A COMPARISON OF CENTER AND SURFACE WINDING USING THE WOUND-IN-TENSION METHOD

by

J.K. Good, J. Hartwig , and R. Markum
Oklahoma State University
USA

ABSTRACT

Pfeiffer first defined the wound-in-tension measurement in 1968[1]. This technique requires the outer layer of web to be pulled away from a winding roll and a measure of the web tension is made prior to returning the web to the surface of the winding roll. In this manner the wound-in-tension can be studied as a function of winder type and as a function of winder and web line operating parameters. In this paper the use of the WIT measurement as a non-interfering method of evaluating roll structure will be examined. WIT will be used to compare surface winding and center winding with a nip. The nip-induced-tension components of the WIT will be determined as well and compared for the different winder types.

NOMENCLATURE

E_r	Radial modulus of elasticity (Pa)
K_1	Empirical constant in E_r expression (Pa)
K_2	Empirical constant in E_r expression
N	Nip load (N/cm)
NIT	Component of WIT induced by the nip via interlayer slippage (N/cm)
P	Interlayer pressure within the wound roll (Pa)
T_w	Web tension prior to entry of the winder (N/cm)
WIT	Tension in the outer layer of the wound roll as affected by T_w and NIT (N/cm)
β	Angle of wrap of the web about the nip in surface winding (rad)
μ_{wn}	Kinetic coefficient of friction between the web and nip (0.20 news/aluminum)
μ_{ww}	Kinetic coefficient of friction between web layers (0.19 for news)
ϕ	Angle of wrap of the web from the nip about the wound roll to the location where it is extracted to perform the WIT measurement (rad)

INTRODUCTION

Surface winders and center winders have been used for many years to wind various web materials. It is often the question if certain webs wind better on one type winder versus another. Methods of evaluating the internal pressures directly are largely destructive tests. The Cameron gap test requires severing layers on the wound roll[2]. Pull tabs and force sensitive resistors must be inserted into the roll, as it is wound and require recovery prior to the shipment of the roll [3,4]. The acoustic roll structure gage measurement described by Swanson overcomes this problem [5]. This method employs an experimental measurement of the time-of-flight of a stress wave propagating radially through a wound roll in conjunction with a wound roll model which calculates an analytical time-of-flight based upon computed radial pressures. One of the input parameters of the model, typically the WIT, is varied until the analytical and experimental values of the time-of-flight converge. Upon convergence one assumes that the radial and tangential stresses computed by the model are those which exist within the roll. This method is novel in that the WIT can be estimated spatially across the width as well. Shortcomings include (1) the inability to determine if the WIT was constant throughout the wind and (2) the signal to noise ratio in the experimental measurement make it an unlikely candidate for evaluating WIT during winding.

The WIT measurement is non-destructive but has never been proven to be a non-interfering test. Pulling the outer layer away from the winding roll to measure its tension may impact the radial pressure profile within the wound roll and thereby the tangential stresses. In this paper results will be presented that will determine if the WIT measurement is non-interfering. To achieve this objective, winding rolls will have pull-tabs inserted such that radial pressures will be known at various radial locations throughout the roll. The WIT will not be measured in these rolls such that the outer layer would remain in contact with the outside of the winding roll. The web and stack properties will be measured and input to a wound roll model. The WIT will be varied as an input to the model until the radial pressures predicted by the model agree with those measured experimentally. The WIT inferred by this method will be compared to the WIT measured directly in a second set of winding tests.

After it has been determined if the WIT measurement is non-interfering, the technique will be used in a comparative study of center and surface winding. From the comparison some interesting conclusions regarding nip-induced-tensions can be drawn.

EXPERIMENTAL PROCEDURE

WIT Measurements

The concept of measuring wound-in-tension must be credited to Pfeiffer[1]. A diagram of Pfeiffer's experimental apparatus is shown in Figure 1. In this case the winder was a surface winder. Note the web passes under the surface driven roll and then proceeds about the load cell where the WIT measurement is made. The web is then returned to the winding roll. The nip load in this apparatus is applied via the cylinder/cable system shown. One shortcoming of this arrangement is that the WIT in the web serves to increase the nip load.

A WIT apparatus has been developed at the Web Handling Research Center, as shown in Figure 2. This web line has one zone of controlled tension, similar to Pfeiffer's line. A magnetic hysteretic brake (Magtrol Model 805-2) provides the braking torque at the unwinding roll. An idler downstream is supported by a MagPowr (Model CL250) load cell from which the web tension is inferred. A MagPowr Digitrac tension control unit varies the current that is input to the hysteretic brake until a target value of web tension is sensed at the load cell. The web passes over a displacement guide (Fife Model OPG-LRA) before proceeding to the winder. An idler roll and the nip roll travel together on a sled on linear ways as shown. The nip roll is pivoted on a swing arm. A pneumatic cylinder that forces the sled towards the winding roll applies the nip load. The sled has load cells (Omega Model CCCB-200) mounted which press upon the nip roll swing arm at the same elevation as the center of the nip roller. The nip load is controlled in a closed loop PID control scheme in LABVIEW in which the air pressure within the pneumatic cylinder is varied by an e->p transducer (Bellofram Type 1000) until a target value of nip load is sensed by the load cells. Note that the idler on the sled is positioned such that the web wraps the nip roller 180 degrees and thereby prevents web tension from affecting the nip load. The idler is moved to other positions at the same elevation to maintain the 180 degree web wrap about the nip for various diameter nip rolls. The web exits the nip roll onto the winding roll where it becomes the outer layer. The web then leaves the surface of the winding roll and proceeds about an idler roller, a roller upon a load cell (BLH Model LTT-100/DXT-15) for measurement of WIT, and another idler before proceeding back to the surface of the winding roll. These three rollers are mounted upon a sled together. The sled is mounted upon horizontal linear ways and can be positioned horizontally by a servo motor/screw drive. An ultrasonic position sensor (Senix Model Ultra S) provides a measurement of the distance between the sled and the winding roll. A controller was designed in LABVIEW software that allows the length of web that has been pulled away from the winding roll for the WIT measurement to be held constant. Results from initial trials run on the apparatus indicated the length of web pulled away from the winding roll had no impact upon the WIT measured. Most webs run to date have been materials that can be assumed elastic, at least for the time duration associated with winding. The WIT measurement may become a function of the web length pulled away for measurement for web materials that exhibit viscoelasticity over time periods similar to that associated with the web running through the WIT loop. The web line is driven by a Rockwell Automation GV3000 drive coupled with a 5 HP AC Vector motor. The output of the motor drives the input of a 12 speed Turner Unidrive transmission (Model 2M6-11 LLR). The output of the transmission drives either the winding roll or the nip roll such that either center winding or surface winding can be performed.

Pull Tab Measurements

Pull-tabs have been used to measure the radial pressure as a function of radial location in wound rolls for some time[3,4,5]. Pull-tabs are simply pieces of metal shim stock that have been wound into a winding roll. A force gage is used to partially extract the pull-tab after winding is completed. If the coefficient of friction between the pull-tab and the web is known the amplitude of the normal force which was present on the tab can be calculated. By dividing the normal force by the area of contact one can determine the radial pressure at the radial location the pull-tab was wound in. The repeatability of the pressure data obtained from pull-tab measurements can be much improved if one pays attention to details including:

- Encasing the pull-tab in a sheath of metal shim will improve the repeatability of the data. The sheath metal is usually dissimilar to the metal used for the pull-tab, which results in a lower coefficient of friction. Low friction coefficient is also desirable, as it will allow higher pressure measurements prior to failure. In these experiments steel shim 1.27 cm wide and 25.4 μm thick was used for the pull-tab and brass shim 25.4 μm thick was used for the sheath. After bending the brass into a sheath and inserting the pull-tab one has a pressure sensor which is roughly 2.54 cm wide with a maximum thickness of 76.2 μm. The sheath and pull-tab should be long enough to protrude out of both sides of the roll.
- The repeatability of the data obtained from pull-tabs can also be improved by calibrating it within a stack of the web material, which is to be wound. Calibration is achieved by subjecting the web stack to known pressures and then measuring the force required to dislodge the pull-tab. If the force is plotted versus the stack pressure a very linear behavior is exhibited. Although this is time consuming it is necessary to overcome variability in surface finish and burrs at the edges of the tabs, the burrs resulting from slitting the shim that is, in fact, a web.

- Finally, the use of statistics whenever possible will help improve the data quality. Multiple measurements of extraction force should be conducted and averaged during calibration and testing. Multiple rolls should be wound at the same winder conditions and the pressure data derived from pull-tabs at like radii should be averaged. The non-repeatability of pressure data measured by the pull tab can be due to the variability of the pressure transducer (i.e. the pull tab) and the inability of the winder to duplicate the operating parameters such as web tension, nip loading, or drum torque from one wind to the next.

VERIFICATION OF THE WIT METHOD

Newsprint was chosen as the web material. First the WIT measurements were collected. Rolls were center-wound with a nip roller, 15.2 cm in diameter, at nip loads of 4.38, 8.75, 17.5, 35, and 52.5 N/cm. Web tension was held constant at 1.75 N/cm. All rolls were wound on steel cores (7.62 cm ID, 8.63 cm OD) to final diameters of approximately 27.9 cm. The plots of WIT for one of three experiments wound at a given winding condition are shown in Figure 3. Note that the four lower nip loads (4.38-35 N/cm) exhibit a WIT that appears independent of the wound roll radius. Note that at the highest nip load of 52.5 N/cm there appears to be some dependency on wound roll radius but that the amplitude of WIT is nearly that of the case in which the nip load was 35 N/cm. Disregard the disturbances in WIT at wound roll radii less than 5 cm, this was due to overshoot of the nip load at startup. Each winding case was tested three times. The WIT recorded for each winding test was averaged and then an average was taken of the three WIT averages that resulted from the three experiments conducted at that winding condition. The averages along with the 95% confidence intervals are shown in Table 1.

Rolls were then wound with pull-tabs inserted for the same winding conditions in which the WIT data was acquired (i.e. center wound at nip loads of 4.38, 8.75, 17.5, 35, and 52.5 N/cm with web tension held constant at 1.75 N/cm). Each winding case was repeated three times. This resulted in three pressure measurements at each radial location of which means were taken and 95% confidence intervals were established. The data is shown in Figure 4 and the confidence intervals have been plotted as error bars upon the means. The lines of pressure data in Figure 4 resulted from executing a computer code of a wound roll model of the type discussed by Hakiel for calculating radial pressures and circumferential stress [6]. Wound roll models require the input of wound roll dimensions, core properties, web and stack material properties, and most important in terms of impact upon the output, the winding tension profile. All of the winding parameters used as input to the model are given in Table 2, with the exception of the winding tension. The winding code developed also allowed the user to input experimental radial pressure data and the radial location at which the pressure was measured. The code would then be started with an initial guess of the winding tension and the code would determine the radial pressure profile associated with the guess. An error term was then computed by taking the sum of the differences of experimentally measured pressures and those computed by the model at the same radial location. The code would then minimize this error term by iterating upon the winding tension. The winding tension associated with the minimal error was assumed to be the WIT that would be compared to the WIT that was measured in the previous winding experiments. It should be noted that it was assumed that the winding tension was constant, independent of wound roll radius, based upon the WIT data that was presented in Figure 3. A flow chart of this computer code is given in Figure 5.

The measured WIT for various nip loads are compared to WIT inferred from the winding code in Figure 6. The agreement was not good. The measured WIT is typically 30% in error with respect to the WIT inferred from pull tab measurements, refer to Table 1. After checking all potential sources for errors it was concluded that the WIT measurement, at least in the configuration shown in Figure 2, was an interfering measurement. To corroborate the evidence that some of the WIT was being lost a second set of winding experiments were conducted. In these tests the web was routed over the rollers used in the WIT measurement. Pull-tabs were inserted between the web and winding roll just as the web returned to the winding roll after the WIT measurement. The pressures recorded during these experiments are shown in Figure 7. When compared to the data in Figure 4 it is evident that a sizable loss in WIT has occurred due to the WIT measurement. It is known that the nip roller induces a component of the WIT above and beyond the web line tension called the nip-induced tension[7,8]. The source of this nip-induced-tension is an elongating machine direction strain in the outer layer due to contact mechanics. As incoming web proceeds about the nip roll and enters and exits the contact zone between the winding roll and the nip, the web tension undergoes a near step jump in tension, the nip-induced-tension. If the outer layer between the nip roller and the point at which the web is extracted to make the WIT measurement slips relative to the layer beneath, less WIT will be measured. The decreased level WIT which is measured should be that associated with friction loss and can be predicted using the band brake or capstan expression:

$$WIT_{measured} = \frac{WIT}{e^{\mu_{ww}\phi}} \qquad \{1\}$$

where μ_{ww} is the kinetic coefficient of friction between web layers and ϕ is the angle of wrap between the nip and the point at which the web is extracted for the WIT measurement. The angle of wrap ϕ, shown in Figure 2, varies from 90 degrees at the start of the wind, to 110 degrees, as the roll finishes winding. An expression was developed for ϕ such that it could be estimated at various wound roll radii. The records of measured WIT, similar to those shown in Figure 3, could now be corrected to account for friction loss. These corrected WITs can be seen in Figure 8, overlaid upon the data from Figure 6. The corrected WITs now differ 5% or less, refer to Table 1, from the WITs inferred from pull tab pressures in which the web was not routed over the rollers where the WIT measurements are made. Thus it appears that even though the WIT measurement is an interfering method that the measurements can in fact be corrected to yield the true WITs. It is important that any means used to evaluate roll structure ultimately leads to correct pressures and circumferential stresses within the wound roll that can be related to roll defects[9].

THE EFFECT OF NIP LOAD AND WEB TENSION ON WIT

A set of winding tests were run in which one winder operating parameter was varied while all other parameters were held constant. For both center and surface winding the two parameters that were varied were web tension, just prior to the winder, and nip loading. In all cases the web wrapped the nip roller 180 degrees, thus preventing any interaction between web tension and nip load. It should be noted that other parameters might affect the WIT. Other authors have, for instance, discussed the impact of the angle of wrap of the web about the nip on surface winding[10]. These tests were again performed using newsprint.

The results of a centerwinding test are shown in Figure 9. In this experiment the web tension was stepped in .875 N/cm from 1.75 to 5.25 N/cm. The nip load was held constant at 17.5 N/cm. Note that increasing the web tension directly affects the WIT, a step of .875 N/cm in web tension appears to add an equivalent step in WIT.

The results of a second centerwinding test are shown in Figure 10. In this experiment the nip load was stepped from 52.5to 35 to 17.5 to 8.75 and finally to 4.38 N/cm. The web tension was held constant at 1.75 N/cm. Note that as the nip load was decreased from 8.75 to 4.38 N/cm that the corresponding drop in WIT was approximately 0.5 N/cm. So it appears that even though the nip load directly affects WIT that only a fraction of the nip load becomes part of the WIT.

The results of a surface winding test are shown in Figure 11. This experiment was conducted identically to the test whose results were shown in Figure 9, except the torque required to wind the roll was input to the nip roll rather than the core of the winding roll. Note that the steps in web tension have very little effect on the WIT.

The results of a second surface winding test are shown in Figure 12. This experiment was conducted identically to the test whose results were shown in Figure 10, except the torque required to wind the roll was input to the nip roll rather than the core of the winding roll. Do note that the lowest nip load was 8.75 N/cm in this test, when the nip load was decreased to 4.38 N/cm the winding roll stalled. Note that comparable decreases in nip load appear to yield comparable decreases in WIT between the centerwinding test results shown in Figure 10 and the surface winding results shown in Figure 12.

A COMPARISON OF CENTER AND SURFACE WINDING

Several tests were performed such that the differences between the WIT associated with center winding could be compared with surface winding. These tests were performed upon newsprint, but on a different lot of material from that used in the verification tests. These tests were also conducted with a 15.2 cm nip roll. The results of these tests are shown in Figure 13. Note that at low nip loads the WIT associated with surface winding is much less than that associated with center winding. At higher nip loads, the WIT produced by the two winding methods differ much less. Also note that web tension appears to influence the WIT in center winding for the entire range of nip load. The behavior in surface-winding is very different: at low nip loads there appears to be little or no effect of web tension on WIT while at high nip loads there is a significant effect.

In Figure 14 the WIT data for only the center winding tests are shown. Please note that if the WIT is extrapolated back to zero nip load the traces would intercept the WIT axis at values near the web tension associated with each trace. Also note that the separation between the traces is nearly constant and equal to the increment in web tension between the traces, 0.875 N/cm. Thus it is shown here empirically that when center-winding with a nip roll that all of the web tension becomes part of the WIT. Since the WIT is a primary variable in the development of pressure and circumferential stress within the wound roll this is quite important. Based upon the data shown herein, good control of WIT at lower nip loads may be possible only in a center-winding configuration. Certainly the other advantage of center winding with a nip compared to surface winding is not having to deal with the winding roll stalling at low nip loads due to inadequate traction between the surface driven and winding rolls. Since it is apparent that all of the web tension, Tw, becomes part of the WIT in center winding then the portion of the WIT in excess of the web tension must be attributed to the nip. This portion of the WIT is called the nip-induced-tension (NIT). Thus the wound-in-tension for center winding with a nip can be written as two components per:

$$WIT_{center\ winding} = T_w + NIT \qquad \{2\}$$

The web tension associated with each center winding case was subtracted from the measured WIT and the results are plotted in Figure 14. Note that the NIT for all center winding cases now coincide for all cases. The source of nip-induced-tension has been documented [8]. It is essentially a rolling contact problem in which the outer layer of the winding roll is elongated more than the layer beneath. In rolling contact problems the pressures and stresses in the contact zone normally depend upon the moduli of the bodies in contact. In wound rolls, the radial modulus of elasticity is a state dependent property, dependent upon the pressure at a radial location. If the WITs for the cases in which the web tension was 1.75 and 3.5 N/cm are compared in Figure 14 and per equation {2}, it is shown that the WIT differs by 1.75 N/cm at all nip loads. Now refer back to Figure 4 and note the pressure profiles associated with the WITs of 4.04 and 5.58 N/cm. In particular note that the pressure in the plateau regions increases from about 160 to almost 300 KPa. The form of the radial modulus used in this case is similar to one coined by Pfeiffer[11]:

$$E_r = K_2(K_1 + P) \qquad \{3\}$$

where P is the radial pressure. Thus the radial pressure has nearly doubled and per expression {3} the average radial modulus of the roll has doubled as well. The intriguing point is that with the modulus more than doubling in the cases in Figure 14, the NITs are unaffected. Thus it appears the NIT, which is known to be due to rolling contact, is independent of the average radial modulus of the wound roll.

In Figure 15 the WITs that resulted from surface winding are shown. It appears that at the lower nip load levels, from 3.5 to 17.5 N/cm, that the WIT is nearly independent of web tension. At higher nip loads, 35 and 58.3 N/cm, there appears to be some dependence upon web tension that increases with increasing nip load. The following algorithms were derived empirically with the objective of delineating what portion of the WIT was due to web tension and what portion was due to the NIT:

$$WIT_{surface\ winding} = NIT \quad 0 \le \text{Nip Load} \le 17.5\ \text{N/cm}$$

$$WIT_{surface\ winding} = NIT + \frac{T_w}{e^{\mu_{wn}\beta}} \frac{N}{58.3} \quad 17.5 \le \text{Nip Load} \le 58.3\ \text{N/cm} \qquad \{4\}$$

in which β represents the angle of wrap of the web about the nip roll (180 degrees), μ_{wn} represents the kinetic coefficient of friction between the web and the nip roll, and N represents the nip load (N/cm). Using expression {4} the NIT can be inferred for the surface winding tests which have been shown in Figure 15 as well.

In Figure 16 the NITs are shown for both the center and surface winding experiments. Note that the correlation is not perfect but that it appears this is strong evidence that the NITs are the same regardless whether the roll is either center or surface wound.

CONCLUSIONS

There are several interesting conclusions to be drawn from the experimental results presented herein including:

- ❑ The WIT measurement method is an interfering technique.
- ❑ It appears that, at least in some cases, the WIT measurement can be corrected to yield the true value of WIT that was inferred from pull-tab data in which the web was not pulled away from the winding roll to make the pull tab measurement.
- ❑ The WIT in center winding with an undriven nip appears to be directly a function of web tension and less a function of nip load.
- ❑ The WIT in surface winding appears to be a function of nip load but is nearly unaffected by web tension, but note this conclusion is drawn from test results given herein for a case in which the web wraps the nip roll 180 degrees. Pfeiffer's results show clearly that for a low angle of wrap, nearly zero per his experimental setup in Figure 1, the WIT is more dependent on web tension[1].
- ❑ The NIT appears to be independent of whether one center or surface winds. Center winders can exercise much better control of the WIT when there is a high angle of wrap of the web about the nip roll since the web tension can be varied to directly affect the WIT at any nip load. Thus rolls can be center wound at low nip loads with high WIT resulting mainly from web tension. When surface winding at low nip loads the winder can stall and the roll can be loosely wound at higher nip loads since most of the WIT results from a fraction of the nip load.
- ❑ The WIT appears to be independent of the pressures that develop due to winding within the wound roll.

REFERENCES

1. Pfeiffer, J.D., "Nip Forces and their effect on wound-in tension," Tappi Journal , Vol. 60, no. 2, February 1977.
2. "Routine Control Method RC 317," (The Cameron Strain Test), TAPPI vol. 46, no. 12, pp. 123, December 1963.
3. Monk, D.W., Lautner, W.K. and McMullen, J.F. "Internal Stresses Within Rolls of Cellophane.", Tappi Journal , Vol. 58, no. 8, August 1975.
4. Good, J.K., and Fikes, M.W.R., "Using FSRs to Measure Radial Pressure in Wound Rolls / Predicting the Internal Stresses in Center-wound Rolls with an Undriven Nip Roller", TAPPI Journal, Vol.74, No. 6, June 1991.
5. Swanson, R.P., "Determination of Wound Roll Structure Using Acoustic Time of Flight Measurement," ," Proceedings of the First International Conference on Web Handling, Web Handling Research Center, Stillwater, Oklahoma, May 19-22, 1991.
6. Hakiel, Z. "Nonlinear Model for Wound Roll Stress.", Tappi Journal, Vol. 70, no. 5, pp. 113-117, 1987.
7. Pfeiffer, J.D., "Mechanics of a Rolling Nip on Paper Webs," Tappi Journal , Vol. 51, no. 8, August 1968.
8. Good, J.K. and Wu, Z., "The Mechanism of Nip Induced Tension in Wound Rolls", Journal of Applied Mechanics, Vol. 60, No. 4, December 1993.
9. Vaidyanathan, N. and Good, J.K., "The Importance of Torque Capacity in Predicting Crepe Wrinkles and Starring within Wound Rolls," Proceedings of the Third International Conference on Web Handling, Web Handling Research Center, Stillwater, Oklahoma, June 18-21, 1995.
10. Pfeiffer, J.D., "Relative Motion between Web And Winder Drum at the Nip and the Effect of Additional Torque," Advances and Trends in Winding Technology, Proceedings of the First International Conference on Winding Technology, Stockholm, Sweden, 1987, pp. 39-51.
11. Pfeiffer, J.D., "Measurement of the K2 Factor for Paper," Tappi Journal , Vol. 64, no. 4, April 1981.

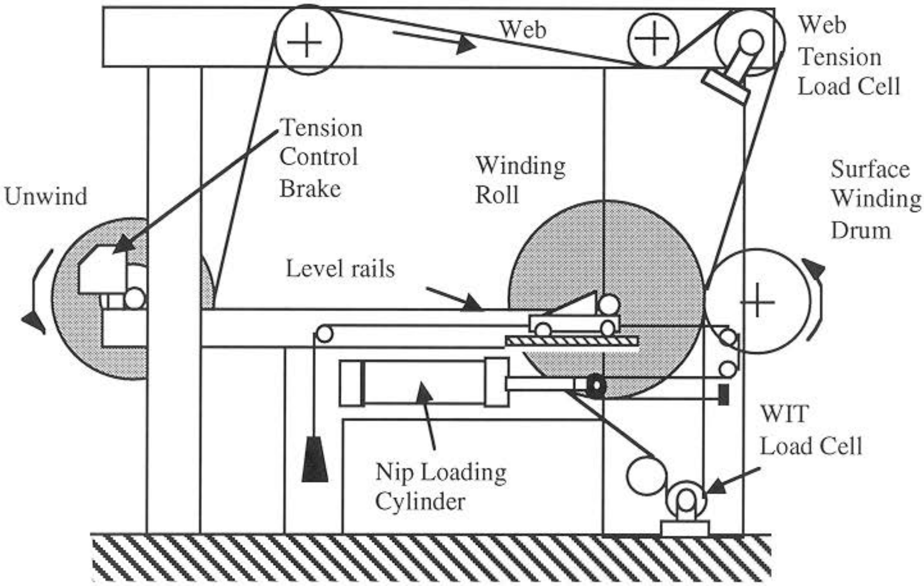

Figure 1 – Pfeiffer's WIT Apparatus

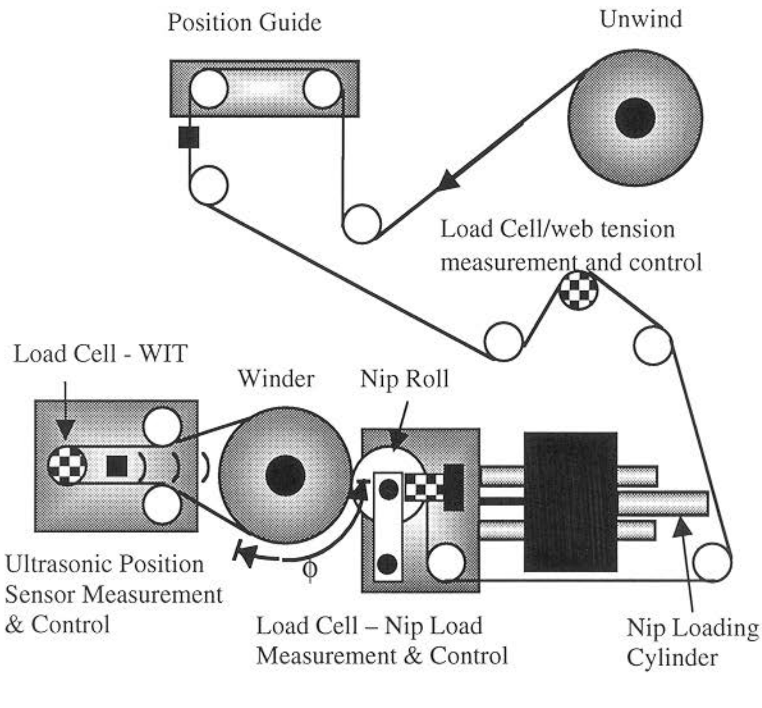

Figure 2 – WHRC WIT Apparatus

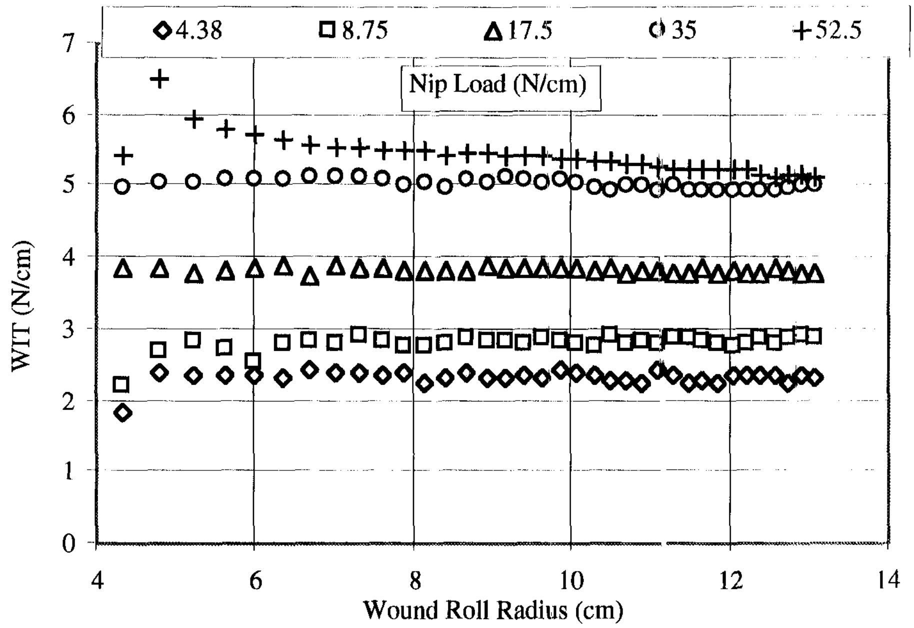

Figure 3 – WIT for Newsprint Center-Wound with 1.75 N/cm of Web Tension

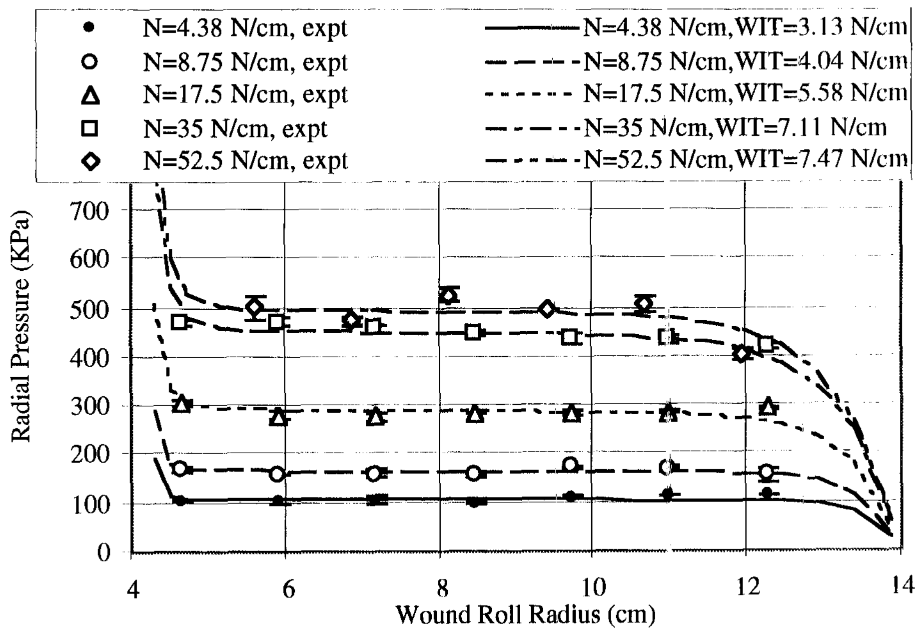

Figure 4 – Radial Pressures from Pull Tab Tests and Pressure Profiles that Resulted from the Winding Code for Center-Winding Cases. Web bypassed WIT Measurement Rollers while Pull Tabs were inserted. N(Nip Load).

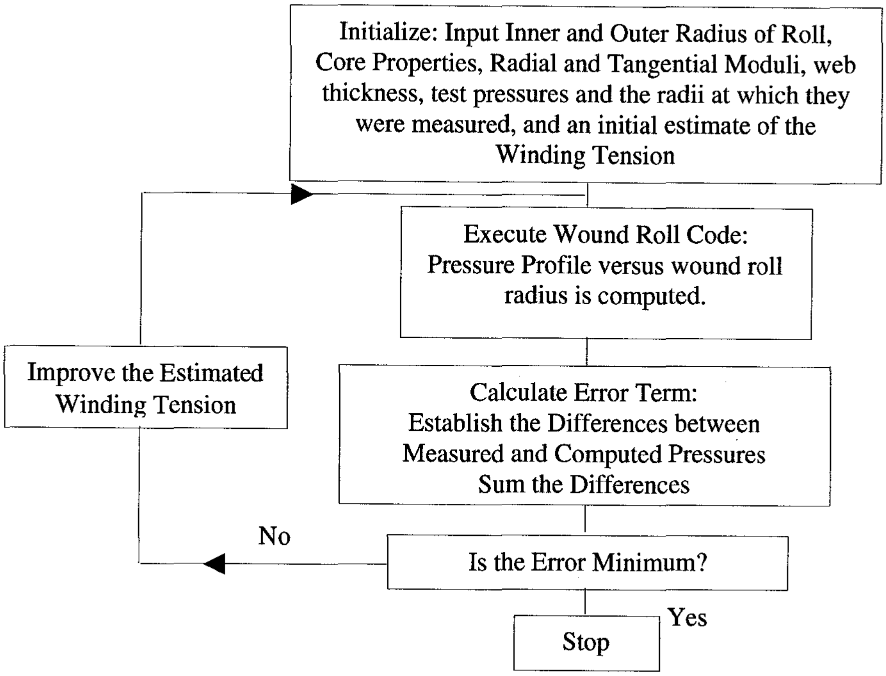

Figure 5 – Flow Chart of Code used to Estimate WIT

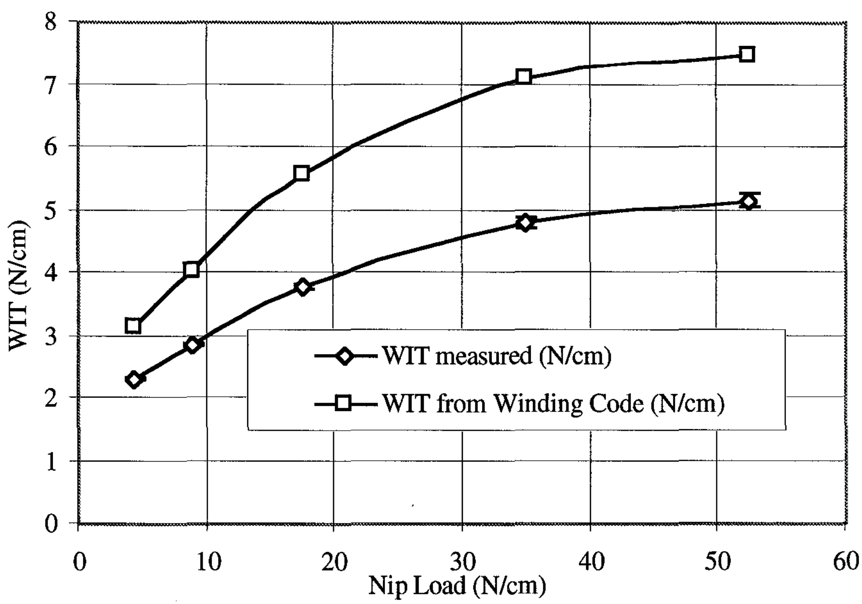

Figure 6 - Comparison of WIT, Measured and Inferred from the Winding Code

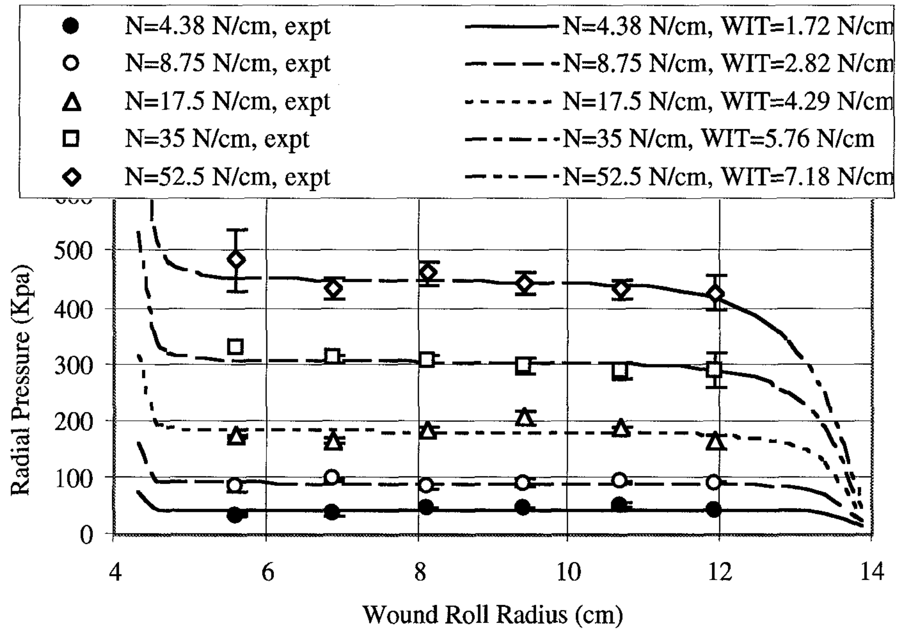

Figure 7 – Radial Pressures from Tests and Pressure Profiles that Resulted from the Winding Code for Center-Winding Cases. Pull Tabs were inserted while WIT Measurements were acquired. N (Nip Load).

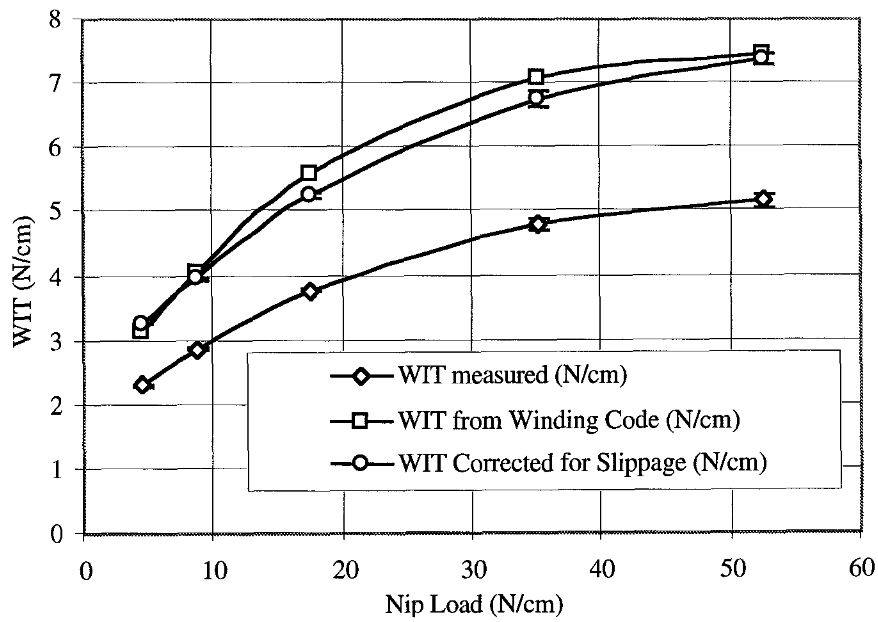

Figure 8 – WIT Corrected for Slippage

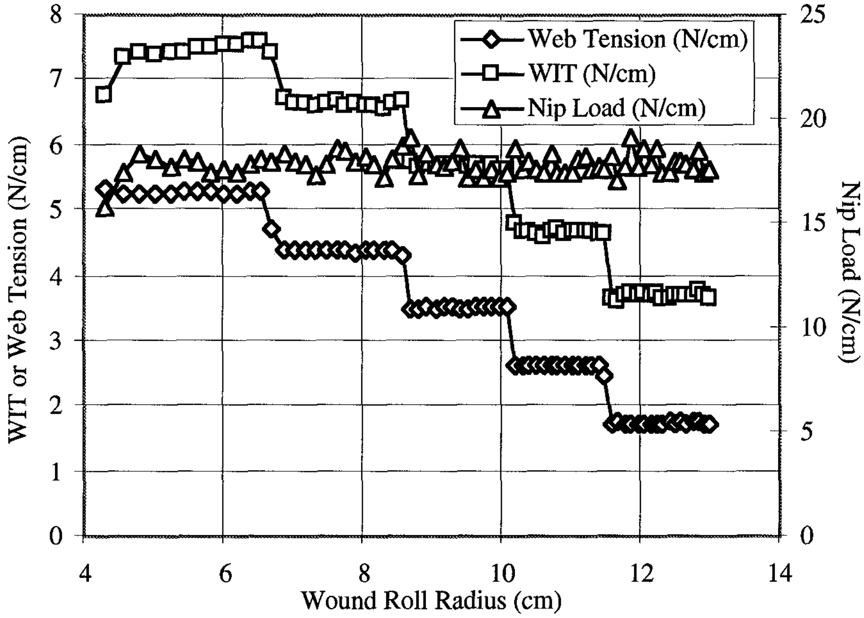

Figure 9 – WIT for Center winding Newsprint with Constant Nip Load but Varying Web Tension

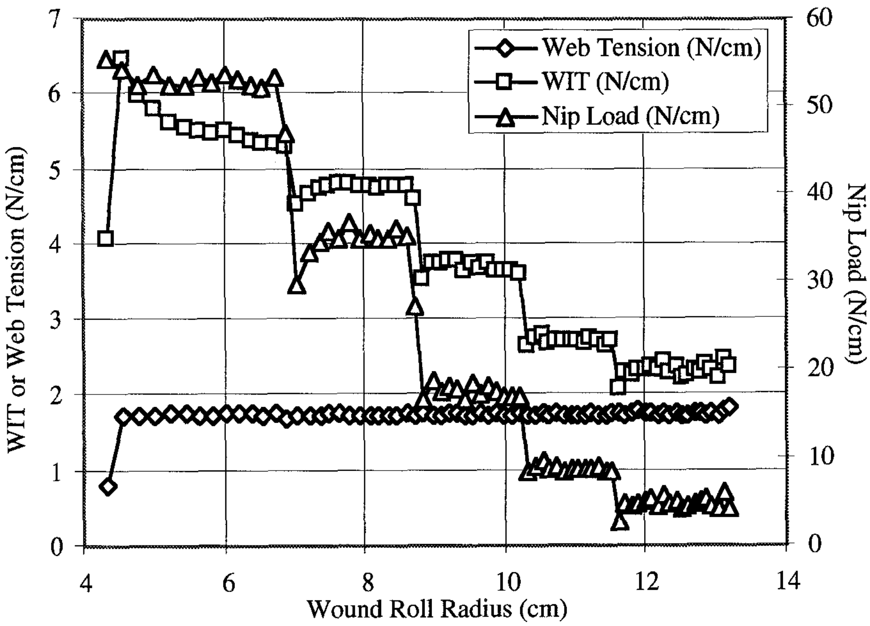

Figure 10 – WIT for Center winding Newsprint with Constant Web Tension but Varying Nip Load

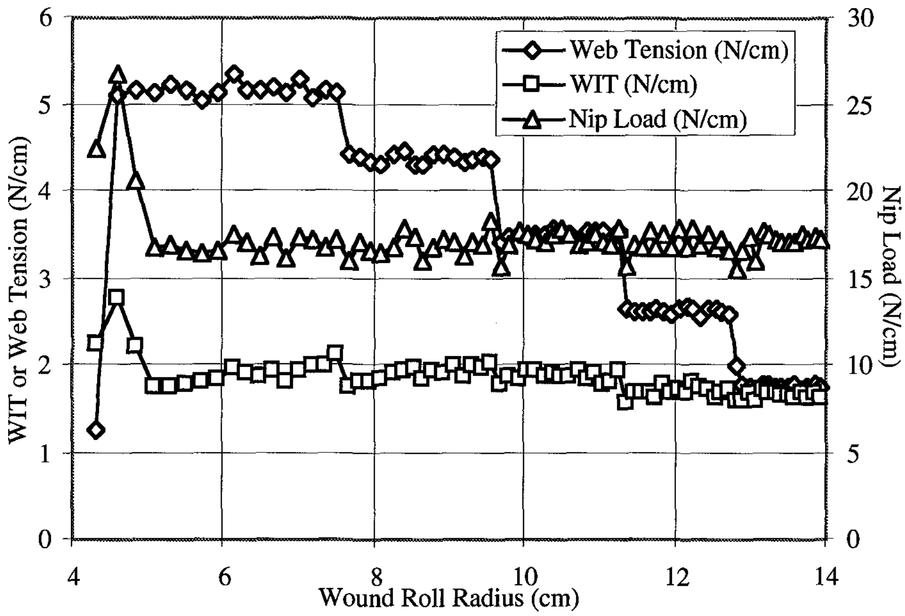

Figure 11. - WIT for Surface Winding Newsprint with Constant Nip Load but Varying Web Tension

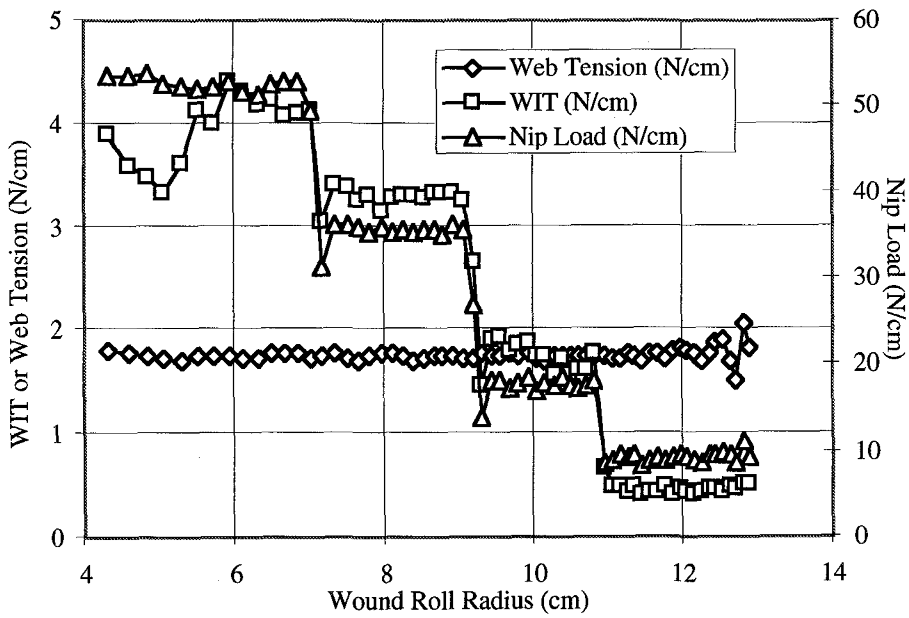

Figure 12. - WIT for Surface Winding Newsprint with Constant Web Tension but Varying Nip Load

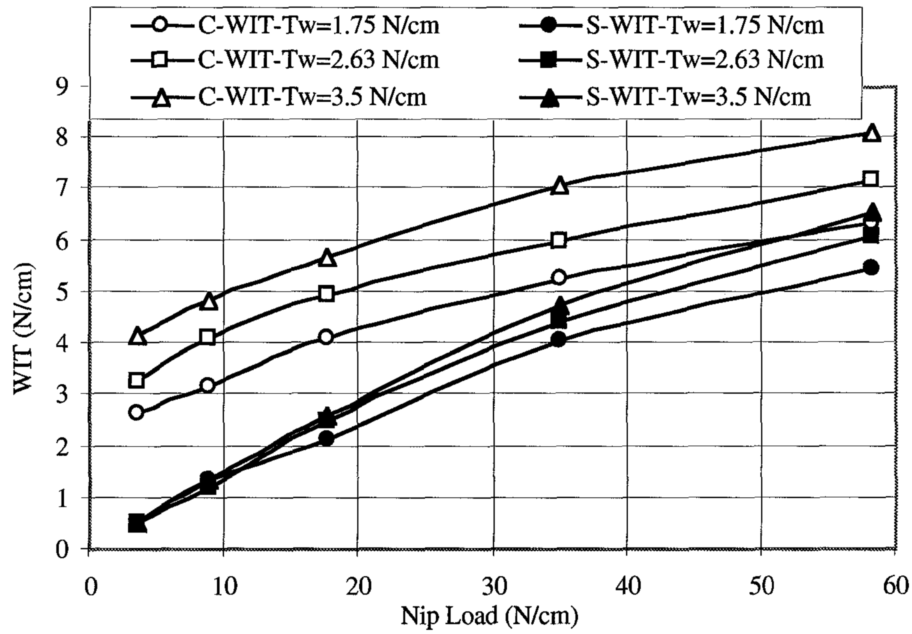

Figure 13 – WIT for Center and Surface-Winding Newsprint

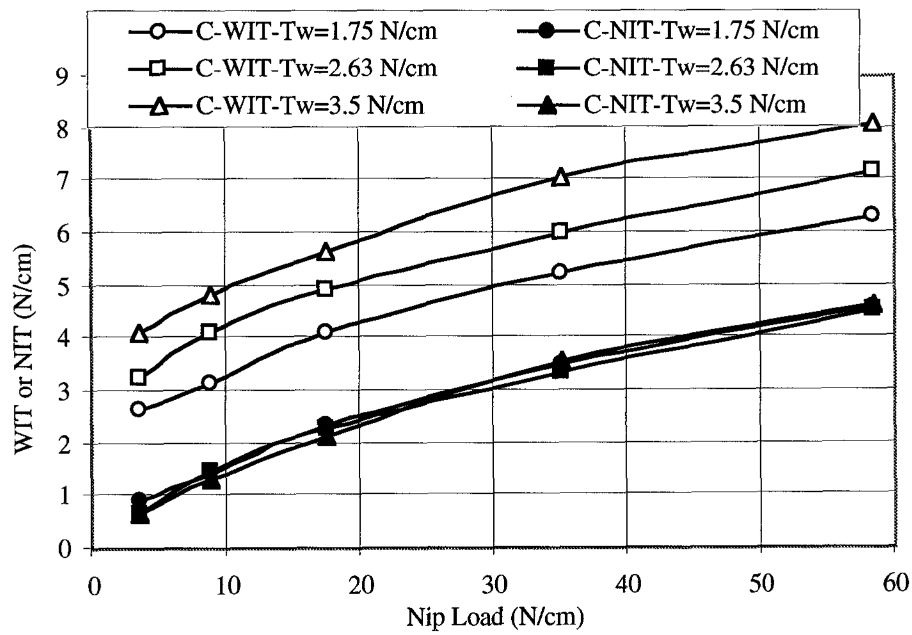

Figure 14 – WIT and NIT for Center-Winding Newsprint

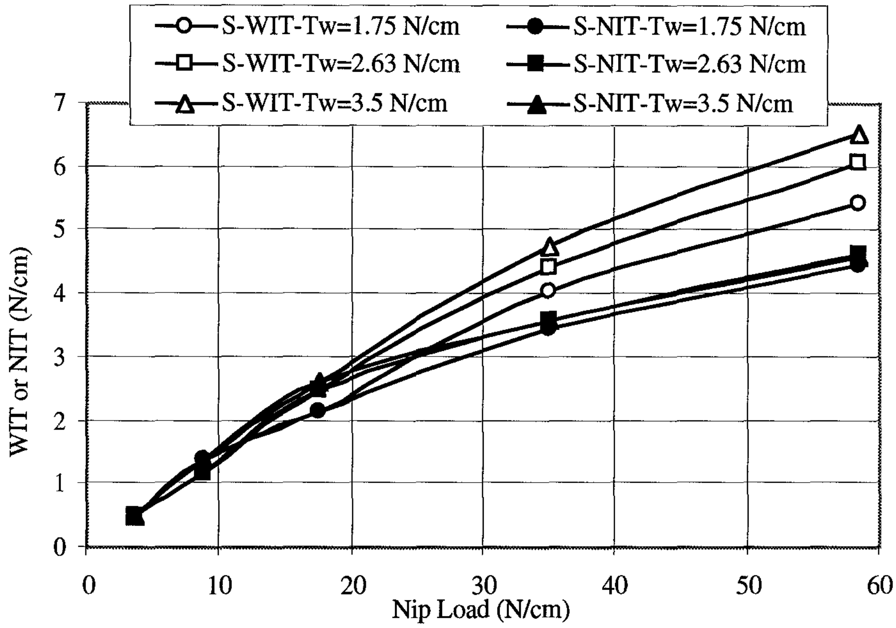

Figure 15 – WIT and NIT for Surface-Winding Newsprint

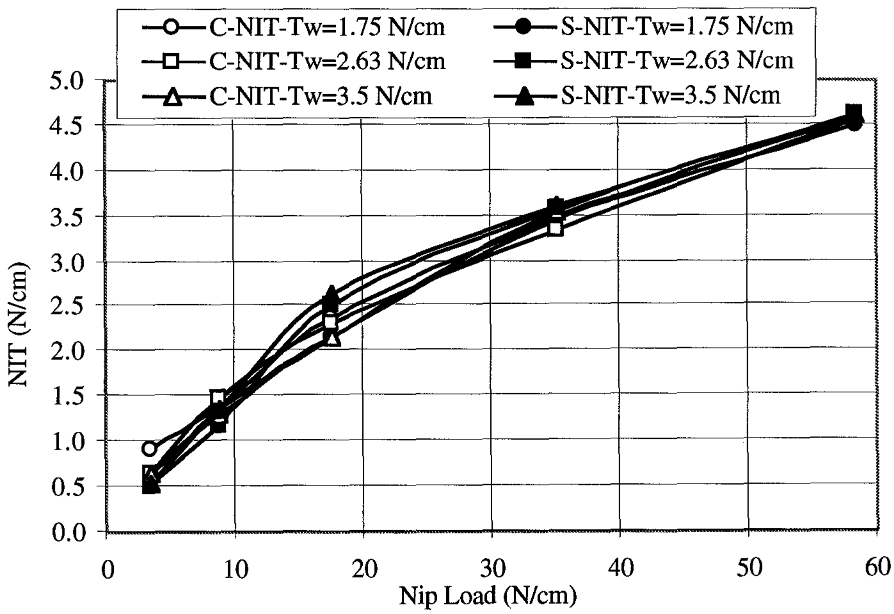

Figure 16 – NIT for Center and Surface Winding Newsprint

Nip Load (N/cm)	WIT (N/cm)	95% CI (N/cm)	WIT Winding Code (N/cm)	% Error WIT WC vs. WIT	WIT corrected for Slippage (N/cm)	95% CI (N/cm)	% Error WIT WC vs.WIT corrected for Slippage
4.38	2.31	0.02	3.13	26.4	3.27	0.01	-4.44
8.75	2.87	0.03	4.04	29.1	3.96	0.01	2.02
17.5	3.79	0.04	5.58	32.1	5.26	0.04	5.72
35	4.80	0.10	7.11	32.4	6.75	0.13	4.95
52.5	5.17	0.11	7.47	30.8	7.37	0.08	1.35

Table 1 – Average WIT Measurements and 95% Confidence Intervals, WIT extracted from Pull Tab Measurements and a Winding Code, and WIT corrected for Slippage for Center-Winding Experiments

Winding Start Radius (cm)	4.32
Nominal Final Radius (cm)	14
Core Stiffness (GPa)	19
In-Plane Modulus Et (GPa)	5.14
K1 (KPa)	14.5
K2	36.9
Poisson's Ratio	0.01

Table 2 – Input Data for Wound Roll code used to infer WIT from Pull Tab Pressure Measurements

J. K. Good, J. Hartwig, And R. Markum

A Comparison of Center and Surface Winding Using the Wound-In-Tension Method

6/7/99 Session 1 1:00 – 1:25 p.m.

Question – Duane Smith, Black Clawson Co.

I'm glad to see that you said as long as you have considerable wrap the actual web tension does not have a major effect on the wound in tension which is what I found about ten years ago. However, I was also proven to be wrong when I later worked with non-woven webs where you have a highly extensible web and I think you used newsprint in your tests? So I would like you to comment on that.

Answer – Keith Good, Oklahoma State University

On a surface winder the surface driven drum has two functions: (1) it must draw in web out of the last zone in the web machine and so in doing that there has got to be friction loss between web and that drum and (2) through nip-induced tension the surface driven roll must induce some wound-in-tension. When webs are highly extended the slippage associated with this friction loss maybe small with respect to the web extension prior to the surface driven roll. In these cases it is possible web tension does affect wound-in-tension when surface–winding.

It is also possible when the angle of wrap of the web about the surface driven roll is small prior to the web entering the nip that not all of the web tension can be lost in friction. The results reported by J.D. Pfeiffer support this. He had almost no wrap angle and he had effects of web tension evident within his wound-in-tension.

Comment – David Pfeiffer, JDP Innovations Inc.

I think I can clarify Duane 's point a little bit because in winding with a nip there is a creep wave of material rejected back toward the unwind and it travels across a winding drum. If your web is a rather stiff web, or a newsprint web, or a Mylar web or a fine paper web, a very small % of rejected material moving backwards on the drum will cause the tension to be lost so you are entering the nip with practically no web carrying tension at the point that you go into the nip. Now if the web is extensible and rubbery and that material has been laid back tightly on the drum, then one or two % of creep backwards is not going to spill all of the web tension and it will enter the winding roll. So it is this backward wave or rejected wave of paper slipping backwards on winding drum that does this.

Answer – Keith Good, Oklahoma State University

Exactly.