Practical applications of unwind systems for converting slitter rewinders

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ABSTRACT

All converting slitter rewinders require an unwinding system. Although often considered a simple function, the selection of a proper unwinding system is extremely important to the overall productivity of the slitter rewinder. The major tradeoff of an unwinding system is cost vs. efficiency. A light-duty unwind may be the most cost effective for a low-production operation, but for high-production operation, a rugged-duty, shaftless, floor pickup is often more suitable for maximum operation speed and roll-changing efficiency. The shaft selection, chucking system, type of chucks, braking system, tension control, web-squaring, side-shifting, and edge-guiding equipment will also affect the overall performance.

Application:

This paper discusses the proper selection of an unwind and the auxiliary equipment needed to ensure the maximum performance and productivity from a slitter rewinder.

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DESIGN CRITERIA

The first things that must be established are the basic design criteria. The following must be determined:

- Materials to be processed: (a) types: composites, extensible, nonextensible, (b) basis weight range, and (c) thickness range for each material and basis weight
- Roll diameters and weights
- Speed of operation
- Tensile strength of materials
- Core materials and sizes: length variations, inside diameter and tolerances, and outside diameters
- Roll delivery systems.

These design criteria will help select the design of unwind that is best suited for the application. Unfortunately, there are no hard-and-fast rules. The variation of these parameters dictates the flexibility required and therefore the complexity and cost of the system. It is important to be realistic when specifying the required range for best value and performance of the unwinding system.

FRAME CONSTRUCTION

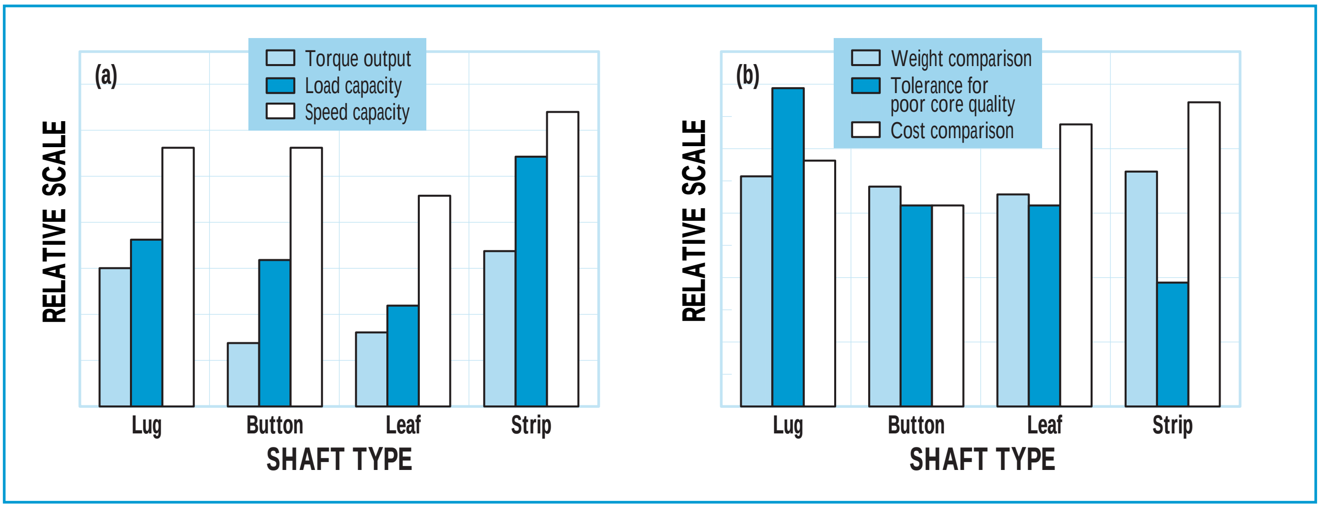
The frame construction for unwind stands of typical converting slitters can range from machine-mounted plate steel for lightweight rolls to separate unwind stands fabricated from heavy weldments or castings. Heavier roll weights and higher-speed operations require separate rigid-frame construction for quick acceleration and deceleration rates, smoother unwinding of out-of-round rolls at the higher speeds, and precise web guiding without vibrations or tension upsets.

EDGE GUIDING

A primary function of the unwind is to provide a guided web into the slitter rewinder for accuracy in locating the web for slitting or to realign the edge of the web in a straight rewinding operation. The framing of the unwind is typically mounted to the floor on cross-direction slides. Roll weight and speed determine the type of slides. Lightweight units may be as simple as sleeve bearing, nylon races or cam followers. In high-speed and heavy-roll applications, the framing is rigidly mounted to the floor and is sideshifted on linear bearings and hardened rails.

For automatic edge guiding, a leadout idler roll must be connected to the sideshifting unwind frame. This idler roll should have a nonslip surface and provide a constant web lead into a floor-mounted edge-position sensor, which is part of the edge-guiding system. The sensor may be a pneumatic or an infrared edge-position unit. It is important that the sensor is located as close to the leadout roll as possible. The sideshifting mechanism is typically a hydraulic cylinder or a servo motor. Both systems work well on most applications, but each has its own benefit. The pneumatic/hydraulic system is the least expensive and can provide the greatest shifting force. The electrical/mechanical servo system is cleaner and more accurate on a critical high-speed edge-alignment application.

Oscillation of the unwind may also be required when handling web materials that have higher-caliper bands in localized areas in the cross-machine direction. These thicker bands cause ridges in the rolls when they are wound one layer on top of another to the full roll diameter. By oscillating the unwinding web before the slitting operation, these high-caliper bands are randomized in the roll. Typically, the edge-guide sen-



1. Shaft type comparison (data courtesy of Tidland Corp.)

Material	Modulus of elasticity, 10^6 psi	Ultimate strength tubular form, 10^6 psi	Density, lb/in.^{3}	Endurance rating	Abrasion rating	Stiffness/ density ratio, 10^6 psi
Fiberglass	2	50	0.09	Good	Poor	23
Aluminum (6061-T4)	10	35	0.10	Poor	Good	100
Aluminum (7075-T6)	10	03	0.10	Poor	Good	100
Titanium (6 Al-4V)	16	140	0.16	Good	Very good	100
Steel (4130 cold-worked)	30	110	0.20	Good	Very good	107
Steel (4340 hardened & tempered)	30	160	0.20	Very good	Excellent	107
Carbon-fiber composite (33×10^6 fiber modulus impregnated with epoxy resins)	16	250	0.06	Excellent	Poor	267
Carbon-fiber composite ($57/33 \times 10^6$ fiber modulus impregnated with epoxy resins)	23	200	0.06	Excellent	Poor	383
Carbon-fiber composite (57×10^6 fiber modulus impregnated with epoxy resins)	30	100	0.06	Excellent	Poor	500

I. Comparison of shaft housing material (data courtesy of Double E Co.)

sor is moved back and forth during the unwinding operation to accomplish this randomization. This requires making a trim that is wider than the amount of oscillation. The suggested oscillation speed is 1 in./min per 500 ft/min of winding speed *(1)*.

SHAFTED OPERATION

The simplest and least expensive unwinds are of a shafted design. For shafted operations, the core diameters and roll weight must be limited for narrow widths wound on wider machines. Narrow widths cannot be unwound on small-diameter shafts without excessive deflection at higher speeds. Shafted unwinds require an overhead hoist to load the shafted rolls into the frames.

The selection of shaft type is critical for optimum unwinding operation. For each core size, the required selection criteria are as follows:

- Shaft load capacity
- Shaft torque capacity
- Shaft speed capacity
- Shaft weight
- Shaft tolerance to poor quality cores
- Shaft cost.

Most shafts pneumatically expand, and the expanding elements are either lug, button, leaf, or strip. Since load, torque, and speed are generally the most critical factors, either a lug or strip shaft is preferred for an unwinding application. For comparison of lug, button, leaf, and strip shafts, see **Fig. 1.**

The shaft material must then be selected. The three most common materials are steel, aluminum, and carbon-fiber composite shafts. This selection is based on shaft load capacity vs. shaft weight and cost. Steel shafts have the highest load capacity. However, steel shafts often require special handling equipment or additional personnel. Aluminum shafts are lighter-weight alternatives but cannot support heavy loads and are less durable. Carbon-fiber composite shafts can have the strength and stiffness of steel with less weight than aluminum. For a comparison of shaft materials, see **Table I.**

Composite shaft cost can be justified by the following benefits:

- There may be fewer operator injuries from handling of shafts.
- One operator may be able to handle a shaft that previously took two people to handle.
- There is a lower fatigue factor when the shaft is handled multiple times per day.

Composite shafts are proving to have longer lives compared to aluminum shafts. Typical wear on an air shaft occurs in the holes in the shaft body. The buttons or lugs tend to wear the holes larger due to continuous movement while transmitting torque from the roll to the drive or brake. Aluminum tends to wear rapidly in this situation, whereas composite bodies seem to become polished by the lugs and show little wear.

Shafted unwinds need to have secure latching, the capability to support the shaft's and roll's weight, and the capability to transmit the braking torque. This may be done by using shaft clamps around bearing housings and a sliding coupling or by pneumatic latching. Pneumatic latching must feature safety latches to prevent accidental unlatching while unwinding. Today, the most common shaft-latching mechanism is the mechanical safety chuck, which automatically closes as the roll is rotated. For a typical mechanical safety chuck and capacities, see **Fig. 2 and Table II.**

Max. square opening, in. (mm)	Load capacity/pair, lb. (kg)	Torque capacity/chuck, in.·lb. (N·m)
0.75 (20)	330 (150)	348 (38)
1.00 (25)	880 (400)	1080 (120)
1.25 (30)	1760 (800)	1560 (170)
1.50 (40)	3520 (1600)	3000 (330)
2.00 (50)	6200 (3800)	9600 (1060)
3.12 (80)	15,400 (7,000)	20,400 (2260)
4.75 (120)	26,450 (12,000)	87,600 (9700)
7.00 (180)	48,500 (22,000)	177,800 (19,700)
7.90 (200)	70,500 (32,000)	222,000 (24,000)
9.00 (230)	141,000 (64,000)	363,600 (40,400)

II. Application chart—Mechanical safety chuck (data courtesy of Boschert)

2. Mechanical safety–type chucks (photo courtesy of Boschert)

SHAFTLESS OPERATION

For applications that feature a large variation in web widths on smaller-diameter cores—typically 3 in. (76 mm)—or there is a wide variation of core sizes, then a shaftless unwind operation is preferred. Shaftless unwinds are more complex, with a greater number of moving parts; they also take up more space and are more expensive. However, these unwinds are much more versatile and productive than a shafted operation. Typically, the rolls are brought to the unwind from the floor, and no overhead hoist is required. The arms move in and out on a shaftless unwind to accommodate various widths and to chuck a new roll and unchuck an empty core. Many shaftless unwinds allow the arms to move down and pick up the roll from the floor or a loading cart. The arms then lift the roll to the unwinding and guiding position.

3. Pneumatic tire–type chucks (photo courtesy of Tidland Corp.)

Core size, in. (mm)	AIR PRESSURE, psi (bar) 60 (4.1)	90 (6.2)
4 (100)	3100 (350)	3820 (431)
5 (120)	3580 (404)	4060 (458)
6 (150)	4310 (487)	4060 (608)
8 (200)	14,900 (1690)	20,100 (2275)
10 (250)[b]	10,900 (1235)	15,200 (1722)
12 (300)	28,800 (3250)	39,200 (4424)

[a]Torque in metal core is approx. 10% higher.
[b]Lower torque due to internal design

III. Application chart—Torque capacity per chuck in fiber cores. Units in in.·lb. (N·m) (data courtesy of Tidland Corp.)[a]

In a shaftless unwinding operation, the shaftless chuck selection is as critical as the shaft selection in a shafted operation. For each core size required, the selection criteria are as follows:

- Chuck load capacity
- Chuck torque capacity
- Chuck roll-centering capability
- Physical space available
- Ease of making core size changes
- Core I.D. tolerances
- Cost.

Two types of shaftless chucks are commonly used in unwinding applications. These are the pneumatically expanding chucks and the mechanically expanding units. The expansion permits centering the roll and transmitting the braking torque.

Pneumatic chucks can provide positive locking and roll centering on both sides even if the torque is being transmitted on only one side. Pneumatic tire–type chucks are the least expensive and the most forgiving for loose-core I.D. tolerances. However, they are generally not as durable or maintenance free as an all-metal chuck. They also have limited torque capacity and roll-centering capabilities. For typical pneumatic chucks and capacities, see **Fig. 3 and Table III.**

Air-powered lug chucks are self centering and provide a uniform radial grip with alloy steel lugs. Torque capacity is generally significantly higher than with tire-type chucks. Core size changes are quick and easy with adapter rings. The major drawback to this style of chuck is expense when there is only one core size requirement. For a typical air-powered lug chuck, adapter ring, and capacities, see **Fig. 4 and Table IV.**

A drawback for pneumatically actuated chucks is that operators must ensure that sufficient air pressure is applied to the chucks; air leaks will result in loss of torque.

Mechanically expanding chucks use torque to automatically expand the chuck and grip the cores. They have good torque capacity and centering capability. The expansion does not require operator interaction, and insufficient air pressure or air-leak problems do not exist. The maximum core I.D. tolerances and compressibility of the cores need to be considered because, after the chucks expand to their limit, they can no longer transmit torque. Also, releasing the mechanically expanding lugs may be a problem on this style of chuck.

For applications using predominately two core sizes, stepped chucks may be a good solution for ease of core size changes. For typical mechanically expanding and stepped mechanically expanding chucks and capacities, see **Fig. 5 and Table V.**

When converting existing unwinds to stepped chucks, check the load capacity of the bearings and spindles. Heavy rolls supported on the smaller-size chucks produce high overhung loads and high bending stress on the spindles.

BRAKE APPLICATIONS

The unwind must provide web tension for web tracking, spreading, stability of cross-machine web width, and wound roll density. Low-modulus or highly extensible materials should be unwound with minimal tension. For these materials, a belt tension unwind is preferred, with draw or speed control between the unwind and rewinder. For higher-modulus or relatively nonextensible materials, the suggested winding tension is 10%–25% of the yield strength *(2)*. **Table VI** *(3)* gives the suggested tension per mil (0.001 in.) of thickness for a number of common materials.

The roll must never be unwound at a tension level higher than the roll was previously wound to prevent cinching and/or telescoping. When tension isolation between the unwind and rewind is provided, unwinding at 60% of winding tension is suggested.

The selection and size of the unwind brake is made from the maximum torque requirements. Tension horsepower is calculated as follows:

$$TH = wts/33{,}000 \qquad (1)$$

where

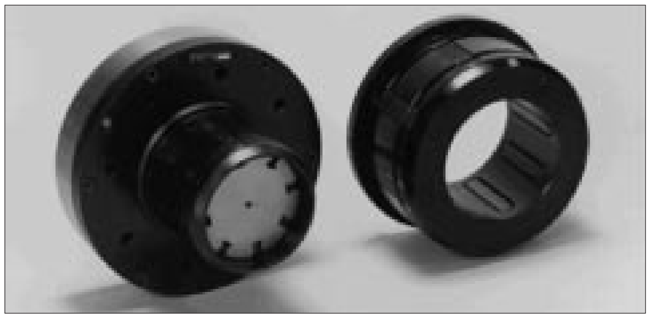
TH = tension horsepower
w = web width, in.
t = tension, pli
s = speed, ft/min.

For low-tension and -horsepower applications, magnetic particle brakes provide excellent braking and smooth control. Most converting applications use air-cooled disc brakes, which are easy to maintain and require no external cooling. Shaftless unwinds typically have brakes on both sides. This allows distributing the torque to both ends of the core and provides roll centering on both sides. On floor pickup unwinds, this also allows the use of smaller-diameter brakes so that smaller-diameter rolls can be picked up off the floor. However, for higher-tension horsepower applications, especially when operating at slower speeds, the heat dissipation of these brakes may be inadequate. Water-cooled disc brakes are then required. It is important to automatically shut off the cooling water at zero speed to prevent sweating problems.

For applications with high winding speeds, fast acceleration rates, and light tensions, regenerative DC or AC vector braking systems must be supplied. Although these systems are initially expensive, they provide excellent tension control, faster acceleration capability, and web payout and takeup functions. Regenerative tension control systems also provide savings in power consumption and maintenance costs; over the long term, this can be significant *(4)*.

TENSION CONTROL SYSTEMS

All converting unwinds must have a tension control system that controls the brake's torque as a function of the unwind's diminishing diameter, compensates for the roll's inertia during acceleration/deceleration, and compensates for winding and friction losses to achieve constant web tension. Dancer control systems are preferred for slitter rewinders where the unwind tension is isolated from the winding tension. A dancer system is more expensive than a transducer system, and web threading is generally more complicated. However, dancers allow unwinding out-of-round rolls at higher speeds. Electronic transducer control systems are preferred when the winding tension is being controlled from the unwind. Transducers provide faster response to tension upsets and provide a direct readout of the winding tension. Roll center-



4. Air-powered lug-type chucks (photo courtesy of Schlumpf)

Core size, in. (mm)	Duty	Load capacity/ pair, lb. (kg)	Torque capacity/ chuck, in.·lb. (N·m)
3 (76)	Medium	4400 (2000)	2349 (265)
	Heavy	7200 (3275)	3915 (440)
	Ex. heavy	11,000 (5000)	5829 (658)
4 (102)	Medium	4400 (2000)	3045 (345)
	Heavy	7200 (3275)	5220 (590)
	Ex. heavy	11,000 (5000)	7656 (865
5 (127)	Medium	4400 (2000)	4698 (530)
	Heavy	7200 (3275)	7656 (865)
	Ex. heavy	11,000 (5000)	9222 (1,040)
6 (152)	Medium	4400 (2000)	5638 (640)
	Heavy	7200 (3275)	9222 (1040)
	Ex. heavy	11,000 (5000)	11,484 (1300)
8 (203)	Medium	4400 (2000)	7515 (854)
	Heavy	7200 (3275)	12,293 (1400)
	Ex. heavy	11,000 (5000)	15,307 (1740)
10 (254)	Ex. heavy	11,000 (5000)	20,406 (2320)
12 (305)	Ex. heavy	11,000 (5000)	27,201 (3090)

IV. Application chart—Air-powered lug-type chucks (data courtesy of Schlumpf)

5. Mechanically expanding–type chuck (photo courtesy of Double E Co.)

Core size, in. (mm)	Size	Load capacity/ pair, lb. (kg)	Torque capacity/ chuck, in.·lb. (N·m)
3 (76)	Standard	6000 (3000)	4200 (475)
	Long	9900 (4500)	6300 (710)
4 (102)	Standard	12,400 (5600)	8600 (980)
	Long	17,700 (8000)	12,000 (1400)
5 (127)	Standard	17,400 (7900)	12,000 (1400)
	Long	20,000 (9000)	18,000 (2000)
6 (152)	Standard	20,000 (9000)	18,000 (2000)
8 (203)	Standard	20,000 (9000)	24,000 (2700)
10 (254)	Standard	20,000 (9000)	26,800 (3300)
12 (305)	Standard	20,000 (9000)	36,000 (4100)

V. Application chart—Mechanically expanding–type chucks (data courtesy of Double E Co.)

ing and roundness are critical for high productivity of smooth-sided rolls when unwinding and winding tension isolation is not provided.

WEB SQUARING

Even cross-machine web tension is important for proper spreading and good winding. When caliper or moisture variations occur across a roll being unwound, skewing of the unwind or one of the rolls after the unwind is required to even the tension from one side of the web to the other. It is important to provide a scale so that the unwind or roll can be brought back to the center position after the problem roll has been processed.

OPERATOR CONTROL STATIONS

Another important consideration for an unwinding system is the placement of the operator controls. For safe and efficient operation, the control stations need to be within easy reach of the area where the operator is working. On a shaftless floor pickup unwind, the arms should have controls to chuck a roll, raise and lower the arms, and sidelay the unwind. The ability to turn the stall tension on and off should also be provided at the arms to allow making a splice at the unwind and tightening the web before starting the rewinding operation.

An operator station at the unwind should also be provided. This station should have speed control and stop/start pushbuttons to allow slowing and stopping the operation for inspection or for cutting off quality control material. This operator station should also have an edge-guide auto/manual selector if this function is not automatic. Finally, the station should feature an emergency-stop mushroom head–type pushbutton.

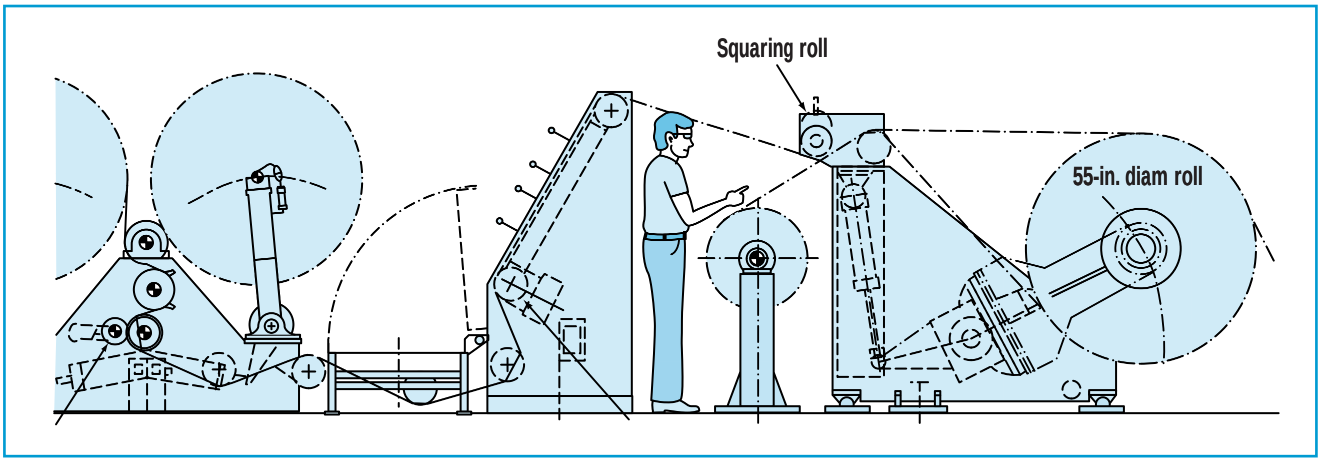
SPLICE TABLE AND SCRAP WINDERS

Rewinding operations require the splicing of webs due to web breaks, cutting out bad material in the roll being unwound, or rewinding a large-diameter roll from multiple smaller rolls. A splice table between the unwind and slitters provides the ability to consistently produce quality butt splices, which are made at an angle from the perpendicular to the edge of the web. The angular splice is important for the next process of the rewound roll. It allows introducing the splice into a nip in a wedge fashion rather than causing a severe bump.

When rewinding rolls containing large amounts of material that need to be cut out, a scrap winder also increases the efficiency, helps prevent operator fatigue, and increases safety of the operation. These small winders are located between the unwind and splice table, "packaging" the scrap rather than manually rolling it and loading it into carts. See **Fig. 6.**

CONCLUSION

Too often, the unwind on a slitter rewinder operation doesn't get the respect it deserves. How many times have you heard this operation called the unwinding, slitting, and rewinding operation? Proper selection of the unwind and auxiliary equipment is very important to ensure the maximum performance and productivity of a slitter rewinder. The information presented in this paper can hopefully be applied to select an unwinding system that will enhance the slitter rewinder operation. TJ



6. Splice table and scrap winder

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Received for review May 12, 1998.
Accepted June 12, 1998.

Material	Winding tension, lb/in./mil
Paper and paperboard	0.55
Polyester (Mylar)	0.50
Nylon	0.25
Polypropylene (unoriented)	0.25
Polypropylene (oriented)	0.50
Polyethylene	0.25
Polystyrene	1.00
Cellophane	0.75
Acetate	0.50
Aluminum foil	1.00

VI. Winding tension vs. material and thickness (3)

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