

Modern converting equipment and controls for source and waste reduction

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THE MOST VISIBLE TYPE OF WASTE in extrusion coated products is the unusable product roll that comes off a winder. Many different problems cause this. For example, gauge bands can create high spots and an uneven finish on the roll. Web handling problems can create many different types of wrinkles in the product. Poor web tension control or lack of guiding can result in starring or ends that are not square. Problems of roll formation are fundamental to successful operation of any extrusion coating line. This paper will not discuss these problems. It will examine other types of waste that contribute to cost of a product. Some items are edge bead, edge trim, splice tail waste, and scrap at finished roll transfer. Extrusion coating operations commonly accept these types of material waste as a necessary part of the operation.

Other types of waste in this process are hidden waste. Downtime, setup time, and handling are examples of hidden waste.

Downtime results from something in the machinery or process that causes stopping until the problem is fixed. Some key questions can easily locate problem areas:

- Does a particular part always seem to break, wear out, or need maintenance?
- Do some parts need cleaning more than others?
- Can one identify a common or frequent cause of downtime?

A positive answer to any question identifies an area where new parts or techniques could help to reduce costs.

Setup time is the time necessary for a machine to produce quality product. This could include time for threading, adjustment of die bolts, slitters, or edge guides. Setup time also includes tension adjustment, draw adjustments, and nip loading adjustments. Even preparing for different quality checks can consume time. Many necessary activities reduce the available productive time of the machine.

Handling time for a product is the number of times required to process the product. For example, a product may require processing through an extrusion coating line twice to coat each side. After this, the material may go to a slitter and winder for processing into final widths. If the product includes printing with graphics, this requires yet another line. Combining processes can greatly reduce such handling. Combinations could include in-line printing, in-line slitting, or tandem coating. Note that increasing line functionality can cause additional downtime and longer setups. Care is necessary to avoid complicating the process.

ECONOMICS OF PRODUCING EXTRUSION COATING AND LAMINATING PRODUCTS

The product cost of a typical extrusion coating product has three components. The first is material cost. The easiest measurement of material cost is cost per unit weight. The resin por-

ABSTRACT

Waste can be the difference between success and failure in business. Most plants track waste. This effort is often part of the total quality program to ensure production of product as planned. Such programs often result in continuous improvements of the existing process, but they seldom look beyond the inherent limitations of the process. This paper addresses some accepted limitations by noting their costs and how new technology can be a cost-effective method to increase productivity. It examines specific sections of a basic extrusion coating line. Possible disadvantages of each solution will evaluate the feasibility of the solutions. Each section will have a variety of equipment, controls, or source ideas to give several alternatives.

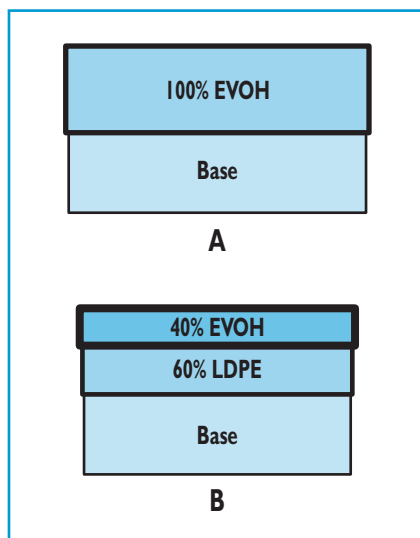
Application:

Various alternative are available to reduce waste in an extrusion coating or laminating operation.

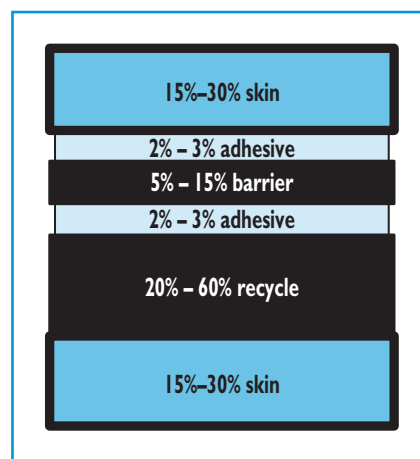
tion of this cost is the ratio of the saleable resin produced divided by the resin used multiplied by the resin cost. This ratio accounts for all losses including off-line drool.

Using 50,000 kg resin costing US\$ 1.00/kg, the actual resin cost is US\$ 1.11 if 45,000 kg are the resulting usable amount of resin ($\$1 \times 50,000/45,000$). Adding the cost of resin to the cost and weight of any other materials used in the structure gives the total material cost and weight.

Machine cost is the next component. Since material cost uses cost per unit weight, the machine cost should have similar units. This value should include the cost of labor and benefits for the operators, amount of setup time for the product, total number of run hours, and through-



1. Coextrusion using a less expensive resin



2. Coextruded structure containing recycled material

put in kg/h.

The last cost for an extrusion coating product is allocated cost. This includes utilities, maintenance, operating supplies, and other miscellaneous items of production. Dividing these costs by the hours incurred gives cost/h. This value divided by the throughput in kg/h gives cost per unit weight.

Consider as an example the product cost for toothpaste tube stock (1). The raw material cost was US\$ 2.09/kg (US\$ 0.950/lb), machine cost was US\$ 0.165/kg (US\$ 0.075/lb),

and allocated cost was US\$ 0.011/kg (US\$ 0.005/lb). Total cost was US\$ 2.365/kg (US\$ 1.075/lb). In this example, 88% of the total cost is resin, 7% is converted costs, and 5% is indirect costs. These numbers are only an example to demonstrate costs of extrusion coating products and show that most cost relates to material. The biggest target areas for improving total economics of the operation should therefore be resin and material waste reduction.

COST AND WASTE REDUCTION OPTIONS

Resin related structures and coextrusion

Resins that have very specific purposes in extrusion coating and laminating are usually expensive. Examples of special purpose resins are those that bond to foil, provide better control of oxygen or water vapor transmission, give odor protection, offer a surface more acceptable to printing and metallizing, or improve sealing properties. The process of coextrusion usually combines special purpose resins. Coextrusions produce several layers of plastic simultaneously. These layers often consist of adhesive or tie layers to promote bonding of adjacent layers of plastic. This provides the properties necessary in a product while lowering resin costs.

As an example of cost reduction, consider ethylene vinyl alcohol copolymer (EVOH), a primary barrier resin. Flexible barrier packaging has gradually been supplanting some uses of foil laminations and glass. The advantages are lower cost, easier processing, good transparency, and long shelf life. EVOH is an expensive resin. Other new or refined resins are under examination to reduce cost. One possible resin is 3 layer, monoaxially oriented nylon (m-OPA). Although this resin has a high oxygen barrier transmission rate, it has use for less demanding

applications. Material savings using m-OPA over EVOH are approximately 42% (2).

Using resin blends can reduce costs. For example, ionomer resins blended with EVOH provide characteristics and processing of EVOH at lower costs. Another technique is coextrusion of an inexpensive resin such as low density polyethylene (LDPE) with EVOH as Fig. 1 shows. The challenge in coextrusion is matching resin properties. The viscosity, shear rate, and velocity of the resins being combined must be almost identical. If product A in Fig. 1 is EVOH and product B is 40% EVOH and 60% LDPE for example, resin costs would be 54% lower for the same coating thickness. This is because EVOH is about 4.4 times (3) more expensive than LDPE. The disadvantage of this product would be reduced clarity. A typical application might be high barrier, flexible cookie packages. These packages are typically oriented polypropylene (OPP), EVOH, and LDPE laminations (4).

Multiple layer coextrusions can also have a layer of recycled material in the center. The product of Fig. 2 is a six layer structure with 20%–60% recycled material. If a converter only had one extruder, additional extruders and a feed block with a changeable plug would be necessary. This extra equipment can be expensive, but resins savings and the flexibility for other products can easily justify these costs.

Edge bead reduction dies

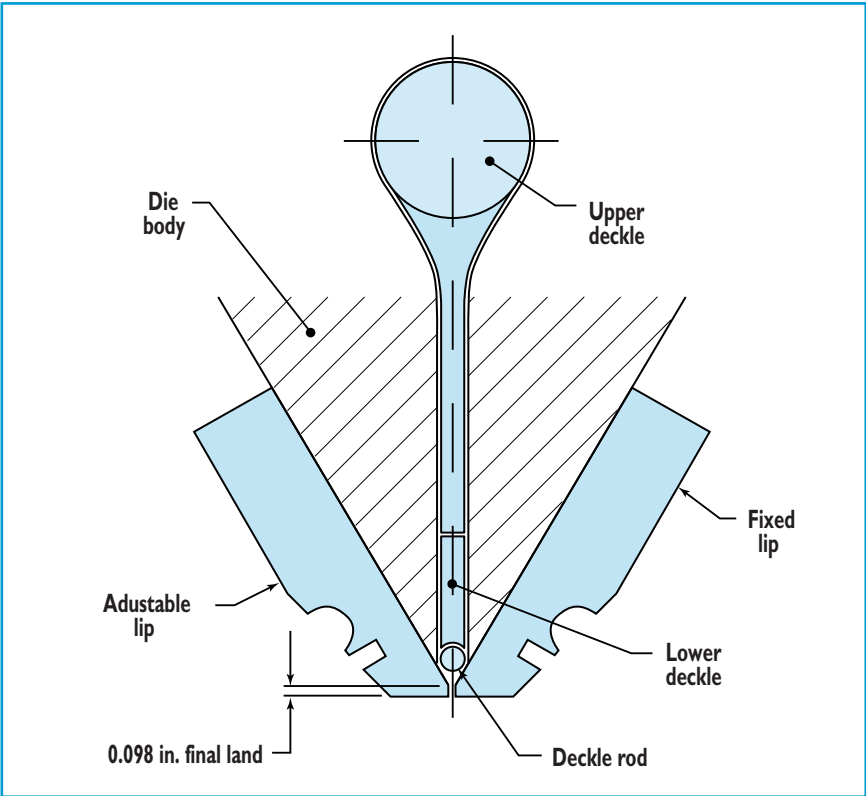
Oxidation is an important effect necessary for bonding in extrusion coating and laminating. For high speed extrusion processing, long air gaps are necessary to allow adequate time for oxidation to occur. This contributes to excessive edge beads. A large air gap between the die and chill roll causes the hot polymer to neck-in further. Increased neck-in results in heavier edge beads. Other factors that cause increased edge

bead are high melt temperatures, slow line speeds, lower viscosity resins, and low melt strength resins. These factors cannot be changed significantly to provide cost savings. The only other choice is to decrease the polymer on the edges as it leaves the die to create a flat profile after neck-in.

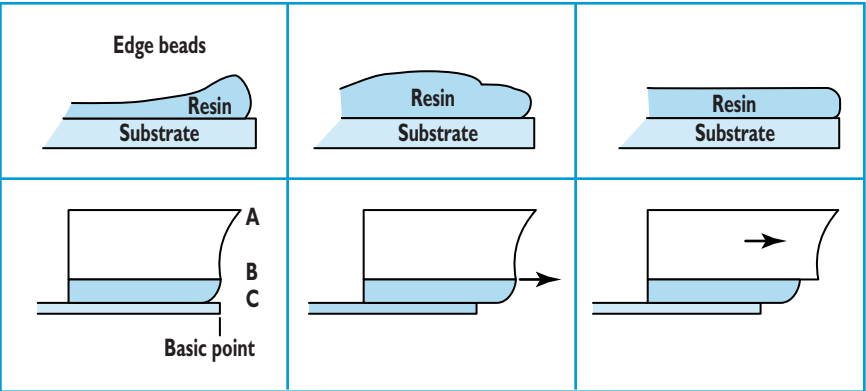
Edge bead reduction is possible in external and internal deckled dies. The premise and basic parts for both dies are very similar. Most edge bead reduction dies have three decks as Fig. 3 shows. The graphics for this discussion use an internally deckled die. In Fig. 4, the upper deckle, lower deckle, and rod start in line. A sample edge bead is collected and measured with a micrometer accurate to 0.0025 mm (0.0001 in.). Rod "C" remains in position while the upper deckle "A" and deckle flag "B" move together. This provides coarse adjustment. The "A" deckle then moves to reduce the thickness of the bead. The deckle system can then be moved to decrease the coating width. After the edge is flat, the process can run with or without overcoat. For either option, the amount of edge trim can be reduced or eliminated. In addition to cost and waste savings, wrap-ups at the chill roll can be reduced because edges are thinner and cool more rapidly. Nip roll life increases due to a more even polymer thickness across the web. These characteristics also help to reduce downtime.

How much money can be saved using a bead reduction die (BRD)? Table I (5) shows possible savings in one year from a simple base material with polyethylene extruded on both sides using edge bead reduction. Financial savings result from reductions in resin use, downtime, and waste. As base stock costs and resin costs increase, the potential savings from this technology grow accordingly.

Three obstacles must be over-



3. Edge bead reduction die



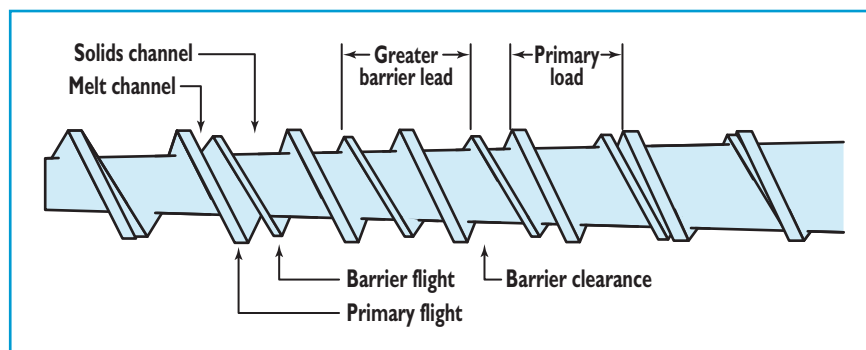
4. Basic patterns for deckle adjustment (Rod always remains at basic point when lower deckle, upper deckle, or both are forwarded. Then locate the adjusted assembly (A+B+C) to the substrate edge.)

come for successful edge bead reduction. The first is investment for a new die. This is easy because the money saved in resin alone means that the die will pay for itself in a matter of months. The next problem is operator mindset. Many operators are accustomed to seeing a die with edge bead that requires trimming. The idea of running without trim is

often foreign to them. The biggest obstacles are the amount of practice that is necessary to learn edge bead reduction and the possibility that some polymers may not be able to run without a bead. Considerable training and persistence by the operator is necessary, but the benefits can be substantial.

STRUCTURE COST				
Structure	Weight, g/m ²	Cost, US\$/1000 m ²	Cost, US\$/ft ²	
16 g/m ² (10 lb/ream) LDPE	16	17.65	1.64	
80 g/m ² (50 lb/ream) Bleached kraft	80	123.54	11.48	
16 g/m ² (10 lb/ream) LDPE	16	17.65	1.64	
Totals	112	158.83	14.76	
WASTE ANALYSIS				
Width (1500 mm finished)	Before BRD, mm	Overcoat/trim After BRD, mm	Difference, mm	
1st pass polyethylene trim	205	10	195	
2nd pass polyethylene trim	205	10	195	
Paper trim	51	8	43	
WASTE SAVINGS				
Width (1500 mm finished)	Weight saved, kg/h	Savings, US\$/h	Available h/year	Savings, US\$/year
1st pass polyethylene trim	10	11	6989	73,596
2nd pass polyethylene trim	10	11	6989	73,596
Paper trim	11	16	6989	113,602
Total				260,794
MATERIAL USE				
	Metric	US		
Line speed	305 m/min	1000 ft/min		
Width	1.52 m	60 in.		
Square area/day	667,584 m	7,200,000 ft		
Downtime	20%	20%		
1000 square area/year	194,935 m	2,102,400 ft		
Material cost/year	US\$ 30,961,841	US\$ 30,961,841		
Waste (1% of total use)	US\$ 309,618	US\$ 309,618		
DOWNTIME SAVINGS				
Machine hour rate	US\$ 1000/h			
Edge bead web breaks	50/year			
Downtime cost	US\$ 50,000/year			
SAVINGS SUMMARY				
Reduced resin use	US\$147,192			
Reduced substrate use	US\$ 113,602			
Reduced waste	US\$ 309,618			
Reduce downtime	US\$50,000			
Total	US\$620,412			

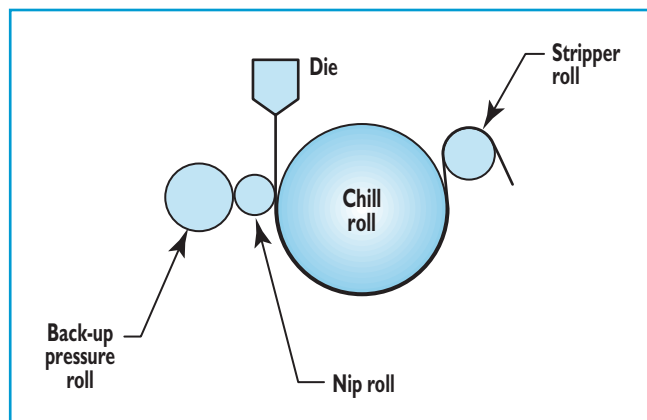
1. Savings analysis using a bead reduction die



5. Extra flight for barrier screw

Downtime and screw design

Few extrusion coating lines run a dedicated product and resin through their extruders. After optimization of a screw for a particular resin, the screw may perform poorly with other resins. A screw change may be necessary for significant product changes. This can be very expensive depending on how much disassembly of equipment is necessary. Most cases require removing the feed pipes, valve, and screen changer. Depending on design, the die, feed



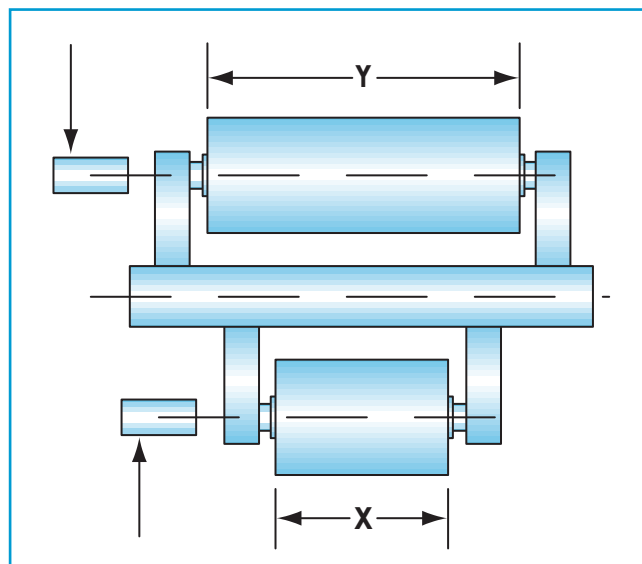
6. Laminator

block, or die support may also need disassembly. Removing the screw itself is also difficult after the other parts are disassembled. This entire process can take 2–8 hours. A machine running 300 m/min (1000ft/min) loses production of 36,000–144,000 m (120,000–480,000 ft) of material.

One answer to this problem is a general purpose screw design. The screw designer considers all the resins the screw will run, their product importance, amount of running time, cost, and processing limitations. A screw is designed that can run all the materials within some defined processing limits. This is a good solution provided output is sufficiently high to produce the desired coating weights at top line speeds. When deciding on a new screw design, one must be realistic. Do not ask for a design that will run everything imaginable. This is impossible. Concentrate on current needs. The cost of changing to a different screw later may be much less than the cost of poor performance with a screw designed for possible future needs.

A barrier screw design may have use as a general purpose screw. This screw has an extra flight in the transition to the metering section as Fig. 5 shows. This flight is not as deep as the primary flight because its purpose is only to separate the melt from the unmelted material. This is a very efficient method for melting a polymer with low shear input and improves output. Smaller screw diameter gives less improvement in output. This screw style is not always the best answer for very high temperature applications. If desired output from a general purpose screw is still insufficient, multiple screws optimized for specific materials may have use to increase outputs and improve melt quality.

The time required to change a screw is important. A pull through valve and screen changer can have use in place of a traditional valve and screen changer. This valve has a removable cap and stem. The screw can be pushed through this valve without any other disassembly. A specific resin screw can give higher outputs while minimizing changeover time. Removing the cap and stem from



7. Adjustable arm unwind

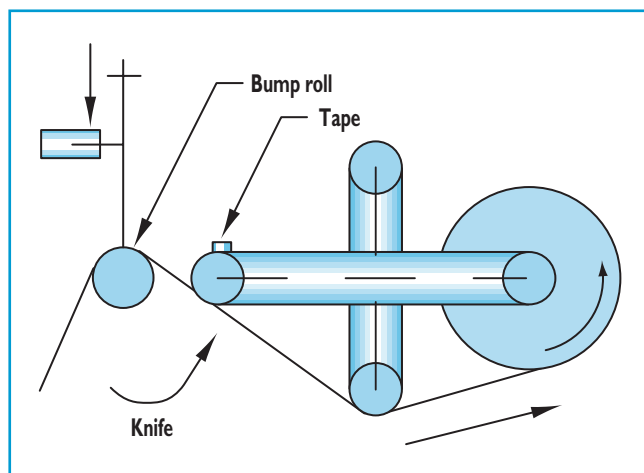
the valve should take about 15 min compared with 2–8 hours of disassembly depending on system design.

Setup time for extrusion coater and laminator

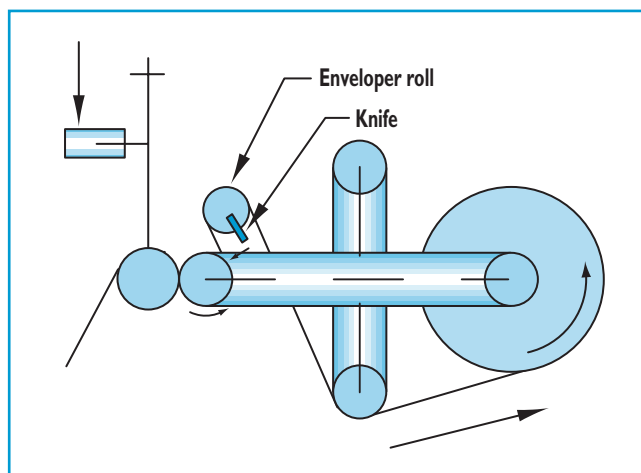
Today's extrusion coating machines incorporate many small details that save setup time and improve efficiency as Fig. 6 shows. The backup pressure roll has double shell construction for more efficient cooling. This allows higher extruder outputs and provides the capability of nip load adjustment. Precision nip loading controls allow repeatable and even impressions across the chill roll. This adjustability allows running a wide range of products on the line.

The rubber-covered nip roll may require frequent changing due to wear from the effects of overcoating. In addition, cleaning polymer wrap ups can easily damage this roll. The roll may have mounting in the frames for easy lifting. Fifteen minutes is necessary to change a nip roll.

Chill roll design is very important. Typically, a heavy inner shell supports the thin outer shell with spiraled flights for rapid and efficient heat transfer on heavy coating weights. Design of this roll can also provide quick changing. Cartridge style bearings mounted in a housing and held by a quick removal retainer plate facilitate changing. The mechanical drive can have two gears—one nylon and the other steel. These allow instant separation after removal of the guard. Rotary unions with quick disconnects complete the quick-change package. After removal of the plates that capture the chill roll bearings, the roll with bearings, nylon gear, and rotary unions lift out together. Another roll with bearings, gear, and unions can readily take its place. The machine can be ready for operation in less than 30 min. This is a great feature for lines that need a mirror finished chill roll for some products and a matte finish roll for others. Another time saver is providing a threading chute that runs around the chill roll. Because this is a very difficult roll to thread on the



8. Bump and cut



9. Core enveloper

line, the device works well with heavy paper products or board.

Most extrusion coating operations use polytetrafluoroethylene tape on the nip roll. This tape is expensive and quickly damages the rubber on the nip roll. Polytetrafluoroethylene belt systems are available to replace tape on the nip roll. These systems use an endless belt that winds around the nip roll with a tensioned take-up pulley. Two types of belts are available: fiberglass or aramid fiber impregnated. The aramid fiber belts last longer than the fiberglass but cost considerably more. Heavy edge beads can cause heat distortion of polytetrafluoroethylene belts leading to premature failure. To combat this heat distortion problem, vortex air coolers can blow chilled air on the tape for cooling. The entire belt system can be motorized and provided with a linear voltage displacement transducer (LVDT) for position feedback when accurate and frequent positioning is necessary. Setup can be less with use of this system. The nip roll will last longer. This means fewer removals for regrinding and recovering.

An automatic drool catcher is a unique feature that protects machine elements from the melt curtain when the extruders and die move on and off line. This allows easier operation,

reduces clean up, avoids possible wrap-ups, and prevents polymer interference with the nip roll loading system.

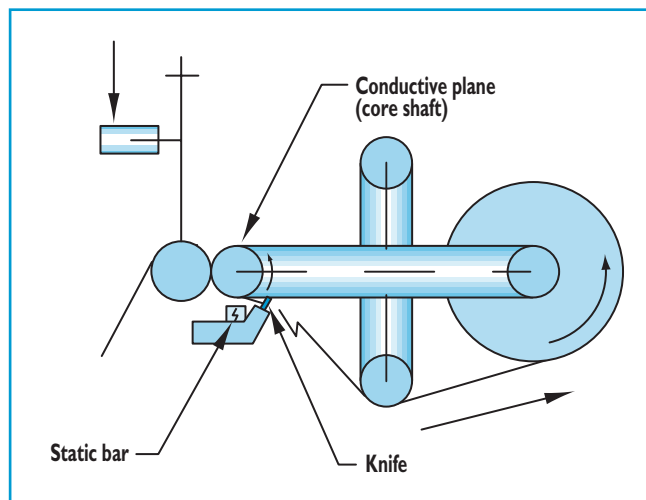
Setup time time for unwinds and splicers

Consideration of the benefits of shafted vs. shaftless operation is important. Handling of heavy core shafts can cause operator fatigue and contribute to back injuries. On wider lines, aluminum shafts may not be sufficiently strong for the roll weights. Steel shafts are very heavy and require more time and effort to set up the unwind. Carbon fiber shafts are lightweight like aluminum but with strength comparable to steel. These shafts are expensive. Composite shafts can have a modulus greater than steel with weight less than aluminum. Any of the above shafts can have automatic shaft inflation. This removes the chance that an operator will forget to inflate the shaft and damage machinery or waste material. With shafted operation, one spindle can handle one width while another undergoes setup.

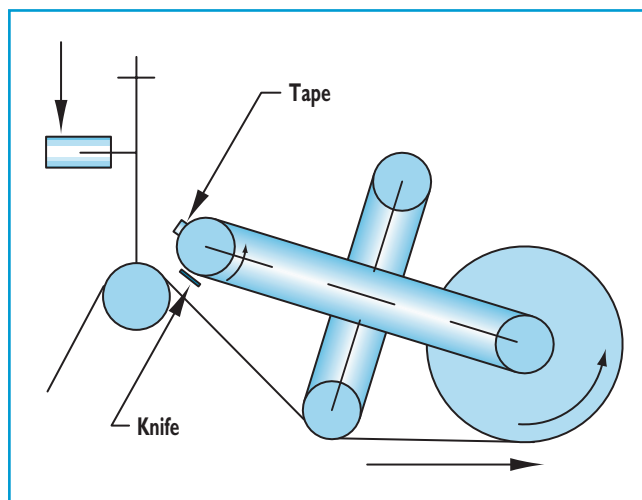
A shaftless unwind operation removes the extra handling necessary for shafted operation and makes loading of rolls easier. As with shafted operation, automatic inflation is pos-

sible on the chucks. Traditional shaftless operation does not allow running dramatically different widths on each spindle. If the width is different, the line must stop for removal of both rolls. Addition of individually adjustable arms on the unwind as Fig. 7 shows solves this problem. Shaftless operation saves money through the lower cost of no replacement shafts and decreased setup time. Shafted winders are least expensive followed by shaftless and shaftless with adjustable arms. Independently adjustable shaftless units are the most expensive.

Additional savings are possible through the available features of modern splicers. Rolls as small as 25%–33% of the maximum roll diameter can be spliced. This means that small foil rolls or small runs of material can be put into the machine without stopping and making a manual splice. This saves material and time. Noncontact diameter input is a feature that allows unwinding a roll as close to the core as possible without accidentally running the web off the core. Spindle splicing targets eliminate the need for reflective tape that can fall off or become lost. The adjustable target rotates to the prepared splice on the incoming roll to ensure a good splice. All these features allow unwind splicing effi-



10. Static transfer



11. Stationary knife

ciency of 98% or better to reduce downtime and waste.

Automatic roll change systems

Many different methods are available for automatic roll changes. They include bump and cut, static, core enveloper, and stationary knife cut-over. All these methods have specific applications that depend on speed, materials, and core preparation.

The bump and cut is the least sophisticated method. It usually has use on slower speed lines of 300 m/min (1000 ft/min) or less. The method requires tape on the core for transfer and is the least effective method for waste reduction. The core is taped, the bump roll is actuated with a cylinder, and the knife is fired as Fig. 8 shows. The disadvantages of the method besides requiring tape are a large amount of fold-back and poor core starts.

The core enveloper of Fig. 9 consists of a lay-on roll that nips the winding web against the new core and an enveloper roll and knife on an arm. The enveloper arm pivots around the new core to wrap it. The knife on the arms cuts the web. The cut web is drawn into the nip between the lay-on roll and the core. This method needs no tape and is effective for speeds up to 400 m/min (1300 ft/min). Some fold-back occurs with this method, but it is small and very uniform. This method saves the cost of tape and limits waste at the

core start. For highest effectiveness, the knife speed at cut must exceed the web speed. This requires a sophisticated system to accelerate and stop the knife in a short span. The system may be maintenance intensive.

The patented static transfer method puts a charge on the web as it is cut. Figure 10 shows the method. The finished roll is indexed into the outboard position. A lay-on roll nips the new core. An arm is pivoted into the web. As the arm approaches the web, a static charge accumulates on the web causing attraction to the grounded core shaft. After the charge has developed, the knife cuts through the web. The static holds the web to the core shaft, and the transfer is complete. The biggest saving from this method is the elimination of tape. Less setup is necessary to prepare for the roll change. The method is effective for speeds up to 457 m/min (1500 ft/min). The amount of fold-back on the start of the core depends on mechanical design and web speed. When the knife is closer to the core, the amount of fold-back will be smaller. This method generates only small waste at the start of the roll. Shafted winders are necessary for static transfer operation to provide a path to ground for the static charge. The method is only effective on light flexible products. Metallized foils, alu-

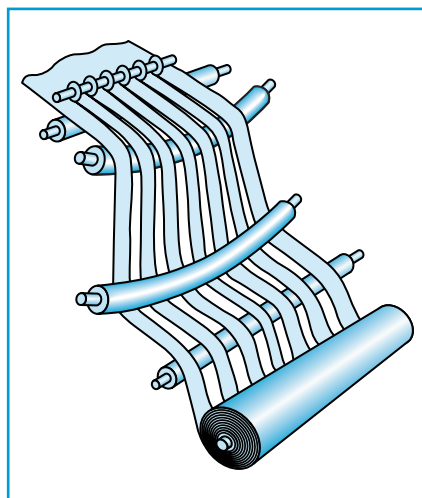
minum foils, and heavy paper will not work.

The last method is the stationary knife method of Fig. 11. This patented technique is the only one that has cut-off knives on the turret instead of the roll changer. The new core is brought into roll change position. This position is 25 mm away from the lay-on roll. The stationary knife cylinder is actuated to bring the knife close to the core. The actual roll change occurs by indexing the turret into the lay-on roll. The geometry of indexing moves the knife into the path of the web—the knife does not “fire” into the web. This provides a few key advantages over other systems. The technique has no practical speed limit and no fold-back of material. The material has a square cut. All these factors mean an excellent core start to give the best opportunity for a perfectly wound roll with no waste at the beginning. The only disadvantage to this method is the need for tape.

PROCESS REDUCTION OPTIONS

In-line printing

A typical extrusion coating company has several types of machinery. An area contains extrusion coating and laminating lines. Another area has printing lines. Still another area has slitters and rewinders. In many cases, material undergoes printing on one line followed by extrusion coating or



12. Dual expander rolls

laminating on another line. This requires handling the material more than once and provides opportunities for error or damage. Duplicate equipment exists on each line such as winders and unwinds. In-line printing reduces equipment costs, number of operators, material handling, and process time. Many considerations are necessary before attempting in-line printing. The first is changeover time necessary for most printers. This fact could limit production. The second item is the complexity of the printing involved. If a product needs six different ink colors for example, considerable downtime could occur in the process. If the printing jobs are simple and need few cylinder changes, in-line printing may save money.

In-line slitting and edge trim

After printing and extrusion coating, the finished product goes to a slitter rewinder for final processing. Avoiding this operation is possible for certain products. The necessary conditions are proper web handling, edge trim, and in-line slitters. Web handling should produce finished rolls that are flat and square. The line should have edge guiding capabilities in each primer, laminator, and laminate unwind path. Most converters take trim on their extrusion coating lines

to remove the overcoat or edge bead. This edge is often retrimmed at the slitter rewinder. If the blades undergo proper maintenance and changing when dull, the edge trim slitters on the extrusion coating line can be the final edge cut. The best location for these slitters is directly after the laminator.

If the final width of product is narrower than the width being run, in-line slitters should be on the roll changer just before the winder. This is possible with two methods. The first method requires taking bleed trims of 12–25 mm (0.50–1.00 in.) width between each finished product roll. A less expensive method is use of the dual expander rolls of Fig. 12. The two rubber-covered bow rolls spread the slits apart without undue stress or distortion. No bleed trims are necessary. This method will not work for all products. For example, a slippery product will slide around too much for a decent finished edge. Although all products cannot be finished by this method, any products that can will provide savings. Besides generating waste with bleed trims, trims can seldom be recycled back into the product at this point. Disposal fees therefore occur.

Tandem extrusion coating and laminating lines

Many coated products require coating each side of the substrate. A tandem extrusion coating and laminating line is more expensive, but it offers many benefits over a single-station line. A tandem unit eliminates the need for double-pass products. This saves machine use and may provide resin changeover savings. If a product consists of a base structure that has one resin structure on one side and a different resin structure on the other side, changeover for the second side requires material and time expenditures. A tandem line allows running a structure without any changeover. Twice as much product processes through a tandem line

compared with a single-station line.

Another feature of this line structure is the setup time savings for products that only need a single station. If the first station is running product A, the second station is bypassed. The second station can be cleaned, and preparation can occur for product B. When product A is complete, the first station can be taken off line. The second is already set up for product B. The operators can start running immediately and ready the first station for the next product. This setup provides flexibility for unknown future products.

Controls and supervisory system

How many different panels do operators have to use before starting an extrusion coating line? When the line goes down, a splice is missed, or the web breaks, how many different places must an operator be before restarting the line? If the line will not start, how long does it take the operator to find the cause? The answers to these questions depend on the type of machine control. If the line has a supervisory control system, most functions can occur at one station. The supervisory station can have a comprehensive list of operating parameters for the line. Recipes can be saved for a particular product. Running each particular product can use a specific recipe. Operators do not need to remember or relearn the optimum running parameters. The supervisory system can handle many systems such as resin handling and treating. The operator can obtain a good view of the machine and current running conditions of all systems in one place. Besides operating parameters, alarms can display detailed information on the nature of a problem. The operator only needs to go to one place to determine the location of the problem. All functions, alarm history, tending, and recipes are stored and retrieved to make reports easy and accurate. A supervisory system can easily adapt

to each customer's needs. The supervisory system's touch screen interface and monitors provide more data, ease of operation, reduced maintenance, installation, and calibration costs.

SUMMARY

Most cost of producing an extrusion-coated product is due to materials consumed. Reducing the consumption of raw materials through careful selection of equipment and selecting the least expensive resin or combination of resins for the desired product characteristics are therefore important for reducing costs. No single method or type of equipment will

accomplish this task. A thorough understanding of the product structure is necessary with careful consideration about how best to meet the requirements. This paper gives a starting point and a variety of ideas to achieve a less expensive product. **TJ**

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