

New-design duplex winder from conception to operation

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ABSTRACT: *A new, high-torque, center-wind, duplex winder was designed to provide advanced roll structure control, enabling jumbo rolls to be wound with consistently reliable roll quality.*

KEYWORDS: *drums, machine design, operations, productivity, quality, torque, winders, winding, wound rolls.*

An objective of all mills is to produce high-quality, defect-free, large-diameter rolls—jumbo rolls. Due to paper properties and machine constraints, roll sizes are often limited to diameters that can assure reliable roll quality and performance. Beloit and Bowater realized that if larger-diameter rolls could be built with high quality then economic gains could be realized by printers. In addition, both machine builder and papermaker would have an advantage in their respective markets.

New rotogravure presses are being designed and installed to handle larger-diameter and larger-width rolls. New presses, up to 3 m (118 in.) wide, recently have been installed, and with these new presses printers have been requesting the larger rolls. In an effort to satisfy the printers, mills have produced large-diameter rolls, but with limited success. As a result, pressrooms are usually provided with 965–1066-mm-diameter (38–42 in.) lightweight coated (LWC) and roto-gravure rolls, diameters which have

greater running reliability with current surface (nip) winding technology. Pressrooms are anxious to accept the larger rolls and are looking for a producer to provide these rolls.

To wind larger-diameter rolls with reliable roll quality required that the current winding technology be improved. A limitation to optimal roll structure on current duplex winders was the absence of full center-torque capability; therefore, a new high-torque centerwind “super” machine (HTCS) was developed. This new single-drum machine was designed to build these rolls by providing maximum roll structure control through the use of full center torque. In addition to the center torque, a flexible roll-structure system controls closed-loop digital nip regulation and dual independent and isolated tension systems. The winding geometry of the rolls provides the ideal roll load distribution. These elements, along with other innovative features, have advanced the concept and control of paper winding.

This paper is designed to give the reader an understanding of current winder technology and how machines are being designed. It also points the way to future pressroom demands and what mills must expect if they are to be prepared for business in the future.

Mill perspective and partnership

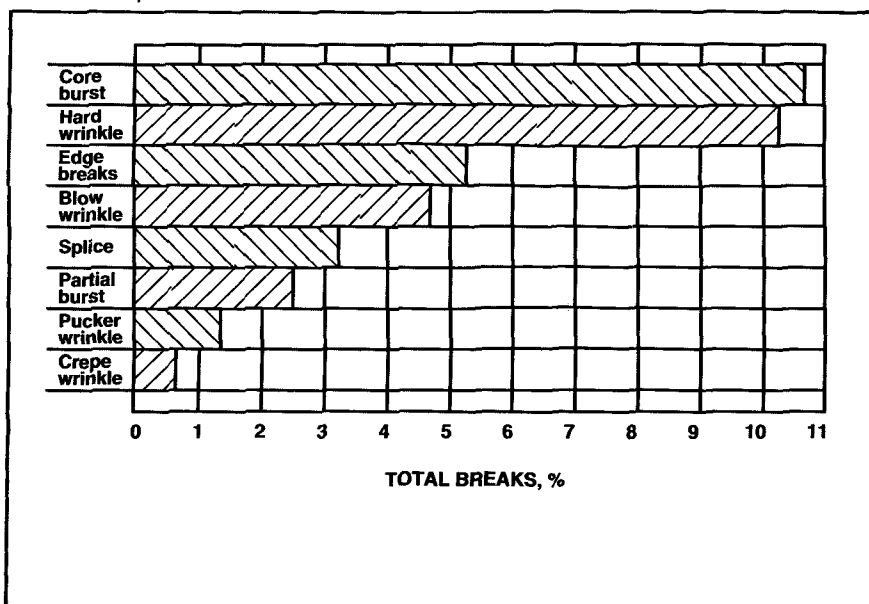
The No. 2 paper machine produces 20 grades of lightweight coated paper with basis weight ranges of 50–81 g/m² (34–55 lb/3300 ft²). The primary grades produced are web offset and rotogravure. Rotogravure, with its low coefficient of friction, has historically been a difficult grade to wind.

Limitations with the existing two-drum machine have been realized when roll diameters exceed 45 in. To produce larger rolls, a new winder had to be purchased. Machine studies taken in the pressrooms indicated current two-drum and duplex winding technology could not produce large-diameter rolls with the same quality and runnability as smaller-diameter rolls. Concurrently, a new duplex winder was being researched which required an interested customer willing to install the new-technology machine.

A partnership was formed between machine builder and papermaker with a mutual goal to wind high-quality, large-diameter, rotogravure rolls. A machine performance specification was defined which detailed the machine's productivity and quality improvement levels. The mill provided the manpower, floor space, energy, and resources to operate the machine while

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1. Causes of pressroom breaks



I. Machine specifications

Operating speed	2,210 m/min (7,250 ft/min)
Basis weight	50–81 g/m ² (34–55 lb/3,300 ft ²)
Web width	7,915 mm (312 in.)
Rewind diameter	1,524 mm (60 in.)
Rewind width	560–3,100 mm (22–122 in.)
Roll weight	
Type 60	4,000 kg (8,800 lb)
Type 100	6,000 kg (13,200 lb)
Unwind tension	525 N/m (3 pli)
Rewind tension	700 N/m (4 pli)

the builder provided the machine. Following the completion of the machine, the team would then monitor roll quality, tune roll-structure control parameters, and refine machine operations.

Pressroom studies

During the 1980s, a great deal of focus was put on product quality, which naturally brought the producer and buyer together. Pressroom studies have been conducted extensively since then to gain a better understanding of roll defects and their effect in the pressroom. A great deal of energy also has been spent in quantifying the types of pressroom breaks in an attempt to better understand their causes.

Winder-related paper breaks in the pressroom have been quantified into over 40 categories. The categories include core bursts, air shear bursts, edge bursts, edge cracks, crepe wrinkles, OD bursts in the form of caliper shear bursts, tension-related defects, and others. According to one pressroom study, a major runnability problem on wide, large-diameter rolls is core burst (Fig. 1). By analyzing each category of defects, the cause of the defect can be better understood.

After determining the defects, the winding-related causes of these defects

were analyzed. Core bursts were identified as a major problem, and through another investigation an overwhelming cause of pressroom problems was nonuniform nip. The high-torque center wind allowed tight starts without relying on nip, reducing nip related defects and providing a solid foundation for large-diameter rolls.

Defects such as wrinkles, caused by layer-to-layer slippage and gearing, also were reduced with the center-torque capability. Tension bursts were reduced by providing a dual, independent tension system which isolates unwind from windup tension. OD caliper shear burst, as well as rope and corrugation defects, were reduced by allowing roll weight to be distributed between the drum nip and the core. Through defect analysis and cause evaluation, the HTCS machine was designed to accommodate known roll quality problems and extend known winding limits.

Overall design

The machine is a duplex winder with 10 winding stations, five stations per side (Fig. 2). The winding is done on a 1500-mm-diameter (59 in.) center drum at the 10 o'clock and 2 o'clock positions. This geometry provides for opti-

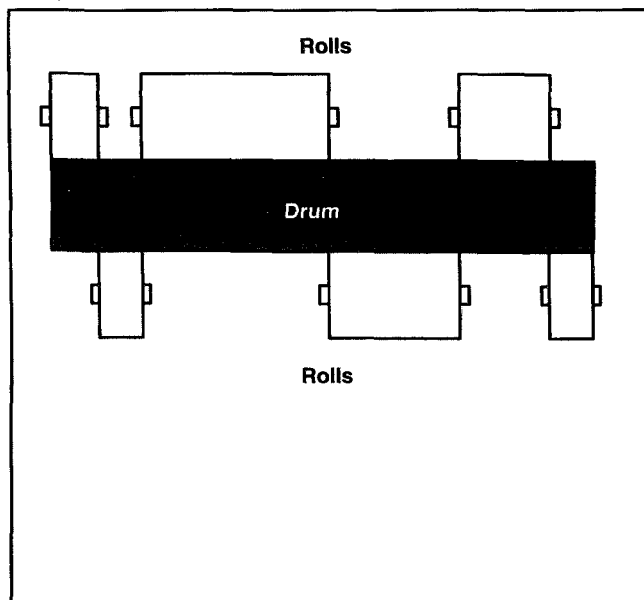
mum roll support by allowing the full roll load to be selectively distributed between the drum nip and cores.

The machine has independent, individually controlled winding stations for optimum roll structure control. Each winding station's torque and nip is regulated based on roll diameter, width, weight, and location. The sheet run travels from the unwind stand to below the operating floor. Under the floor, the web passes across one cross-tension equalization (CTE) roll, around the tension isolating roll, and then across another CTE roll. Next, the sheet travels up through the slitter section and then onto the traction coated, ventagrooved, vacuum drum. From the drum, the paper is wound on cores held individually in the winding stations (Fig. 3 and Table I).

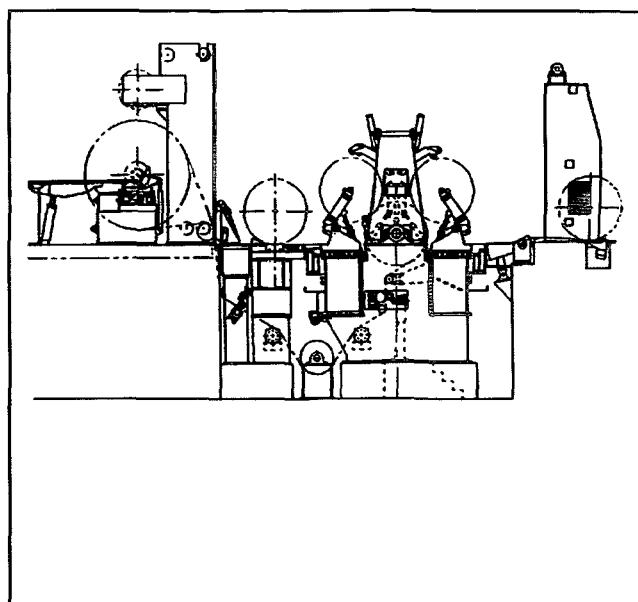
Extensive process automation was incorporated on the machine to optimize productivity. All processes are automated, including set change, slitter positioning, station positioning, and rider-roll selection.

The machine consists of a number of unique systems which advance the winding process. Following is a list and discussion of each winding system and its benefits.

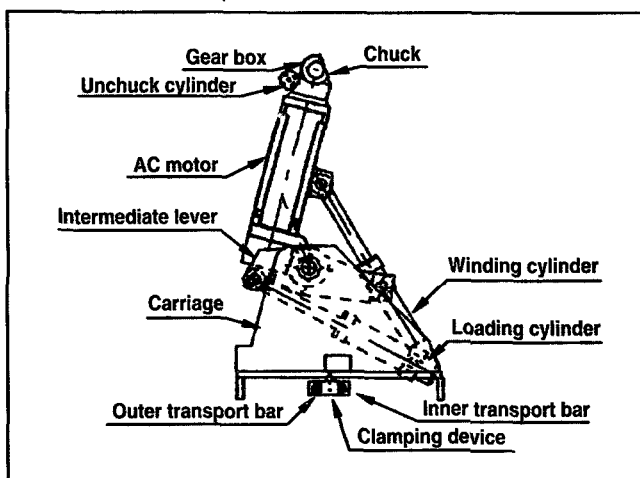
2. Top view with six stations active



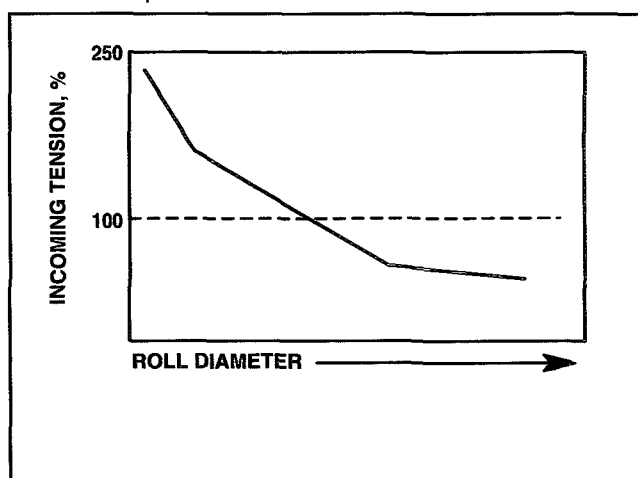
3. HTCS elevation view



4. Station arm with torque motor



5. Tension torque vs. diameter



High-torque centerwind

Nip pressure alone on the core will produce very little of the tension required in the critical first wraps of paper on the core. A main feature of the HTCS is the incorporation of high-torque ac motors in the winding station arms (Fig. 4). The winding process begins with a very high center torque to assure an exceptionally tight start. With a solid foundation on the core, larger-diameter rolls can be wound. The motors are specially designed and built to provide maximum power output in a limited space. A single motor is

rated at 25 kW (33 hp) and 181 Nm (134 ft-lb). The motors are designed to handle overload current of 180%, or 327 Nm. The winding station can therefore provide over 650 Nm (484 ft-lb) of center-torque power.

The motor torque is transmitted through right-angle gearboxes and torque actuated, expanding-leaf core chucks into the roll. The winding torque is controlled as a function of rewind diameter. The output torque also takes into account the operator entered torque setpoint (Fig. 5), incoming web tension, system friction, and system

inertia requirements during acceleration and deceleration. The motors are digitally controlled, incorporating slip-detection software to assure that the torque is transmitted into the roll and the chuck is not slipping. Torque is limited to 250% of the incoming tension. This results in up to 1750 N/m (10 pli) of tension torque at the core. The actual torque that can be applied is dependent on a number of machine variables which include the tensile strength of the paper, the strength and deflection of the core, and the uniformity of the nip against the drum.

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The ability to apply torque to the core has also allowed acceleration and deceleration effects to be minimized. This compensates for the situation typical with two-drum winders when, during deceleration of a wound roll, the roll will tend to climb onto the front drum, and nip loading will increase, creating a hard outer surface. With center-torque control, the winding roll can be accelerated or decelerated, and torque will be added to compensate for roll inertia.

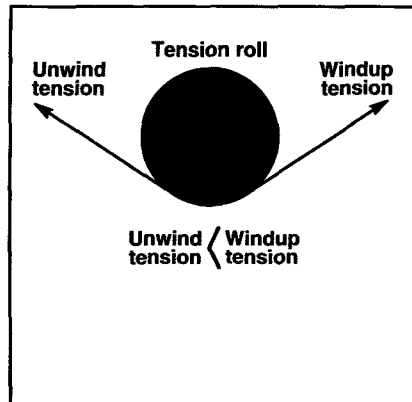
The slip-detection software not only guarantees torque transmission but also prevents core delaminations caused by the core chuck turning inside the core. The machine is currently installed with type 80 gearboxes, which enable winding on 89-mm (3.5 in.), 102-mm (4 in.), and 112-mm (4.5 in.) cores. Rotogravure paper wound on 89-mm iron cores and offset grades wound on 112-mm fiber cores (with or without inserts) use a six-point chuck design. Other offset rolls wound on straight 112-mm fiber cores use a three-point chuck. The new torque-actuated core chuck design, in conjunction with the slip detection software, has proven to be a successful combination for positive torque transmission into the roll.

Isolated dual-tension control

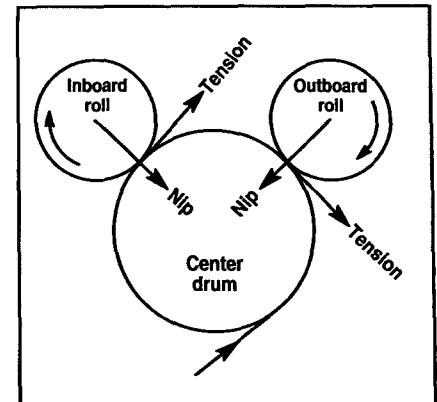
The machine incorporates dual, closed-loop tension control, which allows the unwind tension to be isolated from the windup tension. This is achieved through the use of the tension isolation roll, an 800-mm-diameter (31.5 in.), driven, tungsten carbide coated, ventagrooved roll. The web has 45° wrap to allow good tension isolation and separation (Fig. 6).

The dual-tension system allows the unwind tension to be set below the windup tension. By unwinding the paper from the spool using the lowest possible unwind tension, better runnability can be achieved. The windup tension is set as a percentage of the unwind tension. This range is adjustable from 130% to 105% of the unwind tension. The windup tension setpoint is adjusted to provide for op-

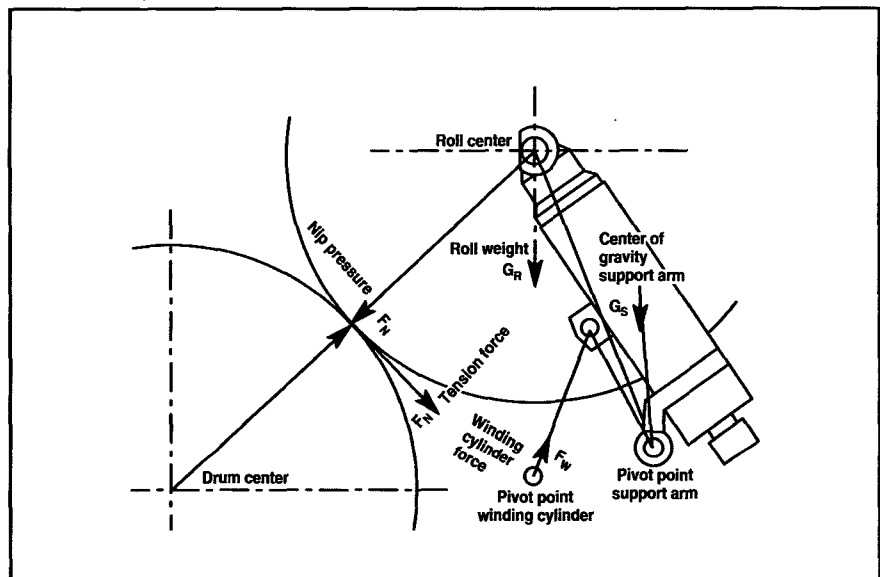
6. Tension isolation roll



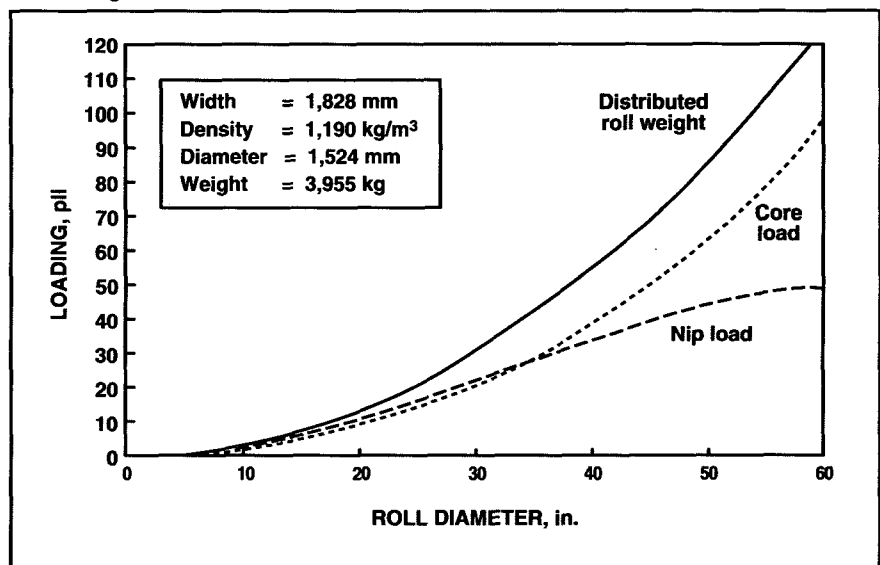
7. Tension effect on nip



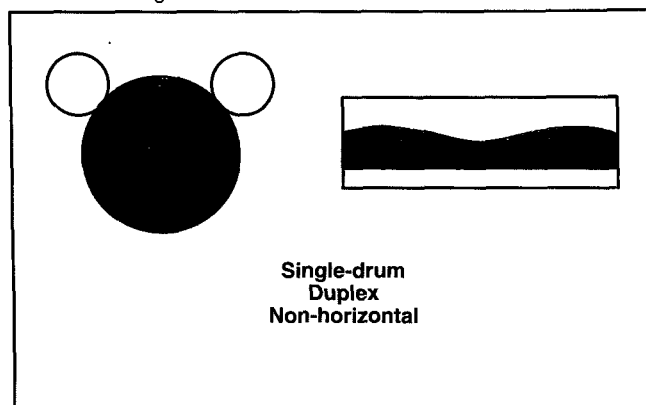
8. Station nip geometry



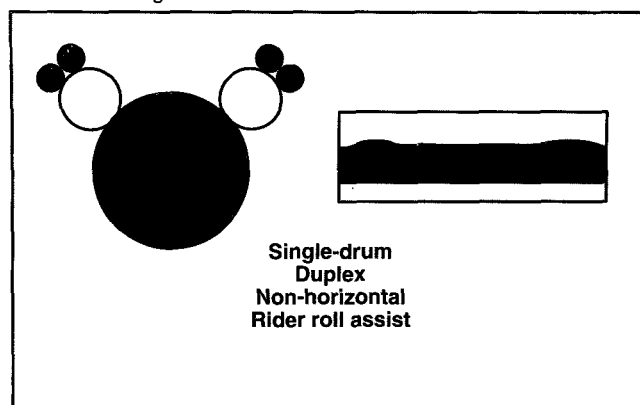
9. Roll weight distribution



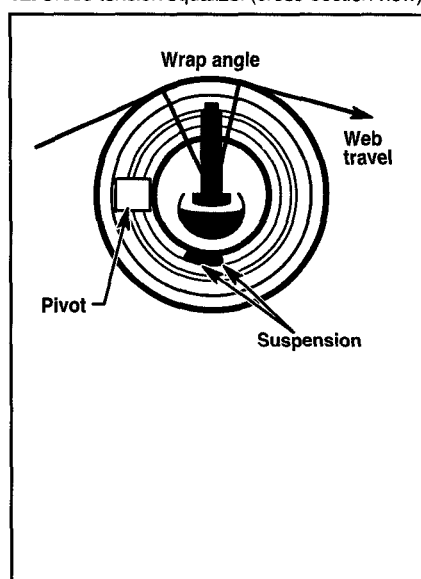
10. Core loading without rider roll



11. Core loading with rider roll



12. Cross-tension equalizer (cross-section view)



timum roll structure. Furthermore, the dual-tension system can dampen any tension disturbance from the spool or paper wound on the spool before it reaches the winding roll.

Low windup tension settings caused the web to relax and allowed sheet movement across the drum in caliper variation areas. Experience showed us that, when running at higher tensions [700–575 N/m (4–3.3 pli)], the web remained stable and roll edge quality was greatly improved. The effect of increasing tension to improve edge appearance will also increase roll hardness. Excessive roll hardness can be controlled by reducing the torque.

Drum nip and regulation

The nip force of each rewind station is individually controlled based on paper density, roll width, roll diameter, and roll location. Roll nip is the most complicated calculation in this winding process. The nip must take into account roll diameter, the winding location, and width. The geometry of the machine is such that the outboard station's web approaches from below the roll, where as the inboard station's web approaches from over the top of the drum and thus above the roll. For the outboard station, this web will add to the desired nip, by pulling the core and roll into the drum; the inboard station will subtract from the nip (Fig. 7).

The pressure to the cylinders must take into account the desired nip, as set through the operator console, the effect of web tension acting on the inboard or outboard locations, the weight of the station arms, and the roll weight. During the winding process, the effect of each of these elements acts through a changing lever arm, that is the distance of the force from the winding cylinder (Fig. 8). A high-speed embedded controller is used to make these calculations individually for each of the 10 stations 10 times a second. The desired nip of the roll against the drum is defined by the operator using an adjustable three-point roll-nip curve. The controller does all calculations to compensate for the myriad of factors.

For this machine, the nip is used primarily for load distribution. The nip starts low to allow the center-wind drives to add tension into the core without having the paper "locked" onto the drum. A minimum nip is always present to eliminate air entrapment during high-speed winding. As the roll builds, the nip is increased to equalize the core and nip load (Fig. 9). As with two-drum geometry, at some point roll weight, even if distributed, will exceed the paper's physical tensile strength. With the duplex design this point—the point where excessive loading occurs—can be extended. By equalizing the load distribution, core as well as nip defects can be minimized.

The following equations exhibit the effect roll weight will have on the nip. Larger-diameter, heavier rolls make load distribution more critical. For our example, we use a roll with these dimensions: 2540-mm (100 in.) width, 1140-mm (45 in.) diameter, and a density of 1050 kg/m³. First, roll weight is determined:

$$\text{weight} = \pi \times (1.140/2)^2 \times 2.54 \times 1050 \quad (1)$$

The equation yields the roll weight, which then can be evaluated in terms of Newtons per meter:

$$2700 \text{ kg} \times 9.81 \text{ N/kg} = 26,500 \text{ N} \quad (2)$$

$$26,500 \text{ N}/2.54 \text{ m} = 10,500 \text{ N/m (60 pli)} \quad (3)$$

The HTCS has the ability to distribute this load between the roll face and the core. This allows greater flex-

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ibility in winding. LWC papers, which exhibit a good caliper profile, can safely tolerate over 6000 N/m (34 pli) of force before sheet deformation occurs.

Rider roll system

All cores exhibit some degree of deflection, and this deflection can have detrimental effects in the form of wrinkles and crepes, both of which can lead to core bursts. To minimize this deflection, the machine utilizes rider rolls. There are 10 individual rider rolls, which can be automatically or operator-selected and are used to cradle cores during the start of the winding process.

Unlike two-drum machines, the cores are supported by two-point loads. With wide cores, it is not possible to distribute the station loading equally (Fig. 10). Realizing this, if a roll is 1.2–2.0 meters (48–78 in.) wide, a rider roll is used to help support the core (Fig. 11). The rider-roll loading is relieved as the roll builds, and they are pulled off the roll at 250 mm (10 in.). Two rider rolls are used on rolls that are 2.0–3.2 meters (78–126 in.) wide. Rider rolls are effective in reducing core deflection and creating a more uniform nip.

Cross-tension equalizing roll

The segmented, rubber-covered, and grooved roll is designed for optimum web handling and increased runnability by combining spreading and web tension equalization. Cross-directional tension is stabilized through pressure equalization within a water-filled bladder (Fig. 12). A high-tension area depressing one segment will cause the pressure in the bladder to increase and raise the other segments, thus increasing, or distributing, the high-tension area across the web. In addition to equalization, it provides both web oscillation and vibration reduction, as well as preslitting spreading.

Threading system

The threading of the machine is entirely automatic. The threading system incorporates a full-width threading bar, which in its starting position is rotated and winds a full-width web onto the bar. When threading is initiated, the threading bar travels along steel guides driven by a variable-speed drive. The speed is coordinated with the surface speed of the unwind payout. The web is kept taut throughout the threading, slitters are automatically engaged, and the drives switch into stall tension regulation. When the threading bar reaches the windup position, the bar is rotated to pull the slits up to the stations. Using the in-board core beam, the web is automatically cut off and left for the operator to attach to the core. The threading system allows for unassisted hands-off operation.

Operator controls and roll structure

To achieve roll structure control and maintain high productivity, sophisticated controls, systems, and software were developed and used. The objective in the control strategy was to keep the operator controls simple and easy to understand. The main operator interface is a PC-based system. From here the operator selects the roll set desired, the roll structure curves for the paper grade, and automatic stopping parameters. With the trim plan selected, the computer will determine the required stations and slitters and their respective positions. Roll structure curves are entered for tension roll tension, center torque, and drum nip. Various computer systems compensate the requested setpoints for variable widths, densities, and unwind tensions.

Feedback is provided for machine speed, roll density, unwind and rewind tension, station nip load, and station torque. Station torque is depicted as the deviation from the 100% requested torque. Core chuck slippage will cause the torque to be reduced, and the feedback will depict the percentage of

torque being transmitted into the roll. Another monitor displays the current diameter and width of all winding rolls.

The operator interface screen also has an on-line diagnostic or error message system with over 10,000 time- and date-stamped errors. The message system will report an error from which further information can be accessed. Because of the winder sophistication, the error message system has proven invaluable in keeping the machine operational.

Machine performance

Since April 1991, the machine has been in operation producing rolls of various sizes of rotogravure and offset grades. The mill's operating and trade personnel are fully trained in winder operation and maintenance requirements. A great number of rolls were initially rewound to assure roll structure quality. Currently, all rolls produced on the HTCS are tracked according to which pressroom they are sent, and pressrooms are queried for quality feedback. The quality feedback to date has been encouraging.

Because of the new technology involved with the machine, production was limited until positive feedback was available. The machine is now used for rotogravure as well as web offset grades. During rotogravure runs, the machine generally gets 80% of the paper from the paper machine. Machine productivity averages 52 sets per day. To date, over 30,000 rolls have been wound.

A great deal of rotogravure rolls run are 2340 mm (92 in.) wide by 1066 mm (42 in.) in diameter. Smaller-width rolls of 1700 mm (67 in.) are wound to a diameter of 1150 mm (45 in.). Currently, the majority of rolls are wound at a 1080-mm diameter.

In separate trials, the machine has successfully produced 1270-mm-diameter (50 in.) rotogravure and web offset rolls and rolls over 3700 kg (8,300 lb). Web offset rolls of this width (1270 mm) have gone to printers with no breaks reported. Parameters are still

being adjusted as feedback is received from the pressrooms. The available center torque, the flexible nip load distribution, and the variable tension system have considerable range, which allows all these roll structure parameters to be widely adjusted. With ample feedback and time, the machine should become finely tuned for all paper grades and roll sizes.

Roll performance goals

Once we have determined the proper winding parameters to successfully build 1150-mm-diameter rolls, 1270-mm-diameter rolls will be investigated further. Our primary goal is to successfully produce wide, large-diameter rolls up to 1270 mm which exhibit improved quality and superior runnability. ■

Received for review Feb. 18, 1992.

Accepted May 8, 1992.

Presented at the TAPPI 1992 Calendering and Winding Short Course.