"Tension Control in a Turret Winder"

Clarence Klassen, P.Eng.

Abstract:

Turret winders are designed to produce batches of rolls from a continuously moving web. Typically, two spindles are mounted on a turret, 180 degrees apart. The winding roll remains in the inside (winding) position until it is nearly completed. Then the large winding roll is indexed to the outside (off-loading) position as a new core moves to the winding position. At the correct length, the web is cut and wrapped onto the fresh core at winding position.

While most of the roll winds in steady-state, indexing and transferring to the new core subjects the winding roll to numerous disturbances. Disturbances include web length changes as the lay-on roller moves, and as the turret indexes. The incoming core contacts the web as the turret indexes. The web is nipped between the core and lay-on roller prior to the cut. The final insult is the cut and transfer of control to the inside spindle. We will discuss the impact of these disturbances on tension and roll quality. Controls to mitigate these disturbances will be recommended.

Introduction

Turret winders are designed to keep the line running, not necessarily to keep tension variations to a minimum or to produce the best quality rolls. The motions involved with turret winders introduce a number of known sources of tension variations. These include changes in web path lengths, removing and adding nip forces, accelerations and deceleration of winding rolls, and the introduction and removal of drive zones. All of these factors are worsened with stiff materials and at low speeds. Turret winder motions which may affect web tension and roll quality include:

- The turret indexes
- The diameter calculator or measurement no longer works
- The incoming core hits the web
- The knife hits the web
- The web may slip on incoming core
- The lay-on roller lifts and lowers
- The lay-on roller creates an additional nip point at the core
- Load cells or dancers may produce invalid measurements during indexes
- Closed loop tension regulation may be infeasible during indexes
- The web contacts additional rollers
- Web contacts additional rollers
- Roll taping affects the wound roll
- The web may stop and re-start

These factors will be described and illustrated with videos of specific motions in a turret winder at speeds that show the required accelerations and decelerations.

Increased Web Path Length

Several motions increase the web path length. An increase in the web path length will naturally increase tension. Simply, the speed of the web entering the turret winder cannot increase as its speed is determined by upstream processes. So the additional length is created by stretching, unrolling from the winding roll, or reducing the rate at which web is added to the winding roll. Tension increases high enough to stretch the web will typically damage the web or the roll and should be avoided. Therefore the only practical way to minimize the tension increase is to slow the winding roll as web path length increases. Slowing (rotational deceleration) of the winding roll requires energy which may come from an increase in the web tension or from the motor driving the roll. Note that at the end of motion increasing the web length, the roll must accelerate back to web speed.

The turret index, the lay-on roller down and the incoming core hitting the web increase the web path length.

Decreased Web Path Length

Other turret index motions decrease the web path length. One is the lay-on roller lifting from the winding roll. A longer web path naturally decreases web tension. To avoid this the winding roll must accelerate to accommodate the extra web. The energy from acceleration can only come from the motor driving the winding roll. Again we note that following the acceleration, a deceleration to web speed is required.

Additional Rotating Elements Contact the Web

Depending on the turret winder and the relative maximum diameters of the wound rolls, additional rollers may contact the web. The core is a roller that will always contact the web as the turret indexes. The core will have a dedicated motor and can be accelerated to web speed or slightly faster prior to contact. Other rollers such as center rollers 90 degrees from the spindles and auxiliary lay-on rollers are often undriven, so will contact the web while stopped. Some winders drive these auxiliary rollers. The lay-on roller breaks and makes contact with the winding roll and the incoming core, but has sufficient wrap to keep it running at the web speed.

The cutting and enveloping mechanisms should have rollers at the point of contact with the web.

Any element contacting the web at a surface speed different from the web is likely to cause a measurable tension variation and may introduce scratches on the web.

New Drive (Tension) Zones

We see that new drive zones are introduced during the index cycle. The main new drive zone is introduced by the core wrapped nearly 180 degrees and nipped by the lay-on roller also wrapped nearly 180 degrees. The tension seen upstream of the core and between the core and the winding roll can certainly be vastly different. The amount of traction caused by the core and lay-on roller depends on the turret angle, the speed of the core and position of the lay-on roller. We observe that the geometry and forces around the core are very dynamic over a few seconds.

The new drive zone exists for only a few seconds each cycle and raises questions about how carefully tension should be controlled. What is the ideal tension upstream of the core? What is the ideal tension of the winding roll in the outboard position knowing the lay-on roller is not providing nip force, or an auxiliary lay-on roller is supplying a nip force, and knowing that a cut will occur very shortly?

Load Cell or Dancer

Dynamics involved in a turret index raise questions about the validity of load cell readings or dancer operation. One expects that wrap angles into and out of the dancer or load cell are constant during the index, but sometimes this expectation is not realized. If the wrap angle changes, tension measurements will not be calibrated over the entire cycle.

The new tension zones imply that the load cell or dancer reads tension where it is located and in the zone up to the core. Control of tension is generally performed by the winding spindle and it is unlikely that its torque or speed can provide the correct tension before and after the core. An ancient control strategy is to switch the drive for the outboard winding roll to a ***Torque Hold*** mode. This will keep torque constant for the entire cycle. That makes torque about the only factor that remains constant during the index cycle. Torque Hold allows the drive speed to vary while providing enough torque to produce minimum tension through the entire cycle. If we cannot measure tension, this strategy is not wrong.

Roll Diameter Calculator

Accurate diameter of the winding roll is required in order to get the spindle RPM and Torque correct. Any disturbance (error) in diameter is directly proportional to a tension variation.

The winding roll diameter is often calculated as the ratio of line speed divided by spindle RPM. The assumption is the]at line speed is identical to web speed at the spindle. As previously discussed, web speed at the winding spindle changes when the layon roller moves, when the turret indexes, and when the new core contacts the web. A dancer is also capable of changing web speed at the spindle. The standard diameter calculation produces incorrect results if the web speed at the spindle is not correct.

The control solution is to freeze diameter (*Diameter Hold*) at the last good value measured before disturbances due to indexing have begun. We note that the actual diameter continues to increase as the index proceeds. For very slow speed lines, the diameter may decrease slightly for a short time as the turret indexes.

Incoming Core Speed

The incoming core contacts the web at some particular angle as the turret indexes. Then the layon roller contacts the core with large wrap angles and high nip pressure. The resulting traction demands that the speed of the incoming core be correct to avoid large tension disturbances. The core diameter must be entered correctly and provision must be made for adjusting the core RPM to minimize tension variations.

The spindle drive controls RPM until it contacts the web. After the cut is made, the spindle is switched to control tension though either RPM or torque. During the intermediate time, the drive system may be designed to operate in open loop RPM or torque control.

Additional Roller Contact the Web

On many turret winders, there may be additional rollers that contact the web only during the Index. These may be rollers near the center of the turret or they may be auxiliary layon rollers. These are often small diameter idler rollers. In some cases, the auxiliary layon rollers are accelerated to web speed before contacting the web.

Clean Cuts

Significant scrap can be produced if the web is not cut cleanly. Clean cuts require the web at the cut point be tight. The cut point is between the incoming core and the outgoing roll. Tension in this zone is controlled by the outgoing spindle drive. Torque boost may be applied to the outgoing spindle to get tension as low as possible for a consistent good cut. Some stretchy webs may require 300% torque boost at the instant of cutting.

The knife position and angel are also critical for a good cut. In some winders, the knife carriage may be moved to different positions or may even be finely positioned to place the knife in the optimum position for a good cut.

Getting a clean cut may violate some of our guidelines for the good TNT's of winding. Increasing tension on the outside wraps of a roll may introduce numerous roll defects.

Square Cuts

If the rolls must have a clean square cut as is the case for many construction materials, there are a few options. A flying knife is sometimes used. The flying knife clamps to the web and moves with the web as the cross-machine direction cut is made. Flying knife arrangements have severe space restrictions when applied to turret winders.

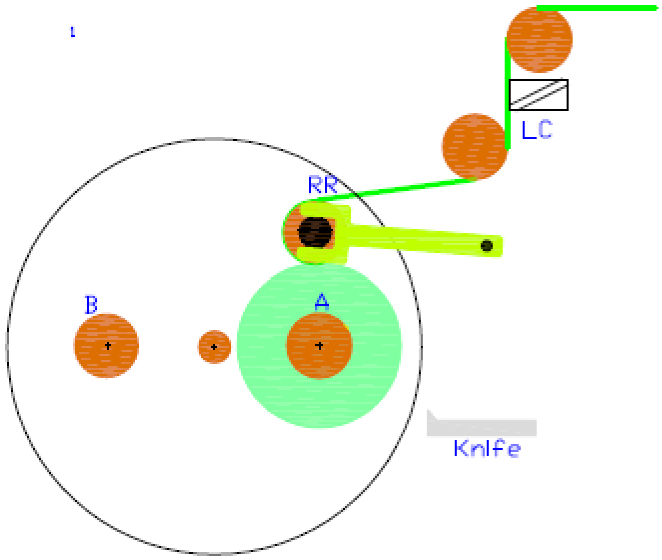
Generally, square cuts are made with the winder stopped. This entails that some form of accumulation such as a festoon, is required. Festoons introduce many new challenges for maintaining desired tension. The spindles must stop and restart with an overspeed. The accumulator must fill and then empty during the overspeed. The many bearings introduce a lot of drag in the system. Keeping all the rollers in a festoon aligned is another challenge.

Stages of an Index

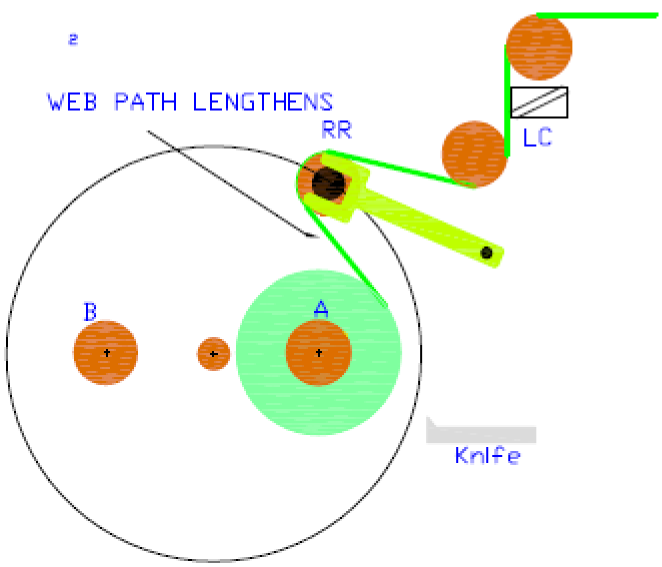
The following diagrams show the factor affecting tension during a turret index.

1) Initial conditions – The layon roller runs in contact or gap mode with the winding roll in the inside position. The inside spindle runs in tension mode using a load cell or dancer and calculates diameter. The incoming core is loaded, diameter is preset, but he incoming spindle is

stopped.

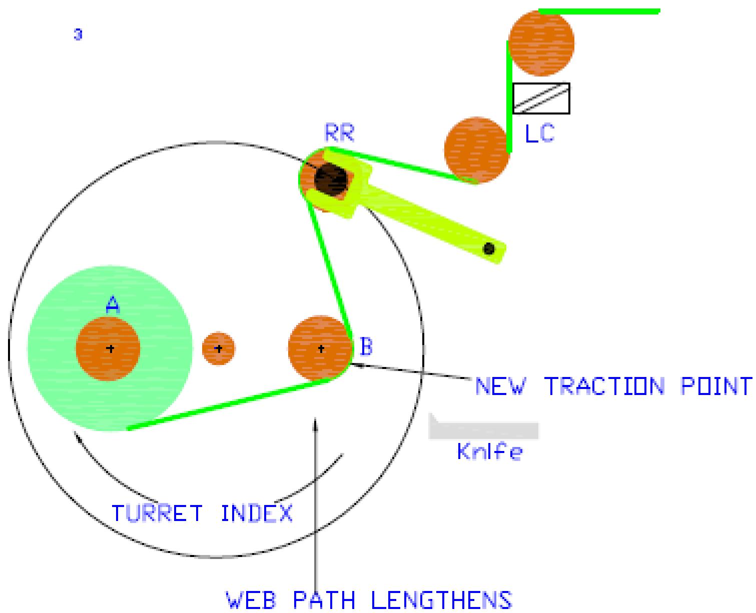


2) Layon Roller lifts – The layon roller must lift from the inside winding roll so it will not interfere with turret indexing. Lifting the layon roller lowers the wound on tension for this roll. Often tension is boosted just prior to lifting the layon rolled. The increased tension partially compensates for the loss of nip loading. Often the outgoing spindle drive memorizes the torque at this time and hold tension until the cut is complete. Lifting the layon roller lengthens the web path and momentarily increases tension. The spindle must decelerate and then accelerate back to web speed to compensate for the change in web length.

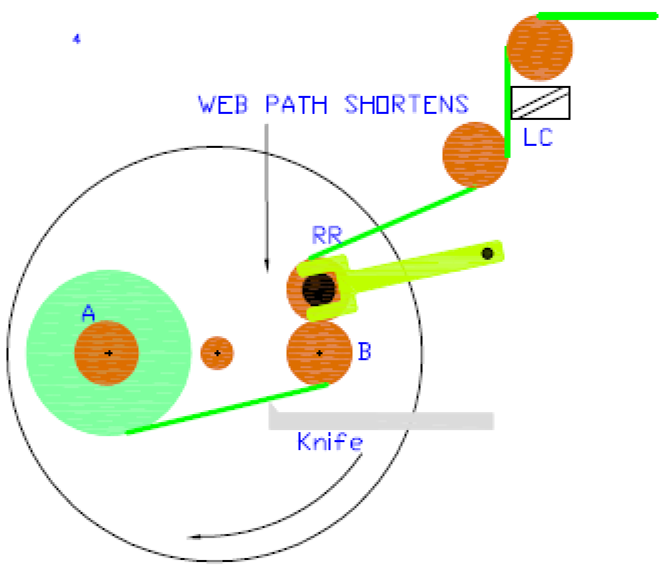


3) Turret Indexes – The turret is accelerated, runs at a steady speed for a few seconds and then decelerated to stop at exactly 180 degrees. During the turret motion, the web length increases, naturally increasing tension. At some point after 90 degrees, the incoming core will contact the

web. The core must be rotating at web speed when in contact with the web.

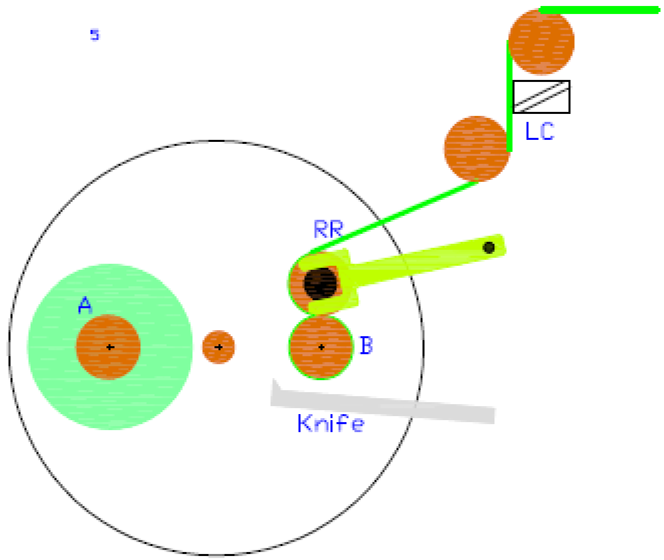


4) Lay-on is Lowered – the web path gets shorter when the lay-on is lowered. This will naturally reduce tension. Equally significant is the new traction point introduced at the core as it is nipped by the lay-on roller with significant starting pressure.



5) The Knife/Enveloper contacts the web – this will naturally increase tension. The index should be initiated as late-as-possible in order to minimize the time the knife carriage contacts the web. The tension between the core and outgoing spindle must be controlled in order to get a clean cut. After the cut, the inside spindle with the core is switched to tension control. The outside

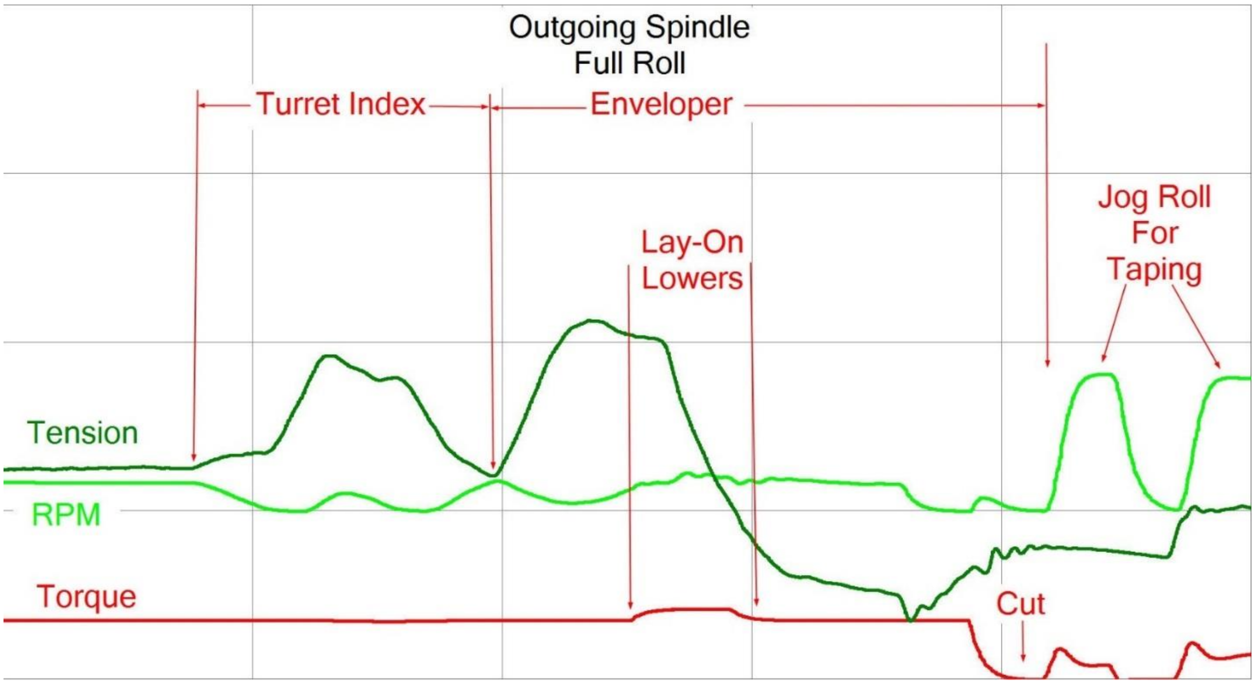
completed roll is stopped.



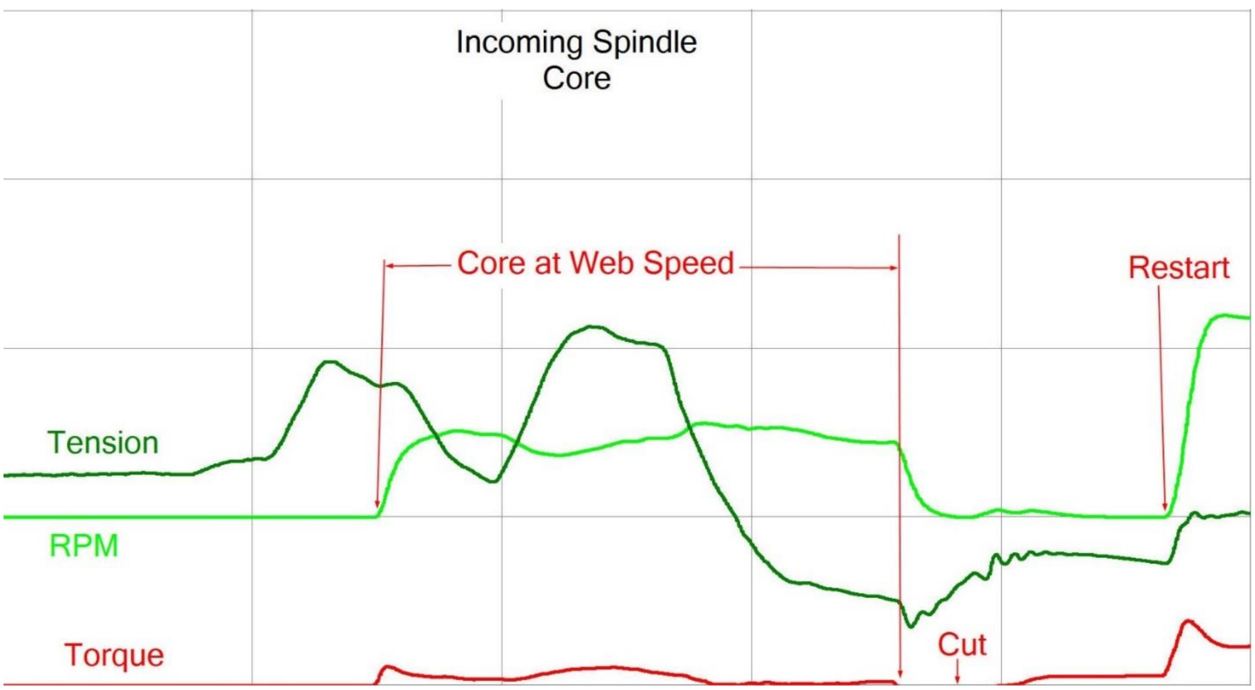
Tension Measurements

As shown in the figure above, tension is measured upstream of the winder and applies most closely to the inboard spindle. During a turret index before the knife cut, the measured tension does not correctly reflect the tension at the winding roll in the outboard position. The tension seen by the load cell has a contribution from the incoming core as well as the outboard winding roll.

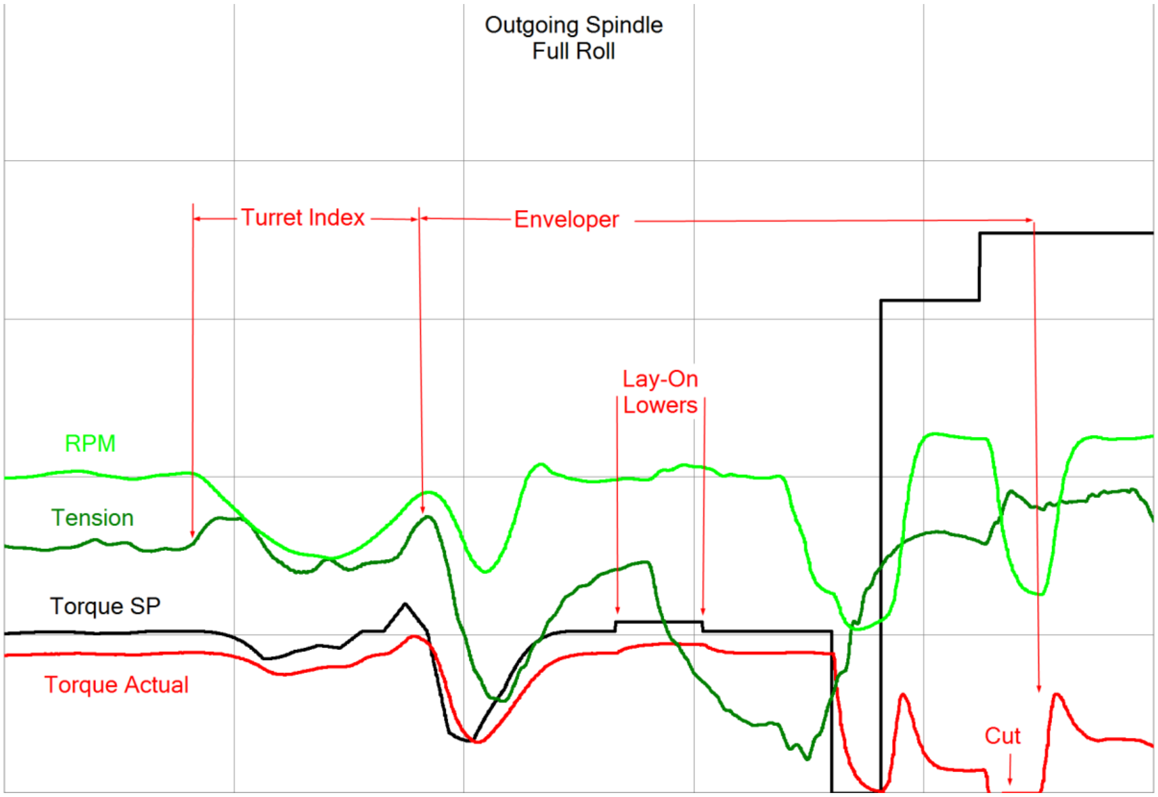
The disturbances mentioned to this point may show in actual tension as shown below. These measurements were taken during the index of a slow speed line. The line is running with a tension of 1.5 PLI 263 N/m). This chart shows tension for a turret winder with the outgoing roll running in torque hold mode during the index. The torque is boosted slightly while the lay-on roller lowers. We see that when the layon roll lifts and the turret indexes, tension may double from its normal running value. After the cut we see the outgoing roll remain stopped, then jog to take up the tail, stop for the tape heads to be applied and restart briefly to tape the roll. All motions up to the cut are complete in a 15 second index cycle.



The chart below shows tension and torque for the incoming core for the same index. The incoming core is run to web speed with a speed regulator. We see torque vary as the turret moves and the lay-on roller lowers. After the cut, the web is attached to the core and the core is accelerated to an overspeed before settling into its steady running under tension control.



The next chart shows how feed-forward techniques can be implemented. Torque is adjusted up or down at different parts of the index cycle to account for web length changes and other disturbances. The feed-forward techniques can be based on models of tension during the index or empirically based on tension disturbances as measured by the load cell. In this case the torque was modified empirically. Compensations were set at one speed and later modified by line speed to achieve satisfactory results for all operating conditions. We found that dividing the turret motion into 15 degree increments provided suitable resolution, but required 24 torque settings to be determined empirically.



In this case, the spindle control was by tension through the torque regulator. In the case of spindle control using tension through the speed regulator we note that the tension regulator is often disabled by torque hold or torque memorize during the turret index. Some spindle drives remain in speed control during the index and feed-forward techniques are available to modify the spindle RPM during the index to hold tension to acceptable values.

An interesting paper by G. Oedl [1] suggested using servos on the turret and lay-on roller and co-ordinating the motions such that web length disturbances are minimized. This may be effective during part of the cycle, but not all turret and lay-on roller motions can be compensated perfectly.

Conclusions

We observe that turret winders subject the web to tension disturbances during index cycles. These disturbances are more severe at lower line speeds and with stiffer (high modulus) webs. It may be necessary to use feed-forward techniques to minimize tension variations. These will compensate for turret motion, lay-on roller motion, core speed, enveloping and cutting of the web. A faster index cycle will minimize the time the disturbances occur over, but will increase the magnitude of tension variations. It may be that a turret winder is not recommended for your particular web.

References

[1] ***IWEB 2015 Conference, Fast Winder Change with Reduced Influence on Film Tension***, G. Oedl and S. Schuster, Brückner Maschinenbau GmbH & Co. KG, GERMANY