CONCERNING WOUND MILL ROLL QUALITY AND TAKE-UP TENSION CONTROL

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ABSTRACT

Biaxially oriented web manufactured by the tenter method is first wound into a mill roll as the middle stage of the product roll manufacturing process. It is well known that mill roll winding quality greatly affects final product roll quality and productivity when finished by a slitter-rewinder. The key determinant of rewind quality is of course the basic performance of the winding system itself and its operation technique. However, another point which is rarely mentioned, yet is perhaps more important, is that of the tension control function which has an effect on web take-up as it comes out of the tenter. My paper introduces and explains some examples of practical facilities technology, focusing on this point.

THE RELATIONSHIP BETWEEN THE FILM MANUFACTURING PROCESS AND MILL ROLL REWIND QUALITY

The film manufacturing process dealt with in this paper refers to a T-die (tenter) system biaxially orienting facility. Typical films produced by this manufacturing process include polyester (PET), polypropylene (OPP) and polystyrene among others. This manufacturing process is featured in mass production as a facility capable of producing wide films at a high speed. This lengthy process begins by inputting the raw material resin and finishes with mill roll winding by means of integrating the diverse range of equipment, each with a specific function. (Refer to Fig-1.)

If we assume that we do not wind the manufactured film into an interim mill roll, that is, if we consider the situation whereby the film is laid out on the floor as it is produced, then such film problems as thickness variation and stretching (tension) variation across the film width rarely adversely affect the commercial value of the film, providing that they remain within the limits of standard, commercially produced films. However, if such a film is wound even once, it is possible that the film's commercial value will be seriously devalued, or in a worst-case projection even zeroed due to extreme film damage. Additionally, in commercial production a mill roll wound from such a film will contrarily affect the processing speed, work rate and product yield rate in the final finishing process at the slitter-rewinder, further influencing cost concerns.

The cause of this damage sometimes rests upon an easily identifiable and solvable problem in one of the many facilities in the long manufacturing process. Occasionally, however, the cause is far more complicated and vague. Such an almost unsolvable problem cannot be easily rectified in any single structure in the manufacturing process because, as the film is coming from the upstream, there is a great deal of difficulty in pinpointing the exact origin of the problem.

THE MOST EFFECTIVE LOCATION TO CHECK MILL ROLL WIND QUALITY

To date, an accurate and rational way to confirm mill roll quality in the winding operation has yet to be developed. In addition, it is almost impossible to visually confirm the internal condition of a mill roll after it has been fully wound. (Note; large wrinkles are clearly visible on the mill roll surface as a symptom of poor quality during the winding operation.) At present, therefore, the sole available way to check mill roll quality is to observe the rotating condition of the mill roll and the running condition of the web as it passes between the guide rollers of the next process, the slitter-rewinder.

By this means it is possible to check the winding condition of the mill roll over its whole length. As slit rolls are delivered to customers as final products, the manufacturer is usually unable to adequately investigate the unwound condition of the slit rolls. Hence, confirming the wind quality of an interim mill roll at the unwind section of the slitter-rewinder becomes the most practical, effective method of quality control.

DEFECTIVE QUALITY SYMPTOMS; THE PROCESS CORRELATION BETWEEN THE SURMISED CAUSES AND THEIR COUNTERMEASURES (Refer to Fig-3)

Supplementary explanation

[A] Film quality is decided in this process. (A concrete explanation and typical symptom examples are given in the section entitled "Typical Symptoms and Examples of Mill Roll Quality").

[B] This is the process which winds the formed web into an interim mill roll.

[C] The mill roll quality verification process is executed here at the slitter-rewinder's unwind section. This is an important operation which, after classifying the verified symptoms, not only determines the cause of the symptoms, but also specifies the equipment

[D] This is a necessary step if a factor necessary to improve mill roll quality involves a winding condition modification in accordance with the winding theory.

[E] As above, this is a necessary step if measures involving the hardware, based on the winding theory correctly constructed for proper mill roll quality, are necessary. (The hardware must be both mechanically and electrically integrated.)

[F] When measures for improving web quality are taken by adjusting and revising the operation conditions in the film manufacturing process. (as per [D])

[G] As above, when measures for improving web quality in the film manufacturing process involve hardware measures. (as per[E])

TYPICAL SYMPTOMS AND EXAMPLES OF MILL ROLL QUALITY

We here introduce the most rational method to verify mill roll quality at the unwind section of the slitter-rewinder. (Refer to Fig-4.)

The tension distribution condition of the entire web width as it is transported between the guide rollers after being unwound from a mill roll can be easily observed between A-A' and subsequently classified into the 3 conditions shown in Table 1.

Observable Mill Roll Characteristic Symptoms According to the Tension Distribution Condition against the Width-wise Direction of the Web

Hypothesis as to the Cause of the Symptoms Found in Case A and their Place of Occurrence

It is generally premised that vertical (MD) wrinkles occur when excessive winding tension is applied to the web. Particularly when winding a web formed like Case A into a mill roll (refer to Table 1), the winding tension, originally provided for the entire width of the web, applies an excessively intense force to only its central portion. In this state, both edge portions narrowly hold a tension level which is close to the minimum value necessary for maintaining wind quality. If the wind tension is set to a lower level so as to eliminate the vertical (MD) wrinkles in the center portion, the web at both edges slips into a no-tension state resulting in fluttering, web slackening and folded wrinkling. Substantiating that the tension has worked intensely on the center can be easily obtained by checking the various opening conditions, dependent upon the degree of residual stress, of the mill roll surface when it is lightly split in the width-wise direction.

The downstream of the film manufacturing process ranges from the exit of the transverse direction stretching machine and reaches the wound roll after passing through the guide rollers of the take-up winder. In an actual production line, the take-up winder's roller layout is comprised of about 15-20 rollers, and the machine is designed according to the fundamental rule that all rollers be parallel to one another. (Refer to Fig-5.)

Let us now consider the cause and source of the symptoms of the web forming characteristics resulting in the mill roll shown as Case A by analyzing the behavior of the web in the transverse (TD) direction process. As easily anticipated from the TD mechanism which transports the web only at both edges, thus stretching the web in the transverse direction, the web in the process is being transported in an unstable condition. The symptoms found in Case A appear quite clearly when the transport tension is not properly applied to the web while it is passing from the TD stretching machine to the take-up winder.

The method the authors have adopted to verify this is to stamp a mark near the entrance of the TD machine (that portion marked X) and to carefully observe the subsequent stretching pattern of the marked web around the TD machine's exit. (Manually stamp the web in a safe area just upstream from the entrance of the TD machine with a simple jig using an ink-saturated sponge.) This test clearly shows the bow pattern at the exit of the TD machine as shown in Fig.5, indicating that the edge portions have been stretched more than the center in the forming process. As it is possible to measure the bow amount "a," the difference of the stretching rate can be numerically expressed as "a" / "b" x 100 (%). (It is sufficient to use the processing length of the machine as "b" and to measure the approximate bow amount as a rough value while the web is running for "a".)

Regarding the thickness variation along the entire width in this case, we can surmise that the web at both sides has become thinner than that of the center portion, although it is a miniscule amount for a web in the tens of microns in thickness. A mill roll made of this web, with forming characteristic Case A and wound into a large diameter, will not be finished cylindrically. The center will show vertical (MD) wrinkling and be finished harder and have a smaller diameter than the outer edges.

Conversely, both sides of the web will have a higher stretching rate and be thinner and longer. They will therefore be finished softer and longer than the center when wound into a mill roll because of the low tension. From our experience, if such a mill roll is slit into several product rolls by the slitter-rewinder, the product rolls produced from the center of the mill roll can be finished into a stable rewind roll, maintaining a uniform tension over the entire width. Those produced from the sides of the mill roll, however, may tend to flutter or contain irregular diagonal wrinkles, and the roll end may easily telescope or become misaligned. (Refer to Fig-6.)

In Case B (Tables 1 and 2), the completely opposite web forming characteristics from Case A are exhibited, with the pattern becoming a reverse bow to that of Case A. The symptoms liable to occur in an actual film production line generally tend to be those of Case A.

An ideally stretched web shows the web forming characteristics of Case C (Tables 1 and 2); uniform in both the MD and TD stretching conditions, displaying no stretching pattern bow and with little or no web thickness irregularities. In this case, a high quality, cylindrical mill roll with no surface wrinkling can be produced.

The Causes and Measures of the Quality Problem as Diagnosed from the Mill Roll Inspection

By carefully observing the fully wound mill roll with a critical eye, it is possible to know both the technological level of both the hardware and software in the production line. In addition to the relationship between the web stretching characteristics and mill roll quality discussed earlier, it must be pointed out that mill roll quality must be considered from a variety of angles. Here we would briefly like to introduce quality verifications based on mill roll appearance, and the cause and measures related to the winder. (Refer to Table 3.)

TAKE-UP TENSION CONTROL

In the section titled "Typical Symptoms and Examples of Mill Roll Quality" we noted how important it is to understand the web action in the transverse direction and how necessary it is to obtain a straight TD stretching pattern with no directional bow. It was also shown that the bow is greatly affected by the tension in the front and rear processes.

The Relationship between the Transverse Stretching Machine and the Take-up Winder

The web forming characteristics (the bowed stretching pattern reshown in Fig-7) explained as Case A in the section titled "Typical Symptoms and Examples of Mill Roll Quality" appears when the take-up tension (this is mostly identical to constant TD stretching tension) generated at the take-up unit is low. Regarding the take-up tension control, we introduce reference material showing realistic and effective examples of execution, while omitting its explanation here.

It is important to operate the take-up unit and winder individually so that the differing tension levels and patterns at each unit do not affect each other, making the tension isolation function (nip roller 1) used for this purpose indispensable.

The Relationship between the Machine Direction and Transverse Direction Stretching Machines

Even if the take-up tension is set to a higher level using the measures explained in the section titled "The Relationship between the Transverse Stretching Machine and the Take-up Winder," there may be no visible improvement in the stretching pattern and the bow will not vary even if the tension is set to a lower level also. In this case, it is considered that the high tension generated by the MD stretching (achieved through the roll speed difference of the MD stretching machine located upstream of the TD stretching process) is adversely affecting the entrance area of the TD stretching process.

As the web fed into the TD process is clipped firmly at both edges, the high tension produced in the MD process acts as a back tension on the edges. The tension pattern in this area is shown as hypothetical line *1. (Refer to the tension pattern at the bottom of Fig-7.) We know that back tension over the entire width is present, as both edges being clipped are diagonally pulling the middle, unrestrained portion of the web, causing the bow pattern. The back tension gradually eases in towards the web center. This can be expressed as hypothetical line *2 in the tension pattern in Fig-7.

In such a case, and in the actual production line, we can deduce that the bow pattern (stretching pattern) has been fixed in the early stages of the TD stretching zone close to the entrance of the TD stretching process where it is a long pathway in a heated condition. In connection with this, the bow caused by the mechanism due to the action of the tension transmitted to the web being clipped at both sides corresponds to the bow pattern appearing when the take-up tension is too high. (the opposite symptom of what happens when the take-up tension is too low as explained in the section titled "Hypothesis as to the Cause of the Symptoms Found in Case A and their Place of Occurrence.")

We have discovered that the most effective way to solve this problem is to install a tension isolation function (nip roller 2 in Fig-7) which securely isolates the combined tensions of the machine and transverse direction stretching machines. It is necessary to take such measures on the hardware so that the influences resulting from the high tension of the MD stretching process are not applied to the TD stretching process. (The tension pattern expressed by the solid line in Fig-7 explains this ideal situation.)

CONCLUSION

This paper is a collection of our practical knowledge and theories written from our position as a concerned manufacturer in this industrial field. Although this paper does not display an overly-academic scholastic level, it should be viewed from a business perspective for the manufacturing and selling of plastic film. From such a viewpoint the source of market competitiveness lies in the successful synthesis of "quality," "cost" and "delivery," the most important of which is surely "quality". Thus, from a quality standpoint, we are convinced that this paper can, in some small measure, further the technological development of this industry.

Finally, we would like to express our deep appreciation for being given this opportunity to submit our study paper to the First International Web Handling Conference and its members.

REFERENCE

Kataoka, Hiroshi, "Take-out/Take-up Tension Control Apparatus", Patent No. 4,775,086, United States Patent, Vol.19, Oct. 4, 1988

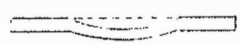
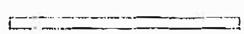
Classification	Web condition at A-A'	Observation result
Case A		The center portion of the web is running stably with proper tension. Both edges are experiencing no-tension fluttering (only rarely does this occur on a single side).
Case B		Both edges are running stably with proper tension. The center portion of the web is fluttering due to a lack of tension.
Case C		The unwind tension is working uniformly over the entire width of the web and the web is running stably.

Table 1 Observation results and classification of the unwound web at the slitter-rewinder's unwind section.

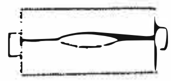
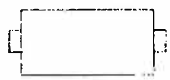
Tension distribution condition (Table 1)	Wrinkle pattern appearing on mill roll surface	Opening pattern of the mill roll surface when it is cut slightly along the transverse direction
Case A	 • Vertical (MD) wrinkles occur in the central portion. • The smaller the mill roll becomes through unwinding, the more the wrinkles increase in both severity and amount.	 • The center portion opens more than the edges.
Case B	 • Diagonal (or vertical) wrinkles appear at both ends.	 • Both edges open but not the center.
Case C	 • Cylindric and concentric mill roll • No wrinkling occurs.	 • The opening amount is uniform and slight over the entire width.

Table 2 Observation results and classification of the mill roll

Visual symptom of mill roll	Major causes	Advice for measures
① Mill roll surface irregularities	① Web thickness unevenness is too great.	• Thickness adjustment • Disperse unevenness using oscillation winding
	② Wound roll is too hard.	• Tension, touch pressure adjustment
② Eccentric mill roll	① Wound roll is too soft.	• Tension, touch pressure adjustment
	② Both edges are too thick.	• Thickness adjustment • Trimming position adjustment
	③ Winding ratio is too big.	• Increase core outer diameter
③ Section of the mill roll is polygonal in shape or distorted (not concentric)	① Poor core cylindricality	• Lathe core outer surface
	② Eccentricity at core chuck part	• Improve chucking mechanism
	③ Touch roller vibration	• Recheck design mechanism • Control system
	④ Wind tension unstableness and/or hunting	• Low mechanical loss (chuck and drive transmission portions) • Control system
④ Roll edge sliding or telescoping	① Thickness variation is too large. (Particularly at both edges or one side.)	• Thickness adjustment • Trimming adjustment
	② Excessive touch roller vibration or poor roller parallelism (touch pressure unstableness and/or hunting)	• Recheck design mechanism • Control system
	③ Wound roll is too soft.	• Tension, touch pressure adjustment
	④ Wind tension unstableness and/or hunting	• Low mechanical loss (chuck and drive transmission portions) • Control system
⑤ Transverse wrinkles at the beginning of winding	① Shrinkage due to residual stress	• Recheck taper tension
	② Winding ratio is too big.	• Increase core outer diameter

Table 3 Causes of poor mill rolls and advice for measures

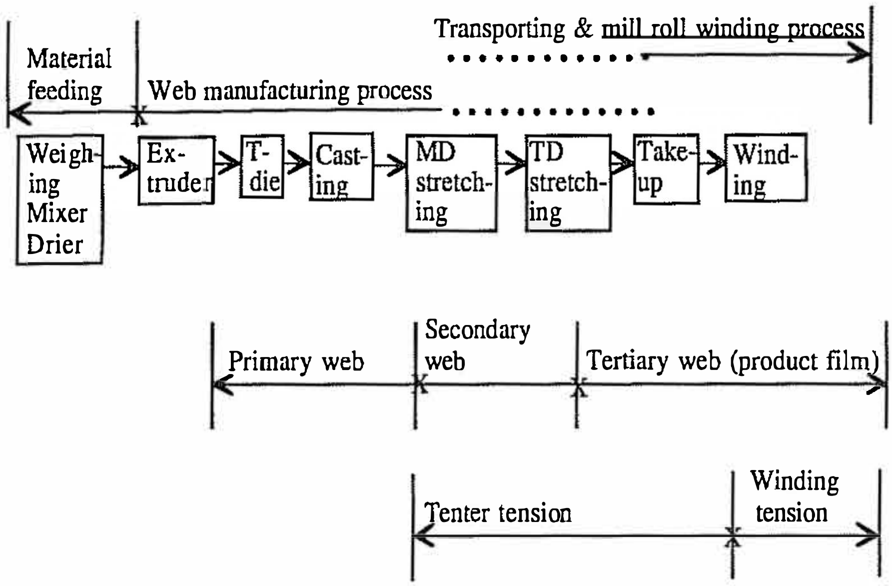


Fig-1 T-die system (tenter system) biaxially oriented film manufacturing process and its function explanation

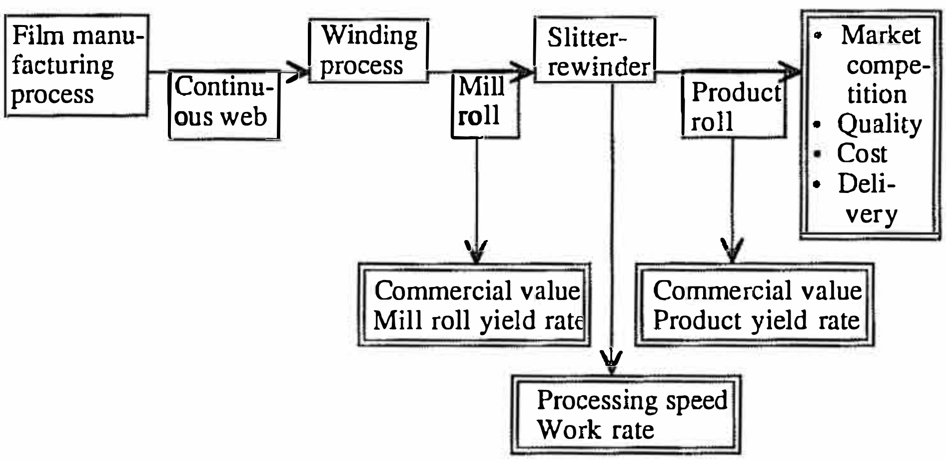


Fig-2 Problems arising from winding film into a mill roll.

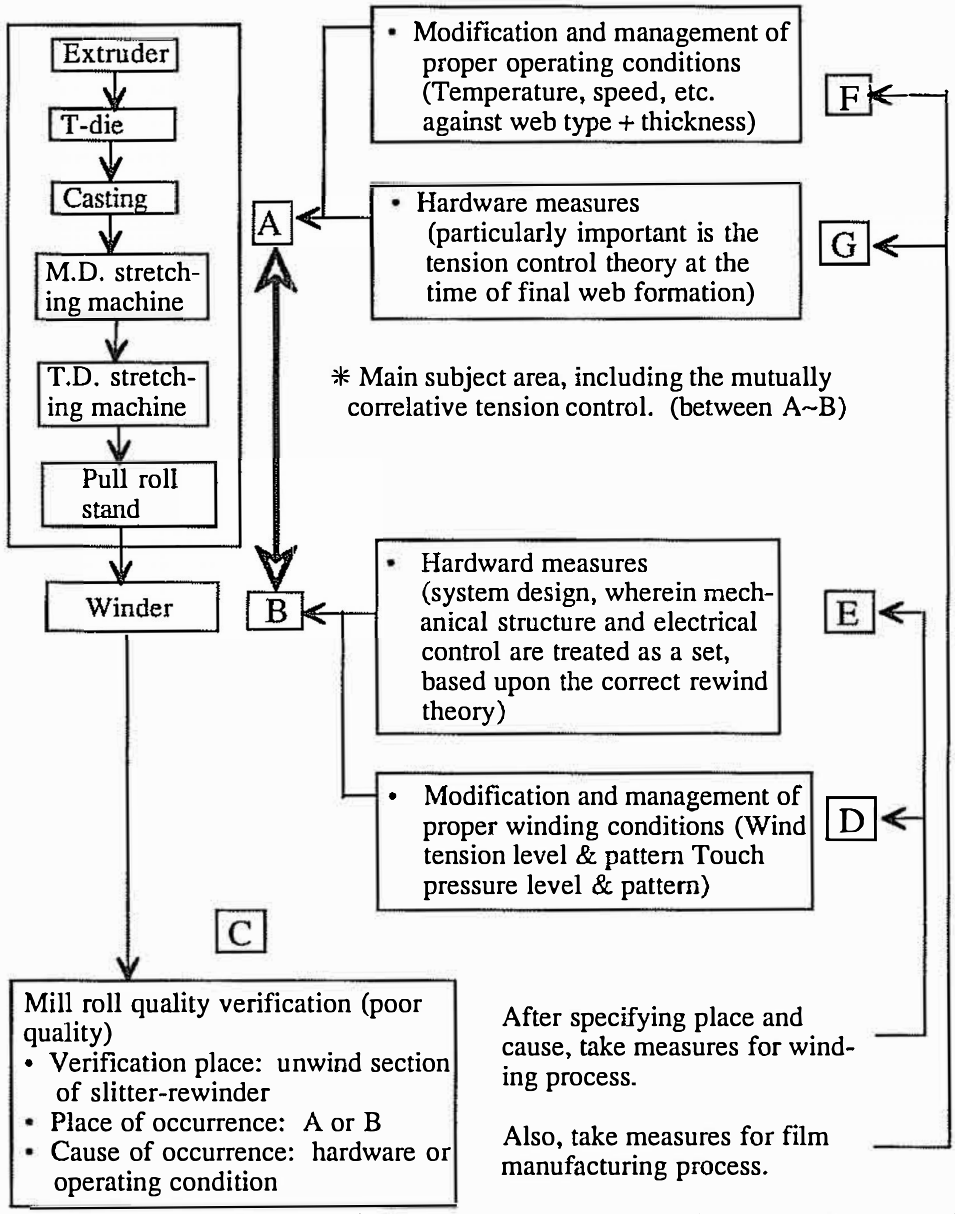


Fig-3 Basic flow for executing countermeasures according to mill roll quality verification

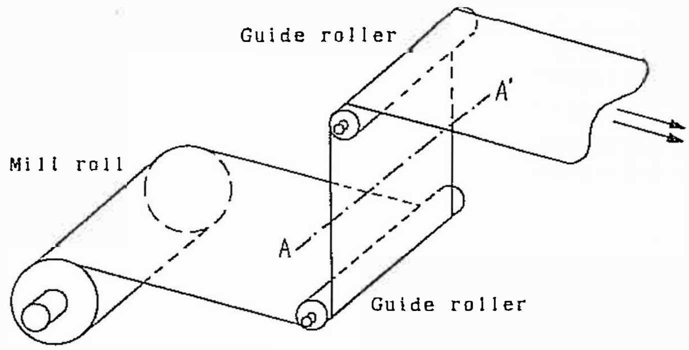


Fig-4 Unwind section of the slitter-rewinder

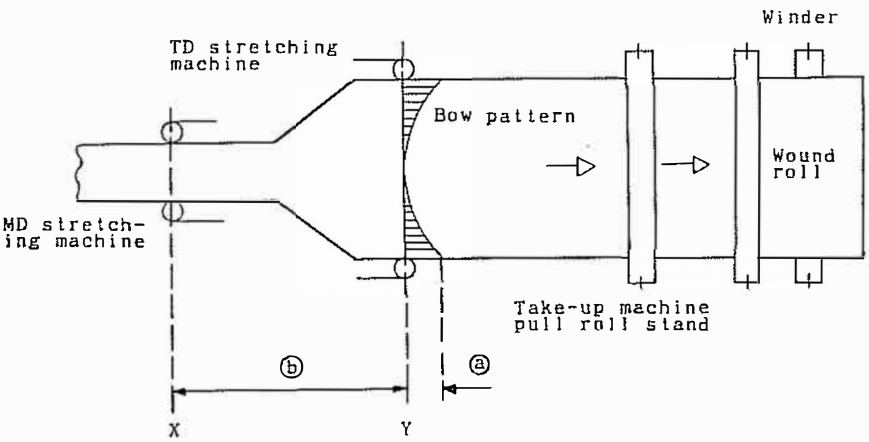


Fig-5 The downstream of the film manufacturing process

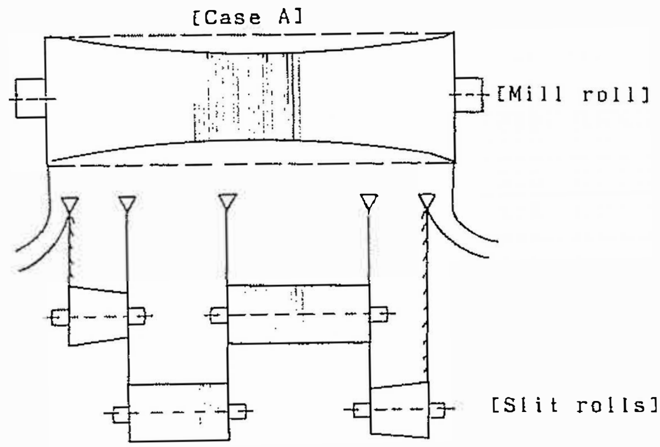


Fig-6 Mill roll slit into product rolls by the slitter-rewinder

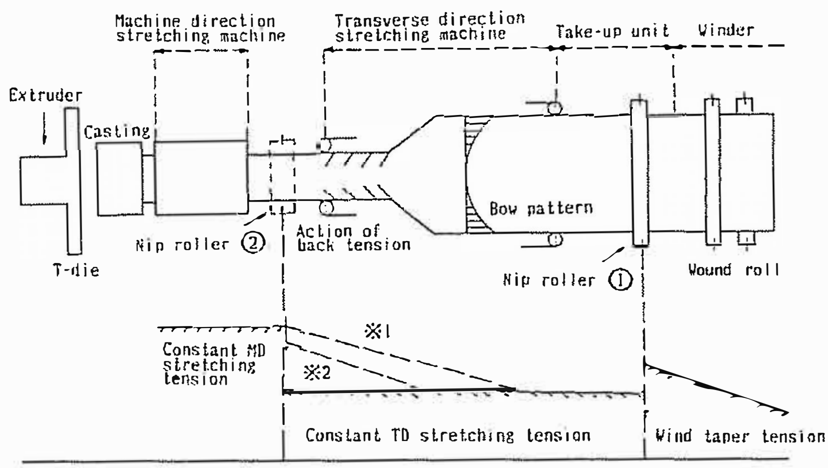


Fig-7 Rough plane sketch of the film manufacturing process and tension pattern