Evolution of calender roll adjust systems

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“Calender roll adjust systems” describes the means of adjusting one roll with respect to another. The description is usually specific to the mechanism for opening or closing the gap between two adjacent rolls. For our purposes we will broaden the definition to include the means of correcting for changes in roll deflection—roll crossing or skewing, and roll bending—and extend it still further to the control of pressure in the laminating nip.

While the specifics of what follows deal explicitly with calenders employed to coat fabric or cord and wire for the production of tires, much of what will be covered is equally applicable to any coating operation carried out in a calender.

Tire cord calendering initially was carried out in three-roll vertical calenders. A layer or coat of rubber of the required thickness was formed between the top roll and middle roll, and transferred or laminated to the substrate between the middle roll and the bottom roll.

Double coating was accomplished by running the web back through the calender with the other side up. Efficiency was improved by adding a second, or tandem, three-roll calender, and coating the second side of the web in line.

In more recent times, four-roll calenders have become the prevalent choice. In a four-roll calender one layer of rubber or compound from the calender roll to the substrate and “striking through” the fabric, or at least penetrating the weave sufficiently to minimize air entrapment and ensure proper bonding in subsequent assembly and curing operations.

Accomplishing this objective successfully under a variety of operating conditions requires an understanding of the relationship between product (compound) characteristics, the mechanics of rolls, the operation of the roll positioning systems, the method and operation of the coating or web thickness measurement system, and the interplay between the sheet forming operation in the first nip and the laminating or coating operation in the second.

Roll adjust or positioning systems

There are three primary systems in use today, each with variations: mechanical screw and nut, hybrid hydraulic/screw and nut, and full hydraulic.

Executive summary

The evolving technologies for calender roll position and nip pressure control are reviewed and compared in this paper. The influence of roll nip control on the uniformity of sheet thickness, “strike through” in fabric coating/laminating operations and cord spacing when double-coating reinforcing cord and wire are discussed. Broad guidelines for the selection and employment of available technologies are developed with an emphasis on practical application across the spectrum of calendering operations common to the tire industry.

Screw and nut. For well over a century and a half, the primary mechanism for adjusting the gap between two adjacent rolls has utilized a screw and a nut. The screw bears against the bearing box of the movable roll. The bearing box is coupled to the end of the screw by gravity (for the bottom roll in a vertical stack) or by means of a lever mechanism, with some means of rotating the screw in the nut.

Over the years, various methods have been employed to improve precision and operation of these mechanisms. Initially, roll adjust drive trains were comprised of a large hand wheel with a simple transmission, jack shafts, bevel gears and cross shafts with jaw clutches to worms and worm gears—all open gearing. Eventually, most systems settled on individual two-speed motors with brakes driving each screw or nut through two-stage worm gear reducers.

Thrust bearings of various types have been interposed between the screw and the roll bearing box. Some builders opted for rotating nuts with non-rotating screws—thereby moving the thrust bearing from the bearing box to the calender frame or housing. Thrust bearings were added to the lifter assembly to reduce friction and permit the reduction of clearance in the total assembly.

Screw thread profiles and the number of threads per inch have been experimented with, and screws have increased in size to improve stiffness.

Screw and nut roll positioning systems are gap control systems. The position of the roll bearing box is adjusted to achieve the gap necessary between two adjacent rolls to produce a sheet or layer of material of the desired thickness; to successfully transfer the sheet or layer to a substrate; and, to fully encapsulate cord or wire. In the case of thickness, with some form of measurement—even as simple as manual “snap gauging,” the gap could be achieved to adjust the desired size. It was generally understood that in the case of laminating or coating operations, gap or position control was a “stand in” for pressure.

In the early 1950s load cell technology evolved and it became possible to build into roll adjust systems a strain gauge load cell to actually measure the force being supported by the roll adjust system—and, at least in theory, providing the ability to control that force.

In practice, the electronics of the time were at best cumbersome to use.

In most instances, for another 20 years or so, load cells in calenders so equipped were more useful as means of obtaining design data than as a means of feedback for adjusting the roll position system.

Split relief. As calender lines became more sophisticated and line speeds increased, it became desirable to splice the tail end of one roll of fabric or cord to the leading end of the next, first to reduce thread-up time, and then to avoid having to change line speed—to run as continuously as possible.
Fig. 4. Full hydraulic roll adjust mechanism.

Some means was needed to permit rapidly opening and re-closing the laminating nip to permit a splice to pass. The solution was a short-stroke hydraulic cylinder interposed between the roll adjust thrust bearing and the roll bearing housing. The cylinder was usually built into the lifter assembly itself, and close observation was necessary to detect their presence.

In some more recent four-roll “Z” or “S” calenders, the splice relief cylinder has been installed between what would normally be the “fixed” roll and the calender end frame or housing, a choice made possible both by virtue of the roll arrangement and the almost universal adoption of individual roll drive.

As it turned out, if a small accumulator of some sort was added to the splice relief cylinder hydraulic circuit close to the cylinder, it was, in most instances, not necessary to open the cylinder. The splice would force the fluid out of the cylinder into the accumulator, and when the splice passed, the accumulator would force the stored fluid back into the cylinder, restoring the proper operating gap or pressure.

The addition of the splice relief cylinder also provided a means of directly controlling the pressure in the laminating or coating nip, and also added a complication that persists and will be discussed at greater length in this paper: Is the theoretical ability, with the proper controls and valves, to respond very rapidly to changes in operating conditions—specifically, the ability to change the effective gap quickly in response to measured deviations from target gauge or thickness. The capability of rapidly opening a roll nip in the event of an accident or a loss of product, and protection of the roll from overload.

The retention of the adjusting screw and nut in the design permitted operation in gap mode, using traditional means of monitoring the opening and closing of the roll nip. If the hydraulic pressure in the cylinders was high enough to create an essentially rigid column from the screw through the cylinder to the roll bearing block, the cylinder would operate exactly as if it were a conventional screw and nut machine.

A secondary feature of the hybrid system is that only a relatively short stroke is required to achieve the listed advantages. Although we think of fluids as being incompressible, and that simplifying assumption works for most applications, fluids do compress under load.

Full hydraulic roll positioning
The reliable implementation of this concept required the development of servo control valves and high precision linear displacement transducers, as well as the electronics technology necessary to process the data and issue the necessary control signals. Position transducers are necessary to provide feedback to the servo valves.

The combination of precision position measurement, rapid signal processing and precise and rapid valve response provided the means necessary to control the change in volume of the oil in the cylinder when a load was applied.

Two different approaches to implementing full hydraulic roll positioning were pursued:

- In the late 1960s and early 1970s, Farrel developed and fielded two variations of an hydraulic roll adjust system that essentially made the roll adjust itself a large servo-valve; and
- With the evolution of hydraulic control technology and precision displacement measurement devices, precision servo valves were applied to what are basically short-stroke large diameter hydraulic cylinders. This design approach, separating the cylinder from the positioning system, has become the predominate approach.

Roll bearings and roll position
The improvements described were all directed at making the motion of the roll adjust drive train more repeatable by minimizing the mechanical hysteresis inherent in a mechanical drive train. At least two problem areas remained, and remained.

The first of these is that what is being adjusted is the position of the roll bearing. Modern calenders employ precision anti-friction bearings with very small radial clearances, making this less of a concern than it once was. However, a substantial portion of the installed calender base continues to operate with plain or sleeve bearings.

These bearings require an annular clearance between the journal and the bearing in order to operate. Where the journal operates in that clearance depends on the resultant of the roll separating force (RSF) and the roll weight.

The second is similar to the first—screws, nuts, bearings, and mechanical drive trains all require clearances in order to function. When loaded in compression, these clearances are one side of the tooth or bearing; when adjusted under no load conditions, depending on the orientation of the screw, they are on the other side.

To improve control of the roll position, or perhaps more accurately, the center of rotation of the roll journal, preload or zero-clearance bearings were added to the roll adjust positioning system.

Preloads consist of a second bearing outboard of the main bearing coupled to the calender frame by a means of applying load to that bearing. The arrangement permits pulling the roll closer to the position it will operate in when under load, and at the same time, removes the clearances in the lifter bearings and the screw and nut.

When large anti-friction bearings began to take the place of plain bearings, preload bearings were no longer as necessary. Some builders shifted to applying a load to the main bearing boxes, thereby preloading the roll adjust bearings, screw and nut, while relying on the close clearances of the anti-friction bearing to control the position of the roll journal.

Crown and crown correction
From a mechanical standpoint, a calender roll is a flat surface, we know, deflect under load. Vary the load, the deflection varies with it.

To compensate for the deflection, we can change the shape of the beam so that when it deflects under load, it presents a flat surface. With rolls, the shape takes the form of a very skinny barrel, and we say that such a roll is “crowned” or has a crown of such and such. (Crown is measured on the diameter; the amount of crown necessary to correct for the deflection of the roll is twice the amount of the deflection.)

Because loads are not always the same, two basic techniques have evolved for making gap between two adjacent rolls appear to be straight or “flat” under a range of load conditions: Roll crossing.

One roll can be

See Calender, page 18

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 crossed or “skewed” with respect to the other. Put the crossing point at the middle of the two rolls, pick the right amount of crossing and, when you deflect, the gap between them presents itself as uniform across the roll face.

The roll crossing mechanism is comprised of a motor-driven screw turning in a flange nut, applying force against one side of a main bearing housing, with that force opposed by a hydraulic cylinder and bearing on the other side of the bearing box, thereby “capturing” the box between screw and cylinder. The mechanism is applied to both main bearing boxes of the roll to be crossed, with the drive trains arranged to move the boxes in opposite directions.

Normally, there is a means of coupling the two drive trains to ensure that the bearing boxes are moved the same distance in opposite directions, to keep the crossing point at the center of the roll face.

Roll bending. Roll bending is the application of a force to the roll that either opposes or cooperates with the load imposed on the roll by the product, depending on whether there is too much or too little crown on the rolls comprising the nip.

The mechanism entails a second bearing mounted outboard of the main bearing at each end of the roll. A hydraulic cylinder or screw applies a force to this bearing, and the main bearing acts as a fulcrum about which the resulting moment is applied to the roll.

As with full hydraulic roll adjust systems, the response can be very quick. There is no hysteresis (lag in response, especially when changing the sense or direction of the correction) in the system. When applied in a positive mode, that is, in opposition to the RSF, roll bending can also serve to preload the main bearing and/or the roll adjust mechanism.

Measurement systems

The ability to quickly adjust and precisely maintain the relative position of a pair of rolls takes on utility only when there is some means of measuring the result of that action with a speed and accuracy commensurate with the capability of the positioning system. We want the measurement system to tell us how close the positioning system is to the desired result, relying on the stability of the preceding process to insure that the job is done within acceptable tolerance. The two variables which we need to control are nip pressure and material thickness. Most discussions on calendering focus on nip pressure (RSF) as it relates to forming a sheet. In that operation, which immediately precedes the laminating or coating operation, we know that the RSF varies directly with line speed, bank size and viscosity, and inversely with gauge or thickness. These relationships generally hold in the laminating nip as the material seeks to form manner in the machine direction. The ideal placement for the thickness sensors is on the second and third rolls in a four-roll double-coating calender.

The production of wire or tire cord ply coating nip is in certain respects different than most other coating operations. As noted earlier, the objective is to completely encapsulate each cord or wire with rubber, while maintaining a constant and uniform spacing of the cord or wire. The combined layers of rubber and wire or cord are greater in thickness than the combined thickness of the upper and lower rubber layers. In other words, the pressure developed in the coating nip must be sufficient to compress the rubber around and into the spaces between the wire and cord. When the resulting web exits the coating nip, it will do so as a ribbed sheet.

If there are two kinds of wire or cord spacing errors: balance errors, the position of the cord or wire between the upper and lower coatings, and spacing, the distance between the cords or wires.

The method of establishing the cord or wire spacing in the first place, and maintaining it during the laminating or coating nip, is a subject unto itself, and outside the scope of this paper. Suffice it to say that precise operation will not improve a bad situation, if the cords or wires are not properly spaced to start. In other words, that spacing will not be improved in the calender.

Similarly, the means of establishing and controlling web or wire tension through the laminating nip, although essential to most coating purposes, assumed to be in place and performing properly, are beyond the scope of this paper.

Coaxial, Core and Finger Style Coating System

The coating nip is formed by the combination of roll pressures and nip spacing. The nip is formed by the combination of roll pressures and nip spacing. The nip is formed by the combination of roll pressures and nip spacing.
Pirelli adds new N.A. sales initiatives

By Jeff Yip
Tire Business

AUSTIN, Texas—Using the inaugural U.S. Grand Prix at Austin as a stage, Pirelli Tire North America Inc. shared some Texas-sized ambitions with about 300 of its dealers and distributors that include plans for a certified Pirelli dealership program and an expanded marketing and promotional campaign.

Meeting in San Antonio prior to attending the recent Formula 1 race at the Circuit of the Americas near Austin, Pirelli dealers learned of the tire maker’s strategies for North America for 2015 and beyond.

Among the initiatives Pirelli executives outlined were:

● Improved fill rates, thanks to its new factory in Silao, Mexico. Once the plant is up to speed, Silao can pump out 5 million tires a year. The new Cinturato P7 All Season original equipment tire and the replacement version, the All Season 2, are now available, as are the Silao-made Cinturato P7 All Season 2.

● Traveling tire demonstrations will concentrate on the new Cinturato P7 All Season. Proposed cities include Los Angeles; Phoenix; New York/New Jersey; Atlanta; Miami; Boston; St. Louis; Baltimore/Philadelphia; San Francisco; Chicago; Detroit and Dallas.

● A big push into print and online marketing and community building. The firm has “lot of great stories to tell,” said Rafael Navarro III, vice president of communications.

● New sales are strong, particularly in NAFTA region. Partnership with noted car customizer Chip Foose of “Overhaulin’” and Ken Block, co-founder of the Gymkhana viral videos he popularized on the Internet.

● To reach its targets, Pirelli will “keep in mind the texture and circumstances to which we’re adapting.”

The tire maker announced an incentive program in which dealers who reach Pirelli’s sales targets will win a trip to Sicily, Italy. Joining the dealer meeting was 1970’s fitness model with the U.S. Grand Prix at Austin tied into Pirelli Tyre’s role as the exclusive race tire supplier to Formula 1. We focus on minimizing short-term variation by careful operation. Operating personnel must know how the machine works, how changes in process variables affect outcomes, and how changes in spring time and process conditions can overcome those changes. They need to know enough to be able to run the plant under complete manual control as they will understand the importance of maintaining as close to steady-state operation as possible.

The secondary benefit of that knowledge is that they will then be able to operate the line without the gauge or the automatic set-up, if they ever need to do so.

What if?

What if the calender at hand is not fitted with hydraulic roll positioning systems, perhaps lacks roll bending or even roll crossing?

What if the calender runs primarily a fabric or cord substrate, and hence only a single scanning transmission gauge or open-loop manner, to minimize the impact of short-term variations in stock thickness and/or viscosity. The capability exists to apply crown correction to both the forming nips and the laminating nip, to ensure that the cross-sheet profile and laminating pressure are as uniform as possible.

What if the mass per unit of roll face length is not consistent, then the laminating pressure will not be consistent across the nip, and localized cord or wire spacing will not be consistent across the nip, and uniform or consistent.

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