012	.0010	.0007	.0003	.0000
3	.0014	0014	.0012	.0010	.0008	.0005	.0003	.0000
2	.0007	.0006	.0006	.0005	.0004	.0002	.0001	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

APPENDIX B.2.1

PREAMBLE OF COMPUTER CODE AND USER INPUTS OF HOLE MODEL

```
****************************************************
*                                                  *
*  THE EFFECT OF AIR-GAP, INLET HOLE DIAMETER AND  *
*    INLET DYNAMIC PRESSURE ON THE FLOW BETWEEN    *
*       THE CIRCULAR AIR-TURN BAR (WITH AIR-       *
*           EMITTING HOLE) AND THE RIGID           *
*                  STATIONARY WEB                  *
*                                                  *
*            WRITTEN BY: CHEE LOON NG              *
*      THESIS ADVISOR: PROF. PETER M. MORETTI      *
*                                                  *
*  THIS COMPUTER PROGRAM CALCULATES THE HORIZONTAL *
*  AND VERTICAL VELOCITY COMPONENTS, STREAM FUNC-  *
*  TION AND VORTICITY BETWEEN THE AIR-TURN BAR     *
*  WITH AIR-EMITTING HOLE AND THE WEB IN 2-D CY-   *
*  LINDRICAL COORDINATES.  THE FLOW IS MODELED AS  *
*  TRANSIENT VISCOUS INCOMPRESSIBLE WITH NO BODY   *
*  FORCE.  THE SURFACE OF THE AIR-TURN BAR AND THE *
*  WEB IS CONSIDERED AS NO-SLIP BOUNDARY.  IT IS   *
*  ASSUMED THAT THE CENTERLINE AND INLET CONSISTS  *
*  OF ONLY HORIZONTAL VELOCITY COMPONENT. IT IS    *
*  ASSUMED THAT THE OUTLET CONSISTS OF ONLY VERTI- *
*  CAL VELOCITY COMPONENT.                         *
*                                                  *
****************************************************

PLEASE ENTER THE NUMBER OF VERTICAL GRID
(MAXIMUM 8)
8

PLEASE ENTER THE NUMBER OF HORIZONTAL GRID
(IN ODD NUMBER)
5

PLEASE ENTER THE TIME STEP
DEFAULT SUGGESTION: 0.00001
0.00001

PLEASE ENTER THE INITIAL DYNAMIC PRESSURE OF THE
AIR-EMITTING HOLE (INCHES OF WATER)
1

PLEASE ENTER THE AIR-GAP
```

```
(IN MM)
1.3

PLEASE ENTER THE HOLE DIAMETER
(IN MM)
4

PLEASE ENTER THE KINEMATIC VISCOSITY AND
DENSITY OF AIR
AT STANDARD ATMOSHERIC PRESSURE AND TEMPERATURE-->
KINEMATIC VISCOSITY = 1.56E-5, DENSITY = 1.184
1.56E-5
1.184

PLEASE ENTER THE STREAM FUNCTION (ERPSIM) AND
VORTICITY (EROMM) CONVERGENCE CRITERIA
DEFAULT SUGGESTION: ERPSIM = 0.00001
DEFAULT SUGGESTION: EROMM = 0.00025
0.00001
0.00025
```

[Note: In addition to the modifications described in appendix A.2.2, the user must enter zero for kinematic viscosity when generating output solution for frictionless flow.]

APPENDIX B.2.2

OUTPUT SOLUTION OF THE HOLE MODEL THAT UNDERGOES ACTUAL FLOW

First intermediate solution:

TIME	PSI(3,3)	OM(3,3)	U(3,3)	V(3,3)	PSIRES	OMRES
.000010	.0000	4.3554	.0660	.7384	.58895E-06	-.18969E+12
.000020	.0000	25.1635	.1000	.8363	.96579E-07	-.43298E+13
.000030	.0000	56.2666	.1218	.8487	.68872E-06	-.96740E+13
.000040	.0000	94.6003	.1374	.8389	-.74909E-06	-.14695E+14
.000050	.0000	138.1215	.1493	.8229	-.12292E-05	-.18941E+14
.000060	.0000	185.3343	.1588	.8063	.66561E-06	-.22290E+14
.000070	.0000	235.0912	1665	.7907	.10157E-05	-.24757E+14
.000080	.0000	286.4859	.1728	.7769	.28510E-06	-.26414E+14
000090	.0000	338.7928	.1781	.7646	-.32456E-05	-.27360E+14
.000100	.0000	391.4297	.1825	.7539	.34006E-05	-.27706E+14
.000110	.0000	443.9320	1862	.7444	-.89297E-06	-.27565E+14
.000120	.0000	495.9320	.1894	.7361	.22870E-05	-.27040E+14
.000130	.0000	547.1432	1920	.7286	.15525E-05	-.26226E+14
.000140	.0000	597.3453	.1943	.7218	-.14525E-05	-.25203E+14
.000150	0000	646.3730	1962	.7157	-.75259E-06	-.24037E+14
.000160	.0000	694.1058	.1979	.7101	-.19349E-05	-.22784E+14
000170	.0000	740.4593	.1993	.7050	.28583E-05	-.21486E+14
000180	.0000	785.3782	2006	.7002	-.33302E-05	-.20177E+14
000190	.0000	828.8307	.2018	.6958	-.16049E-05	-.18881E+14
000200	0000	870.8034	.2028	.6916	.50539E-06	-.17617E+14

```
***** INTERMEDIATE SOLUTION *****
      TIME = .000200
```

U-VELOCITY (M/S)

I

J	1	2	3	4	5	6	7	8
5	.0000	-.0004	-.0006	-.0006	-.0004	-.0002	.0000	.0000
4	0000	-.0179	-.0120	-.0036	0010	.0022	.0014	.0000
3	.7058	.2438	.2028	.1601	.1182	.0770	.0361	.0000
2	.7058	.6805	.5562	.4236	.3032	.1933	.0900	.0000
1	.7058	.6079	.5060	.4021	.2982	.1948	.0919	.0000

V-VELOCITY (M/S)

I

J	1	2	3	4	5	6	7	8
5	.0000	.2499	.2883	.2882	.2864	.2855	.2692	.0000
4	.0000	.3119	3928	.3968	.3916	.3874	.3636	.0000
3	.0000	.4028	6916	.6811	.6200	.5742	.5205	.0000
2	.0000	.2690	2771	2798	.2791	.2776	.2622	.0000
1	.0000	.0000	0000	.0000	.0000	.0000	.0000	.0000

VORTICITY (1/S)

I

J	1	2	3	4	5	6	7	8
5	2329.8590	418.0484	27.9861	1.2053	-.0825	-5.6622	-172.8956	-2727.3570
4	2628.5820	822.5804	104.1053	8.0562	.2714	-7.6218	-233.8222	-3675.0830

J	1	2	3	4	5	6	7	8
3	1525.4660	3637.7020	870.8034	108.3429	8.1469	-9.3226	-309.1424	-5205.7370
2	.0000	10.1679	4.7254	1.0672	.0448	-4.8029	-156.2517	-2663.4430
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

STREAM FUNCTION (M**3/S)

J \ I	1	2	3	4	5	6	7	8
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

<u>Final steady state solution:</u>

TIME	PSI(3,3)	OM(3,3)	U(3,3)	V(3,3)	PSIRES	OMRES
.018410	.0000	1565.6010	.2852	.4535	.14213E-05	-.75155E+02
.018420	.0000	1565.6010	.2852	.4535	.14213E-05	.00000E+00
.018430	.0000	1565.6010	.2852	.4535	.16654E-05	-.77295E+02
.018440	.0000	1565.6010	2852	.4535	.19096E-05	-.76479E+02
.018450	.0000	1565.6010	.2852	.4535	-.13699E-05	-.75662E+02
.018460	.0000	1565.6010	2852	.4535	.19263E-05	.00000E+00

TIME = .018460

U-VELOCITY (M/S)

J \ I	1	2	3	4	5	6	7	8
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0071	.0203	.0246	.0147	-.0023	-.0102	.0000
3	.7058	.2848	.2852	.2527	.1905	.1099	.0350	.0000
2	.7058	.6867	.6200	.5182	.3902	.2440	.0964	.0000
1	.7058	.6169	.5223	.4195	.3078	.1888	.0724	.0000

V-VELOCITY (M/S)

J \ I	1	2	3	4	5	6	7	8
5	.0000	.0337	.1562	.3317	.4777	.4960	.3192	0000
4	.0000	.0088	.2035	.4362	.6162	.6639	.4793	0000
3	.0000	.2312	4535	.6186	7384	.7908	.6569	0000
2	.0000	2471	.2657	.2888	3105	.3168	.2542	0000
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	0000

VORTICITY (1/S)

J \ I	1	2	3	4	5	6	7	8
5	-63.4461	410.9371	872.1757	978.9759	552.2504	-408.9142	-1547.8610	-1911.2910
4	-692.3105	825.0070	1383.1140	1278.4860	808.3245	-195.0511	-1752.4100	-3403.3740
3	1111.2200	2016.5150	1565.6010	1211.8780	866.1358	268.2837	-1377.9630	-5591.9970
2	.0000	11.6341	21.6080	29.8879	22.5651	-91.3249	-662.5952	-2098.9240
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

STREAM FUNCTION (M**3/S)

J \ I	1	2	3	4	5	6	7	8
5	0000	0000	.0000	.0000	.0000	.0000	.0000	.0000
4	0000	0000	.0000	.0000	.0000	.0000	.0000	.0000
3	0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

APPENDIX B.2.3

OUTPUT SOLUTION OF THE HOLE MODEL THAT UNDERGOES FRICTIONLESS FLOW

First intermediate solution:

TIME	PSI(3,3)	OM(3,3)	U(3,3)	V(3,3)	PSIRES	OMRES
.000010	0000	.0000	.0650	.6768	-.70060E-06	.00000E+00
.000020	0000	8.0849	.0982	.7644	-.14353E-05	-.65366E+12
.000030	.0000	21.6287	.1192	7750	-.14497E-05	-.18343E+13
.000040	.0000	39.3152	.1340	.7664	-.53455E-06	-.31281E+13
.000050	.0000	60.2592	.1452	.7531	.10888E-05	-.43865E+13
.000060	.0000	83.8017	.1541	7397	-.12925E-06	-.55425E+13
.000070	.0000	109.4252	.1612	.7277	.52749E-06	-.65656E+13
.000080	.0000	136.7070	1671	.7174	.48643E-06	-.74430E+13
.000090	.0000	165.2943	.1718	.7087	.51815E-06	-.81723E+13
.000100	.0000	194.8895	.1758	.7014	.23340E-05	-.87587E+13
.000110	.0000	225.2412	.1791	.6952	-.12492E-06	-.92123E+13
.000120	.0000	256.1372	.1819	.6899	.10212E-05	-.95457E+13
.000130	.0000	287.3989	.1842	.6854	-.84367E-06	-.97729E+13
.000140	.0000	318.8761	.1862	.6815	.17069E-05	-.99081E+13
.000150	.0000	350.4430	.1879	.6780	-.24567E-05	-.99647E+13
.000160	.0000	381.9943	.1893	.6749	-.12595E-06	-.99548E+13
.000170	.0000	413.4421	.1905	.6721	.16464E-05	-.98897E+13
.000180	.0000	444.7132	.1916	.6696	-.11415E-05	-.97788E+13
.000190	.0000	475.7466	.1926	.6672	.11930E-05	-.96307E+13
.000200	.0000	506.4917	1934	.6649	.22347E-05	-.94526E+13

***** INTERMEDIATE SOLUTION *****
TIME = .000200

U-VELOCITY (M/S)

J \ I	1	2	3	4	5	6	7	8
5	.0000	-.0004	-.0005	-.0005	-.0005	-.0003	-.0002	.0000
4	.0000	.0229	-.0122	-.0024	.0024	.0035	.0023	.0000
3	.7058	.2334	.1934	.1534	.1142	.0758	.0378	.0000
2	.7058	.6726	.5378	.4067	.2916	.1885	.0926	.0000
1	.7058	.6063	.5034	.3998	.2976	.1973	.0984	.0000

V-VELOCITY (M/S)

J \ I	1	2	3	4	5	6	7	8
5	.2576	.2557	.2554	.2531	.2508	.2491	.2486	.2472
4	.3254	.3218	.3527	.3499	.3432	.3376	.3347	.3326
3	.0000	.4202	.6649	.6154	.5456	.4974	.4711	.4676
2	.0000	.2531	.2582	.2572	.2532	.2490	.2466	.2450
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

VORTICITY (1/S)

J \ I	1	2	3	4	5	6	7	8
5	2574.4840	12.3299	.7097	.0227	.0005	.0000	.0000	-2472.7210
4	2969.4130	304.0804	30.1539	1.3734	.0399	.0008	.0000	-3319.0630

3	1747.5890	3308.8040	506.4917	38.0356	1.6324	.0413	.0006-4596.7530	
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000-2443.6230	
1	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

STREAM FUNCTION (M**3/S)

	I							
J	1	2	3	4	5	6	7	8
5	.0000	.0000	.0000	.0000	.0000	0000	.0000	.0000
4	.0000	.0000	0000	.0000	.0000	0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0000	.0000	0000	.0000	.0000	.0000	.0000	.0000

Final steady state solution:

TIME	PSI(3,3)	OM(3,3)	U(3,3)	V(3,3)	PSIRES	OMRES
093810	.0000	1266.8790	.3119	.3627	.20818E-05	.00000E+00

TIME = .093810

U-VELOCITY (M/S)

	I							
J	1	2	3	4	5	6	7	8
5	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
4	.0000	.0343	.0843	.1492	.1345	.1057	.0602	.0000
3	.7058	.2880	.3119	.3060	.2719	.2074	.1151	.0000
2	.7058	.6903	.6325	.5452	.4352	.3063	1607	.0000
1	.7058	.6248	.5385	.4447	.3428	.2335	1185	.0000

V-VELOCITY (M/S)

	I							
J	1	2	3	4	5	6	7	8
5	-.2245	-.2245	-.2496	.0585	.4619	.6218	.7792	.7792
4	-.0877	-.0877	.0150	.2150	.4167	.6159	.7886	.7886
3	.0000	.1833	.3627	.4933	.5973	.6863	.7657	.7657
2	.0000	.2092	.2251	.2446	.2639	.2804	.2919	.2919
1	.0000	.0000	.0000	.0000	.0000	0000	.0000	.0000

VORTICITY (1/S)

	I							
J	1	2	3	4	5	6	7	8
5	-2184.0590	.0932	-63.2385	3540.6700	972.8594	985.4969	819.5837-8530.0760	
4	-878.2252	.1319	1052.6690	962.9057	1078.3600	994.9102	809.8184-8663.5070	
3	777.8681	1691.1880	1266.8790	976.4711	763.5444	602.3554	465.6132-8033.1610	
2	.0000	.0000	.0000	.0000	.0000	.0000	.0000-2961.3380	
1	0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

STREAM FUNCTION (M**3/S)

	I							
J	1	2	3	4	5	6	7	8
5	.0000	0000	.0000	0000	.0000	.0000	.0000	.0000
4	.0000	.0000	.0000	0000	.0000	.0000	.0000	.0000
3	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
2	.0000	.0000	.0000	0000	.0000	.0000	.0000	.0000
1	.0000	0000	.0000	.0000	.0000	.0000	.0000	.0000

APPENDIX C: COMPUTATIONAL SOLUTIONS OF h/b OR h/d AND REYNOLDS NUMBER ON INLET DISCHARGE COEFFICIENT

C.1 The Effect of h/b on Inlet Discharge Coefficient of the Slot Model

C.1.1 Reynolds number, Re = 405
C.1.2 Reynolds number, Re = 181
C.1.3 Reynolds number, Re = 57
C.1.4 Reynolds number, Re = 18

C.2 The Effect of h/d on Inlet Discharge Coefficient of the Hole Model

C.2.1 Reynolds number, Re = 405
C.2.2 Reynolds number, Re = 181
C.2.3 Reynolds number, Re = 57
C.2.4 Reynolds number, Re = 18

APPENDIX C.1.1

INLET DISCHARGE COEFFICIENT OF THE SLOT MODEL FOR REYNOLDS NUMBER, Re = 405

Table 1. The Effect of h/b on Inlet Discharge Coefficient for Reynolds Number, Re = 405

h/b	$U_{inlet(F)}$ (m/s)	$U_{inlet(R)}$ (m/s)	A_{inlet} (m)	$\frac{U_{inlet(F)} A_{inlet}}{U_{inlet}}$ (m)	$\frac{U_{inlet(R)} A_{inlet}}{U_{inlet}}$ (m)	k	$k_{Viscous}$
0.00			0.0E+00	0.000E+00	0.000E+00		
0.05	1.3540	1.3183	4.0E-04	3.432E-04	3.341E-04	8.353E-01	9.736E-01
0.06	1.3546	1.3237	5.0E-04	4.291E-04	4.193E-04	8.387E-01	9.772E-01
0.08	1.3554	1.3280	6.0E-04	5.153E-04	5.048E-04	8.414E-01	9.798E-01
0.09	1.3563	1.3317	7.0E-04	6.015E-04	5.906E-04	8.438E-01	9.819E-01
0.10	1.3573	1.3349	8.0E-04	6.880E-04	6.766E-04	8.458E-01	9.835E-01
0.11	1.3584	1.3380	9.0E-04	7.746E-04	7.630E-04	8.477E-01	9.850E-01
0.13	1.3597	1.3408	1.0E-03	8.615E-04	8.495E-04	8.495E-01	9.861E-01
0.14	1.3610	1.3435	1.1E-03	9.486E-04	9.364E-04	8.512E-01	9.871E-01
0.15	1.3624	1.3462	1.2E-03	1.036E-03	1.024E-03	8.529E-01	9.881E-01
0.16	1.3639	1.3488	1.3E-03	1.123E-03	1.111E-03	8.546E-01	9.889E-01
0.18	1.3655	1.3513	1.4E-03	1.211E-03	1.199E-03	8.562E-01	9.896E-01
0.19	1.3671	1.3538	1.5E-03	1.299E-03	1.287E-03	8.578E-01	9.903E-01
0.20	1.3688	1.3563	1.6E-03	1.388E-03	1.375E-03	8.593E-01	9.909E-01
0.21	1.3706	1.3588	1.7E-03	1.476E-03	1.464E-03	8.609E-01	9.914E-01
0.23	1.3724	1.3612	1.8E-03	1.565E-03	1.552E-03	8.624E-01	9.918E-01
0.24	1.3742	1.3636	1.9E-03	1.654E-03	1.642E-03	8.640E-01	9.923E-01
0.25	1.3761	1.3660	2.0E-03	1.744E-03	1.731E-03	8.655E-01	9.927E-01
0.26	1.3779	1.3684	2.1E-03	1.833E-03	1.821E-03	8.670E-01	9.931E-01
0.28	1.3798	1.3707	2.2E-03	1.923E-03	1.911E-03	8.685E-01	9.934E-01
0.29	1.3817	1.3731	2.3E-03	2.014E-03	2.001E-03	8.700E-01	9.938E-01
0.30	1.3836	1.3754	2.4E-03	2.104E-03	2.091E-03	8.714E-01	9.941E-01
0.31	1.3855	1.3776	2.5E-03	2.195E-03	2.182E-03	8.728E-01	9.943E-01
0.33	1.3874	1.3799	2.6E-03	2.286E-03	2.273E-03	8.743E-01	9.946E-01
0.34	1.3893	1.3820	2.7E-03	2.377E-03	2.364E-03	8.756E-01	9.947E-01
0.35	1.3912	1.3842	2.8E-03	2.468E-03	2.456E-03	8.770E-01	9.950E-01
0.36	1.3931	1.3864	2.9E-03	2.560E-03	2.547E-03	8.784E-01	9.952E-01
0.38	1.3950	1.3884	3.0E-03	2.652E-03	2.639E-03	8.797E-01	9.953E-01
0.39	1.3969	1.3905	3.1E-03	2.744E-03	2.731E-03	8.810E-01	9.954E-01

h/b	$U_{inlet(F)}$ (m/s)	$U_{inlet(R)}$ (m/s)	A_{inlet} (m)	$\frac{U_{inlet(F)}A_{inlet}}{U_{inlet}}$ (m)	$\frac{U_{inlet(R)}A_{inlet}}{U_{inlet}}$ (m)	k	$k_{Viscous}$
0.40	1.3987	1.3925	3.2E-03	2.836E-03	2.823E-03	8.823E-01	9.956E-01
0.41	1.4006	1.3944	3.3E-03	2.928E-03	2.915E-03	8.835E-01	9.956E-01
0.43	1.4024	1.3963	3.4E-03	3.021E-03	3.008E-03	8.847E-01	9.957E-01
0.44	1.4040	1.3981	3.5E-03	3.113E-03	3.100E-03	8.858E-01	9.958E-01
0.45	1.4056	1.3999	3.6E-03	3.206E-03	3.193E-03	8.870E-01	9.959E-01
0.46	1.4071	1.4017	3.7E-03	3.299E-03	3.286E-03	8.881E-01	9.962E-01
0.48	1.4086	1.4035	3.8E-03	3.391E-03	3.379E-03	8.892E-01	9.964E-01
0.49	1.4101	1.4051	3.9E-03	3.484E-03	3.472E-03	8.903E-01	9.965E-01
0.50	1.4115	1.4068	4.0E-03	3.577E-03	3.565E-03	8.913E-01	9.967E-01
0.53	1.4142	1.4099	4.0E-03	3.584E-03	3.573E-03	8.933E-01	9.970E-01
0.55	1.4167	1.4128	4.0E-03	3.590E-03	3.581E-03	8.951E-01	9.972E-01
0.58	1.4191	1.4156	4.0E-03	3.597E-03	3.588E-03	8.969E-01	9.975E-01
0.60	1.4212	1.4181	4.0E-03	3.602E-03	3.594E-03	8.985E-01	9.978E-01
0.63	1.4232	1.4205	4.0E-03	3.607E-03	3.600E-03	9.000E-01	9.981E-01
0.65	1.4251	1.4227	4.0E-03	3.612E-03	3.606E-03	9.014E-01	9.983E-01
0.68	1.4267	1.4248	4.0E-03	3.616E-03	3.611E-03	9.027E-01	9.987E-01
0.70	1.4282	1.4266	4.0E-03	3.620E-03	3.616E-03	9.039E-01	9.989E-01
0.73	1.4296	1.4282	4.0E-03	3.623E-03	3.620E-03	9.049E-01	9.990E-01
0.75	1.4308	1.4297	4.0E-03	3.626E-03	3.623E-03	9.058E-01	9.992E-01
0.78	1.4318	1.4311	4.0E-03	3.629E-03	3.627E-03	9.067E-01	9.995E-01
0.80	1.4327	1.4324	4.0E-03	3.631E-03	3.630E-03	9.076E-01	9.998E-01

APPENDIX C.1.2

INLET DISCHARGE COEFFICIENT OF THE SLOT MODEL FOR REYNOLDS NUMBER, Re = 181

Table 2. The Effect of h/b on Inlet Discharge Coefficient for Reynolds Number, Re = 181

h/b	$U_{inlet(F)}$ (m/s)	$U_{inlet(R)}$ (m/s)	A_{inlet} (m)	$\frac{U_{inlet(F)} A_{inlet}}{U_{inlet}}$ (m)	$\frac{U_{inlet(R)} A_{inlet}}{U_{inlet}}$ (m)	k	$k_{Viscous}$
0.00			0.0E+00	0.000E+00	0.000E+00		
0.05	0.6055	0.5805	4.0E-04	3.432E-04	3.290E-04	8.225E-01	9.587E-01
0.10	0.6070	0.5902	8.0E-04	6.880E-04	6.690E-04	8.362E-01	9.723E-01
0.15	0.6093	0.5965	1.2E-03	1.036E-03	1.014E-03	8.451E-01	9.790E-01
0.20	0.6122	0.6020	1.6E-03	1.388E-03	1.365E-03	8.529E-01	9.833E-01
0.25	0.6154	0.6071	2.0E-03	1.744E-03	1.720E-03	8.602E-01	9.865E-01
0.30	0.6187	0.6118	2.4E-03	2.104E-03	2.080E-03	8.668E-01	9.888E-01
0.35	0.6220	0.6163	2.8E-03	2.468E-03	2.445E-03	8.732E-01	9.908E-01
0.40	0.6253	0.6204	3.2E-03	2.835E-03	2.813E-03	8.790E-01	9.922E-01
0.45	0.6286	0.6241	3.6E-03	3.206E-03	3.183E-03	8.842E-01	9.928E-01
0.50	0.6312	0.6274	4.0E-03	3.577E-03	3.556E-03	8.889E-01	9.940E-01
0.55	0.6336	0.6303	4.0E-03	3.591E-03	3.572E-03	8.930E-01	9.948E-01
0.60	0.6356	0.6329	4.0E-03	3.602E-03	3.587E-03	8.967E-01	9.958E-01
0.65	0.6373	0.6351	4.0E-03	3.612E-03	3.599E-03	8.998E-01	9.965E-01
0.70	0.6387	0.6370	4.0E-03	3.620E-03	3.610E-03	9.025E-01	9.973E-01
0.75	0.6399	0.6386	4.0E-03	3.627E-03	3.619E-03	9.048E-01	9.980E-01
0.80	0.6407	0.6398	4.0E-03	3.631E-03	3.626E-03	9.065E-01	9.986E-01
0.85	0.6414	0.6408	4.0E-03	3.635E-03	3.632E-03	9.079E-01	9.991E-01
0.90	0.6418	0.6415	4.0E-03	3.637E-03	3.636E-03	9.089E-01	9.995E-01

APPENDIX C.1.3

INLET DISCHARGE COEFFICIENT OF THE SLOT MODEL FOR REYNOLDS NUMBER, Re = 57

Table 3. The Effect of h/b on Inlet Discharge Coefficient for Reynolds Number, Re = 57

h/b	$U_{inlet(F)}$ (m/s)	$U_{inlet(R)}$ (m/s)	A_{inlet} (m)	$\frac{U_{inlet(F)} A_{inlet}}{U_{inlet}}$ (m)	$\frac{U_{inlet(R)} A_{inlet}}{U_{inlet}}$ (m)	k	$k_{Viscous}$
0.00			0.0E+00	0.000E+00	0.000E+00		
0.05	0.1915	0.1795	4.0E-04	3.432E-04	3.217E-04	8.042E-01	9.373E-01
0.10	0.1919	0.1824	8.0E-04	6.878E-04	6.538E-04	8.172E-01	9.505E-01
0.15	0.1927	0.1849	1.2E-03	1.036E-03	9.941E-04	8.284E-01	9.595E-01
0.20	0.1936	0.1872	1.6E-03	1.388E-03	1.342E-03	8.387E-01	9.669E-01
0.25	0.1946	0.1893	2.0E-03	1.744E-03	1.696E-03	8.481E-01	9.728E-01
0.30	0.1957	0.1912	2.4E-03	2.104E-03	2.056E-03	8.566E-01	9.770E-01
0.35	0.1967	0.1930	2.8E-03	2.468E-03	2.421E-03	8.647E-01	9.812E-01
0.40	0.1978	0.1946	3.2E-03	2.836E-03	2.790E-03	8.719E-01	9.838E-01
0.45	0.1988	0.1961	3.6E-03	3.206E-03	3.163E-03	8.786E-01	9.864E-01
0.50	0.1996	0.1974	4.0E-03	3.577E-03	3.538E-03	8.844E-01	9.890E-01
0.55	0.2004	0.1985	4.0E-03	3.591E-03	3.557E-03	8.893E-01	9.905E-01
0.60	0.2010	0.1995	4.0E-03	3.602E-03	3.575E-03	8.938E-01	9.925E-01
0.65	0.2015	0.2003	4.0E-03	3.611E-03	3.590E-03	8.974E-01	9.940E-01
0.70	0.2020	0.2010	4.0E-03	3.620E-03	3.602E-03	9.005E-01	9.950E-01
0.75	0.2023	0.2016	4.0E-03	3.625E-03	3.613E-03	9.032E-01	9.965E-01
0.80	0.2026	0.2021	4.0E-03	3.631E-03	3.622E-03	9.055E-01	9.975E-01
0.85	0.2028	0.2024	4.0E-03	3.634E-03	3.627E-03	9.068E-01	9.980E-01
0.90	0.2029	0.2027	4.0E-03	3.636E-03	3.633E-03	9.082E-01	9.990E-01

APPENDIX C.1.4

INLET DISCHARGE COEFFICIENT OF THE SLOT MODEL FOR REYNOLDS NUMBER, Re = 18

Table 4. The Effect of h/b on Inlet Discharge Coefficient for Reynolds Number, Re = 18

h/b	$U_{inlet(F)}$ (m/s)	$U_{inlet(R)}$ (m/s)	A_{inlet} (m)	$\frac{U_{inlet(F)} A_{inlet}}{U_{inlet}}$ (m)	$\frac{U_{inlet(R)} A_{inlet}}{U_{inlet}}$ (m)	k	$k_{Viscous}$
0.00			0.0E+00	0.000E+00	0.000E+00		
0.05	0.0606	0.0561	4.0E-04	3.433E-04	3.178E-04	7.946E-01	9.257E-01
0.10	0.0607	0.0566	8.0E-04	6.878E-04	6.414E-04	8.017E-01	9.325E-01
0.15	0.0609	0.0573	1.2E-03	1.035E-03	9.739E-04	8.116E-01	9.409E-01
0.20	0.0612	0.0580	1.6E-03	1.387E-03	1.314E-03	8.215E-01	9.477E-01
0.25	0.0615	0.0587	2.0E-03	1.742E-03	1.663E-03	8.314E-01	9.545E-01
0.30	0.0619	0.0594	2.4E-03	2.104E-03	2.019E-03	8.414E-01	9.596E-01
0.35	0.0622	0.0602	2.8E-03	2.467E-03	2.388E-03	8.527E-01	9.678E-01
0.40	0.0625	0.0608	3.2E-03	2.833E-03	2.756E-03	8.612E-01	9.728E-01
0.45	0.0629	0.0614	3.6E-03	3.207E-03	3.131E-03	8.697E-01	9.762E-01
0.50	0.0631	0.0620	4.0E-03	3.575E-03	3.513E-03	8.782E-01	9.826E-01
0.55	0.0634	0.0624	4.0E-03	3.592E-03	3.535E-03	8.839E-01	9.842E-01
0.60	0.0636	0.0628	4.0E-03	3.603E-03	3.558E-03	8.895E-01	9.874E-01
0.65	0.0637	0.0632	4.0E-03	3.609E-03	3.581E-03	8.952E-01	9.922E-01
0.70	0.0639	0.0635	4.0E-03	3.620E-03	3.598E-03	8.994E-01	9.937E-01
0.75	0.0640	0.0637	4.0E-03	3.626E-03	3.609E-03	9.023E-01	9.953E-01
0.80	0.0641	0.0639	4.0E-03	3.632E-03	3.620E-03	9.051E-01	9.969E-01
0.85	0.0641	0.0640	4.0E-03	3.632E-03	3.626E-03	9.065E-01	9.984E-01
0.90	0.0642	0.0641	4.0E-03	3.637E-03	3.632E-03	9.079E-01	9.984E-01

APPENDIX C.2.1

INLET DISCHARGE COEFFICIENT OF THE HOLE MODEL FOR REYNOLDS NUMBER, Re = 405

Table 5. The Effect of h/d on Inlet Discharge Coefficient for Reynolds Number, Re = 405

h/d	$U_{inlet(F)}$ (m/s)	$U_{inlet(R)}$ (m/s)	A_{inlet} (m^2)	$\frac{U_{inlet(F)}A_{inlet}}{U_{inlet}}$ (m^2)	$\frac{U_{inlet(R)}A_{inlet}}{U_{inlet}}$ (m^2)	k	$k_{Viscous}$
0.0000			0.000E+00	0.000E+00	0.000E+00		
0.0500	1.3541	1.3128	2.513E-06	2.156E-06	2.090E-06	8.318E-01	9.695E-01
0.0625	1.3548	1.3189	3.142E-06	2.697E-06	2.625E-06	8.356E-01	9.735E-01
0.0750	1.3557	1.3238	3.770E-06	3.238E-06	3.162E-06	8.388E-01	9.765E-01
0.0875	1.3567	1.3280	4.398E-06	3.781E-06	3.701E-06	8.414E-01	9.788E-01
0.1000	1.3579	1.3318	5.027E-06	4.325E-06	4.241E-06	8.438E-01	9.808E-01
0.1125	1.3592	1.3353	5.655E-06	4.870E-06	4.784E-06	8.460E-01	9.824E-01
0.1250	1.3606	1.3386	6.283E-06	5.417E-06	5.329E-06	8.481E-01	9.838E-01
0.1375	1.3621	1.3418	6.912E-06	5.965E-06	5.876E-06	8.502E-01	9.851E-01
0.1500	1.3638	1.3449	7.540E-06	6.515E-06	6.425E-06	8.521E-01	9.861E-01
0.1625	1.3655	1.3480	8.168E-06	7.067E-06	6.976E-06	8.541E-01	9.872E-01
0.1750	1.3673	1.3510	8.796E-06	7.620E-06	7.530E-06	8.560E-01	9.881E-01
0.1875	1.3692	1.3540	9.425E-06	8.176E-06	8.085E-06	8.579E-01	9.889E-01
0.2000	1.3711	1.3570	1.005E-05	8.733E-06	8.644E-06	8.598E-01	9.897E-01
0.2125	1.3732	1.3600	1.068E-05	9.293E-06	9.204E-06	8.617E-01	9.904E-01
0.2250	1.3753	1.3629	1.131E-05	9.855E-06	9.766E-06	8.635E-01	9.910E-01
0.2375	1.3774	1.3658	1.194E-05	1.042E-05	1.033E-05	8.654E-01	9.916E-01
0.2500	1.3795	1.3687	1.257E-05	1.098E-05	1.090E-05	8.672E-01	9.922E-01
0.2625	1.3817	1.3715	1.257E-05	1.100E-05	1.092E-05	8.690E-01	9.926E-01
0.2750	1.3839	1.3744	1.257E-05	1.102E-05	1.094E-05	8.708E-01	9.931E-01
0.2875	1.3861	1.3772	1.257E-05	1.104E-05	1.097E-05	8.726E-01	9.936E-01
0.3000	1.3884	1.3800	1.257E-05	1.105E-05	1.099E-05	8.744E-01	9.939E-01
0.3125	1.3906	1.3828	1.257E-05	1.107E-05	1.101E-05	8.761E-01	9.944E-01
0.3250	1.3928	1.3856	1.257E-05	1.109E-05	1.103E-05	8.779E-01	9.948E-01
0.3375	1.3950	1.3883	1.257E-05	1.111E-05	1.105E-05	8.796E-01	9.952E-01
0.3500	1.3972	1.3910	1.257E-05	1.112E-05	1.108E-05	8.813E-01	9.956E-01
0.3625	1.3994	1.3936	1.257E-05	1.114E-05	1.110E-05	8.830E-01	9.959E-01
0.3750	1.4016	1.3962	1.257E-05	1.116E-05	1.112E-05	8.846E-01	9.961E-01
0.3875	1.4037	1.3988	1.257E-05	1.118E-05	1.114E-05	8.863E-01	9.965E-01

h/d	$U_{inlet(F)}$ (m/s)	$U_{inlet(R)}$ (m/s)	A_{inlet} (m^2)	$\frac{U_{inlet(F)} A_{inlet}}{U_{inlet}}$ (m^2)	$\frac{U_{inlet(R)} A_{inlet}}{U_{inlet}}$ (m^2)	k	$k_{Viscous}$
0.4000	1.4057	1.4013	1.257E-05	1.119E-05	1.116E-05	8.879E-01	9.969E-01
0.4125	1.4077	1.4037	1.257E-05	1.121E-05	1.118E-05	8.894E-01	9.972E-01
0.4250	1.4097	1.4061	1.257E-05	1.122E-05	1.120E-05	8.909E-01	9.974E-01
0.4375	1.4116	1.4084	1.257E-05	1.124E-05	1.121E-05	8.924E-01	9.977E-01
0.4500	1.4134	1.4107	1.257E-05	1.125E-05	1.123E-05	8.938E-01	9.981E-01
0.4625	1.4152	1.4129	1.257E-05	1.127E-05	1.125E-05	8.952E-01	9.984E-01
0.4750	1.4170	1.4151	1.257E-05	1.128E-05	1.127E-05	8.966E-01	9.987E-01
0.4875	1.4186	1.4172	1.257E-05	1.129E-05	1.128E-05	8.979E-01	9.990E-01
0.5000	1.4203	1.4192	1.257E-05	1.131E-05	1.130E-05	8.992E-01	9.992E-01

APPENDIX C.2.2

INLET DISCHARGE COEFFICIENT OF THE HOLE MODEL FOR REYNOLDS NUMBER, Re = 181

Table 6. The Effect of h/d on Inlet Discharge Coefficient for Reynolds Number, Re = 181

h/d	$U_{inlet(F)}$ (m/s)	$U_{inlet(R)}$ (m/s)	A_{inlet} (m^2)	$\frac{U_{inlet(F)} A_{inlet}}{U_{inlet}}$ (m^2)	$\frac{U_{inlet(R)} A_{inlet}}{U_{inlet}}$ (m^2)	k	$k_{Viscous}$
0.0000			0.000E+00	0.000E+00	0.000E+00		
0.0500	0.6065	0.5774	2.513E-06	2.160E-06	2.056E-06	8.181E-01	9.520E-01
0.0750	0.6063	0.5834	3.770E-06	3.238E-06	3.116E-06	8.266E-01	9.622E-01
0.1000	0.6073	0.5881	5.027E-06	4.325E-06	4.188E-06	8.332E-01	9.684E-01
0.1250	0.6085	0.5919	6.283E-06	5.417E-06	5.269E-06	8.386E-01	9.727E-01
0.1500	0.6099	0.5954	7.540E-06	6.515E-06	6.360E-06	8.436E-01	9.762E-01
0.1750	0.6115	0.5987	8.796E-06	7.621E-06	7.462E-06	8.483E-01	9.791E-01
0.2000	0.6132	0.6019	1.005E-05	8.734E-06	8.573E-06	8.528E-01	9.816E-01
0.2250	0.6150	0.6050	1.131E-05	9.855E-06	9.695E-06	8.572E-01	9.837E-01
0.2500	0.6169	0.6081	1.257E-05	1.098E-05	1.083E-05	8.616E-01	9.857E-01
0.2750	0.6189	0.6111	1.257E-05	1.102E-05	1.088E-05	8.658E-01	9.874E-01
0.3000	0.6208	0.6140	1.257E-05	1.105E-05	1.093E-05	8.699E-01	9.890E-01
0.3250	0.6228	0.6169	1.257E-05	1.109E-05	1.098E-05	8.740E-01	9.905E-01
0.3500	0.6248	0.6196	1.257E-05	1.112E-05	1.103E-05	8.779E-01	9.917E-01
0.3750	0.6267	0.6222	1.257E-05	1.116E-05	1.108E-05	8.816E-01	9.928E-01
0.4000	0.6286	0.6248	1.257E-05	1.119E-05	1.112E-05	8.852E-01	9.940E-01
0.4250	0.6303	0.6272	1.257E-05	1.122E-05	1.117E-05	8.886E-01	9.951E-01
0.4500	0.6319	0.6296	1.257E-05	1.125E-05	1.121E-05	8.920E-01	9.964E-01
0.4750	0.6335	0.6318	1.257E-05	1.128E-05	1.125E-05	8.952E-01	9.973E-01
0.5000	0.6349	0.6339	1.257E-05	1.130E-05	1.129E-05	8.981E-01	9.984E-01

APPENDIX C.2.3

INLET DISCHARGE COEFFICIENT OF THE HOLE MODEL FOR REYNOLDS NUMBER, Re = 57

Table 7. The Effect of h/d on Inlet Discharge Coefficient for Reynolds Number, Re = 57

h/d	$U_{inlet(F)}$ (m/s)	$U_{inlet(R)}$ (m/s)	A_{inlet} (m^2)	$\frac{U_{inlet(F)} A_{inlet}}{U_{inlet}}$ (m^2)	$\frac{U_{inlet(R)} A_{inlet}}{U_{inlet}}$ (m^2)	k	$k_{Viscous}$
0.0000			0.000E+00	0.000E+00	0.000E+00		
0.0500	0.1915	0.1787	2.513E-06	2.156E-06	2.012E-06	8.006E-01	9.332E-01
0.0750	0.1917	0.1802	3.770E-06	3.238E-06	3.044E-06	8.073E-01	9.400E-01
0.1000	0.1920	0.1816	5.027E-06	4.324E-06	4.090E-06	8.136E-01	9.458E-01
0.1250	0.1924	0.1831	6.283E-06	5.416E-06	5.154E-06	8.203E-01	9.517E-01
0.1500	0.1929	0.1844	7.540E-06	6.516E-06	6.229E-06	8.262E-01	9.559E-01
0.1750	0.1934	0.1858	8.796E-06	7.622E-06	7.323E-06	8.324E-01	9.607E-01
0.2000	0.1939	0.1871	1.005E-05	8.733E-06	8.427E-06	8.383E-01	9.649E-01
0.2250	0.1945	0.1884	1.131E-05	9.855E-06	9.546E-06	8.441E-01	9.686E-01
0.2500	0.1951	0.1897	1.257E-05	1.098E-05	1.068E-05	8.499E-01	9.723E-01
0.2750	0.1957	0.1909	1.257E-05	1.102E-05	1.075E-05	8.553E-01	9.755E-01
0.3000	0.1963	0.1921	1.257E-05	1.105E-05	1.082E-05	8.607E-01	9.786E-01
0.3250	0.1970	0.1933	1.257E-05	1.109E-05	1.088E-05	8.660E-01	9.812E-01
0.3500	0.1976	0.1945	1.257E-05	1.113E-05	1.095E-05	8.714E-01	9.843E-01
0.3750	0.1982	0.1956	1.257E-05	1.116E-05	1.101E-05	8.763E-01	9.869E-01
0.4000	0.1988	0.1966	1.257E-05	1.119E-05	1.107E-05	8.808E-01	9.889E-01
0.4250	0.1993	0.1976	1.257E-05	1.122E-05	1.113E-05	8.853E-01	9.915E-01
0.4500	0.1999	0.1986	1.257E-05	1.125E-05	1.118E-05	8.898E-01	9.935E-01
0.4750	0.2004	0.1995	1.257E-05	1.128E-05	1.123E-05	8.938E-01	9.955E-01
0.5000	0.2008	0.2004	1.257E-05	1.131E-05	1.128E-05	8.978E-01	9.980E-01

APPENDIX C.2.4

INLET DISCHARGE COEFFICIENT OF THE HOLE MODEL
FOR REYNOLDS NUMBER, Re = 18

Table 8. The Effect of h/d on Inlet Discharge Coefficient
for Reynolds Number, Re = 18

h/d	$U_{inlet(F)}$ (m/s)	$U_{inlet(R)}$ (m/s)	A_{inlet} (m^2)	$\frac{U_{inlet(F)} A_{inlet}}{U_{inlet}}$ (m^2)	$\frac{U_{inlet(R)} A_{inlet}}{U_{inlet}}$ (m^2)	k	$k_{Viscous}$
0.0000			0.000E+00	0.000E+00	0.000E+00		
0.0500	0.0606	0.0560	2.513E-06	2.157E-06	1.994E-06	7.932E-01	9.241E-01
0.0750	0.0606	0.0562	3.770E-06	3.236E-06	3.001E-06	7.960E-01	9.274E-01
0.1000	0.0607	0.0565	5.027E-06	4.322E-06	4.023E-06	8.003E-01	9.308E-01
0.1250	0.0608	0.0569	6.283E-06	5.411E-06	5.064E-06	8.059E-01	9.359E-01
0.1500	0.0610	0.0572	7.540E-06	6.515E-06	6.109E-06	8.102E-01	9.377E-01
0.1750	0.0611	0.0576	8.796E-06	7.613E-06	7.177E-06	8.159E-01	9.427E-01
0.2000	0.0613	0.0580	1.005E-05	8.729E-06	8.259E-06	8.215E-01	9.462E-01
0.2250	0.0615	0.0585	1.131E-05	9.852E-06	9.371E-06	8.286E-01	9.512E-01
0.2500	0.0617	0.0589	1.257E-05	1.098E-05	1.048E-05	8.343E-01	9.546E-01
0.2750	0.0619	0.0594	1.257E-05	1.102E-05	1.057E-05	8.414E-01	9.596E-01
0.3000	0.0621	0.0599	1.257E-05	1.105E-05	1.066E-05	8.484E-01	9.646E-01
0.3250	0.0623	0.0603	1.257E-05	1.109E-05	1.073E-05	8.541E-01	9.679E-01
0.3500	0.0625	0.0608	1.257E-05	1.112E-05	1.082E-05	8.612E-01	9.728E-01
0.3750	0.0627	0.0612	1.257E-05	1.116E-05	1.089E-05	8.669E-01	9.761E-01
0.4000	0.0629	0.0616	1.257E-05	1.120E-05	1.096E-05	8.725E-01	9.793E-01
0.4250	0.0630	0.0621	1.257E-05	1.121E-05	1.105E-05	8.796E-01	9.857E-01
0.4500	0.0632	0.0624	1.257E-05	1.125E-05	1.111E-05	8.839E-01	9.873E-01
0.4750	0.0634	0.0628	1.257E-05	1.128E-05	1.118E-05	8.895E-01	9.905E-01
0.5000	0.0636	0.0632	1.257E-05	1.132E-05	1.125E-05	8.952E-01	9.937E-01

APPENDIX D: COMPUTATIONAL SOLUTIONS OF HORIZONTAL VELOCITY COMPONENT

D.1 Horizontal Velocity Component of the Slot Model

D.1.1 Actual flow

D.1.1.1 $P_{dyn} = 5.0$ in. of water, b = 4 mm, time step = $1x10^{-6}$ s

D.1.1.2 $P_{dyn} = 1.0$ in. of water, b = 4 mm, time step = $1x10^{-5}$ s

D.1.1.3 $P_{dyn} = 0.1$ in. of water, b = 4 mm, time step = $1x10^{-5}$ s

D.1.1.4 $P_{dyn} = 0.01$ in. of water, b = 4 mm, time step = $1x10^{-5}$ s

D.1.2 Frictionless flow

D.1.2.1 $P_{dyn} = 5.0$ in. of water, b = 4 mm, time step = $1x10^{-6}$ s

D.1.2.2 $P_{dyn} = 1.0$ in. of water, b = 4 mm, time step = $1x10^{-5}$ s

D.1.2.3 $P_{dyn} = 0.1$ in. of water, b = 4 mm, time step = $1x10^{-5}$ s

D.1.2.4 $P_{dyn} = 0.01$ in. of water, b = 4 mm, time step = $1x10^{-5}$ s

D.2 Horizontal Velocity Component of the Hole Model

D.2.1 Actual flow

D.2.1.1 $P_{dyn} = 5.0$ in. of water, d = 4 mm, time step = $1x10^{-6}$ s

D.2.1.2 $P_{dyn} = 1.0$ in. of water, d = 4 mm, time step = $1x10^{-5}$ s

D.2.1.3 $P_{dyn} = 0.1$ in. of water, d = 4 mm, time step = $1x10^{-5}$ s

D.2.1.4 $P_{dyn} = 0.01$ in. of water, d = 4 mm, time step = $1x10^{-5}$ s

D.2.2 Frictionless flow

D.2.2.1 $P_{dyn} = 5.0$ in. of water, d = 4 mm, time step = 1×10^{-6} s

D.2.2.2 $P_{dyn} = 1.0$ in. of water, d = 4 mm, time step = 1×10^{-5} s

D.2.2.3 $P_{dyn} = 0.1$ in. of water, d = 4 mm, time step = 1×10^{-5} s

D.2.2.4 $P_{dyn} = 0.01$ in. of water, d = 4 mm, time step = 1×10^{-5} s

APPENDIX D.1.1.1

HORIZONTAL VELOCITY COMPONENT OF SLOT MODEL UNDERGOES ACTUAL FLOW

$[P_{dyn} = 5.0 \text{ in. of water}, b = 4 \text{ mm}, \text{time step} = 1\text{x}10^{-6} \text{s}]$

Table 9. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0399	-0.0852	-0.1228	-0.141	-0.1255	-0.0674	0
3	1.5783	0.8331	0.7588	0.6079	0.4166	0.2218	0.0657	0
2	1.5783	1.5286	1.3593	1.1049	0.7966	0.4677	0.1681	0
1	1.5783	1.3183	1.0581	0.7981	0.5413	0.2977	0.0963	0

Table 10. Horizontal Velocity Component for Air-gap, h = 0.25 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0411	-0.0868	-0.1249	-0.145	-0.1328	-0.0751	0
3	1.5783	0.8322	0.7598	0.6119	0.4226	0.2273	0.0682	0
2	1.5783	1.5308	1.3655	1.1157	0.8118	0.4842	0.1792	0
1	1.5783	1.3237	1.0685	0.813	0.5588	0.314	0.1052	0

Table 11. Horizontal Velocity Component for Air-gap, h = 0.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0416	-0.0867	-0.1243	-0.1457	-0.1368	-0.0809	0
3	1.5783	0.8319	0.7617	0.6166	0.4291	0.2334	0.0713	0
2	1.5783	1.5324	1.3699	1.1238	0.8235	0.4975	0.1887	0
1	1.5783	1.328	1.0769	0.8248	0.573	0.3278	0.1133	0

Table 12. Horizontal Velocity Component for Air-gap, h = 0.35 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0416	-0.0855	-0.122	-0.1441	-0.1384	-0.0852	0
3	1.5783	0.832	0.7641	0.6217	0.436	0.2398	0.0747	0
2	1.5783	1.5335	1.3731	1.1299	0.8327	0.5085	0.197	0
1	1.5783	1.3317	1.084	0.8348	0.585	0.3396	0.1207	0

Table 13. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0412	-0.0833	-0.1185	-0.141	-0.138	-0.0882	0
3	1.5783	0.8325	0.767	0.627	0.4429	0.2464	0.0785	0
2	1.5783	1.5342	1.3755	1.1346	0.84	0.5176	0.2042	0
1	1.5783	1.3349	1.0902	0.8435	0.5954	0.3501	0.1275	0

Table 14. Horizontal Velocity Component for Air-gap, h = 0.45 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0405	-0.0804	-0.1139	-0.1365	-0.1362	-0.09	0
3	1.5783	0.8334	0.7702	0.6326	0.45	0.2532	0.0825	0
2	1.5783	1.5348	1.3772	1.1383	0.846	0.5252	0.2106	0
1	1.5783	1.338	1.0959	0.8514	0.6047	0.3594	0.1338	0

Table 15. Horizontal Velocity Component for Air-gap, h = 0.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0394	-0.0768	-0.1084	-0.131	-0.1332	-0.0909	0
3	1.5783	0.8345	0.7738	0.6384	0.4571	0.26	0.0866	0
2	1.5783	1.5351	1.3785	1.1412	0.8509	0.5317	0.2163	0
1	1.5783	1.3408	1.1012	0.8586	0.6132	0.368	0.1396	0

Table 16. Horizontal Velocity Component for Air-gap, h = 0.55 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0379	-0.0725	-0.1021	-0.1246	-0.1291	-0.0909	0
3	1.5783	0.8359	0.7776	0.6443	0.4642	0.2668	0.0908	0
2	1.5783	1.5353	1.3793	1.1434	0.8548	0.5373	0.2214	0
1	1.5783	1.3435	1.1063	0.8654	0.621	0.3758	0.1451	0

Table 17. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0362	-0.0677	-0.0952	-0.1174	-0.1242	-0.0902	0
3	1.5783	0.8375	0.7817	0.6503	0.4713	0.2735	0.0951	0
2	1.5783	1.5353	1.3799	1.1451	0.8581	0.542	0.2259	0
1	1.5783	1.3462	1.1111	0.8719	0.6284	0.3832	0.1503	0

Table 18. Horizontal Velocity Component for Air-gap, h = 0.65 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0341	-0.0624	-0.0876	-0.1096	-0.1186	-0.0889	0
3	1.5783	0.8393	0.786	0.6564	0.4784	0.2802	0.0993	0
2	1.5783	1.5353	1.3802	1.1463	0.8608	0.5461	0.23	0
1	1.5783	1.3488	1.1159	0.8781	0.6354	0.39	0.1552	0

Table 19. Horizontal Velocity Component for Air-gap, h = 0.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0318	-0.0565	-0.0795	-0.1013	-0.1123	-0.0869	0
3	1.5783	0.8413	0.7904	0.6625	0.4854	0.2868	0.1036	0
2	1.5783	1.5352	1.3803	1.1472	0.863	0.5496	0.2336	0
1	1.5783	1.3513	1.1205	0.8841	0.6421	0.3965	0.1599	0

Table 20. Horizontal Velocity Component for Air-gap, h = 0.75 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0292	-0.0502	-0.071	-0.0924	-0.1056	-0.0845	0
3	1.5783	0.8435	0.7951	0.6688	0.4923	0.2934	0.1078	0
2	1.5783	1.535	1.3802	1.1478	0.8647	0.5527	0.2369	0
1	1.5783	1.3538	1.125	0.8899	0.6485	0.4027	0.1643	0

Table 21. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0264	-0.0435	-0.062	-0.0832	-0.0984	-0.0817	0
3	1.5783	0.8458	0.7998	0.675	0.4992	0.2998	0.1119	0
2	1.5783	1.5347	1.38	1.1482	0.8662	0.5554	0.2399	0
1	1.5783	1.3563	1.1294	0.8956	0.6547	0.4087	0.1685	0

Table 22. Horizontal Velocity Component for Air-gap, h = 0.85 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0233	-0.0363	-0.0526	-0.0736	-0.0908	-0.0784	0
3	1.5783	0.8483	0.8047	0.6813	0.506	0.3061	0.116	0
2	1.5783	1.5344	1.3796	1.1483	0.8673	0.5577	0.2426	0
1	1.5783	1.3588	1.1338	0.9012	0.6607	0.4143	0.1726	0

Table 23. Horizontal Velocity Component for Air-gap, h = 0.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.02	-0.0289	-0.0428	-0.0638	-0.0829	-0.0749	0
3	1.5783	0.8509	0.8098	0.6876	0.5128	0.3123	0.1199	0
2	1.5783	1.534	1.3791	1.1483	0.8682	0.5597	0.245	0
1	1.5783	1.3612	1.1381	0.9066	0.6665	0.4198	0.1765	0

Table 24. Horizontal Velocity Component for Air-gap, h = 0.95 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0165	-0.021	-0.0328	-0.0536	-0.0749	-0.0711	0
3	1.5783	0.8537	0.8149	0.6939	0.5195	0.3183	0.1238	0
2	1.5783	1.5335	1.3785	1.1481	0.869	0.5615	0.2473	0
1	1.5783	1.3636	1.1424	0.912	0.6722	0.4251	0.1802	0

Table 25. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0127	-0.0129	-0.0225	-0.0433	-0.0666	-0.0671	0
3	1.5783	0.8565	0.8201	0.7002	0.526	0.3243	0.1277	0
2	1.5783	1.5331	1.3779	1.1479	0.8695	0.5631	0.2493	0
1	1.5783	1.366	1.1466	0.9173	0.6778	0.4302	0.1838	0

Table 26. Horizontal Velocity Component for Air-gap, h = 1.05 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0088	-0.0045	-0.012	-0.0329	-0.0582	-0.063	0
3	1.5783	0.8595	0.8255	0.7065	0.5326	0.3302	0.1314	0
2	1.5783	1.5326	1.3772	1.1475	0.8699	0.5645	0.2512	0
1	1.5783	1.3684	1.1508	0.9224	0.6832	0.4351	0.1873	0

Table 27. Horizontal Velocity Component for Air-gap, h = 1.10 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0059	0.0014	-0.0039	-0.0243	-0.0509	-0.0592	0
3	1.5783	0.8607	0.8272	0.7096	0.5364	0.3341	0.1342	0
2	1.5783	1.532	1.3763	1.1467	0.8698	0.5653	0.2527	0
1	1.5783	1.3707	1.1549	0.9274	0.6884	0.4399	0.1906	0

Table 28. Horizontal Velocity Component for Air-gap, h = 1.15 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0025	0.0085	0.0049	-0.0152	-0.0433	-0.0552	0
3	1.5783	0.8627	0.8304	0.7134	0.5408	0.3384	0.1371	0
2	1.5783	1.5315	1.3754	1.146	0.8697	0.5661	0.2542	0
1	1.5783	1.3731	1.1589	0.9324	0.6935	0.4444	0.1938	0

Table 29. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0023	0.0173	0.0154	-0.005	-0.035	-0.0508	0
3	1.5783	0.8673	0.8361	0.7196	0.5469	0.3438	0.1405	0
2	1.5783	1.5309	1.3746	1.1456	0.87	0.5672	0.2557	0
1	1.5783	1.3754	1.1629	0.9373	0.6985	0.449	0.1969	0

Table 30. Horizontal Velocity Component for Air-gap, h = 1.25 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0066	0.0263	0.027	0.0071	-0.0254	-0.0458	0
3	1.5783	0.8703	0.8412	0.7262	0.5545	0.3503	0.1444	0
2	1.5783	1.5303	1.3737	1.145	0.8701	0.5682	0.2572	0
1	1.5783	1.3776	1.1668	0.9421	0.7035	0.4533	0.2	0

Table 31. Horizontal Velocity Component for Air-gap, h = 1.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0104	0.0338	0.0361	0.0162	-0.0178	-0.0417	0
3	1.5783	0.8725	0.8445	0.7301	0.5587	0.3542	0.1471	0
2	1.5783	1.5296	1.3728	1.1441	0.8698	0.5687	0.2584	0
1	1.5783	1.3799	1.1707	0.9467	0.7082	0.4575	0.2029	0

Table 32. Horizontal Velocity Component for Air-gap, h = 1.35 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0143	0.0414	0.0452	0.0252	-0.0104	-0.0376	0
3	1.5783	0.8746	0.8478	0.734	0.5627	0.3581	0.1497	0
2	1.5783	1.529	1.3717	1.1432	0.8695	0.5692	0.2594	0
1	1.5783	1.382	1.1744	0.9513	0.7128	0.4616	0.2057	0

Table 33. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0182	0.0489	0.0543	0.0341	-0.003	-0.0335	0
3	1.5783	0.8769	0.8511	0.7378	0.5667	0.3618	0.1522	0
2	1.5783	1.5283	1.3707	1.1423	0.8691	0.5696	0.2604	0
1	1.5783	1.3842	1.1781	0.9557	0.7172	0.4655	0.2084	0

Table 34. Horizontal Velocity Component for Air-gap, h = 1.45 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0234	0.0596	0.0681	0.0491	0.0111	-0.0261	0
3	1.5783	0.8806	0.8575	0.7464	0.5772	0.3733	0.1586	0
2	1.5783	1.5276	1.3699	1.142	0.8696	0.5709	0.2621	0
1	1.5783	1.3864	1.1818	0.9602	0.7218	0.4695	0.2111	0

Table 35. Horizontal Velocity Component for Air-gap, h = 1.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0273	0.0671	0.0769	0.0576	0.018	-0.0222	0
3	1.5783	0.8827	0.8606	0.7499	0.5807	0.3764	0.1608	0
2	1.5783	1.5269	1.3688	1.1411	0.8692	0.5712	0.263	0
1	1.5783	1.3884	1.1853	0.9644	0.7261	0.4732	0.2137	0

Table 36. Horizontal Velocity Component for Air-gap, h = 1.55 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0314	0.0745	0.0856	0.0659	0.0248	-0.0183	0
3	1.5783	0.8849	0.8636	0.7532	0.5841	0.3795	0.1629	0
2	1.5783	1.5262	1.3677	1.1401	0.8687	0.5715	0.2638	0
1	1.5783	1.3905	1.1888	0.9685	0.7302	0.4768	0.2161	0

Table 37. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0354	0.082	0.0942	0.0741	0.0314	-0.0145	0
3	1.5783	0.8871	0.8666	0.7566	0.5874	0.3825	0.165	0
2	1.5783	1.5254	1.3666	1.1391	0.8683	0.5717	0.2645	0
1	1.5783	1.3925	1.1921	0.9725	0.7341	0.4802	0.2185	0

Table 38. Horizontal Velocity Component for Air-gap, h = 1.65 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0395	0.0895	0.1027	0.0822	0.038	-0.0108	0
3	1.5783	0.8893	0.8696	0.7598	0.5906	0.3854	0.1669	0
2	1.5783	1.5247	1.3655	1.1382	0.8678	0.5719	0.2652	0
1	1.5783	1.3944	1.1954	0.9764	0.738	0.4836	0.2207	0

Table 39. Horizontal Velocity Component for Air-gap, h = 1.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0436	0.0969	0.1111	0.0901	0.0443	-0.0072	0
3	1.5783	0.8915	0.8725	0.763	0.5938	0.3882	0.1689	0
2	1.5783	1.5239	1.3644	1.1372	0.8673	0.572	0.2659	0
1	1.5783	1.3963	1.1986	0.9802	0.7417	0.4868	0.223	0

Table 40. Horizontal Velocity Component for Air-gap, h = 1.75 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0478	0.1043	0.1195	0.0979	0.0506	-0.0036	0
3	1.5783	0.8937	0.8755	0.7662	0.5969	0.391	0.1707	0
2	1.5783	1.5231	1.3633	1.1362	0.8668	0.5722	0.2666	0
1	1.5783	1.3981	1.2017	0.9838	0.7454	0.4899	0.2251	0

Table 41. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0519	0.1117	0.1277	0.1055	0.0567	0	0
3	1.5783	0.8959	0.8783	0.7693	0.5999	0.3937	0.1725	0
2	1.5783	1.5223	1.3622	1.1353	0.8664	0.5723	0.2672	0
1	1.5783	1.3999	1.2047	0.9874	0.7489	0.4929	0.2271	0

Table 42. Horizontal Velocity Component for Air-gap, h = 1.85 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0563	0.1197	0.1368	0.1144	0.0644	0.0053	0
3	1.5783	0.8984	0.8819	0.7735	0.6044	0.3983	0.1766	0
2	1.5783	1.5215	1.3611	1.1346	0.8663	0.5729	0.2681	0
1	1.5783	1.4017	1.2077	0.9909	0.7524	0.4959	0.2292	0

Table 43. Horizontal Velocity Component for Air-gap, h = 1.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0605	0.1271	0.1451	0.1221	0.0707	0.0092	0
3	1.5783	0.9007	0.8849	0.7768	0.6077	0.4014	0.179	0
2	1.5783	1.5207	1.3601	1.1337	0.8659	0.5731	0.2688	0
1	1.5783	1.4035	1.2106	0.9943	0.7557	0.4988	0.2312	0

Table 44. Horizontal Velocity Component for Air-gap, h = 1.95 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0647	0.1345	0.1531	0.1296	0.0769	0.013	0
3	1.5783	0.903	0.8878	0.78	0.6109	0.4044	0.1813	0
2	1.5783	1.5199	1.359	1.1329	0.8656	0.5733	0.2695	0
1	1.5783	1.4051	1.2134	0.9976	0.7589	0.5016	0.2331	0

Table 45. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0689	0.1417	0.1611	0.1369	0.0828	0.0167	0
3	1.5783	0.9052	0.8907	0.7831	0.6141	0.4072	0.1835	0
2	1.5783	1.519	1.3579	1.132	0.8652	0.5736	0.2701	0
1	1.5783	1.4068	1.2161	1.0008	0.7621	0.5042	0.2349	0

Table 46. Horizontal Velocity Component for Air-gap, h = 2.10 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0772	0.156	0.1765	0.151	0.0941	0.0237	0
3	1.5783	0.9096	0.8963	0.7891	0.62	0.4127	0.1877	0
2	1.5783	1.5174	1.3558	1.1304	0.8646	0.574	0.2713	0
1	1.5783	1.4099	1.2212	1.0068	0.768	0.5093	0.2384	0

Table 47. Horizontal Velocity Component for Air-gap, h = 2.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0854	0.17	0.1912	0.1643	0.1047	0.0303	0
3	1.5783	0.9138	0.9017	0.7948	0.6255	0.4177	0.1915	0
2	1.5783	1.5156	1.3536	1.1288	0.864	0.5745	0.2724	0
1	1.5783	1.4128	1.2261	1.0124	0.7735	0.514	0.2416	0

Table 48. Horizontal Velocity Component for Air-gap, h = 2.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0935	0.1835	0.2052	0.1768	0.1147	0.0365	0
3	1.5783	0.918	0.9068	0.8001	0.6307	0.4224	0.195	0
2	1.5783	1.5139	1.3515	1.1272	0.8634	0.5749	0.2735	0
1	1.5783	1.4156	1.2306	1.0177	0.7787	0.5185	0.2447	0

Table 49. Horizontal Velocity Component for Air-gap, h = 2.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1015	0.1966	0.2186	0.1886	0.1239	0.0422	0
3	1.5783	0.922	0.9117	0.8052	0.6355	0.4267	0.1983	0
2	1.5783	1.5121	1.3494	1.1257	0.8628	0.5753	0.2745	0
1	1.5783	1.4181	1.2348	1.0225	0.7835	0.5226	0.2476	0

Table 50. Horizontal Velocity Component for Air-gap, h = 2.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1093	0.2092	0.2313	0.1996	0.1326	0.0476	0
3	1.5783	0.9259	0.9164	0.81	0.64	0.4307	0.2013	0
2	1.5783	1.5103	1.3472	1.1242	0.8623	0.5757	0.2755	0
1	1.5783	1.4205	1.2387	1.0271	0.7879	0.5264	0.2502	0

Table 51. Horizontal Velocity Component for Air-gap, h = 2.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1169	0.2214	0.2433	0.21	0.1406	0.0526	0
3	1.5783	0.9297	0.9208	0.8144	0.6442	0.4344	0.2041	0
2	1.5783	1.5084	1.3451	1.1227	0.8617	0.576	0.2764	0
1	1.5783	1.4227	1.2423	1.0313	0.792	0.53	0.2528	0

Table 52. Horizontal Velocity Component for Air-gap, h = 2.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1244	0.2332	0.2548	0.2196	0.148	0.0572	0
3	1.5783	0.9333	0.9249	0.8185	0.648	0.4377	0.2067	0
2	1.5783	1.5066	1.343	1.1212	0.8612	0.5764	0.2773	0
1	1.5783	1.4248	1.2456	1.0351	0.7959	0.5333	0.2551	0

Table 53. Horizontal Velocity Component for Air-gap, h = 2.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1193	0.2376	0.261	0.2256	0.153	0.0606	0
3	1.5783	0.9383	0.9276	0.8202	0.6495	0.4393	0.2082	0
2	1.5783	1.5047	1.3407	1.1194	0.8601	0.5761	0.2778	0
1	1.5783	1.4266	1.2485	1.0384	0.7991	0.5362	0.2571	0

Table 54. Horizontal Velocity Component for Air-gap, h = 2.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1105	0.24	0.2658	0.2304	0.1572	0.0635	0
3	1.5783	0.9438	0.9296	0.8209	0.65	0.4402	0.2093	0
2	1.5783	1.5027	1.3383	1.1173	0.8588	0.5757	0.2781	0
1	1.5783	1.4282	1.251	1.0413	0.8019	0.5386	0.259	0

Table 55. Horizontal Velocity Component for Air-gap, h = 3.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1113	0.2475	0.2737	0.2372	0.1625	0.0669	0
3	1.5783	0.947	0.9319	0.8229	0.652	0.442	0.2109	0
2	1.5783	1.5007	1.3359	1.1154	0.8577	0.5755	0.2786	0
1	1.5783	1.4297	1.2534	1.044	0.8046	0.541	0.2608	0

Table 56. Horizontal Velocity Component for Air-gap, h = 3.10 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1198	0.259	0.2837	0.2452	0.1684	0.0705	0
3	1.5783	0.9496	0.9353	0.8263	0.655	0.4446	0.2129	0
2	1.5783	1.4987	1.3338	1.1139	0.8572	0.5758	0.2793	0
1	1.5783	1.4311	1.2557	1.0467	0.8073	0.5435	0.2626	0

Table 57. Horizontal Velocity Component for Air-gap, h = 3.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.128	0.2699	0.2931	0.2526	0.1738	0.0738	0
3	1.5783	0.9521	0.9384	0.8293	0.6578	0.447	0.2146	0
2	1.5783	1.4967	1.3316	1.1125	0.8566	0.5759	0.28	0
1	1.5783	1.4324	1.2577	1.0491	0.8098	0.5457	0.2643	0

APPENDIX D.1.1.2

HORIZONTAL VELOCITY COMPONENT OF SLOT MODEL UNDERGOES ACTUAL FLOW

[P_{dyn} = 1.0 in. of water, b = 4 mm, time step = $1x10^{-5}$ s]

Table 58. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.014	-0.0303	-0.0433	-0.0476	-0.0389	-0.0182	0
3	0.7058	0.3755	0.3414	0.2711	0.1834	0.0962	0.0285	0
2	0.7058	0.6788	0.5956	0.4739	0.3303	0.1839	0.0605	0
1	0.7058	0.5805	0.4556	0.3325	0.2149	0.1104	0.0325	0

Table 59. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0167	-0.0355	-0.0514	-0.059	-0.0523	-0.0277	0
3	0.7058	0.3729	0.3397	0.2718	0.1859	0.0988	0.0294	0
2	0.7058	0.6825	0.6052	0.4899	0.3512	0.2044	0.0723	0
1	0.7058	0.5902	0.4739	0.3572	0.2414	0.1318	0.0421	0

Table 60. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0163	-0.0335	-0.0486	-0.058	-0.0551	-0.0326	0
3	0.7058	0.3727	0.342	0.2768	0.1924	0.1045	0.032	0
2	0.7058	0.6837	0.6088	0.4969	0.3617	0.2163	0.0806	0
1	0.7058	0.5965	0.4858	0.3732	0.2593	0.1475	0.0503	0

Table 61. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0142	-0.0274	-0.0402	-0.0504	-0.0518	-0.034	0
3	0.7058	0.3741	0.3464	0.2838	0.2005	0.1116	0.0358	0
2	0.7058	0.6839	0.6099	0.4999	0.3673	0.2238	0.0866	0
1	0.7058	0.602	0.4958	0.3863	0.2736	0.1606	0.0578	0

Table 62. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0105	-0.0182	-0.0277	-0.0384	-0.0443	-0.0328	0
3	0.7058	0.3765	0.3524	0.2921	0.2096	0.1194	0.0401	0
2	0.7058	0.6834	0.6096	0.5008	0.3702	0.2287	0.0911	0
1	0.7058	0.6071	0.5049	0.3979	0.2862	0.172	0.0647	0

Table 63. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0054	-0.0064	-0.0123	-0.0236	-0.0338	-0.0295	0
3	0.7058	0.3796	0.3593	0.301	0.2191	0.1276	0.0448	0
2	0.7058	0.6826	0.6085	0.5007	0.3718	0.232	0.0946	0
1	0.7058	0.6118	0.5133	0.4084	0.2974	0.1821	0.071	0

Table 64. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0	0.0054	0.0031	-0.0083	-0.0224	-0.025	0
3	0.7058	0.3823	0.3645	0.3082	0.2269	0.1347	0.049	0
2	0.7058	0.6816	0.607	0.4997	0.3723	0.2342	0.0974	0
1	0.7058	0.6163	0.521	0.418	0.3073	0.191	0.0767	0

Table 65. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0065	0.019	0.0202	0.0087	-0.0095	-0.0193	0
3	0.7058	0.3861	0.3711	0.3166	0.2363	0.1427	0.0536	0
2	0.7058	0.6804	0.6054	0.4987	0.3726	0.2362	0.0999	0
1	0.7058	0.6204	0.5281	0.4266	0.3163	0.199	0.082	0

Table 66. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0132	0.0327	0.0374	0.0263	0.0051	-0.0124	0
3	0.7058	0.3895	0.3772	0.3248	0.246	0.1526	0.0592	0
2	0.7058	0.6791	0.6037	0.4977	0.3731	0.2381	0.1023	0
1	0.7058	0.6241	0.5344	0.4344	0.3242	0.2062	0.0868	0

Table 67. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0195	0.0447	0.0516	0.0398	0.0158	-0.0071	0
3	0.7058	0.3924	0.3816	0.3299	0.2514	0.1577	0.0624	0
2	0.7058	0.6776	0.6017	0.4963	0.3728	0.2392	0.104	0
1	0.7058	0.6274	0.54	0.441	0.331	0.2123	0.0909	0

Table 68. Horizontal Velocity Component for Air-gap, h = 2.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0259	0.0564	0.0648	0.0522	0.0255	-0.002	0
3	0.7058	0.3952	0.3857	0.3347	0.2564	0.1622	0.0653	0
2	0.7058	0.676	0.5998	0.4949	0.3725	0.2401	0.1056	0
1	0.7058	0.6303	0.5448	0.4467	0.3369	0.2176	0.0946	0

Table 69. Horizontal Velocity Component for Air-gap, h = 2.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0324	0.0678	0.0775	0.0641	0.0352	0.0035	0
3	0.7058	0.3982	0.3899	0.3396	0.2616	0.1674	0.0691	0
2	0.7058	0.6744	0.5979	0.4937	0.3724	0.2412	0.1072	0
1	0.7058	0.6329	0.5491	0.4518	0.3421	0.2223	0.098	0

Table 70. Horizontal Velocity Component for Air-gap, h = 2.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0388	0.0787	0.0891	0.0746	0.0438	0.0085	0
3	0.7058	0.401	0.3937	0.3439	0.2662	0.1718	0.0725	0
2	0.7058	0.6728	0.596	0.4925	0.3724	0.2422	0.1087	0
1	0.7058	0.6351	0.5527	0.4561	0.3466	0.2265	0.101	0

Table 71. Horizontal Velocity Component for Air-gap, h = 2.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0451	0.0888	0.0996	0.084	0.0513	0.013	0
3	0.7058	0.4037	0.3972	0.3478	0.2702	0.1757	0.0754	0
2	0.7058	0.671	0.5941	0.4913	0.3723	0.2431	0.1101	0
1	0.7058	0.637	0.5558	0.4598	0.3504	0.2301	0.1037	0

Table 72. Horizontal Velocity Component for Air-gap, h = 3.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0513	0.0984	0.1091	0.0923	0.0578	0.0169	0
3	0.7058	0.4063	0.4004	0.3512	0.2737	0.179	0.078	0
2	0.7058	0.6693	0.5921	0.4902	0.3722	0.244	0.1114	0
1	0.7058	0.6386	0.5584	0.4629	0.3537	0.2332	0.1062	0

Table 73. Horizontal Velocity Component for Air-gap, h = 3.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0573	0.1073	0.1176	0.0995	0.0635	0.0204	0
3	0.7058	0.4087	0.4033	0.3542	0.2767	0.1819	0.0802	0
2	0.7058	0.6674	0.5902	0.489	0.372	0.2447	0.1125	0
1	0.7058	0.6398	0.5605	0.4655	0.3565	0.236	0.1083	0

Table 74. Horizontal Velocity Component for Air-gap, h = 3.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0633	0.1156	0.1252	0.1058	0.0684	0.0235	0
3	0.7058	0.4109	0.4058	0.3568	0.2792	0.1843	0.0822	0
2	0.7058	0.6655	0.5882	0.4878	0.3718	0.2453	0.1136	0
1	0.7058	0.6408	0.5622	0.4676	0.3588	0.2384	0.1103	0

Table 75. Horizontal Velocity Component for Air-gap, h = 3.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0631	0.1198	0.13	0.11	0.0719	0.0258	0
3	0.7058	0.4128	0.4071	0.3578	0.2802	0.1855	0.0834	0
2	0.7058	0.6635	0.586	0.4862	0.3711	0.2455	0.1143	0
1	0.7058	0.6415	0.5632	0.469	0.3605	0.2401	0.1119	0

APPENDIX D.1.1.3

HORIZONTAL VELOCITY COMPONENT OF SLOT MODEL UNDERGOES ACTUAL FLOW

[$P_{dyn} = 0.1$ in. of water, b = 4 mm, time step = $1x10^{-5}$ s]

Table 76. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0023	-0.0048	-0.0067	-0.0071	-0.0054	-0.0023	0
3	0.2232	0.1204	0.1103	0.0878	0.0594	0.0312	0.0093	0
2	0.2232	0.2124	0.1831	0.1419	0.0953	0.0504	0.0154	0
1	0.2232	0.1795	0.1366	0.0958	0.0589	0.0286	0.0079	0

Table 77. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0034	-0.0072	-0.0103	-0.0112	-0.0089	-0.004	0
3	0.2232	0.1192	0.1086	0.0862	0.0582	0.0305	0.0091	0
2	0.2232	0.2135	0.1857	0.1459	0.0999	0.0543	0.0172	0
1	0.2232	0.1824	0.1418	0.102	0.0647	0.0324	0.0093	0

Table 78. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0038	-0.0082	-0.0118	-0.0132	-0.011	-0.0052	0
3	0.2232	0.1184	0.1076	0.0854	0.0578	0.0304	0.009	0
2	0.2232	0.2141	0.1872	0.1483	0.1029	0.057	0.0186	0
1	0.2232	0.1849	0.1463	0.1076	0.07	0.0361	0.0107	0

Table 79. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0038	-0.008	-0.0118	-0.0137	-0.0119	-0.006	0
3	0.2232	0.1179	0.1072	0.0854	0.058	0.0306	0.0092	0
2	0.2232	0.2143	0.1879	0.1496	0.1048	0.0589	0.0198	0
1	0.2232	0.1872	0.1504	0.1127	0.075	0.0398	0.0122	0

Table 80. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0034	-0.007	-0.0105	-0.0128	-0.0118	-0.0064	0
3	0.2232	0.1177	0.1073	0.0858	0.0586	0.0312	0.0094	0
2	0.2232	0.2143	0.188	0.1503	0.106	0.0603	0.0206	0
1	0.2232	0.1893	0.1541	0.1173	0.0796	0.0433	0.0137	0

Table 81. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0026	-0.0052	-0.0082	-0.0109	-0.0109	-0.0064	0
3	0.2232	0.1177	0.1078	0.0867	0.0596	0.032	0.0098	0
2	0.2232	0.2142	0.1879	0.1505	0.1067	0.0613	0.0214	0
1	0.2232	0.1912	0.1575	0.1216	0.084	0.0467	0.0152	0

Table 82. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0016	-0.0028	-0.0051	-0.0082	-0.0094	-0.0062	0
3	0.2232	0.1179	0.1086	0.0879	0.0609	0.033	0.0102	0
2	0.2232	0.2139	0.1876	0.1504	0.1071	0.0621	0.022	0
1	0.2232	0.193	0.1607	0.1255	0.0879	0.0498	0.0167	0

Table 83. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0003	0	-0.0016	-0.0049	-0.0074	-0.0056	0
3	0.2232	0.1182	0.1095	0.0892	0.0622	0.034	0.0107	0
2	0.2232	0.2135	0.1871	0.1502	0.1073	0.0627	0.0225	0
1	0.2232	0.1946	0.1635	0.129	0.0914	0.0527	0.0181	0

Table 84. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0011	0.0031	0.0023	-0.0014	-0.0052	-0.0049	0
3	0.2232	0.1186	0.1105	0.0906	0.0637	0.0351	0.0113	0
2	0.2232	0.2131	0.1866	0.1498	0.1074	0.0632	0.023	0
1	0.2232	0.1961	0.166	0.1321	0.0946	0.0553	0.0194	0

Table 85. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0027	0.0064	0.0065	0.0025	-0.0025	-0.0041	0
3	0.2232	0.119	0.1116	0.0923	0.0656	0.0366	0.012	0
2	0.2232	0.2127	0.186	0.1495	0.1076	0.0637	0.0235	0
1	0.2232	0.1974	0.1682	0.1348	0.0974	0.0577	0.0207	0

Table 86. Horizontal Velocity Component for Air-gap, h = 2.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0043	0.0096	0.0102	0.006	-0.0002	-0.0032	0
3	0.2232	0.1195	0.1125	0.0934	0.0668	0.0377	0.0125	0
2	0.2232	0.2122	0.1854	0.1491	0.1076	0.0642	0.0239	0
1	0.2232	0.1985	0.1701	0.1371	0.0998	0.0598	0.0219	0

Table 87. Horizontal Velocity Component for Air-gap, h = 2.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.006	0.013	0.0143	0.0099	0.0027	-0.0021	0
3	0.2232	0.12	0.1137	0.0951	0.0689	0.0396	0.0134	0
2	0.2232	0.2117	0.1848	0.1489	0.1079	0.0648	0.0245	0
1	0.2232	0.1995	0.1718	0.1392	0.102	0.0618	0.0231	0

Table 88. Horizontal Velocity Component for Air-gap, h = 2.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0077	0.016	0.0179	0.0131	0.005	-0.0012	0
3	0.2232	0.1205	0.1146	0.0963	0.0701	0.0407	0.014	0
2	0.2232	0.2111	0.1842	0.1485	0.108	0.0652	0.0249	0
1	0.2232	0.2003	0.1732	0.1409	0.1038	0.0634	0.0241	0

Table 89. Horizontal Velocity Component for Air-gap, h = 2.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0093	0.019	0.0212	0.0161	0.0071	-0.0004	0
3	0.2232	0.121	0.1155	0.0974	0.0713	0.0418	0.0145	0
2	0.2232	0.2105	0.1835	0.1482	0.108	0.0657	0.0254	0
1	0.2232	0.201	0.1743	0.1423	0.1054	0.0649	0.0251	0

Table 90. Horizontal Velocity Component for Air-gap, h = 3.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.011	0.0218	0.0242	0.0188	0.0091	0.0005	0
3	0.2232	0.1215	0.1163	0.0984	0.0725	0.0428	0.0151	0
2	0.2232	0.2099	0.1828	0.1479	0.1081	0.0661	0.0258	0
1	0.2232	0.2016	0.1753	0.1435	0.1067	0.0663	0.026	0

Table 91. Horizontal Velocity Component for Air-gap, h = 3.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0127	0.0245	0.0271	0.0213	0.0109	0.0013	0
3	0.2232	0.1221	0.1171	0.0994	0.0736	0.0438	0.0157	0
2	0.2232	0.2093	0.1822	0.1475	0.1082	0.0666	0.0263	0
1	0.2232	0.2021	0.1761	0.1445	0.1079	0.0674	0.0268	0

Table 92. Horizontal Velocity Component for Air-gap, h = 3.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0144	0.027	0.0297	0.0236	0.0126	0.0021	0
3	0.2232	0.1226	0.1179	0.1003	0.0746	0.0448	0.0163	0
2	0.2232	0.2087	0.1815	0.1472	0.1083	0.067	0.0267	0
1	0.2232	0.2024	0.1767	0.1454	0.1089	0.0685	0.0276	0

Table 93. Horizontal Velocity Component for Air-gap, h = 3.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.016	0.0294	0.032	0.0256	0.0141	0.0028	0
3	0.2232	0.1231	0.1186	0.1011	0.0755	0.0456	0.0168	0
2	0.2232	0.208	0.1809	0.1468	0.1084	0.0674	0.0272	0
1	0.2232	0.2027	0.1772	0.146	0.1097	0.0694	0.0283	0

APPENDIX D.1.1.4

HORIZONTAL VELOCITY COMPONENT OF SLOT MODEL UNDERGOES ACTUAL FLOW

[P_{dyn} = 0.01 in. of water, b = 4 mm, time step = $1x10^{-5}$ s]

Table 94. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0003	-0.0006	-0.0008	-0.0008	-0.0006	-0.0002	0
3	0.0706	0.0384	0.0354	0.0283	0.0192	0.0101	0.003	0
2	0.0706	0.0667	0.0569	0.0435	0.0287	0.0148	0.0044	0
1	0.0706	0.0561	0.042	0.0289	0.0175	0.0083	0.0023	0

Table 95. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0004	-0.001	-0.0014	-0.0014	-0.0011	-0.0005	0
3	0.0706	0.0381	0.035	0.0279	0.0189	0.0099	0.003	0
2	0.0706	0.0669	0.0573	0.0441	0.0293	0.0153	0.0046	0
1	0.0706	0.0566	0.0429	0.03	0.0183	0.0089	0.0024	0

Table 96. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0005	-0.0012	-0.0017	-0.0019	-0.0015	-0.0006	0
3	0.0706	0.0379	0.0346	0.0275	0.0185	0.0097	0.0029	0
2	0.0706	0.067	0.0576	0.0445	0.0298	0.0157	0.0048	0
1	0.0706	0.0573	0.044	0.0312	0.0194	0.0095	0.0026	0

Table 97. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0006	-0.0012	-0.0019	-0.0021	-0.0017	-0.0008	0
3	0.0706	0.0376	0.0342	0.0271	0.0182	0.0096	0.0029	0
2	0.0706	0.067	0.0577	0.0447	0.0301	0.016	0.0049	0
1	0.0706	0.058	0.0452	0.0326	0.0206	0.0102	0.0029	0

Table 98. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0005	-0.0012	-0.0018	-0.0021	-0.0018	-0.0009	0
3	0.0706	0.0373	0.0338	0.0267	0.018	0.0094	0.0028	0
2	0.0706	0.067	0.0577	0.0448	0.0303	0.0162	0.0051	0
1	0.0706	0.0587	0.0465	0.034	0.0218	0.0111	0.0032	0

Table 99. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0004	-0.0009	-0.0016	-0.002	-0.0018	-0.0009	0
3	0.0706	0.0371	0.0335	0.0264	0.0178	0.0093	0.0028	0
2	0.0706	0.0669	0.0576	0.0448	0.0304	0.0164	0.0052	0
1	0.0706	0.0594	0.0477	0.0355	0.0231	0.0119	0.0035	0

Table 100. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0002	-0.0006	-0.0012	-0.0017	-0.0017	-0.0009	0
3	0.0706	0.0369	0.0332	0.0262	0.0176	0.0092	0.0028	0
2	0.0706	0.0668	0.0575	0.0447	0.0304	0.0165	0.0052	0
1	0.0706	0.0602	0.049	0.0369	0.0244	0.0128	0.0038	0

Table 101. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0	-0.0001	-0.0006	-0.0012	-0.0014	-0.0009	0
3	0.0706	0.0367	0.0331	0.026	0.0175	0.0092	0.0028	0
2	0.0706	0.0667	0.0573	0.0446	0.0304	0.0165	0.0053	0
1	0.0706	0.0608	0.0501	0.0382	0.0256	0.0136	0.0041	0

Table 102. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0003	0.0005	0.0001	-0.0007	-0.0011	-0.0008	0
3	0.0706	0.0366	0.0329	0.026	0.0175	0.0092	0.0028	0
2	0.0706	0.0666	0.0571	0.0444	0.0303	0.0166	0.0053	0
1	0.0706	0.0614	0.0511	0.0394	0.0268	0.0144	0.0045	0

Table 103. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0006	0.0011	0.0008	0	-0.0007	-0.0007	0
3	0.0706	0.0365	0.0329	0.0259	0.0175	0.0092	0.0028	0
2	0.0706	0.0664	0.0569	0.0443	0.0303	0.0166	0.0054	0
1	0.0706	0.062	0.052	0.0405	0.0278	0.0151	0.0048	0

Table 104. Horizontal Velocity Component for Air-gap, h = 2.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.001	0.0018	0.0016	0.0007	-0.0003	-0.0005	0
3	0.0706	0.0365	0.0329	0.026	0.0176	0.0093	0.0028	0
2	0.0706	0.0662	0.0566	0.0441	0.0302	0.0166	0.0054	0
1	0.0706	0.0624	0.0528	0.0414	0.0287	0.0158	0.005	0

Table 105. Horizontal Velocity Component for Air-gap, h = 2.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0014	0.0026	0.0025	0.0014	0.0001	-0.0004	0
3	0.0706	0.0365	0.0329	0.0261	0.0177	0.0094	0.0029	0
2	0.0706	0.066	0.0564	0.0439	0.0302	0.0167	0.0055	0
1	0.0706	0.0628	0.0535	0.0422	0.0294	0.0164	0.0053	0

Table 106. Horizontal Velocity Component for Air-gap, h = 2.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0018	0.0033	0.0033	0.0021	0.0006	-0.0002	0
3	0.0706	0.0365	0.033	0.0262	0.0179	0.0095	0.0029	0
2	0.0706	0.0658	0.0561	0.0438	0.0301	0.0167	0.0055	0
1	0.0706	0.0632	0.054	0.0429	0.0301	0.0169	0.0055	0

Table 107. Horizontal Velocity Component for Air-gap, h = 2.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0022	0.0041	0.0042	0.0028	0.001	-0.0001	0
3	0.0706	0.0365	0.0331	0.0264	0.018	0.0097	0.003	0
2	0.0706	0.0656	0.0559	0.0436	0.0301	0.0168	0.0056	0
1	0.0706	0.0635	0.0545	0.0434	0.0306	0.0173	0.0058	0

Table 108. Horizontal Velocity Component for Air-gap, h = 3.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0027	0.0048	0.005	0.0035	0.0014	0.0001	0
3	0.0706	0.0365	0.0332	0.0265	0.0182	0.0098	0.003	0
2	0.0706	0.0654	0.0556	0.0434	0.0301	0.0168	0.0057	0
1	0.0706	0.0637	0.0548	0.0438	0.0311	0.0177	0.0059	0

Table 109. Horizontal Velocity Component for Air-gap, h = 3.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0031	0.0056	0.0058	0.0042	0.0019	0.0002	0
3	0.0706	0.0366	0.0333	0.0267	0.0184	0.01	0.0031	0
2	0.0706	0.0652	0.0554	0.0432	0.03	0.0169	0.0057	0
1	0.0706	0.0639	0.0551	0.0442	0.0314	0.018	0.0061	0

Table 110. Horizontal Velocity Component for Air-gap, h = 3.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0036	0.0063	0.0065	0.0048	0.0022	0.0003	0
3	0.0706	0.0367	0.0334	0.0269	0.0186	0.0101	0.0032	0
2	0.0706	0.0649	0.0551	0.0431	0.03	0.017	0.0058	0
1	0.0706	0.064	0.0553	0.0444	0.0317	0.0183	0.0063	0

Table 111. Horizontal Velocity Component for Air-gap, h = 3.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0041	0.007	0.0072	0.0053	0.0026	0.0005	0
3	0.0706	0.0367	0.0336	0.0271	0.0188	0.0103	0.0033	0
2	0.0706	0.0647	0.0548	0.0429	0.03	0.017	0.0058	0
1	0.0706	0.0641	0.0555	0.0446	0.032	0.0185	0.0064	0

APPENDIX D.1.2.1

HORIZONTAL VELOCITY COMPONENT OF SLOT MODEL UNDERGOES FRICTIONLESS FLOW

[P_{dyn} = 5.0 in. of water, b = 4 mm, time step = $1x10^{-6}$ s]

Table 112. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0028	0.0041	0.0044	0.004	0.003	0.0016	0
3	1.5783	0.8701	0.8473	0.7493	0.5993	0.4158	0.2127	0
2	1.5783	1.5443	1.4079	1.197	0.9347	0.6392	0.3243	0
1	1.5783	1.354	1.1293	0.9043	0.6787	0.4527	0.2264	0

Table 113. Horizontal Velocity Component for Air-gap, h = 0.25 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0044	0.0064	0.0069	0.0062	0.0046	0.0025	0
3	1.5783	0.8711	0.8486	0.7506	0.6004	0.4166	0.2131	0
2	1.5783	1.5441	1.4075	1.1966	0.9343	0.6389	0.3241	0
1	1.5783	1.3546	1.1304	0.9056	0.68	0.4537	0.227	0

Table 114. Horizontal Velocity Component for Air-gap, h = 0.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0063	0.0092	0.0099	0.0089	0.0066	0.0035	0
3	1.5783	0.8724	0.8502	0.7522	0.6018	0.4175	0.2136	0
2	1.5783	1.5439	1.407	1.196	0.9337	0.6384	0.3239	0
1	1.5783	1.3554	1.1318	0.9072	0.6815	0.4549	0.2276	0

Table 115. Horizontal Velocity Component for Air-gap, h = 0.35 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0085	0.0125	0.0134	0.0121	0.009	0.0048	0
3	1.5783	0.8738	0.8521	0.754	0.6033	0.4187	0.2142	0
2	1.5783	1.5436	1.4065	1.1953	0.9331	0.638	0.3237	0
1	1.5783	1.3563	1.1333	0.909	0.6833	0.4563	0.2284	0

Table 116. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0112	0.0163	0.0175	0.0157	0.0117	0.0062	0
3	1.5783	0.8755	0.8542	0.7561	0.6051	0.4199	0.2149	0
2	1.5783	1.5433	1.4059	1.1946	0.9324	0.6374	0.3234	0
1	1.5783	1.3573	1.1351	0.9111	0.6853	0.4578	0.2292	0

Table 117. Horizontal Velocity Component for Air-gap, h = 0.45 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0141	0.0205	0.022	0.0198	0.0147	0.0078	0
3	1.5783	0.8773	0.8566	0.7584	0.607	0.4213	0.2156	0
2	1.5783	1.543	1.4052	1.1937	0.9316	0.6368	0.3231	0
1	1.5783	1.3584	1.137	0.9134	0.6875	0.4596	0.2302	0

Table 118. Horizontal Velocity Component for Air-gap, h = 0.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0174	0.0253	0.0271	0.0243	0.0181	0.0096	0
3	1.5783	0.8793	0.8592	0.761	0.6092	0.4229	0.2164	0
2	1.5783	1.5426	1.4045	1.1928	0.9307	0.6362	0.3227	0
1	1.5783	1.3597	1.1392	0.916	0.6899	0.4615	0.2312	0

Table 119. Horizontal Velocity Component for Air-gap, h = 0.55 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.021	0.0305	0.0326	0.0292	0.0217	0.0115	0
3	1.5783	0.8814	0.862	0.7637	0.6115	0.4246	0.2173	0
2	1.5783	1.5423	1.4037	1.1918	0.9298	0.6355	0.3224	0
1	1.5783	1.361	1.1415	0.9187	0.6926	0.4635	0.2323	0

Table 120. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0249	0.0361	0.0386	0.0345	0.0257	0.0136	0
3	1.5783	0.8837	0.865	0.7667	0.614	0.4264	0.2183	0
2	1.5783	1.5418	1.4029	1.1908	0.9288	0.6347	0.322	0
1	1.5783	1.3624	1.1439	0.9216	0.6953	0.4657	0.2335	0

Table 121. Horizontal Velocity Component for Air-gap, h = 0.65 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0292	0.0422	0.045	0.0402	0.0299	0.0159	0
3	1.5783	0.886	0.8682	0.7698	0.6166	0.4283	0.2193	0
2	1.5783	1.5414	1.402	1.1897	0.9278	0.634	0.3216	0
1	1.5783	1.3639	1.1465	0.9247	0.6983	0.4679	0.2347	0

Table 122. Horizontal Velocity Component for Air-gap, h = 0.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0339	0.0487	0.0518	0.0462	0.0343	0.0182	0
3	1.5783	0.8884	0.8715	0.773	0.6194	0.4303	0.2204	0
2	1.5783	1.5409	1.401	1.1886	0.9267	0.6332	0.3212	0
1	1.5783	1.3655	1.1492	0.9279	0.7014	0.4703	0.236	0

Table 123. Horizontal Velocity Component for Air-gap, h = 0.75 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0389	0.0557	0.0591	0.0527	0.0391	0.0207	0
3	1.5783	0.8908	0.8749	0.7764	0.6223	0.4324	0.2215	0
2	1.5783	1.5404	1.4	1.1874	0.9256	0.6324	0.3208	0
1	1.5783	1.3671	1.152	0.9312	0.7045	0.4728	0.2373	0

Table 124. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0443	0.0631	0.0668	0.0594	0.044	0.0233	0
3	1.5783	0.8932	0.8783	0.7799	0.6252	0.4345	0.2226	0
2	1.5783	1.5399	1.399	1.1861	0.9244	0.6315	0.3204	0
1	1.5783	1.3688	1.1549	0.9347	0.7078	0.4753	0.2387	0

Table 125. Horizontal Velocity Component for Air-gap, h = 0.85 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0503	0.071	0.075	0.0666	0.0493	0.0261	0
3	1.5783	0.8955	0.8818	0.7835	0.6283	0.4368	0.2238	0
2	1.5783	1.5393	1.3979	1.1849	0.9233	0.6307	0.32	0
1	1.5783	1.3706	1.1579	0.9382	0.7112	0.4779	0.2401	0

Table 126. Horizontal Velocity Component for Air-gap, h = 0.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0569	0.0794	0.0836	0.0741	0.0548	0.029	0
3	1.5783	0.8976	0.8854	0.7872	0.6315	0.439	0.225	0
2	1.5783	1.5387	1.3968	1.1835	0.9221	0.6298	0.3196	0
1	1.5783	1.3724	1.161	0.9418	0.7146	0.4805	0.2416	0

Table 127. Horizontal Velocity Component for Air-gap, h = 0.95 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0642	0.0885	0.0928	0.082	0.0605	0.032	0
3	1.5783	0.8996	0.8889	0.7909	0.6347	0.4414	0.2263	0
2	1.5783	1.5381	1.3957	1.1822	0.9209	0.629	0.3191	0
1	1.5783	1.3742	1.1641	0.9454	0.7181	0.4832	0.243	0

Table 128. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0724	0.0982	0.1025	0.0904	0.0666	0.0352	0
3	1.5783	0.9015	0.8925	0.7948	0.6381	0.4439	0.2277	0
2	1.5783	1.5375	1.3945	1.1808	0.9197	0.6281	0.3187	0
1	1.5783	1.3761	1.1672	0.9491	0.7216	0.4859	0.2445	0

Table 129. Horizontal Velocity Component for Air-gap, h = 1.05 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0816	0.1087	0.1129	0.0992	0.0729	0.0385	0
3	1.5783	0.9033	0.8961	0.7989	0.6417	0.4465	0.2291	0
2	1.5783	1.5369	1.3933	1.1795	0.9185	0.6273	0.3183	0
1	1.5783	1.3779	1.1704	0.9528	0.7251	0.4886	0.2459	0

Table 130. Horizontal Velocity Component for Air-gap, h = 1.10 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0917	0.1198	0.1237	0.1083	0.0795	0.0419	0
3	1.5783	0.9051	0.9	0.8031	0.6454	0.4493	0.2305	0
2	1.5783	1.5363	1.3921	1.1781	0.9173	0.6265	0.318	0
1	1.5783	1.3798	1.1736	0.9566	0.7286	0.4914	0.2474	0

Table 131. Horizontal Velocity Component for Air-gap, h = 1.15 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1025	0.1314	0.1349	0.1178	0.0862	0.0454	0
3	1.5783	0.9071	0.904	0.8076	0.6493	0.4522	0.2321	0
2	1.5783	1.5356	1.391	1.1768	0.9162	0.6258	0.3176	0
1	1.5783	1.3817	1.1768	0.9603	0.7322	0.4941	0.2489	0

Table 132. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1135	0.1433	0.1462	0.1272	0.093	0.0489	0
3	1.5783	0.9095	0.9083	0.8123	0.6535	0.4552	0.2337	0
2	1.5783	1.5349	1.3898	1.1756	0.9152	0.6251	0.3173	0
1	1.5783	1.3836	1.18	0.9641	0.7357	0.4968	0.2504	0

Table 133. Horizontal Velocity Component for Air-gap, h = 1.25 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1241	0.155	0.1573	0.1366	0.0996	0.0524	0
3	1.5783	0.9125	0.913	0.8172	0.6578	0.4583	0.2354	0
2	1.5783	1.5342	1.3887	1.1744	0.9142	0.6245	0.3171	0
1	1.5783	1.3855	1.1832	0.9678	0.7393	0.4995	0.2519	0

Table 134. Horizontal Velocity Component for Air-gap, h = 1.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1335	0.166	0.168	0.1455	0.106	0.0557	0
3	1.5783	0.9162	0.9182	0.8224	0.6621	0.4615	0.2371	0
2	1.5783	1.5335	1.3876	1.1733	0.9134	0.624	0.3169	0
1	1.5783	1.3874	1.1864	0.9716	0.7428	0.5023	0.2533	0

Table 135. Horizontal Velocity Component for Air-gap, h = 1.35 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1409	0.1759	0.1777	0.1537	0.1118	0.0587	0
3	1.5783	0.9209	0.9239	0.8278	0.6666	0.4647	0.2388	0
2	1.5783	1.5328	1.3865	1.1724	0.9127	0.6237	0.3168	0
1	1.5783	1.3893	1.1896	0.9753	0.7463	0.505	0.2548	0

Table 136. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1456	0.1844	0.1864	0.1611	0.1172	0.0615	0
3	1.5783	0.9267	0.9301	0.8333	0.671	0.4678	0.2404	0
2	1.5783	1.5321	1.3856	1.1715	0.9122	0.6234	0.3168	0
1	1.5783	1.3912	1.1928	0.979	0.7499	0.5077	0.2563	0

Table 137. Horizontal Velocity Component for Air-gap, h = 1.45 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1471	0.1913	0.1938	0.1676	0.1219	0.064	0
3	1.5783	0.9339	0.937	0.839	0.6754	0.4709	0.242	0
2	1.5783	1.5313	1.3847	1.1708	0.9118	0.6233	0.3168	0
1	1.5783	1.3931	1.196	0.9828	0.7534	0.5104	0.2577	0

Table 138. Horizontal Velocity Component for Air-gap, h = 1.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1424	0.1944	0.1985	0.1722	0.1254	0.0659	0
3	1.5783	0.9426	0.9442	0.8444	0.6793	0.4735	0.2435	0
2	1.5783	1.5306	1.3838	1.1702	0.9115	0.6232	0.3168	0
1	1.5783	1.395	1.1992	0.9865	0.7569	0.5131	0.2592	0

Table 139. Horizontal Velocity Component for Air-gap, h = 1.55 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1328	0.1952	0.2014	0.1754	0.128	0.0673	0
3	1.5783	0.9537	0.9517	0.8493	0.6827	0.4758	0.2446	0
2	1.5783	1.5298	1.3831	1.1698	0.9113	0.6232	0.3169	0
1	1.5783	1.3969	1.2024	0.9902	0.7604	0.5158	0.2607	0

Table 140. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1217	0.1957	0.2039	0.1782	0.1304	0.0687	0
3	1.5783	0.9677	0.9606	0.8549	0.6863	0.4781	0.2458	0
2	1.5783	1.5291	1.3826	1.1696	0.9113	0.6234	0.3171	0
1	1.5783	1.3987	1.2056	0.9939	0.7639	0.5185	0.2621	0

Table 141. Horizontal Velocity Component for Air-gap, h = 1.65 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1088	0.1961	0.2063	0.1809	0.1326	0.0699	0
3	1.5783	0.9854	0.9711	0.8612	0.6904	0.4806	0.2471	0
2	1.5783	1.5283	1.3822	1.1697	0.9117	0.6238	0.3174	0
1	1.5783	1.4006	1.2088	0.9977	0.7675	0.5213	0.2636	0

Table 142. Horizontal Velocity Component for Air-gap, h = 1.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1085	0.2007	0.2114	0.1855	0.136	0.0717	0
3	1.5783	0.9876	0.9724	0.8621	0.6911	0.4811	0.2474	0
2	1.5783	1.5276	1.3811	1.1684	0.9106	0.6231	0.317	0
1	1.5783	1.4024	1.2117	1.001	0.7705	0.5236	0.2649	0

Table 143. Horizontal Velocity Component for Air-gap, h = 1.75 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1063	0.2025	0.2143	0.1885	0.1384	0.073	0
3	1.5783	0.9872	0.9711	0.8608	0.6901	0.4805	0.247	0
2	1.5783	1.5268	1.3797	1.1668	0.9091	0.622	0.3164	0
1	1.5783	1.404	1.2143	1.004	0.7733	0.5257	0.266	0

Table 144. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1049	0.2048	0.2175	0.1917	0.1409	0.0744	0
3	1.5783	0.9865	0.9698	0.8597	0.6892	0.4799	0.2468	0
2	1.5783	1.526	1.3783	1.1652	0.9077	0.6209	0.3158	0
1	1.5783	1.4056	1.2169	1.007	0.776	0.5277	0.2671	0

Table 145. Horizontal Velocity Component for Air-gap, h = 1.85 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.104	0.2075	0.221	0.1951	0.1435	0.0758	0
3	1.5783	0.9856	0.9685	0.8587	0.6885	0.4795	0.2466	0
2	1.5783	1.5252	1.377	1.1636	0.9062	0.6198	0.3153	0
1	1.5783	1.4071	1.2195	1.0098	0.7786	0.5297	0.2681	0

Table 146. Horizontal Velocity Component for Air-gap, h = 1.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1034	0.2103	0.2247	0.1986	0.1462	0.0772	0
3	1.5783	0.9846	0.9673	0.8577	0.6879	0.4791	0.2464	0
2	1.5783	1.5244	1.3756	1.162	0.9047	0.6187	0.3147	0
1	1.5783	1.4086	1.2219	1.0125	0.7812	0.5316	0.2691	0

Table 147. Horizontal Velocity Component for Air-gap, h = 1.95 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1032	0.2134	0.2284	0.2021	0.1488	0.0786	0
3	1.5783	0.9835	0.9661	0.8569	0.6873	0.4787	0.2463	0
2	1.5783	1.5236	1.3742	1.1604	0.9033	0.6176	0.3142	0
1	1.5783	1.4101	1.2243	1.0152	0.7836	0.5334	0.2701	0

Table 148. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1032	0.2166	0.2322	0.2056	0.1515	0.08	0
3	1.5783	0.9824	0.965	0.8561	0.6868	0.4784	0.2462	0
2	1.5783	1.5227	1.3727	1.1589	0.9018	0.6166	0.3137	0
1	1.5783	1.4115	1.2266	1.0177	0.7859	0.5351	0.271	0

Table 149. Horizontal Velocity Component for Air-gap, h = 2.10 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1041	0.2233	0.24	0.2127	0.1567	0.0828	0
3	1.5783	0.9798	0.9628	0.8547	0.686	0.478	0.246	0
2	1.5783	1.521	1.3699	1.1557	0.899	0.6146	0.3127	0
1	1.5783	1.4142	1.2309	1.0226	0.7903	0.5384	0.2728	0

Table 150. Horizontal Velocity Component for Air-gap, h = 2.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1057	0.2302	0.2478	0.2198	0.1619	0.0855	0
3	1.5783	0.9771	0.9608	0.8535	0.6853	0.4777	0.246	0
2	1.5783	1.5192	1.367	1.1526	0.8963	0.6126	0.3117	0
1	1.5783	1.4167	1.2349	1.027	0.7942	0.5413	0.2744	0

Table 151. Horizontal Velocity Component for Air-gap, h = 2.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.108	0.2373	0.2556	0.2266	0.1669	0.0882	0
3	1.5783	0.9742	0.959	0.8526	0.6849	0.4776	0.246	0
2	1.5783	1.5174	1.3642	1.1495	0.8937	0.6108	0.3108	0
1	1.5783	1.4191	1.2386	1.031	0.7979	0.5441	0.2758	0

Table 152. Horizontal Velocity Component for Air-gap, h = 2.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1108	0.2444	0.2631	0.2332	0.1716	0.0906	0
3	1.5783	0.9714	0.9573	0.8518	0.6846	0.4775	0.246	0
2	1.5783	1.5156	1.3613	1.1465	0.8911	0.609	0.31	0
1	1.5783	1.4212	1.242	1.0347	0.8012	0.5465	0.2771	0

Table 153. Horizontal Velocity Component for Air-gap, h = 2.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1139	0.2514	0.2704	0.2395	0.1761	0.093	0
3	1.5783	0.9687	0.9557	0.8511	0.6843	0.4775	0.2461	0
2	1.5783	1.5137	1.3584	1.1435	0.8887	0.6074	0.3092	0
1	1.5783	1.4232	1.2451	1.0381	0.8042	0.5487	0.2783	0

Table 154. Horizontal Velocity Component for Air-gap, h = 2.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1173	0.2582	0.2774	0.2454	0.1804	0.0952	0
3	1.5783	0.966	0.9543	0.8505	0.6842	0.4775	0.2461	0
2	1.5783	1.5117	1.3555	1.1406	0.8863	0.6058	0.3084	0
1	1.5783	1.4251	1.2479	1.0411	0.8069	0.5507	0.2794	0

Table 155. Horizontal Velocity Component for Air-gap, h = 2.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1208	0.2648	0.2841	0.2511	0.1844	0.0972	0
3	1.5783	0.9636	0.9531	0.85	0.684	0.4775	0.2462	0
2	1.5783	1.5097	1.3526	1.1377	0.884	0.6042	0.3077	0
1	1.5783	1.4267	1.2505	1.0439	0.8093	0.5525	0.2803	0

Table 156. Horizontal Velocity Component for Air-gap, h = 2.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1244	0.2712	0.2905	0.2564	0.1881	0.0992	0
3	1.5783	0.9612	0.9519	0.8496	0.6839	0.4775	0.2463	0
2	1.5783	1.5076	1.3497	1.1349	0.8817	0.6027	0.307	0
1	1.5783	1.4282	1.2528	1.0463	0.8114	0.5541	0.2812	0

Table 157. Horizontal Velocity Component for Air-gap, h = 2.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1281	0.2774	0.2966	0.2614	0.1916	0.101	0
3	1.5783	0.9591	0.9509	0.8492	0.6838	0.4775	0.2464	0
2	1.5783	1.5056	1.3468	1.1321	0.8795	0.6013	0.3064	0
1	1.5783	1.4296	1.2548	1.0484	0.8133	0.5555	0.2819	0

Table 158. Horizontal Velocity Component for Air-gap, h = 3.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1319	0.2834	0.3024	0.2661	0.1949	0.1026	0
3	1.5783	0.9571	0.95	0.8489	0.6837	0.4776	0.2465	0
2	1.5783	1.5034	1.3439	1.1294	0.8774	0.6	0.3057	0
1	1.5783	1.4308	1.2566	1.0503	0.815	0.5567	0.2826	0

Table 159. Horizontal Velocity Component for Air-gap, h = 3.10 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1358	0.2892	0.3079	0.2706	0.1979	0.1042	0
3	1.5783	0.9554	0.9492	0.8486	0.6836	0.4776	0.2466	0
2	1.5783	1.5013	1.341	1.1267	0.8753	0.5986	0.3051	0
1	1.5783	1.4318	1.2581	1.0519	0.8164	0.5578	0.2832	0

Table 160. Horizontal Velocity Component for Air-gap, h = 3.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.1399	0.2948	0.3132	0.2748	0.2007	0.1056	0
3	1.5783	0.9538	0.9485	0.8484	0.6835	0.4775	0.2466	0
2	1.5783	1.4991	1.3381	1.124	0.8733	0.5973	0.3046	0
1	1.5783	1.4327	1.2595	1.0533	0.8177	0.5588	0.2837	0

APPENDIX D.1.2.2

HORIZONTAL VELOCITY COMPONENT OF SLOT MODEL UNDERGOES FRICTIONLESS FLOW

[P_{dyn} = 1.0 in. of water, b = 4 mm, time step = $1x10^{-5}$ s]

Table 161. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0013	0.0018	0.002	0.0018	0.0013	0.0007	0
3	0.7058	0.3891	0.3789	0.3351	0.268	0.186	0.0951	0
2	0.7058	0.6906	0.6296	0.5353	0.418	0.2859	0.145	0
1	0.7058	0.6055	0.5051	0.4044	0.3035	0.2025	0.1013	0

Table 162. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.005	0.0073	0.0078	0.007	0.0052	0.0028	0
3	0.7058	0.3915	0.382	0.3381	0.2706	0.1878	0.0961	0
2	0.7058	0.6902	0.6287	0.5342	0.417	0.2851	0.1446	0
1	0.7058	0.607	0.5076	0.4075	0.3065	0.2048	0.1025	0

Table 163. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0112	0.0161	0.0172	0.0154	0.0115	0.0061	0
3	0.7058	0.3952	0.3869	0.3429	0.2746	0.1907	0.0976	0
2	0.7058	0.6895	0.6274	0.5325	0.4154	0.2839	0.144	0
1	0.7058	0.6093	0.5116	0.4122	0.311	0.2082	0.1044	0

Table 164. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0198	0.0282	0.0299	0.0266	0.0197	0.0104	0
3	0.7058	0.3995	0.3928	0.3488	0.2796	0.1943	0.0996	0
2	0.7058	0.6886	0.6257	0.5305	0.4134	0.2824	0.1433	0
1	0.7058	0.6122	0.5165	0.418	0.3165	0.2126	0.1068	0

Table 165. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0319	0.0435	0.0455	0.0401	0.0296	0.0156	0
3	0.7058	0.4031	0.3989	0.3553	0.2852	0.1984	0.1017	0
2	0.7058	0.6876	0.6236	0.5281	0.4113	0.2809	0.1425	0
1	0.7058	0.6154	0.522	0.4245	0.3227	0.2173	0.1093	0

Table 166. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0872	0.0849	0.0812	0.0687	0.0494	0.0257	0
3	0.7058	0.3943	0.3991	0.3609	0.2919	0.2039	0.1048	0
2	0.7058	0.6865	0.6209	0.5246	0.408	0.2786	0.1414	0
1	0.7058	0.6187	0.5275	0.4309	0.3288	0.222	0.1119	0

Table 167. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0802	0.0868	0.0862	0.0742	0.0538	0.0282	0
3	0.7058	0.4021	0.4069	0.3669	0.2964	0.2069	0.1064	0
2	0.7058	0.6852	0.619	0.5226	0.4064	0.2775	0.1409	0
1	0.7058	0.622	0.5332	0.4375	0.335	0.2267	0.1144	0

Table 168. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0691	0.0886	0.0914	0.0798	0.0583	0.0307	0
3	0.7058	0.4131	0.416	0.3734	0.3009	0.2099	0.1079	0
2	0.7058	0.6838	0.6172	0.5211	0.4053	0.2769	0.1407	0
1	0.7058	0.6253	0.5387	0.4438	0.3409	0.2313	0.1169	0

Table 169. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0429	0.0894	0.0954	0.0843	0.0621	0.0328	0
3	0.7058	0.4431	0.4337	0.3839	0.3076	0.2141	0.1101	0
2	0.7058	0.6824	0.6165	0.5212	0.4059	0.2776	0.1412	0
1	0.7058	0.6286	0.5442	0.4503	0.3471	0.236	0.1194	0

Table 170. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0377	0.0926	0.1003	0.0893	0.066	0.035	0
3	0.7058	0.4434	0.4316	0.3816	0.3058	0.213	0.1096	0
2	0.7058	0.681	0.614	0.5183	0.4033	0.2757	0.1402	0
1	0.7058	0.6312	0.5485	0.4552	0.3515	0.2393	0.1212	0

Table 171. Horizontal Velocity Component for Air-gap, h = 2.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0.0001	0	0	0	0	0	0
4	0	0.0362	0.0985	0.1069	0.0954	0.0705	0.0374	0
3	0.7058	0.4423	0.4297	0.3802	0.3049	0.2125	0.1094	0
2	0.7058	0.6794	0.6114	0.5155	0.4008	0.2739	0.1393	0
1	0.7058	0.6336	0.5523	0.4593	0.3552	0.2421	0.1227	0

Table 172. Horizontal Velocity Component for Air-gap, h = 2.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0387	0.1061	0.1146	0.102	0.0753	0.0398	0
3	0.7058	0.4396	0.4281	0.3796	0.3047	0.2125	0.1095	0
2	0.7058	0.6778	0.6088	0.5127	0.3984	0.2722	0.1385	0
1	0.7058	0.6356	0.5554	0.4627	0.3583	0.2444	0.1239	0

Table 173. Horizontal Velocity Component for Air-gap, h = 2.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0.0001	0	0	0	0	0	0
4	0	0.0424	0.1137	0.122	0.1081	0.0796	0.0421	0
3	0.7058	0.4365	0.4268	0.3792	0.3048	0.2127	0.1097	0
2	0.7058	0.676	0.6062	0.5101	0.3962	0.2708	0.1378	0
1	0.7058	0.6373	0.5581	0.4656	0.3608	0.2462	0.1249	0

Table 174. Horizontal Velocity Component for Air-gap, h = 2.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0463	0.1206	0.1286	0.1136	0.0834	0.044	0
3	0.7058	0.4338	0.4257	0.379	0.3049	0.2129	0.1098	0
2	0.7058	0.6742	0.6036	0.5075	0.3942	0.2694	0.1372	0
1	0.7058	0.6387	0.5602	0.4679	0.3628	0.2477	0.1257	0

Table 175. Horizontal Velocity Component for Air-gap, h = 3.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0501	0.127	0.1345	0.1183	0.0866	0.0456	0
3	0.7058	0.4316	0.4249	0.3789	0.305	0.2131	0.11	0
2	0.7058	0.6724	0.601	0.505	0.3922	0.2682	0.1366	0
1	0.7058	0.6399	0.5619	0.4697	0.3644	0.2489	0.1263	0

Table 176. Horizontal Velocity Component for Air-gap, h = 3.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0537	0.1328	0.1397	0.1224	0.0894	0.047	0
3	0.7058	0.4298	0.4242	0.3788	0.3051	0.2131	0.1101	0
2	0.7058	0.6704	0.5984	0.5026	0.3904	0.267	0.1361	0
1	0.7058	0.6407	0.5632	0.471	0.3656	0.2498	0.1268	0

Table 177. Horizontal Velocity Component for Air-gap, h = 3.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0573	0.1383	0.1443	0.1259	0.0918	0.0482	0
3	0.7058	0.4285	0.4238	0.3786	0.305	0.2131	0.1101	0
2	0.7058	0.6684	0.5958	0.5002	0.3886	0.2659	0.1356	0
1	0.7058	0.6414	0.5641	0.472	0.3664	0.2505	0.1272	0

Table 178. Horizontal Velocity Component for Air-gap, h = 3.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0.0001	0	0	0	0	0	0
4	0	0.0607	0.1434	0.1485	0.129	0.0938	0.0492	0
3	0.7058	0.4276	0.4235	0.3785	0.3049	0.2131	0.1101	0
2	0.7058	0.6663	0.5932	0.4979	0.3869	0.2648	0.1352	0
1	0.7058	0.6418	0.5647	0.4725	0.367	0.2509	0.1275	0

APPENDIX D.1.2.3

HORIZONTAL VELOCITY COMPONENT OF SLOT MODEL UNDERGOES FRICTIONLESS FLOW

[P_{dyn} = 0.1 in. of water, b = 4 mm, time step = $1 x 10^{-5}$ s]

Table 179. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0004	0.0006	0.0006	0.0006	0.0004	0.0002	0
3	0.2232	0.123	0.1198	0.106	0.0848	0.0588	0.0301	0
2	0.2232	0.2184	0.1991	0.1693	0.1322	0.0904	0.0459	0
1	0.2232	0.1915	0.1597	0.1279	0.096	0.064	0.032	0

Table 180. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0016	0.0023	0.0025	0.0022	0.0017	0.0009	0
3	0.2232	0.1238	0.1208	0.1069	0.0856	0.0594	0.0304	0
2	0.2232	0.2183	0.1988	0.1689	0.1319	0.0901	0.0457	0
1	0.2232	0.1919	0.1605	0.1289	0.0969	0.0647	0.0324	0

Table 181. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0035	0.0051	0.0055	0.0049	0.0036	0.0019	0
3	0.2232	0.125	0.1223	0.1084	0.0868	0.0603	0.0309	0
2	0.2232	0.218	0.1984	0.1684	0.1314	0.0898	0.0455	0
1	0.2232	0.1927	0.1618	0.1303	0.0983	0.0659	0.033	0

Table 182. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0063	0.0089	0.0094	0.0084	0.0062	0.0033	0
3	0.2232	0.1263	0.1242	0.1103	0.0884	0.0615	0.0315	0
2	0.2232	0.2178	0.1978	0.1677	0.1307	0.0893	0.0453	0
1	0.2232	0.1936	0.1633	0.1322	0.1001	0.0672	0.0338	0

Table 183. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0101	0.0138	0.0144	0.0127	0.0094	0.0049	0
3	0.2232	0.1274	0.1261	0.1123	0.0902	0.0627	0.0322	0
2	0.2232	0.2174	0.1972	0.167	0.13	0.0888	0.0451	0
1	0.2232	0.1946	0.1651	0.1342	0.102	0.0687	0.0346	0

Table 184. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0199	0.0225	0.0224	0.0192	0.014	0.0073	0
3	0.2232	0.1269	0.1275	0.1145	0.0923	0.0643	0.033	0
2	0.2232	0.2171	0.1965	0.1661	0.1293	0.0883	0.0448	0
1	0.2232	0.1957	0.1669	0.1363	0.104	0.0702	0.0354	0

Table 185. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0248	0.0274	0.0273	0.0235	0.017	0.0089	0
3	0.2232	0.1276	0.1291	0.1163	0.094	0.0656	0.0337	0
2	0.2232	0.2167	0.1958	0.1653	0.1286	0.0878	0.0446	0
1	0.2232	0.1967	0.1686	0.1384	0.1059	0.0717	0.0362	0

Table 186. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0188	0.0278	0.0289	0.0252	0.0184	0.0097	0
3	0.2232	0.1344	0.1342	0.1198	0.0963	0.0671	0.0345	0
2	0.2232	0.2162	0.1954	0.1652	0.1286	0.0879	0.0447	0
1	0.2232	0.1978	0.1704	0.1405	0.1079	0.0733	0.037	0

Table 187. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0143	0.0287	0.0305	0.027	0.0198	0.0105	0
3	0.2232	0.1397	0.1371	0.1215	0.0974	0.0678	0.0349	0
2	0.2232	0.2158	0.1949	0.1648	0.1284	0.0878	0.0447	0
1	0.2232	0.1988	0.1721	0.1424	0.1097	0.0746	0.0378	0

Table 188. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0138	0.0303	0.0325	0.0289	0.0213	0.0112	0
3	0.2232	0.1393	0.1365	0.121	0.097	0.0676	0.0348	0
2	0.2232	0.2153	0.1941	0.1639	0.1275	0.0872	0.0444	0
1	0.2232	0.1996	0.1735	0.1439	0.1111	0.0757	0.0383	0

Table 189. Horizontal Velocity Component for Air-gap, h = 2.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.014	0.0322	0.0347	0.0308	0.0227	0.012	0
3	0.2232	0.1386	0.1359	0.1206	0.0968	0.0675	0.0347	0
2	0.2232	0.2149	0.1933	0.163	0.1268	0.0866	0.0441	0
1	0.2232	0.2004	0.1746	0.1452	0.1123	0.0766	0.0388	0

Table 190. Horizontal Velocity Component for Air-gap, h = 2.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0146	0.0343	0.0369	0.0328	0.0241	0.0128	0
3	0.2232	0.1378	0.1354	0.1203	0.0967	0.0674	0.0347	0
2	0.2232	0.2143	0.1925	0.1621	0.126	0.0861	0.0438	0
1	0.2232	0.201	0.1756	0.1463	0.1133	0.0773	0.0392	0

Table 191. Horizontal Velocity Component for Air-gap, h = 2.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0155	0.0363	0.039	0.0346	0.0254	0.0134	0
3	0.2232	0.1371	0.135	0.1202	0.0966	0.0674	0.0348	0
2	0.2232	0.2138	0.1917	0.1613	0.1253	0.0857	0.0436	0
1	0.2232	0.2015	0.1765	0.1472	0.1141	0.0779	0.0395	0

Table 192. Horizontal Velocity Component for Air-gap, h = 2.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0165	0.0383	0.0409	0.0361	0.0265	0.014	0
3	0.2232	0.1364	0.1346	0.1201	0.0966	0.0675	0.0348	0
2	0.2232	0.2132	0.1909	0.1605	0.1247	0.0852	0.0434	0
1	0.2232	0.202	0.1772	0.148	0.1147	0.0784	0.0398	0

Table 193. Horizontal Velocity Component for Air-gap, h = 3.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0176	0.0401	0.0427	0.0375	0.0275	0.0145	0
3	0.2232	0.1358	0.1343	0.12	0.0966	0.0675	0.0348	0
2	0.2232	0.2126	0.1901	0.1597	0.1241	0.0848	0.0432	0
1	0.2232	0.2023	0.1777	0.1485	0.1152	0.0787	0.04	0

Table 194. Horizontal Velocity Component for Air-gap, h = 3.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0187	0.0418	0.0442	0.0388	0.0283	0.0149	0
3	0.2232	0.1353	0.1341	0.1199	0.0966	0.0675	0.0348	0
2	0.2232	0.212	0.1892	0.1589	0.1235	0.0845	0.0431	0
1	0.2232	0.2026	0.1781	0.149	0.1156	0.079	0.0401	0

Table 195. Horizontal Velocity Component for Air-gap, h = 3.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0198	0.0434	0.0456	0.0399	0.0291	0.0153	0
3	0.2232	0.1349	0.134	0.1198	0.0966	0.0675	0.0349	0
2	0.2232	0.2114	0.1884	0.1582	0.1229	0.0841	0.0429	0
1	0.2232	0.2028	0.1784	0.1493	0.1159	0.0792	0.0402	0

Table 196. Horizontal Velocity Component for Air-gap, h = 3.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0209	0.0449	0.0469	0.0408	0.0297	0.0156	0
3	0.2232	0.1347	0.1339	0.1198	0.0965	0.0674	0.0349	0
2	0.2232	0.2107	0.1876	0.1575	0.1224	0.0838	0.0428	0
1	0.2232	0.2029	0.1786	0.1494	0.1161	0.0794	0.0403	0

APPENDIX D.1.2.4

HORIZONTAL VELOCITY COMPONENT OF SLOT MODEL UNDERGOES FRICTIONLESS FLOW

[P_{dyn} = 0.01 in. of water, b = 4 mm, time step = 1×10^{-5} s]

Table 197. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0001	0.0002	0.0002	0.0002	0.0001	0.0001	0
3	0.0706	0.0389	0.0379	0.0335	0.0268	0.0186	0.0095	0
2	0.0706	0.0691	0.063	0.0535	0.0418	0.0286	0.0145	0
1	0.0706	0.0606	0.0505	0.0404	0.0304	0.0202	0.0101	0

Table 198. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0005	0.0007	0.0008	0.0007	0.0005	0.0003	0
3	0.0706	0.0392	0.0382	0.0338	0.0271	0.0188	0.0096	0
2	0.0706	0.069	0.0629	0.0534	0.0417	0.0285	0.0145	0
1	0.0706	0.0607	0.0508	0.0407	0.0306	0.0205	0.0103	0

Table 199. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0011	0.0016	0.0017	0.0015	0.0012	0.0006	0
3	0.0706	0.0396	0.0387	0.0343	0.0275	0.0191	0.0098	0
2	0.0706	0.069	0.0627	0.0533	0.0415	0.0284	0.0144	0
1	0.0706	0.0609	0.0512	0.0412	0.0311	0.0208	0.0104	0

Table 200. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0019	0.0027	0.0029	0.0026	0.0019	0.001	0
3	0.0706	0.0402	0.0394	0.035	0.028	0.0195	0.01	0
2	0.0706	0.0689	0.0626	0.0531	0.0414	0.0283	0.0143	0
1	0.0706	0.0612	0.0517	0.0418	0.0317	0.0213	0.0107	0

Table 201. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0025	0.0039	0.0042	0.0037	0.0027	0.0015	0
3	0.0706	0.0409	0.0402	0.0357	0.0286	0.0199	0.0102	0
2	0.0706	0.0688	0.0624	0.0529	0.0412	0.0281	0.0143	0
1	0.0706	0.0615	0.0522	0.0425	0.0323	0.0217	0.0109	0

Table 202. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0031	0.005	0.0054	0.0048	0.0036	0.0019	0
3	0.0706	0.0417	0.041	0.0364	0.0292	0.0203	0.0104	0
2	0.0706	0.0686	0.0622	0.0527	0.041	0.028	0.0142	0
1	0.0706	0.0619	0.0528	0.0431	0.0329	0.0222	0.0112	0

Table 203. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0036	0.0061	0.0066	0.0059	0.0044	0.0023	0
3	0.0706	0.0425	0.0418	0.037	0.0297	0.0206	0.0106	0
2	0.0706	0.0685	0.062	0.0525	0.0408	0.0279	0.0142	0
1	0.0706	0.0622	0.0534	0.0438	0.0335	0.0227	0.0115	0

Table 204. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.004	0.0072	0.0078	0.007	0.0052	0.0027	0
3	0.0706	0.0432	0.0424	0.0375	0.0301	0.0209	0.0107	0
2	0.0706	0.0684	0.0618	0.0523	0.0407	0.0278	0.0141	0
1	0.0706	0.0625	0.0539	0.0444	0.0341	0.0232	0.0117	0

Table 205. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0043	0.0082	0.0089	0.008	0.0059	0.0031	0
3	0.0706	0.0437	0.0429	0.0379	0.0304	0.0211	0.0108	0
2	0.0706	0.0682	0.0616	0.0521	0.0405	0.0277	0.0141	0
1	0.0706	0.0629	0.0544	0.045	0.0347	0.0236	0.0119	0

Table 206. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0047	0.0092	0.01	0.0088	0.0065	0.0034	0
3	0.0706	0.044	0.0432	0.0382	0.0306	0.0213	0.0109	0
2	0.0706	0.0681	0.0614	0.0518	0.0403	0.0276	0.014	0
1	0.0706	0.0631	0.0549	0.0455	0.0351	0.0239	0.0121	0

Table 207. Horizontal Velocity Component for Air-gap, h = 2.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.005	0.0099	0.0107	0.0095	0.007	0.0037	0
3	0.0706	0.0436	0.043	0.0381	0.0306	0.0213	0.0109	0
2	0.0706	0.0679	0.0611	0.0515	0.0401	0.0274	0.0139	0
1	0.0706	0.0634	0.0552	0.0459	0.0355	0.0242	0.0123	0

Table 208. Horizontal Velocity Component for Air-gap, h = 2.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0053	0.0105	0.0114	0.0101	0.0074	0.0039	0
3	0.0706	0.0433	0.0428	0.038	0.0305	0.0213	0.0109	0
2	0.0706	0.0678	0.0609	0.0513	0.0399	0.0272	0.0139	0
1	0.0706	0.0636	0.0555	0.0463	0.0358	0.0244	0.0124	0

Table 209. Horizontal Velocity Component for Air-gap, h = 2.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0057	0.0111	0.012	0.0106	0.0078	0.0041	0
3	0.0706	0.0431	0.0427	0.038	0.0305	0.0212	0.0109	0
2	0.0706	0.0676	0.0606	0.051	0.0396	0.0271	0.0138	0
1	0.0706	0.0637	0.0558	0.0466	0.0361	0.0246	0.0125	0

Table 210. Horizontal Velocity Component for Air-gap, h = 2.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.006	0.0116	0.0125	0.011	0.008	0.0042	0
3	0.0706	0.0428	0.0426	0.0379	0.0304	0.0212	0.0109	0
2	0.0706	0.0674	0.0604	0.0507	0.0394	0.0269	0.0137	0
1	0.0706	0.0639	0.056	0.0468	0.0363	0.0248	0.0126	0

Table 211. Horizontal Velocity Component for Air-gap, h = 3.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0064	0.012	0.013	0.0113	0.0082	0.0042	0
3	0.0706	0.0427	0.0425	0.0379	0.0304	0.0211	0.0108	0
2	0.0706	0.0672	0.0601	0.0505	0.0392	0.0268	0.0136	0
1	0.0706	0.064	0.0562	0.047	0.0364	0.0249	0.0126	0

Table 212. Horizontal Velocity Component for Air-gap, h = 3.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0068	0.0125	0.0133	0.0116	0.0083	0.0043	0
3	0.0706	0.0425	0.0424	0.0378	0.0303	0.021	0.0108	0
2	0.0706	0.067	0.0598	0.0502	0.039	0.0267	0.0136	0
1	0.0706	0.0641	0.0563	0.0471	0.0365	0.025	0.0127	0

Table 213. Horizontal Velocity Component for Air-gap, h = 3.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0072	0.0129	0.0137	0.0118	0.0084	0.0043	0
3	0.0706	0.0424	0.0424	0.0377	0.0302	0.0209	0.0107	0
2	0.0706	0.0668	0.0596	0.05	0.0388	0.0265	0.0135	0
1	0.0706	0.0641	0.0564	0.0472	0.0366	0.025	0.0127	0

Table 214. Horizontal Velocity Component for Air-gap, h = 3.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0076	0.0133	0.0139	0.0119	0.0084	0.0043	0
3	0.0706	0.0424	0.0424	0.0377	0.0301	0.0208	0.0106	0
2	0.0706	0.0666	0.0593	0.0497	0.0386	0.0263	0.0134	0
1	0.0706	0.0642	0.0564	0.0472	0.0366	0.025	0.0127	0

APPENDIX D.2.1.1

HORIZONTAL VELOCITY COMPONENT OF HOLE MODEL UNDERGOES ACTUAL FLOW

[P_{dyn} = 5.0 in. of water, d = 4 mm, time step = 1×10^{-6} s]

Table 215. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0122	-0.0262	-0.0408	-0.0498	-0.0445	-0.0221	0
3	1.5783	0.5945	0.536	0.4252	0.2835	0.1418	0.0369	0
2	1.5783	1.5383	1.3755	1.1177	0.7969	0.4542	0.1534	0
1	1.5783	1.3128	1.0471	0.7821	0.5215	0.2782	0.0848	0

Table 216. Horizontal Velocity Component for Air-gap, h = 0.25 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0112	-0.0241	-0.0393	-0.051	-0.0484	-0.0254	0
3	1.5783	0.5978	0.5444	0.4366	0.294	0.1481	0.0381	0
2	1.5783	1.5411	1.3839	1.1328	0.8167	0.4732	0.1639	0
1	1.5783	1.3189	1.0589	0.7986	0.5405	0.295	0.093	0

Table 217. Horizontal Velocity Component for Air-gap, h = 0.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0098	-0.0207	-0.0359	-0.05	-0.0507	-0.0283	0
3	1.5783	0.6013	0.553	0.4482	0.3051	0.1552	0.04	0
2	1.5783	1.543	1.3901	1.1444	0.8327	0.4895	0.1734	0
1	1.5783	1.3238	1.0684	0.812	0.5562	0.3094	0.1006	0

Table 218. Horizontal Velocity Component for Air-gap, h = 0.35 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0081	-0.0165	-0.031	-0.0473	-0.0515	-0.0306	0
3	1.5783	0.6048	0.5617	0.46	0.3166	0.163	0.0423	0
2	1.5783	1.5443	1.3947	1.1536	0.8461	0.5036	0.1822	0
1	1.5783	1.328	1.0765	0.8234	0.5697	0.3222	0.1077	0

Table 219. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0061	-0.0116	-0.0249	-0.0432	-0.0512	-0.0325	0
3	1.5783	0.6084	0.5705	0.472	0.3285	0.1714	0.0451	0
2	1.5783	1.5453	1.3982	1.1611	0.8573	0.5161	0.1904	0
1	1.5783	1.3318	1.0837	0.8334	0.5816	0.3337	0.1145	0

Table 220. Horizontal Velocity Component for Air-gap, h = 0.45 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.004	-0.0061	-0.0178	-0.0377	-0.0498	-0.034	0
3	1.5783	0.612	0.5794	0.4843	0.3408	0.1803	0.0485	0
2	1.5783	1.5459	1.401	1.1671	0.8669	0.5272	0.198	0
1	1.5783	1.3353	1.0903	0.8426	0.5923	0.3442	0.121	0

Table 221. Horizontal Velocity Component for Air-gap, h = 0.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0017	-0.0001	-0.0098	-0.0312	-0.0473	-0.035	0
3	1.5783	0.6158	0.5886	0.4967	0.3534	0.1897	0.0523	0
2	1.5783	1.5463	1.4031	1.1722	0.8752	0.5372	0.2051	0
1	1.5783	1.3386	1.0966	0.8511	0.6022	0.3539	0.1272	0

Table 222. Horizontal Velocity Component for Air-gap, h = 0.55 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0004	0.0054	-0.0023	-0.0246	-0.0444	-0.0357	0
3	1.5783	0.6186	0.5951	0.5066	0.364	0.1981	0.0559	0
2	1.5783	1.5465	1.4046	1.1762	0.8821	0.5458	0.2116	0
1	1.5783	1.3418	1.1025	0.8591	0.6115	0.363	0.1331	0

Table 223. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0026	0.0112	0.0057	-0.0175	-0.0409	-0.036	0
3	1.5783	0.6216	0.6023	0.5166	0.3748	0.2066	0.0597	0
2	1.5783	1.5466	1.4058	1.1795	0.8881	0.5537	0.2178	0
1	1.5783	1.3449	1.1083	0.8668	0.6202	0.3716	0.1388	0

Table 224. Horizontal Velocity Component for Air-gap, h = 0.65 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0049	0.0172	0.014	-0.0098	-0.0368	-0.036	0
3	1.5783	0.6246	0.6092	0.5263	0.3854	0.2153	0.0638	0
2	1.5783	1.5466	1.4067	1.1824	0.8934	0.5608	0.2236	0
1	1.5783	1.348	1.1139	0.8743	0.6287	0.3798	0.1443	0

Table 225. Horizontal Velocity Component for Air-gap, h = 0.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0072	0.0234	0.0226	-0.0016	-0.0321	-0.0356	0
3	1.5783	0.6277	0.6162	0.536	0.3961	0.2241	0.0682	0
2	1.5783	1.5465	1.4073	1.1847	0.8981	0.5673	0.229	0
1	1.5783	1.351	1.1195	0.8815	0.6368	0.3877	0.1496	0

Table 226. Horizontal Velocity Component for Air-gap, h = 0.75 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0103	0.0323	0.0362	0.0126	-0.0229	-0.0336	0
3	1.5783	0.6325	0.6277	0.5532	0.416	0.2399	0.0758	0
2	1.5783	1.5462	1.4077	1.187	0.9031	0.5745	0.2352	0
1	1.5783	1.354	1.125	0.8888	0.6449	0.3954	0.1549	0

Table 227. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0127	0.0385	0.0449	0.0212	-0.0174	-0.0326	0
3	1.5783	0.6353	0.6339	0.5618	0.4256	0.2481	0.0802	0
2	1.5783	1.5459	1.4079	1.1886	0.9067	0.5798	0.24	0
1	1.5783	1.357	1.1304	0.8958	0.6526	0.4027	0.16	0

Table 228. Horizontal Velocity Component for Air-gap, h = 0.85 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.015	0.0447	0.0538	0.0299	-0.0115	-0.0312	0
3	1.5783	0.6381	0.6399	0.5701	0.435	0.2563	0.0846	0
2	1.5783	1.5456	1.4079	1.1899	0.91	0.5848	0.2446	0
1	1.5783	1.36	1.1358	0.9027	0.6601	0.4098	0.1648	0

Table 229. Horizontal Velocity Component for Air-gap, h = 0.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0173	0.0509	0.0626	0.0389	-0.0053	-0.0296	0
3	1.5783	0.6409	0.6458	0.5782	0.4441	0.2645	0.0891	0
2	1.5783	1.5452	1.4079	1.191	0.9129	0.5894	0.2489	0
1	1.5783	1.3629	1.1411	0.9096	0.6675	0.4168	0.1696	0

Table 230. Horizontal Velocity Component for Air-gap, h = 0.95 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0192	0.0575	0.0752	0.0557	0.0104	-0.0234	0
3	1.5783	0.6344	0.6459	0.5874	0.4614	0.2855	0.1004	0
2	1.5783	1.5448	1.407	1.1907	0.9145	0.5934	0.2536	0
1	1.5783	1.3658	1.1463	0.9162	0.6747	0.4235	0.1743	0

Table 231. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0205	0.0615	0.0818	0.0632	0.0164	-0.0213	0
3	1.5783	0.6311	0.6452	0.59	0.4664	0.2912	0.1039	0
2	1.5783	1.5443	1.4062	1.1905	0.9155	0.5961	0.2568	0
1	1.5783	1.3687	1.1514	0.9227	0.6816	0.4299	0.1786	0

Table 232. Horizontal Velocity Component for Air-gap, h = 1.05 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0222	0.0663	0.0891	0.0713	0.0229	-0.0189	0
3	1.5783	0.6298	0.6466	0.5942	0.4726	0.2977	0.1078	0
2	1.5783	1.5438	1.4055	1.1904	0.9168	0.5989	0.26	0
1	1.5783	1.3715	1.1565	0.9291	0.6885	0.4362	0.183	0

Table 233. Horizontal Velocity Component for Air-gap, h = 1.10 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0244	0.0722	0.0976	0.0804	0.0301	-0.0161	0
3	1.5783	0.631	0.6506	0.6005	0.4803	0.3052	0.1122	0
2	1.5783	1.5433	1.4049	1.1906	0.9185	0.6021	0.2634	0
1	1.5783	1.3744	1.1616	0.9356	0.6953	0.4424	0.1873	0

Table 234. Horizontal Velocity Component for Air-gap, h = 1.15 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0267	0.078	0.106	0.0893	0.0372	-0.0133	0
3	1.5783	0.6322	0.6545	0.6066	0.4877	0.3125	0.1165	0
2	1.5783	1.5426	1.4043	1.1908	0.92	0.6051	0.2667	0
1	1.5783	1.3772	1.1666	0.9419	0.7021	0.4486	0.1914	0

Table 235. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0289	0.0838	0.1142	0.098	0.0443	-0.0103	0
3	1.5783	0.6333	0.6581	0.6123	0.4948	0.3195	0.1206	0
2	1.5783	1.542	1.4035	1.1908	0.9214	0.6079	0.2698	0
1	1.5783	1.38	1.1716	0.9482	0.7087	0.4546	0.1956	0

Table 236. Horizontal Velocity Component for Air-gap, h = 1.25 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0312	0.0895	0.1224	0.1066	0.0513	-0.0073	0
3	1.5783	0.6343	0.6616	0.6179	0.5017	0.3262	0.1247	0
2	1.5783	1.5413	1.4027	1.1907	0.9226	0.6105	0.2728	0
1	1.5783	1.3828	1.1765	0.9544	0.7152	0.4605	0.1996	0

Table 237. Horizontal Velocity Component for Air-gap, h = 1.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0334	0.0952	0.1303	0.115	0.0582	-0.0043	0
3	1.5783	0.6353	0.6649	0.6232	0.5082	0.3327	0.1287	0
2	1.5783	1.5406	1.4018	1.1905	0.9237	0.613	0.2756	0
1	1.5783	1.3856	1.1813	0.9605	0.7216	0.4663	0.2035	0

Table 238. Horizontal Velocity Component for Air-gap, h = 1.35 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0357	0.1008	0.1382	0.1233	0.065	-0.0012	0
3	1.5783	0.6363	0.6682	0.6283	0.5146	0.3389	0.1325	0
2	1.5783	1.5398	1.4009	1.1903	0.9248	0.6154	0.2783	0
1	1.5783	1.3883	1.1861	0.9664	0.7279	0.4719	0.2074	0

Table 239. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0383	0.1074	0.148	0.1347	0.0759	0.0056	0
3	1.5783	0.6377	0.6729	0.6363	0.5253	0.3512	0.1428	0
2	1.5783	1.539	1.4001	1.1905	0.9265	0.6187	0.2821	0
1	1.5783	1.391	1.1909	0.9725	0.7343	0.4777	0.2113	0

Table 240. Horizontal Velocity Component for Air-gap, h = 1.45 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0406	0.1132	0.1562	0.1436	0.0837	0.0099	0
3	1.5783	0.6388	0.6764	0.6419	0.5325	0.3587	0.1484	0
2	1.5783	1.5382	1.3992	1.1903	0.9277	0.6212	0.2849	0
1	1.5783	1.3936	1.1956	0.9784	0.7404	0.4833	0.2151	0

Table 241. Horizontal Velocity Component for Air-gap, h = 1.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0349	0.1012	0.1506	0.1428	0.0849	0.011	0
3	1.5783	0.6412	0.6821	0.6475	0.5375	0.3634	0.1519	0
2	1.5783	1.5374	1.3983	1.1903	0.929	0.6236	0.2875	0
1	1.5783	1.3962	1.2002	0.9841	0.7465	0.4887	0.2188	0

Table 242. Horizontal Velocity Component for Air-gap, h = 1.55 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0296	0.0903	0.146	0.1428	0.0869	0.0125	0
3	1.5783	0.6434	0.6874	0.6525	0.5421	0.368	0.1554	0
2	1.5783	1.5365	1.3974	1.1903	0.9301	0.6259	0.29	0
1	1.5783	1.3988	1.2047	0.9898	0.7524	0.494	0.2224	0

Table 243. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0319	0.0962	0.1545	0.1519	0.0948	0.0171	0
3	1.5783	0.6443	0.6905	0.6576	0.5488	0.375	0.1607	0
2	1.5783	1.5356	1.3964	1.1901	0.9312	0.6282	0.2927	0
1	1.5783	1.4013	1.2091	0.9953	0.7583	0.4993	0.226	0

Table 244. Horizontal Velocity Component for Air-gap, h = 1.65 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0343	0.102	0.1628	0.1607	0.1026	0.0217	0
3	1.5783	0.6451	0.6935	0.6625	0.5551	0.3818	0.1659	0
2	1.5783	1.5347	1.3954	1.1898	0.9322	0.6304	0.2953	0
1	1.5783	1.4037	1.2134	1.0007	0.764	0.5044	0.2295	0

Table 245. Horizontal Velocity Component for Air-gap, h = 1.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0367	0.1077	0.1709	0.1692	0.1101	0.0262	0
3	1.5783	0.646	0.6963	0.6673	0.5613	0.3884	0.1709	0
2	1.5783	1.5337	1.3943	1.1895	0.9332	0.6326	0.2978	0
1	1.5783	1.4061	1.2176	1.0061	0.7696	0.5095	0.233	0

Table 246. Horizontal Velocity Component for Air-gap, h = 1.75 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0391	0.1132	0.1787	0.1774	0.1174	0.0306	0
3	1.5783	0.6467	0.6991	0.6718	0.5672	0.3947	0.1758	0
2	1.5783	1.5328	1.3933	1.1893	0.9342	0.6348	0.3002	0
1	1.5783	1.4084	1.2217	1.0112	0.7751	0.5144	0.2364	0

Table 247. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0414	0.1187	0.1863	0.1854	0.1245	0.035	0
3	1.5783	0.6475	0.7017	0.6763	0.5729	0.4008	0.1805	0
2	1.5783	1.5318	1.3922	1.189	0.9351	0.6369	0.3027	0
1	1.5783	1.4107	1.2258	1.0163	0.7804	0.5193	0.2397	0

Table 248. Horizontal Velocity Component for Air-gap, h = 1.85 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0437	0.124	0.1937	0.193	0.1313	0.0392	0
3	1.5783	0.6483	0.7043	0.6806	0.5785	0.4067	0.185	0
2	1.5783	1.5308	1.3911	1.1887	0.9361	0.639	0.305	0
1	1.5783	1.4129	1.2297	1.0213	0.7857	0.5241	0.243	0

Table 249. Horizontal Velocity Component for Air-gap, h = 1.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.046	0.1292	0.2009	0.2004	0.1379	0.0434	0
3	1.5783	0.649	0.7068	0.6847	0.5838	0.4125	0.1895	0
2	1.5783	1.5297	1.39	1.1884	0.9371	0.6411	0.3074	0
1	1.5783	1.4151	1.2335	1.0262	0.7909	0.5288	0.2462	0

Table 250. Horizontal Velocity Component for Air-gap, h = 1.95 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0482	0.1342	0.2079	0.2076	0.1443	0.0474	0
3	1.5783	0.6497	0.7092	0.6888	0.589	0.418	0.1938	0
2	1.5783	1.5287	1.3889	1.1882	0.9381	0.6432	0.3097	0
1	1.5783	1.4172	1.2373	1.0309	0.796	0.5334	0.2494	0

Table 251. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0504	0.1392	0.2146	0.2145	0.1504	0.0513	0
3	1.5783	0.6505	0.7116	0.6928	0.5941	0.4234	0.198	0
2	1.5783	1.5276	1.3877	1.1879	0.9391	0.6453	0.312	0
1	1.5783	1.4192	1.2409	1.0355	0.801	0.538	0.2526	0

APPENDIX D.2.1.2

HORIZONTAL VELOCITY COMPONENT OF HOLE MODEL UNDERGOES ACTUAL FLOW

$[P_{dyn} = 1.0 \text{ in. of water}, d = 4 \text{ mm}, \text{time step} = 1 \times 10^{-5} \text{ s}]$

Table 252. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.005	-0.0103	-0.0145	-0.0156	-0.0123	-0.0054	0
3	0.7058	0.2631	0.2323	0.1805	0.1187	0.0597	0.0165	0
2	0.7058	0.6818	0.5992	0.4746	0.3265	0.1774	0.0559	0
1	0.7058	0.5774	0.4495	0.3241	0.2057	0.1028	0.029	0

Table 253. Horizontal Velocity Component for Air-gap, h = 0.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0054	-0.0114	-0.0167	-0.0191	-0.0159	-0.0074	0
3	0.7058	0.2642	0.2353	0.1845	0.1219	0.061	0.0164	0
2	0.7058	0.6849	0.6069	0.4866	0.3403	0.1889	0.0614	0
1	0.7058	0.5834	0.4609	0.339	0.2208	0.1139	0.0332	0

Table 254. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0052	-0.0112	-0.0172	-0.0208	-0.0183	-0.009	0
3	0.7058	0.2656	0.2391	0.1894	0.1262	0.0634	0.0168	0
2	0.7058	0.6866	0.6119	0.495	0.3508	0.1984	0.0662	0
1	0.7058	0.5881	0.4696	0.3507	0.2332	0.1236	0.0373	0

Table 255. Horizontal Velocity Component for Air-gap, h = 0.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0047	-0.01	-0.0162	-0.021	-0.0198	-0.0103	0
3	0.7058	0.2673	0.2433	0.1951	0.1315	0.0666	0.0176	0
2	0.7058	0.6877	0.6153	0.5012	0.359	0.2062	0.0705	0
1	0.7058	0.5919	0.4769	0.3604	0.2438	0.1324	0.0413	0

Table 256. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0039	-0.008	-0.014	-0.0198	-0.0203	-0.0113	0
3	0.7058	0.2691	0.248	0.2015	0.1375	0.0705	0.0187	0
2	0.7058	0.6883	0.6175	0.5058	0.3656	0.213	0.0744	0
1	0.7058	0.5954	0.4834	0.3691	0.2533	0.1406	0.0453	0

Table 257. Horizontal Velocity Component for Air-gap, h = 0.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0028	-0.0053	-0.0107	-0.0175	-0.0199	-0.0121	0
3	0.7058	0.2712	0.2532	0.2084	0.1443	0.075	0.0202	0
2	0.7058	0.6885	0.619	0.5092	0.371	0.2188	0.0781	0
1	0.7058	0.5987	0.4895	0.3772	0.2621	0.1482	0.0492	0

Table 258. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0015	-0.002	-0.0063	-0.0141	-0.0187	-0.0125	0
3	0.7058	0.2735	0.2587	0.2159	0.1516	0.0802	0.0221	0
2	0.7058	0.6886	0.6199	0.5119	0.3755	0.2241	0.0815	0
1	0.7058	0.6019	0.4953	0.3848	0.2704	0.1555	0.0531	0

Table 259. Horizontal Velocity Component for Air-gap, h = 0.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0001	0.0017	-0.0014	-0.0099	-0.0168	-0.0126	0
3	0.7058	0.2755	0.2637	0.223	0.1588	0.0854	0.0242	0
2	0.7058	0.6884	0.6204	0.5138	0.3792	0.2287	0.0846	0
1	0.7058	0.605	0.501	0.3921	0.2784	0.1625	0.057	0

Table 260. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0015	0.0058	0.0042	-0.0049	-0.0142	-0.0125	0
3	0.7058	0.2778	0.269	0.2302	0.1661	0.0909	0.0264	0
2	0.7058	0.6881	0.6206	0.5154	0.3824	0.2329	0.0877	0
1	0.7058	0.6081	0.5065	0.3992	0.286	0.1694	0.0608	0

Table 261. Horizontal Velocity Component for Air-gap, h = 1.10 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0035	0.011	0.0117	0.0023	-0.01	-0.0118	0
3	0.7058	0.2805	0.2757	0.2398	0.1767	0.0989	0.0299	0
2	0.7058	0.6877	0.6206	0.5167	0.3856	0.2372	0.0909	0
1	0.7058	0.6111	0.5119	0.4062	0.2936	0.1761	0.0647	0

Table 262. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0053	0.0156	0.018	0.0084	-0.0063	-0.0111	0
3	0.7058	0.2827	0.2805	0.2464	0.1836	0.1044	0.0324	0
2	0.7058	0.6872	0.6203	0.5176	0.388	0.2407	0.0937	0
1	0.7058	0.614	0.5172	0.4129	0.3008	0.1825	0.0686	0

Table 263. Horizontal Velocity Component for Air-gap, h = 1.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0071	0.0203	0.0246	0.0147	-0.0023	-0.0102	0
3	0.7058	0.2848	0.2852	0.2527	0.1905	0.1099	0.035	0
2	0.7058	0.6867	0.62	0.5182	0.3902	0.244	0.0964	0
1	0.7058	0.6169	0.5223	0.4195	0.3078	0.1888	0.0724	0

Table 264. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0087	0.0248	0.032	0.0232	0.0044	-0.008	0
3	0.7058	0.2832	0.287	0.2586	0.1994	0.1193	0.0396	0
2	0.7058	0.686	0.6192	0.5183	0.3919	0.2471	0.0993	0
1	0.7058	0.6196	0.5272	0.4257	0.3145	0.1949	0.0762	0

Table 265. Horizontal Velocity Component for Air-gap, h = 1.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0099	0.0281	0.0371	0.0288	0.0086	-0.0067	0
3	0.7058	0.2808	0.2868	0.2609	0.2034	0.1234	0.0418	0
2	0.7058	0.6853	0.6181	0.5178	0.3926	0.2491	0.1013	0
1	0.7058	0.6222	0.5318	0.4316	0.3207	0.2006	0.0797	0

Table 266. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0118	0.0328	0.0438	0.0358	0.0137	-0.005	0
3	0.7058	0.282	0.2903	0.2663	0.2097	0.1291	0.0448	0
2	0.7058	0.6845	0.6174	0.518	0.3941	0.2518	0.1038	0
1	0.7058	0.6248	0.5364	0.4374	0.327	0.2063	0.0834	0

Table 267. Horizontal Velocity Component for Air-gap, h = 1.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0136	0.0374	0.0503	0.0425	0.0187	-0.0032	0
3	0.7058	0.283	0.2935	0.2713	0.2156	0.1346	0.0476	0
2	0.7058	0.6837	0.6165	0.518	0.3956	0.2545	0.1063	0
1	0.7058	0.6272	0.5407	0.443	0.333	0.2118	0.087	0

Table 268. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0154	0.0419	0.0567	0.0491	0.0237	-0.0014	0
3	0.7058	0.284	0.2966	0.276	0.2212	0.1398	0.0504	0
2	0.7058	0.6828	0.6157	0.5181	0.3969	0.257	0.1086	0
1	0.7058	0.6296	0.5449	0.4483	0.3388	0.2172	0.0905	0

Table 269. Horizontal Velocity Component for Air-gap, h = 1.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0173	0.0464	0.0633	0.0562	0.0295	0.0012	0
3	0.7058	0.2851	0.2998	0.2811	0.2276	0.1463	0.0547	0
2	0.7058	0.6819	0.6148	0.5182	0.3986	0.2598	0.1113	0
1	0.7058	0.6318	0.5489	0.4535	0.3444	0.2225	0.094	0

Table 270. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0191	0.0508	0.0695	0.0628	0.0349	0.0036	0
3	0.7058	0.286	0.3027	0.2856	0.2333	0.152	0.0584	0
2	0.7058	0.6809	0.6139	0.5183	0.4001	0.2625	0.1139	0
1	0.7058	0.6339	0.5527	0.4584	0.3498	0.2276	0.0975	0

APPENDIX D.2.1.3

HORIZONTAL VELOCITY COMPONENT OF HOLE MODEL UNDERGOES ACTUAL FLOW

[P_{dyn} = 0.1 in. of water, d = 4 mm, time step = $1 x 10^{-5}$ s]

Table 271. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0008	-0.0016	-0.0021	-0.0021	-0.0015	-0.0006	0
3	0.2232	0.083	0.0727	0.0562	0.0371	0.019	0.0055	0
2	0.2232	0.2127	0.1833	0.1415	0.0943	0.0493	0.0148	0
1	0.2232	0.1787	0.1352	0.094	0.0573	0.0275	0.0074	0

Table 272. Horizontal Velocity Component for Air-gap, h = 0.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.001	-0.0021	-0.0028	-0.0029	-0.0021	-0.0009	0
3	0.2232	0.083	0.0728	0.0563	0.0371	0.0189	0.0054	0
2	0.2232	0.2136	0.185	0.1438	0.0967	0.051	0.0155	0
1	0.2232	0.1802	0.1377	0.097	0.0598	0.029	0.0079	0

Table 273. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0012	-0.0024	-0.0033	-0.0035	-0.0027	-0.0011	0
3	0.2232	0.083	0.0729	0.0565	0.0372	0.0189	0.0054	0
2	0.2232	0.2142	0.1863	0.1457	0.0987	0.0526	0.0162	0
1	0.2232	0.1816	0.1403	0.0999	0.0624	0.0307	0.0085	0

Table 274. Horizontal Velocity Component for Air-gap, h = 0.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0013	-0.0026	-0.0037	-0.004	-0.0031	-0.0014	0
3	0.2232	0.083	0.0732	0.0568	0.0374	0.019	0.0053	0
2	0.2232	0.2146	0.1874	0.1472	0.1004	0.0539	0.0168	0
1	0.2232	0.1831	0.1428	0.103	0.0652	0.0325	0.0091	0

Table 275. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0013	-0.0027	-0.0039	-0.0043	-0.0035	-0.0016	0
3	0.2232	0.0832	0.0735	0.0573	0.0378	0.0191	0.0054	0
2	0.2232	0.2149	0.1881	0.1485	0.1018	0.0552	0.0174	0
1	0.2232	0.1844	0.1452	0.106	0.068	0.0343	0.0098	0

Table 276. Horizontal Velocity Component for Air-gap, h = 0.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0013	-0.0027	-0.004	-0.0046	-0.0038	-0.0018	0
3	0.2232	0.0833	0.074	0.0579	0.0383	0.0194	0.0054	0
2	0.2232	0.2151	0.1887	0.1495	0.103	0.0562	0.0179	0
1	0.2232	0.1858	0.1477	0.1089	0.0708	0.0363	0.0105	0

Table 277. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0012	-0.0026	-0.0039	-0.0046	-0.004	-0.0019	0
3	0.2232	0.0835	0.0745	0.0586	0.039	0.0198	0.0055	0
2	0.2232	0.2152	0.1892	0.1503	0.1041	0.0572	0.0184	0
1	0.2232	0.1871	0.15	0.1119	0.0737	0.0383	0.0113	0

Table 278. Horizontal Velocity Component for Air-gap, h = 0.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0011	-0.0023	-0.0037	-0.0046	-0.0041	-0.002	0
3	0.2232	0.0837	0.0751	0.0595	0.0397	0.0202	0.0056	0
2	0.2232	0.2153	0.1894	0.1509	0.105	0.0581	0.0188	0
1	0.2232	0.1884	0.1524	0.1148	0.0765	0.0403	0.0121	0

Table 279. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.001	-0.002	-0.0033	-0.0044	-0.0041	-0.0021	0
3	0.2232	0.084	0.0759	0.0604	0.0406	0.0208	0.0058	0
2	0.2232	0.2152	0.1896	0.1514	0.1058	0.0589	0.0193	0
1	0.2232	0.1897	0.1547	0.1176	0.0793	0.0424	0.0129	0

Table 280. Horizontal Velocity Component for Air-gap, h = 1.10 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0008	-0.0015	-0.0028	-0.004	-0.004	-0.0022	0
3	0.2232	0.0843	0.0767	0.0615	0.0416	0.0214	0.006	0
2	0.2232	0.2152	0.1897	0.1518	0.1065	0.0596	0.0197	0
1	0.2232	0.1909	0.1569	0.1204	0.0821	0.0445	0.0138	0

Table 281. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0005	-0.001	-0.0021	-0.0035	-0.0038	-0.0022	0
3	0.2232	0.0846	0.0775	0.0627	0.0427	0.0221	0.0062	0
2	0.2232	0.2151	0.1897	0.1521	0.1071	0.0603	0.0201	0
1	0.2232	0.1921	0.1591	0.1232	0.0848	0.0466	0.0147	0

Table 282. Horizontal Velocity Component for Air-gap, h = 1.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0002	-0.0003	-0.0013	-0.0029	-0.0036	-0.0022	0
3	0.2232	0.085	0.0785	0.0639	0.0439	0.0229	0.0065	0
2	0.2232	0.2149	0.1896	0.1523	0.1076	0.0609	0.0205	0
1	0.2232	0.1933	0.1612	0.1258	0.0875	0.0487	0.0156	0

Table 283. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0001	0.0004	-0.0003	-0.0021	-0.0032	-0.0021	0
3	0.2232	0.0854	0.0794	0.0652	0.0451	0.0237	0.0068	0
2	0.2232	0.2147	0.1895	0.1525	0.1081	0.0615	0.0208	0
1	0.2232	0.1945	0.1632	0.1284	0.0902	0.0507	0.0165	0

Table 284. Horizontal Velocity Component for Air-gap, h = 1.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0005	0.0013	0.0007	-0.0011	-0.0027	-0.0021	0
3	0.2232	0.0858	0.0804	0.0666	0.0464	0.0246	0.0071	0
2	0.2232	0.2145	0.1893	0.1526	0.1086	0.0622	0.0212	0
1	0.2232	0.1956	0.1652	0.1309	0.0927	0.0528	0.0175	0

Table 285. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0009	0.0022	0.0019	-0.0001	-0.0021	-0.002	0
3	0.2232	0.0862	0.0814	0.0679	0.0477	0.0255	0.0075	0
2	0.2232	0.2143	0.1891	0.1527	0.109	0.0628	0.0216	0
1	0.2232	0.1966	0.1671	0.1333	0.0952	0.0548	0.0184	0

Table 286. Horizontal Velocity Component for Air-gap, h = 1.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0014	0.0033	0.0034	0.0012	-0.0014	-0.0018	0
3	0.2232	0.0867	0.0826	0.0696	0.0494	0.0267	0.0079	0
2	0.2232	0.214	0.1889	0.1528	0.1096	0.0634	0.022	0
1	0.2232	0.1976	0.1689	0.1356	0.0977	0.0568	0.0194	0

Table 287. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0018	0.0044	0.0048	0.0024	-0.0007	-0.0016	0
3	0.2232	0.0872	0.0837	0.0709	0.0508	0.0276	0.0083	0
2	0.2232	0.2137	0.1886	0.1528	0.11	0.064	0.0224	0
1	0.2232	0.1986	0.1706	0.1378	0.1	0.0588	0.0204	0

Table 288. Horizontal Velocity Component for Air-gap, h = 1.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0024	0.0056	0.0064	0.0039	0.0002	-0.0014	0
3	0.2232	0.0877	0.0848	0.0726	0.0525	0.0291	0.0089	0
2	0.2232	0.2135	0.1884	0.153	0.1105	0.0648	0.0229	0
1	0.2232	0.1995	0.1722	0.1399	0.1023	0.0607	0.0214	0

Table 289. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0029	0.0068	0.0079	0.0053	0.0011	-0.0011	0
3	0.2232	0.0881	0.0859	0.074	0.054	0.0302	0.0093	0
2	0.2232	0.2131	0.1881	0.153	0.111	0.0655	0.0234	0
1	0.2232	0.2004	0.1738	0.1419	0.1044	0.0626	0.0223	0

APPENDIX D.2.1.4

HORIZONTAL VELOCITY COMPONENT OF HOLE MODEL UNDERGOES ACTUAL FLOW

[P_{dyn} = 0.01 in. of water, d = 4 mm, time step = 1×10^{-5} s]

Table 290. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0001	-0.0002	-0.0002	-0.0002	-0.0002	-0.0001	0
3	0.0706	0.0262	0.023	0.0178	0.0118	0.0061	0.0018	0
2	0.0706	0.0667	0.0569	0.0434	0.0285	0.0147	0.0043	0
1	0.0706	0.056	0.0418	0.0287	0.0173	0.0082	0.0022	0

Table 291. Horizontal Velocity Component for Air-gap, h = 0.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0001	-0.0002	-0.0003	-0.0003	-0.0002	-0.0001	0
3	0.0706	0.0262	0.023	0.0178	0.0117	0.006	0.0018	0
2	0.0706	0.0668	0.0571	0.0437	0.0288	0.0149	0.0044	0
1	0.0706	0.0562	0.0422	0.0292	0.0176	0.0084	0.0023	0

Table 292. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0002	-0.0003	-0.0004	-0.0004	-0.0003	-0.0001	0
3	0.0706	0.0262	0.0229	0.0177	0.0117	0.006	0.0018	0
2	0.0706	0.0669	0.0573	0.0439	0.0291	0.0151	0.0045	0
1	0.0706	0.0565	0.0427	0.0297	0.0181	0.0087	0.0023	0

Table 293. Horizontal Velocity Component for Air-gap, h = 0.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0002	-0.0003	-0.0005	-0.0005	-0.0004	-0.0002	0
3	0.0706	0.0262	0.0229	0.0177	0.0117	0.006	0.0017	0
2	0.0706	0.067	0.0575	0.0441	0.0293	0.0153	0.0046	0
1	0.0706	0.0569	0.0433	0.0303	0.0186	0.0089	0.0024	0

Table 294. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0002	-0.0004	-0.0005	-0.0005	-0.0004	-0.0002	0
3	0.0706	0.0262	0.0229	0.0177	0.0117	0.006	0.0017	0
2	0.0706	0.067	0.0576	0.0443	0.0295	0.0154	0.0046	0
1	0.0706	0.0572	0.0439	0.031	0.0191	0.0093	0.0025	0

Table 295. Horizontal Velocity Component for Air-gap, h = 0.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0002	-0.0004	-0.0005	-0.0006	-0.0005	-0.0002	0
3	0.0706	0.0262	0.0229	0.0177	0.0117	0.006	0.0017	0
2	0.0706	0.0671	0.0576	0.0444	0.0296	0.0155	0.0047	0
1	0.0706	0.0576	0.0446	0.0317	0.0198	0.0097	0.0027	0

Table 296. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0002	-0.0004	-0.0005	-0.0006	-0.0005	-0.0002	0
3	0.0706	0.0261	0.0229	0.0177	0.0117	0.006	0.0017	0
2	0.0706	0.0671	0.0577	0.0445	0.0298	0.0157	0.0048	0
1	0.0706	0.058	0.0453	0.0325	0.0204	0.0101	0.0028	0

Table 297. Horizontal Velocity Component for Air-gap, h = 0.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0002	-0.0003	-0.0005	-0.0006	-0.0005	-0.0002	0
3	0.0706	0.0261	0.0229	0.0177	0.0117	0.006	0.0017	0
2	0.0706	0.067	0.0577	0.0446	0.0298	0.0158	0.0048	0
1	0.0706	0.0585	0.046	0.0334	0.0212	0.0106	0.003	0

Table 298. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0001	-0.0003	-0.0005	-0.0006	-0.0006	-0.0003	0
3	0.0706	0.0261	0.0229	0.0178	0.0117	0.006	0.0017	0
2	0.0706	0.067	0.0576	0.0446	0.0299	0.0158	0.0049	0
1	0.0706	0.0589	0.0468	0.0343	0.022	0.011	0.0031	0

Table 299. Horizontal Velocity Component for Air-gap, h = 1.10 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0001	-0.0002	-0.0005	-0.0006	-0.0006	-0.0003	0
3	0.0706	0.0261	0.0229	0.0178	0.0118	0.006	0.0017	0
2	0.0706	0.067	0.0576	0.0446	0.03	0.0159	0.0049	0
1	0.0706	0.0594	0.0476	0.0352	0.0228	0.0116	0.0033	0

Table 300. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	-0.0001	-0.0002	-0.0004	-0.0006	-0.0006	-0.0003	0
3	0.0706	0.0261	0.023	0.0179	0.0118	0.0061	0.0018	0
2	0.0706	0.0669	0.0575	0.0445	0.03	0.016	0.0049	0
1	0.0706	0.0599	0.0484	0.0361	0.0236	0.0121	0.0035	0

Table 301. Horizontal Velocity Component for Air-gap, h = 1.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0	-0.0001	-0.0003	-0.0005	-0.0005	-0.0003	0
3	0.0706	0.0261	0.023	0.0179	0.0119	0.0061	0.0018	0
2	0.0706	0.0668	0.0574	0.0445	0.03	0.016	0.005	0
1	0.0706	0.0603	0.0492	0.037	0.0244	0.0126	0.0037	0

Table 302. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0	0	-0.0002	-0.0004	-0.0005	-0.0003	0
3	0.0706	0.0261	0.0231	0.018	0.012	0.0062	0.0018	0
2	0.0706	0.0667	0.0573	0.0444	0.03	0.016	0.005	0
1	0.0706	0.0608	0.05	0.0379	0.0252	0.0132	0.0039	0

Table 303. Horizontal Velocity Component for Air-gap, h = 1.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0001	0.0001	-0.0001	-0.0003	-0.0005	-0.0003	0
3	0.0706	0.0262	0.0232	0.0181	0.0121	0.0062	0.0018	0
2	0.0706	0.0667	0.0572	0.0443	0.0299	0.016	0.005	0
1	0.0706	0.0612	0.0507	0.0388	0.0261	0.0138	0.0041	0

Table 304. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0002	0.0003	0.0001	-0.0002	-0.0004	-0.0003	0
3	0.0706	0.0262	0.0232	0.0182	0.0122	0.0063	0.0018	0
2	0.0706	0.0665	0.057	0.0442	0.0299	0.0161	0.0051	0
1	0.0706	0.0616	0.0515	0.0397	0.0269	0.0143	0.0043	0

Table 305. Horizontal Velocity Component for Air-gap, h = 1.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0003	0.0004	0.0003	-0.0001	-0.0003	-0.0003	0
3	0.0706	0.0262	0.0233	0.0184	0.0123	0.0064	0.0019	0
2	0.0706	0.0664	0.0569	0.0441	0.0299	0.0161	0.0051	0
1	0.0706	0.0621	0.0522	0.0405	0.0276	0.0148	0.0046	0

Table 306. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0003	0.0006	0.0005	0.0001	-0.0002	-0.0002	0
3	0.0706	0.0263	0.0234	0.0185	0.0124	0.0064	0.0019	0
2	0.0706	0.0663	0.0567	0.044	0.0298	0.0161	0.0051	0
1	0.0706	0.0624	0.0528	0.0413	0.0284	0.0154	0.0048	0

Table 307. Horizontal Velocity Component for Air-gap, h = 1.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0004	0.0008	0.0007	0.0003	-0.0001	-0.0002	0
3	0.0706	0.0263	0.0235	0.0187	0.0126	0.0065	0.0019	0
2	0.0706	0.0662	0.0565	0.0438	0.0298	0.0161	0.0051	0
1	0.0706	0.0628	0.0535	0.0421	0.0291	0.0159	0.005	0

Table 308. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0005	0.001	0.0009	0.0005	0	-0.0002	0
3	0.0706	0.0263	0.0237	0.0188	0.0127	0.0066	0.0019	0
2	0.0706	0.066	0.0563	0.0437	0.0297	0.0161	0.0051	0
1	0.0706	0.0632	0.0541	0.0428	0.0298	0.0164	0.0052	0

APPENDIX D.2.2.1

HORIZONTAL VELOCITY COMPONENT OF HOLE MODEL UNDERGOES FRICTIONLESS FLOW

[P_{dyn} = 5.0 in. of water, d = 4 mm, time step = $1x10^{-6}$ s]

Table 309. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0397	0.1121	0.2432	0.2241	0.1764	0.0998	0
3	1.5783	0.6246	0.6479	0.6115	0.5286	0.3947	0.2151	0
2	1.5783	1.5564	1.4366	1.2409	0.9866	0.6877	0.3557	0
1	1.5783	1.3541	1.1296	0.9046	0.6791	0.4531	0.2266	0

Table 310. Horizontal Velocity Component for Air-gap, h = 0.25 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0401	0.1129	0.2438	0.2248	0.177	0.1002	0
3	1.5783	0.6237	0.6478	0.612	0.5293	0.3955	0.2155	0
2	1.5783	1.5563	1.4362	1.2404	0.9861	0.6874	0.3555	0
1	1.5783	1.3548	1.1309	0.9062	0.6806	0.4542	0.2273	0

Table 311. Horizontal Velocity Component for Air-gap, h = 0.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0405	0.1138	0.2444	0.2256	0.1777	0.1006	0
3	1.5783	0.6227	0.6476	0.6126	0.5302	0.3963	0.2161	0
2	1.5783	1.5561	1.4357	1.2397	0.9855	0.687	0.3553	0
1	1.5783	1.3557	1.1324	0.908	0.6824	0.4556	0.2281	0

Table 312. Horizontal Velocity Component for Air-gap, h = 0.35 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0409	0.1148	0.2451	0.2265	0.1785	0.1011	0
3	1.5783	0.6214	0.6474	0.6132	0.5313	0.3973	0.2167	0
2	1.5783	1.5559	1.4351	1.2389	0.9848	0.6865	0.3551	0
1	1.5783	1.3567	1.1342	0.9102	0.6845	0.4573	0.229	0

Table 313. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0415	0.1159	0.2459	0.2275	0.1794	0.1017	0
3	1.5783	0.6199	0.6471	0.614	0.5325	0.3985	0.2175	0
2	1.5783	1.5556	1.4344	1.2381	0.9839	0.6859	0.3549	0
1	1.5783	1.3579	1.1362	0.9126	0.6868	0.4592	0.23	0

Table 314. Horizontal Velocity Component for Air-gap, h = 0.45 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0427	0.1185	0.2485	0.2298	0.1813	0.1028	0
3	1.5783	0.6206	0.6487	0.6162	0.5349	0.4006	0.2187	0
2	1.5783	1.5553	1.4338	1.2373	0.9834	0.6856	0.3549	0
1	1.5783	1.3592	1.1385	0.9153	0.6895	0.4612	0.2311	0

Table 315. Horizontal Velocity Component for Air-gap, h = 0.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0443	0.1214	0.2518	0.2327	0.1835	0.104	0
3	1.5783	0.6219	0.6507	0.619	0.5378	0.403	0.2202	0
2	1.5783	1.5549	1.4331	1.2366	0.9828	0.6854	0.3549	0
1	1.5783	1.3606	1.1409	0.9183	0.6924	0.4635	0.2324	0

Table 316. Horizontal Velocity Component for Air-gap, h = 0.55 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0461	0.1249	0.2558	0.236	0.186	0.1055	0
3	1.5783	0.6231	0.6528	0.6218	0.5408	0.4056	0.2218	0
2	1.5783	1.5546	1.4324	1.2358	0.9823	0.6852	0.3549	0
1	1.5783	1.3621	1.1436	0.9215	0.6955	0.466	0.2337	0

Table 317. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0481	0.1287	0.2602	0.2397	0.1889	0.1071	0
3	1.5783	0.6246	0.6552	0.625	0.5442	0.4085	0.2236	0
2	1.5783	1.5541	1.4317	1.235	0.9817	0.685	0.3549	0
1	1.5783	1.3638	1.1464	0.9249	0.6988	0.4686	0.2352	0

Table 318. Horizontal Velocity Component for Air-gap, h = 0.65 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0501	0.1324	0.2646	0.2435	0.1918	0.1088	0
3	1.5783	0.6262	0.658	0.6287	0.548	0.4118	0.2255	0
2	1.5783	1.5537	1.4308	1.2342	0.9811	0.6848	0.355	0
1	1.5783	1.3655	1.1494	0.9285	0.7023	0.4714	0.2367	0

Table 319. Horizontal Velocity Component for Air-gap, h = 0.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.052	0.1359	0.2687	0.2472	0.1947	0.1105	0
3	1.5783	0.6281	0.6613	0.6328	0.5522	0.4152	0.2276	0
2	1.5783	1.5532	1.4299	1.2333	0.9806	0.6847	0.3552	0
1	1.5783	1.3673	1.1526	0.9323	0.7061	0.4743	0.2383	0

Table 320. Horizontal Velocity Component for Air-gap, h = 0.75 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0538	0.1392	0.2723	0.2507	0.1975	0.1121	0
3	1.5783	0.6301	0.665	0.6373	0.5567	0.4189	0.2298	0
2	1.5783	1.5526	1.429	1.2324	0.9801	0.6847	0.3554	0
1	1.5783	1.3692	1.1559	0.9363	0.7099	0.4773	0.24	0

Table 321. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0554	0.1422	0.2755	0.254	0.2002	0.1136	0
3	1.5783	0.6322	0.6689	0.6421	0.5614	0.4227	0.232	0
2	1.5783	1.5521	1.4281	1.2315	0.9796	0.6846	0.3557	0
1	1.5783	1.3711	1.1593	0.9404	0.7139	0.4805	0.2417	0

Table 322. Horizontal Velocity Component for Air-gap, h = 0.85 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.057	0.145	0.2783	0.2571	0.2028	0.1151	0
3	1.5783	0.6343	0.6729	0.647	0.5661	0.4266	0.2343	0
2	1.5783	1.5515	1.4271	1.2306	0.9792	0.6847	0.3559	0
1	1.5783	1.3732	1.1628	0.9446	0.7181	0.4838	0.2435	0

Table 323. Horizontal Velocity Component for Air-gap, h = 0.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0586	0.1478	0.2809	0.26	0.2053	0.1166	0
3	1.5783	0.6365	0.6769	0.6519	0.571	0.4305	0.2366	0
2	1.5783	1.5509	1.4261	1.2297	0.9787	0.6848	0.3562	0
1	1.5783	1.3753	1.1664	0.949	0.7223	0.4871	0.2454	0

Table 324. Horizontal Velocity Component for Air-gap, h = 0.95 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0602	0.1506	0.2834	0.2629	0.2078	0.1181	0
3	1.5783	0.6386	0.6808	0.6568	0.5758	0.4344	0.2389	0
2	1.5783	1.5502	1.4251	1.2288	0.9783	0.6849	0.3566	0
1	1.5783	1.3774	1.1701	0.9534	0.7266	0.4905	0.2473	0

Table 325. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0618	0.1535	0.2859	0.2659	0.2103	0.1196	0
3	1.5783	0.6406	0.6847	0.6617	0.5806	0.4383	0.2412	0
2	1.5783	1.5495	1.424	1.2279	0.9779	0.685	0.357	0
1	1.5783	1.3795	1.1738	0.9579	0.731	0.494	0.2492	0

Table 326. Horizontal Velocity Component for Air-gap, h = 1.05 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0634	0.1564	0.2884	0.2688	0.2128	0.1211	0
3	1.5783	0.6426	0.6885	0.6665	0.5853	0.4422	0.2435	0
2	1.5783	1.5488	1.4229	1.227	0.9775	0.6852	0.3574	0
1	1.5783	1.3817	1.1776	0.9625	0.7355	0.4975	0.2512	0

Table 327. Horizontal Velocity Component for Air-gap, h = 1.10 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0651	0.1594	0.2911	0.2718	0.2153	0.1227	0
3	1.5783	0.6445	0.6922	0.6712	0.59	0.4461	0.2458	0
2	1.5783	1.5481	1.4218	1.2261	0.9772	0.6854	0.3578	0
1	1.5783	1.3839	1.1814	0.9671	0.7399	0.5011	0.2531	0

Table 328. Horizontal Velocity Component for Air-gap, h = 1.15 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0669	0.1626	0.2939	0.2749	0.218	0.1242	0
3	1.5783	0.6465	0.6959	0.6759	0.5947	0.45	0.2481	0
2	1.5783	1.5474	1.4207	1.2252	0.9768	0.6856	0.3582	0
1	1.5783	1.3861	1.1853	0.9717	0.7445	0.5047	0.2551	0

Table 329. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0687	0.1658	0.2967	0.2781	0.2206	0.1258	0
3	1.5783	0.6483	0.6994	0.6804	0.5993	0.4538	0.2505	0
2	1.5783	1.5466	1.4196	1.2244	0.9766	0.6859	0.3587	0
1	1.5783	1.3884	1.1891	0.9764	0.749	0.5083	0.2571	0

Table 330. Horizontal Velocity Component for Air-gap, h = 1.25 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0705	0.1691	0.2997	0.2813	0.2233	0.1274	0
3	1.5783	0.6502	0.7029	0.685	0.6039	0.4576	0.2528	0
2	1.5783	1.5458	1.4185	1.2235	0.9763	0.6863	0.3593	0
1	1.5783	1.3906	1.193	0.981	0.7536	0.5119	0.2592	0

Table 331. Horizontal Velocity Component for Air-gap, h = 1.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0724	0.1724	0.3027	0.2846	0.2261	0.1291	0
3	1.5783	0.6521	0.7066	0.6897	0.6086	0.4615	0.2552	0
2	1.5783	1.545	1.4174	1.2227	0.9762	0.6867	0.3599	0
1	1.5783	1.3928	1.1968	0.9857	0.7581	0.5156	0.2612	0

Table 332. Horizontal Velocity Component for Air-gap, h = 1.35 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0743	0.1757	0.3057	0.2879	0.2289	0.1308	0
3	1.5783	0.654	0.7103	0.6944	0.6133	0.4655	0.2575	0
2	1.5783	1.5442	1.4162	1.2219	0.9761	0.6872	0.3605	0
1	1.5783	1.395	1.2007	0.9903	0.7627	0.5192	0.2632	0

Table 333. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0762	0.1789	0.3086	0.2912	0.2317	0.1324	0
3	1.5783	0.656	0.714	0.6991	0.618	0.4694	0.2599	0
2	1.5783	1.5433	1.4151	1.2212	0.9761	0.6878	0.3612	0
1	1.5783	1.3972	1.2045	0.9949	0.7672	0.5229	0.2653	0

Table 334. Horizontal Velocity Component for Air-gap, h = 1.45 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0781	0.1821	0.3114	0.2945	0.2344	0.1341	0
3	1.5783	0.658	0.7178	0.7038	0.6228	0.4733	0.2623	0
2	1.5783	1.5425	1.414	1.2205	0.9761	0.6885	0.362	0
1	1.5783	1.3994	1.2083	0.9995	0.7718	0.5265	0.2673	0

Table 335. Horizontal Velocity Component for Air-gap, h = 1.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0798	0.1849	0.3136	0.2974	0.2369	0.1356	0
3	1.5783	0.66	0.7216	0.7087	0.6275	0.4772	0.2646	0
2	1.5783	1.5416	1.4129	1.2198	0.9763	0.6893	0.3628	0
1	1.5783	1.4016	1.2121	1.0041	0.7763	0.5301	0.2694	0

Table 336. Horizontal Velocity Component for Air-gap, h = 1.55 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0798	0.1842	0.3116	0.2969	0.2371	0.1359	0
3	1.5783	0.6603	0.7219	0.7097	0.6289	0.4786	0.2656	0
2	1.5783	1.5407	1.4117	1.2189	0.9759	0.6894	0.3632	0
1	1.5783	1.4037	1.2157	1.0085	0.7806	0.5336	0.2713	0

Table 337. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0794	0.1828	0.3086	0.2957	0.2367	0.1359	0
3	1.5783	0.6596	0.72	0.7087	0.6287	0.479	0.2661	0
2	1.5783	1.5398	1.4103	1.2176	0.9751	0.6893	0.3634	0
1	1.5783	1.4057	1.2192	1.0127	0.7847	0.5369	0.2732	0

Table 338. Horizontal Velocity Component for Air-gap, h = 1.65 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0791	0.1816	0.3059	0.2946	0.2365	0.1361	0
3	1.5783	0.6588	0.718	0.7077	0.6286	0.4794	0.2666	0
2	1.5783	1.5388	1.4089	1.2163	0.9744	0.6891	0.3636	0
1	1.5783	1.4077	1.2226	1.0168	0.7888	0.5402	0.275	0

Table 339. Horizontal Velocity Component for Air-gap, h = 1.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0788	0.1805	0.3034	0.2937	0.2364	0.1363	0
3	1.5783	0.658	0.7159	0.7066	0.6285	0.4799	0.2672	0
2	1.5783	1.5379	1.4075	1.215	0.9736	0.689	0.3638	0
1	1.5783	1.4097	1.226	1.0208	0.7928	0.5434	0.2768	0

Table 340. Horizontal Velocity Component for Air-gap, h = 1.75 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0786	0.1795	0.301	0.293	0.2364	0.1365	0
3	1.5783	0.6573	0.7139	0.7056	0.6284	0.4804	0.2678	0
2	1.5783	1.5369	1.406	1.2137	0.9728	0.6889	0.364	0
1	1.5783	1.4116	1.2292	1.0247	0.7966	0.5465	0.2786	0

Table 341. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0785	0.1787	0.2989	0.2923	0.2365	0.1368	0
3	1.5783	0.6565	0.7119	0.7046	0.6284	0.4809	0.2684	0
2	1.5783	1.5358	1.4046	1.2124	0.9721	0.6888	0.3643	0
1	1.5783	1.4134	1.2324	1.0286	0.8004	0.5496	0.2803	0

Table 342. Horizontal Velocity Component for Air-gap, h = 1.85 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0785	0.178	0.2969	0.2918	0.2366	0.1371	0
3	1.5783	0.6558	0.7098	0.7037	0.6284	0.4815	0.269	0
2	1.5783	1.5348	1.4031	1.211	0.9713	0.6887	0.3646	0
1	1.5783	1.4152	1.2354	1.0323	0.8041	0.5526	0.2821	0

Table 343. Horizontal Velocity Component for Air-gap, h = 1.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0785	0.1774	0.2951	0.2914	0.2369	0.1375	0
3	1.5783	0.6551	0.7078	0.7027	0.6284	0.4822	0.2697	0
2	1.5783	1.5337	1.4015	1.2097	0.9706	0.6886	0.3649	0
1	1.5783	1.417	1.2384	1.0359	0.8077	0.5555	0.2837	0

Table 344. Horizontal Velocity Component for Air-gap, h = 1.95 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0785	0.177	0.2934	0.2911	0.2372	0.1379	0
3	1.5783	0.6544	0.7058	0.7018	0.6285	0.4828	0.2704	0
2	1.5783	1.5326	1.4	1.2083	0.9699	0.6886	0.3652	0
1	1.5783	1.4186	1.2413	1.0394	0.8112	0.5584	0.2854	0

Table 345. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0787	0.1766	0.292	0.2909	0.2376	0.1384	0
3	1.5783	0.6537	0.7038	0.7009	0.6286	0.4836	0.2711	0
2	1.5783	1.5315	1.3984	1.2069	0.9692	0.6886	0.3655	0
1	1.5783	1.4203	1.2441	1.0428	0.8146	0.5612	0.287	0

APPENDIX D.2.2.2

HORIZONTAL VELOCITY COMPONENT OF HOLE MODEL UNDERGOES FRICTIONLESS FLOW

[P_{dyn} = 1.0 in. of water, d = 4 mm, time step = 1×10^{-5} s]

Table 346. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0178	0.0502	0.1088	0.1003	0.0789	0.0446	0
3	0.7058	0.2794	0.2899	0.2736	0.2364	0.1766	0.0962	0
2	0.7058	0.6961	0.6425	0.555	0.4412	0.3076	0.1591	0
1	0.7058	0.6056	0.5052	0.4046	0.3037	0.2026	0.1014	0

Table 347. Horizontal Velocity Component for Air-gap, h = 0.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0181	0.0509	0.1093	0.1009	0.0795	0.045	0
3	0.7058	0.2785	0.2897	0.274	0.2372	0.1773	0.0967	0
2	0.7058	0.6959	0.6421	0.5544	0.4407	0.3072	0.1589	0
1	0.7058	0.6063	0.5064	0.4061	0.3052	0.2038	0.102	0

Table 348. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0186	0.0519	0.11	0.1018	0.0803	0.0455	0
3	0.7058	0.2774	0.2895	0.2747	0.2382	0.1782	0.0973	0
2	0.7058	0.6957	0.6415	0.5537	0.44	0.3068	0.1587	0
1	0.7058	0.6073	0.5081	0.4081	0.3072	0.2053	0.1029	0

Table 349. Horizontal Velocity Component for Air-gap, h = 0.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0196	0.054	0.1122	0.1038	0.0819	0.0464	0
3	0.7058	0.2777	0.2907	0.2766	0.2403	0.1801	0.0984	0
2	0.7058	0.6954	0.6409	0.553	0.4395	0.3065	0.1587	0
1	0.7058	0.6085	0.5102	0.4107	0.3096	0.2073	0.1039	0

Table 350. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0209	0.0567	0.1152	0.1064	0.084	0.0476	0
3	0.7058	0.2786	0.2926	0.2792	0.2431	0.1825	0.0998	0
2	0.7058	0.695	0.6402	0.5522	0.4389	0.3062	0.1587	0
1	0.7058	0.6099	0.5127	0.4136	0.3125	0.2096	0.1052	0

Table 351. Horizontal Velocity Component for Air-gap, h = 0.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0224	0.0597	0.1186	0.1094	0.0863	0.049	0
3	0.7058	0.2796	0.2946	0.2821	0.2462	0.1851	0.1014	0
2	0.7058	0.6946	0.6394	0.5514	0.4383	0.306	0.1587	0
1	0.7058	0.6115	0.5154	0.4169	0.3157	0.2121	0.1066	0

Table 352. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0239	0.0629	0.1224	0.1126	0.0888	0.0504	0
3	0.7058	0.2807	0.2969	0.2852	0.2495	0.188	0.1032	0
2	0.7058	0.6941	0.6386	0.5505	0.4377	0.3058	0.1588	0
1	0.7058	0.6132	0.5184	0.4205	0.3192	0.2149	0.1081	0

Table 353. Horizontal Velocity Component for Air-gap, h = 0.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0256	0.0663	0.1264	0.1161	0.0915	0.052	0
3	0.7058	0.2819	0.2992	0.2885	0.253	0.191	0.105	0
2	0.7058	0.6936	0.6377	0.5496	0.4372	0.3057	0.1589	0
1	0.7058	0.615	0.5216	0.4243	0.3229	0.2178	0.1097	0

Table 354. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0273	0.0699	0.1307	0.1196	0.0943	0.0536	0
3	0.7058	0.2831	0.3017	0.2919	0.2567	0.1942	0.107	0
2	0.7058	0.693	0.6367	0.5487	0.4366	0.3056	0.1591	0
1	0.7058	0.6169	0.5249	0.4283	0.3268	0.2208	0.1114	0

Table 355. Horizontal Velocity Component for Air-gap, h = 1.10 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0291	0.0735	0.1352	0.1233	0.0971	0.0552	0
3	0.7058	0.2843	0.3042	0.2954	0.2605	0.1974	0.109	0
2	0.7058	0.6924	0.6357	0.5478	0.4361	0.3056	0.1594	0
1	0.7058	0.6189	0.5283	0.4324	0.3308	0.224	0.1131	0

Table 356. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0308	0.0771	0.1398	0.127	0.1	0.0569	0
3	0.7058	0.2855	0.3068	0.2989	0.2643	0.2007	0.111	0
2	0.7058	0.6917	0.6346	0.5469	0.4357	0.3057	0.1597	0
1	0.7058	0.6208	0.5317	0.4365	0.3348	0.2271	0.1149	0

Table 357. Horizontal Velocity Component for Air-gap, h = 1.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0326	0.0807	0.1445	0.1308	0.1029	0.0585	0
3	0.7058	0.2868	0.3094	0.3025	0.2681	0.2041	0.1131	0
2	0.7058	0.691	0.6336	0.546	0.4354	0.3059	0.1602	0
1	0.7058	0.6228	0.5351	0.4406	0.3388	0.2303	0.1167	0

Table 358. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0343	0.0843	0.1492	0.1345	0.1057	0.0602	0
3	0.7058	0.288	0.3119	0.306	0.2719	0.2074	0.1151	0
2	0.7058	0.6903	0.6325	0.5452	0.4352	0.3063	0.1607	0
1	0.7058	0.6248	0.5385	0.4447	0.3428	0.2335	0.1185	0

Table 359. Horizontal Velocity Component for Air-gap, h = 1.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.036	0.0878	0.154	0.1381	0.1085	0.0618	0
3	0.7058	0.2892	0.3144	0.3095	0.2756	0.2107	0.1172	0
2	0.7058	0.6895	0.6314	0.5444	0.4351	0.3067	0.1612	0
1	0.7058	0.6267	0.5418	0.4487	0.3467	0.2367	0.1202	0

Table 360. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0371	0.0902	0.1573	0.1406	0.1104	0.063	0
3	0.7058	0.2898	0.3157	0.3118	0.2783	0.2132	0.1188	0
2	0.7058	0.6887	0.6303	0.5436	0.4348	0.3071	0.1618	0
1	0.7058	0.6286	0.545	0.4525	0.3506	0.2398	0.122	0

Table 361. Horizontal Velocity Component for Air-gap, h = 1.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0364	0.0888	0.1557	0.1395	0.11	0.063	0
3	0.7058	0.2886	0.3134	0.3103	0.2779	0.2133	0.1192	0
2	0.7058	0.6878	0.629	0.5423	0.434	0.3068	0.1618	0
1	0.7058	0.6303	0.548	0.4561	0.3541	0.2426	0.1236	0

Table 362. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0357	0.0875	0.1542	0.1385	0.1097	0.063	0
3	0.7058	0.2873	0.311	0.3089	0.2774	0.2135	0.1196	0
2	0.7058	0.6869	0.6276	0.5409	0.4331	0.3065	0.1619	0
1	0.7058	0.6319	0.5508	0.4595	0.3574	0.2453	0.1251	0

Table 363. Horizontal Velocity Component for Air-gap, h = 1.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.035	0.0863	0.1529	0.1377	0.1095	0.0631	0
3	0.7058	0.2861	0.3085	0.3075	0.277	0.2138	0.12	0
2	0.7058	0.686	0.6261	0.5395	0.4322	0.3062	0.1621	0
1	0.7058	0.6335	0.5534	0.4626	0.3605	0.2478	0.1265	0

Table 364. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0344	0.0852	0.1518	0.137	0.1093	0.0632	0
3	0.7058	0.2848	0.306	0.306	0.2766	0.214	0.1204	0
2	0.7058	0.685	0.6246	0.5381	0.4313	0.3059	0.1622	0
1	0.7058	0.6349	0.5559	0.4656	0.3634	0.2502	0.1279	0

APPENDIX D.2.2.3

HORIZONTAL VELOCITY COMPONENT OF HOLE MODEL UNDERGOES FRICTIONLESS FLOW

[$P_{dyn} = 0.1$ in. of water, d = 4 mm, time step = $1x10^{-5}$ s]

Table 365. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0056	0.0159	0.0344	0.0317	0.0249	0.0141	0
3	0.2232	0.0883	0.0916	0.0865	0.0748	0.0558	0.0304	0
2	0.2232	0.2201	0.2032	0.1755	0.1395	0.0973	0.0503	0
1	0.2232	0.1915	0.1598	0.1279	0.096	0.0641	0.0321	0

Table 366. Horizontal Velocity Component for Air-gap, h = 0.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0057	0.0161	0.0346	0.0319	0.0251	0.0142	0
3	0.2232	0.0881	0.0916	0.0866	0.075	0.056	0.0306	0
2	0.2232	0.2201	0.203	0.1753	0.1394	0.0972	0.0503	0
1	0.2232	0.1917	0.1601	0.1284	0.0965	0.0644	0.0323	0

Table 367. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0059	0.0164	0.0348	0.0322	0.0254	0.0144	0
3	0.2232	0.0877	0.0915	0.0868	0.0753	0.0564	0.0308	0
2	0.2232	0.22	0.2029	0.1751	0.1391	0.097	0.0502	0
1	0.2232	0.192	0.1607	0.1291	0.0971	0.0649	0.0325	0

Table 368. Horizontal Velocity Component for Air-gap, h = 0.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0062	0.0171	0.0355	0.0328	0.0259	0.0147	0
3	0.2232	0.0878	0.0919	0.0875	0.076	0.057	0.0311	0
2	0.2232	0.2199	0.2027	0.1749	0.139	0.0969	0.0502	0
1	0.2232	0.1924	0.1614	0.1299	0.0979	0.0655	0.0329	0

Table 369. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0066	0.018	0.0365	0.0337	0.0266	0.0151	0
3	0.2232	0.0881	0.0926	0.0883	0.0769	0.0577	0.0316	0
2	0.2232	0.2198	0.2025	0.1746	0.1388	0.0968	0.0502	0
1	0.2232	0.1929	0.1621	0.1308	0.0988	0.0663	0.0333	0

Table 370. Horizontal Velocity Component for Air-gap, h = 0.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0071	0.019	0.0376	0.0347	0.0273	0.0155	0
3	0.2232	0.0885	0.0932	0.0892	0.0779	0.0586	0.0321	0
2	0.2232	0.2197	0.2022	0.1744	0.1386	0.0968	0.0502	0
1	0.2232	0.1934	0.163	0.1318	0.0998	0.0671	0.0337	0

Table 371. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0077	0.02	0.0389	0.0357	0.0282	0.016	0
3	0.2232	0.0889	0.094	0.0903	0.079	0.0595	0.0327	0
2	0.2232	0.2195	0.2019	0.1741	0.1384	0.0967	0.0502	0
1	0.2232	0.1939	0.1639	0.133	0.101	0.0679	0.0342	0

Table 372. Horizontal Velocity Component for Air-gap, h = 0.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0082	0.0211	0.0402	0.0369	0.029	0.0165	0
3	0.2232	0.0893	0.0948	0.0914	0.0801	0.0605	0.0333	0
2	0.2232	0.2193	0.2017	0.1738	0.1383	0.0967	0.0503	0
1	0.2232	0.1945	0.1649	0.1342	0.1021	0.0689	0.0347	0

Table 373. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0088	0.0222	0.0415	0.038	0.0299	0.017	0
3	0.2232	0.0898	0.0957	0.0926	0.0814	0.0615	0.0339	0
2	0.2232	0.2192	0.2014	0.1735	0.1381	0.0967	0.0504	0
1	0.2232	0.1951	0.166	0.1354	0.1034	0.0698	0.0352	0

Table 374. Horizontal Velocity Component for Air-gap, h = 1.10 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0093	0.0233	0.0428	0.0391	0.0308	0.0175	0
3	0.2232	0.0903	0.0967	0.0938	0.0827	0.0626	0.0346	0
2	0.2232	0.219	0.201	0.1733	0.138	0.0967	0.0505	0
1	0.2232	0.1957	0.1671	0.1367	0.1046	0.0708	0.0358	0

Table 375. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0099	0.0243	0.044	0.0402	0.0317	0.018	0
3	0.2232	0.0908	0.0976	0.0951	0.084	0.0638	0.0352	0
2	0.2232	0.2187	0.2007	0.173	0.1379	0.0968	0.0506	0
1	0.2232	0.1963	0.1681	0.138	0.1059	0.0718	0.0363	0

Table 376. Horizontal Velocity Component for Air-gap, h = 1.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0104	0.0253	0.0451	0.0412	0.0325	0.0185	0
3	0.2232	0.0913	0.0986	0.0964	0.0853	0.0649	0.0359	0
2	0.2232	0.2185	0.2004	0.1728	0.1378	0.0969	0.0507	0
1	0.2232	0.197	0.1692	0.1394	0.1072	0.0729	0.0369	0

Table 377. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0109	0.0263	0.0462	0.0423	0.0333	0.019	0
3	0.2232	0.0918	0.0996	0.0977	0.0866	0.066	0.0366	0
2	0.2232	0.2183	0.2001	0.1725	0.1378	0.097	0.0509	0
1	0.2232	0.1976	0.1703	0.1407	0.1084	0.0739	0.0375	0

Table 378. Horizontal Velocity Component for Air-gap, h = 1.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0114	0.0272	0.0473	0.0432	0.0341	0.0195	0
3	0.2232	0.0923	0.1006	0.0989	0.0879	0.0671	0.0373	0
2	0.2232	0.218	0.1997	0.1723	0.1378	0.0972	0.0511	0
1	0.2232	0.1982	0.1714	0.1419	0.1097	0.0749	0.0381	0

Table 379. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0115	0.0272	0.0471	0.0434	0.0343	0.0196	0
3	0.2232	0.0925	0.1009	0.0994	0.0885	0.0676	0.0376	0
2	0.2232	0.2178	0.1994	0.1721	0.1377	0.0973	0.0513	0
1	0.2232	0.1988	0.1724	0.1432	0.1109	0.0759	0.0386	0

Table 380. Horizontal Velocity Component for Air-gap, h = 1.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0113	0.0267	0.0463	0.0429	0.0342	0.0196	0
3	0.2232	0.0922	0.1003	0.0991	0.0885	0.0677	0.0378	0
2	0.2232	0.2175	0.199	0.1717	0.1375	0.0972	0.0513	0
1	0.2232	0.1993	0.1733	0.1443	0.112	0.0768	0.0391	0

Table 381. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0111	0.0262	0.0455	0.0426	0.0341	0.0196	0
3	0.2232	0.092	0.0997	0.0988	0.0884	0.0678	0.0379	0
2	0.2232	0.2172	0.1986	0.1713	0.1373	0.0972	0.0514	0
1	0.2232	0.1999	0.1742	0.1454	0.1131	0.0777	0.0396	0

Table 382. Horizontal Velocity Component for Air-gap, h = 1.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0109	0.0258	0.0448	0.0423	0.034	0.0197	0
3	0.2232	0.0917	0.0991	0.0985	0.0884	0.068	0.0381	0
2	0.2232	0.2169	0.1981	0.1709	0.137	0.0972	0.0515	0
1	0.2232	0.2004	0.1751	0.1464	0.1141	0.0785	0.0401	0

Table 383. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0108	0.0255	0.0441	0.0421	0.034	0.0198	0
3	0.2232	0.0915	0.0984	0.0982	0.0883	0.0681	0.0383	0
2	0.2232	0.2166	0.1977	0.1705	0.1368	0.0971	0.0515	0
1	0.2232	0.2008	0.1759	0.1474	0.1151	0.0793	0.0405	0

APPENDIX D.2.2.4

HORIZONTAL VELOCITY COMPONENT OF HOLE MODEL UNDERGOES FRICTIONLESS FLOW

[P_{dyn} = 0.01 in. of water, d = 4 mm, time step = 1×10^{-5} s]

Table 384. Horizontal Velocity Component for Air-gap, h = 0.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0018	0.005	0.0109	0.01	0.0079	0.0045	0
3	0.0706	0.0279	0.029	0.0273	0.0236	0.0177	0.0096	0
2	0.0706	0.0696	0.0642	0.0555	0.0441	0.0308	0.0159	0
1	0.0706	0.0606	0.0505	0.0405	0.0304	0.0203	0.0101	0

Table 385. Horizontal Velocity Component for Air-gap, h = 0.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0019	0.0052	0.0111	0.0102	0.008	0.0045	0
3	0.0706	0.0279	0.029	0.0274	0.0237	0.0177	0.0097	0
2	0.0706	0.0696	0.0642	0.0554	0.0441	0.0307	0.0159	0
1	0.0706	0.0606	0.0506	0.0406	0.0305	0.0204	0.0102	0

Table 386. Horizontal Velocity Component for Air-gap, h = 0.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0019	0.0051	0.0109	0.0102	0.0081	0.0046	0
3	0.0706	0.0282	0.0295	0.028	0.0242	0.0181	0.0099	0
2	0.0706	0.0696	0.0642	0.0554	0.0441	0.0308	0.0159	0
1	0.0706	0.0607	0.0508	0.0408	0.0307	0.0205	0.0103	0

Table 387. Horizontal Velocity Component for Air-gap, h = 0.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0018	0.0048	0.0103	0.0099	0.0079	0.0045	0
3	0.0706	0.0285	0.0301	0.0285	0.0246	0.0184	0.01	0
2	0.0706	0.0695	0.0641	0.0554	0.0441	0.0308	0.016	0
1	0.0706	0.0608	0.051	0.0411	0.031	0.0207	0.0104	0

Table 388. Horizontal Velocity Component for Air-gap, h = 0.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.002	0.005	0.01	0.0099	0.008	0.0045	0
3	0.0706	0.0286	0.0304	0.0289	0.025	0.0187	0.0102	0
2	0.0706	0.0695	0.064	0.0553	0.044	0.0308	0.016	0
1	0.0706	0.061	0.0513	0.0414	0.0313	0.021	0.0105	0

Table 389. Horizontal Velocity Component for Air-gap, h = 0.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0022	0.0054	0.0101	0.0101	0.0082	0.0047	0
3	0.0706	0.0288	0.0307	0.0293	0.0254	0.019	0.0104	0
2	0.0706	0.0694	0.064	0.0552	0.044	0.0308	0.016	0
1	0.0706	0.0611	0.0516	0.0417	0.0316	0.0212	0.0107	0

Table 390. Horizontal Velocity Component for Air-gap, h = 0.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0025	0.0059	0.0104	0.0104	0.0084	0.0048	0
3	0.0706	0.029	0.031	0.0298	0.0259	0.0194	0.0106	0
2	0.0706	0.0694	0.0639	0.0552	0.044	0.0308	0.016	0
1	0.0706	0.0613	0.0519	0.0421	0.0319	0.0215	0.0108	0

Table 391. Horizontal Velocity Component for Air-gap, h = 0.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0027	0.0063	0.0107	0.0108	0.0087	0.005	0
3	0.0706	0.0293	0.0314	0.0303	0.0264	0.0198	0.0108	0
2	0.0706	0.0693	0.0638	0.0551	0.0439	0.0308	0.0161	0
1	0.0706	0.0615	0.0522	0.0425	0.0323	0.0218	0.011	0

Table 392. Horizontal Velocity Component for Air-gap, h = 1.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.003	0.0067	0.011	0.0111	0.009	0.0052	0
3	0.0706	0.0295	0.0319	0.0309	0.0269	0.0202	0.0111	0
2	0.0706	0.0693	0.0637	0.055	0.0439	0.0308	0.0161	0
1	0.0706	0.0617	0.0525	0.0429	0.0327	0.0221	0.0112	0

Table 393. Horizontal Velocity Component for Air-gap, h = 1.10 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0032	0.0071	0.0113	0.0114	0.0093	0.0053	0
3	0.0706	0.0298	0.0324	0.0315	0.0275	0.0206	0.0113	0
2	0.0706	0.0692	0.0636	0.055	0.0439	0.0309	0.0162	0
1	0.0706	0.0619	0.0529	0.0433	0.0331	0.0224	0.0113	0

Table 394. Horizontal Velocity Component for Air-gap, h = 1.20 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0034	0.0074	0.0115	0.0117	0.0095	0.0054	0
3	0.0706	0.03	0.0329	0.0321	0.028	0.021	0.0115	0
2	0.0706	0.0691	0.0635	0.0549	0.0439	0.0309	0.0162	0
1	0.0706	0.0621	0.0532	0.0437	0.0335	0.0228	0.0115	0

Table 395. Horizontal Velocity Component for Air-gap, h = 1.30 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0035	0.0076	0.0115	0.0118	0.0096	0.0055	0
3	0.0706	0.0302	0.0332	0.0324	0.0284	0.0213	0.0117	0
2	0.0706	0.0691	0.0634	0.0548	0.0439	0.031	0.0163	0
1	0.0706	0.0623	0.0536	0.0441	0.034	0.0231	0.0117	0

Table 396. Horizontal Velocity Component for Air-gap, h = 1.40 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0036	0.0076	0.0114	0.0117	0.0095	0.0055	0
3	0.0706	0.0302	0.0331	0.0325	0.0284	0.0214	0.0118	0
2	0.0706	0.069	0.0633	0.0548	0.0439	0.031	0.0163	0
1	0.0706	0.0625	0.0539	0.0445	0.0344	0.0234	0.0119	0

Table 397. Horizontal Velocity Component for Air-gap, h = 1.50 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0036	0.0076	0.0113	0.0116	0.0095	0.0054	0
3	0.0706	0.0302	0.033	0.0324	0.0285	0.0215	0.0118	0
2	0.0706	0.0689	0.0632	0.0547	0.0438	0.031	0.0163	0
1	0.0706	0.0627	0.0542	0.0449	0.0348	0.0237	0.0121	0

Table 398. Horizontal Velocity Component for Air-gap, h = 1.60 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0036	0.0076	0.0112	0.0115	0.0094	0.0054	0
3	0.0706	0.0301	0.0328	0.0323	0.0285	0.0215	0.0119	0
2	0.0706	0.0689	0.0631	0.0545	0.0437	0.031	0.0164	0
1	0.0706	0.0629	0.0545	0.0453	0.0351	0.0241	0.0122	0

Table 399. Horizontal Velocity Component for Air-gap, h = 1.70 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0037	0.0076	0.0111	0.0115	0.0094	0.0054	0
3	0.0706	0.03	0.0324	0.0321	0.0285	0.0216	0.0119	0
2	0.0706	0.0688	0.0629	0.0544	0.0436	0.031	0.0164	0
1	0.0706	0.063	0.0548	0.0457	0.0355	0.0243	0.0124	0

Table 400. Horizontal Velocity Component for Air-gap, h = 1.80 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0038	0.0078	0.0111	0.0115	0.0094	0.0053	0
3	0.0706	0.0302	0.0327	0.0325	0.0288	0.0218	0.012	0
2	0.0706	0.0687	0.0628	0.0543	0.0437	0.0311	0.0165	0
1	0.0706	0.0632	0.0552	0.0461	0.0359	0.0247	0.0126	0

Table 401. Horizontal Velocity Component for Air-gap, h = 1.90 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.0039	0.0079	0.0112	0.0115	0.0093	0.0053	0
3	0.0706	0.0303	0.033	0.0329	0.0291	0.022	0.0122	0
2	0.0706	0.0686	0.0627	0.0543	0.0438	0.0312	0.0166	0
1	0.0706	0.0634	0.0555	0.0464	0.0363	0.025	0.0128	0

Table 402. Horizontal Velocity Component for Air-gap, h = 2.00 mm

J\I	1	2	3	4	5	6	7	8
5	0	0	0	0	0	0	0	0
4	0	0.004	0.008	0.0112	0.0115	0.0093	0.0052	0
3	0.0706	0.0305	0.0333	0.0332	0.0294	0.0223	0.0123	0
2	0.0706	0.0685	0.0626	0.0543	0.0438	0.0313	0.0167	0
1	0.0706	0.0636	0.0557	0.0468	0.0366	0.0253	0.013	0

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