Electrostatically assisted core starts on automatic winders

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ABSTRACT: Electrostatically assisted core starting is a method by which the leading edge of various types of films can be adhered to cores after being cut on automatic film winders. The basics of electrostatic charging are discussed, with specific emphasis placed on its application to this core-starting technique. Guidelines for practical installations on winders also are given. The method is compared to other transfer techniques such as double-sided tapes, adhesives, and liquids with respect to operating costs, recyclability of cores, and end-user productivity.

KEYWORDS: Automatic systems, cores, electric charge, electrostatic charge, winders, winding.

For years, converters have used tape and adhesive systems to mechanically bond the tails of cut papers, nonwovens, textiles, and films to new cores on automatic winders. This technique allows for a positive, strong bond of the web to the core during high-speed transfers. However, pressures on converters to reduce operating costs, provide products of the highest possible quality, and be environmentally conscious have caused them to look for alternatives to these core-start methods.

Several problems with these mechanical systems are discussed frequently by the various processors who handle the wound roll. At the converter level, the problems include tape and adhesive cost and 100% recyclability of the cores. At the user level, these problems can slow down the process to manually cut out the glued or taped material and make it impossible to recycle cores 100% or to use all of the converted film that comes from the converter.

Electrostatically assisted core starts

Electrostatically assisted core starts overcome these problems in many automatic winder configurations by applying an electrostatic charge to the film for attraction to the core. A brief synopsis of the electrostatic charging principle will clarify this concept.

Insulating films can be held to each other or in place temporarily by the forces of electrostatic attraction. Once a material has been charged, an electric field can be set up between it and other oppositely charged materials or ground (**Fig. 1**). The presence of this field has an associated force which acts upon the film, pulling it toward other oppositely charged or grounded surfaces. Single or multiple layers can be temporarily held in place by these attractive forces. The material retains this force as long as the charge remains.

There are two parts to an electrostatic charging system (**Fig. 2**) used to create these charges and the associated forces. The first is an electrostatic charging generator, which is used to create the controllable high voltage necessary for proper charging. After taking in standard plant power, the generator rectifies the voltage to a high (30–40 kV) dc potential. Both positive and negative charging generators are available, depending on the type of charge needed. In addition, the generator serves to safely regulate the output current, control the output voltage, and provide signal and control functions (remote on/off, alarm current feedback, over-current protection, etc.). Connected to the generator via an insulated cable is a charging device (bar, single electrode, etc.) which creates air ions. Ions are created near the electrodes and are directed by the electric field that is set up between the electrodes and ground to the material to be charged (**Fig. 3**). The insulating material then is placed between the electrodes, and a ground reference and the charges are "trapped" on the surface of the film

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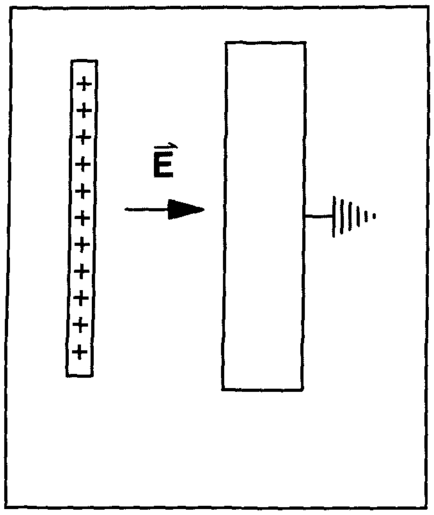
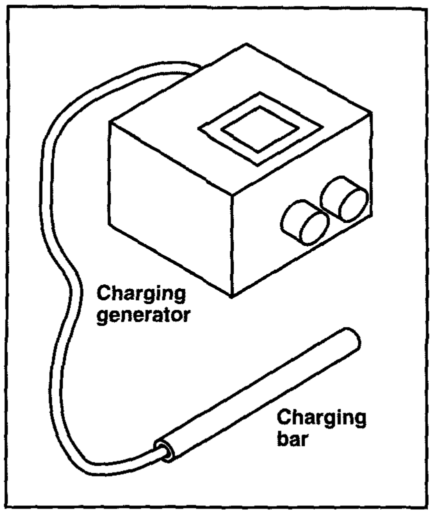
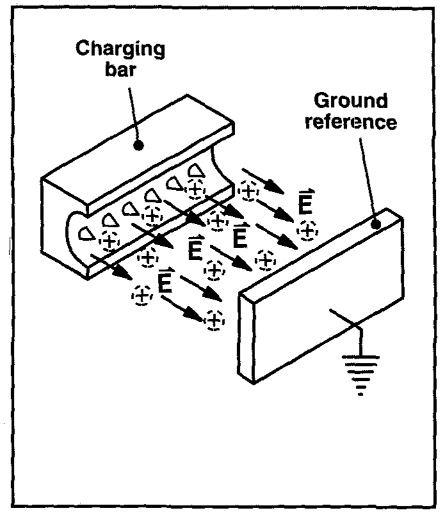
1. Charged web sets up electric field to ground.



2. An electrostatic charging system



3. Ions flow to ground in field set up between electrodes and ground.



(**Fig. 4**). Now the field is established between the film and ground and, therefore, is attracted to that ground reference (**Fig. 5**).

The objective of the electrostatic charging system is to produce sufficient charge density on the surface of the web such that when the cut is made, the leading edge of the charged web is attracted to the core. This means charging must occur prior to firing of the knife. To gain a complete understanding of the web dynamics, a closer look at the forces acting on the web is in order.

Web dynamics

There are several forces acting on the web just after the moment the web has been cut. A force diagram of this dynamic situation is shown in **Fig. 6**.

P is the momentum vector acting on the web in the direction of web travel the moment after it has been cut. Its magnitude is significantly lower than the outgoing tension that existed prior to cutting the web. It is a function of the linear speed and the film's mass. This vector's magnitude increases with heavier-gauge and more dense films and at higher operating speeds. The momentum vector's sign and direction is given by Eq. 1:

$$P = m \times v \qquad (1)$$

where

m = mass of the web

v = velocity of the web.

A basic understanding of both the electrostatic charging principle and web dynamics help to explain electrostatically assisted roll changeovers.

The sequence of events during a typical automatic turret winder roll change is:

1. The outgoing core builds up to a specified diameter where the winder is ready for a changeover (**Fig. 7**).
2. The turret holding the outgoing core rotates (**Fig. 8**), bringing the new incoming core into the changeover position (**Fig. 9**).
3. The knife moves into position and cuts the web. Upon being cut, the web is adhered to the new incoming core (**Fig. 10**).
4. The film begins to wind onto the new core at a position at which it stays until it builds up again (**Fig. 11**).

E is the electrostatic force of attraction acting on the web due to the deposited charge. Both the magnitude of the charge and the electric field play a role in the force's strength. Its direction is radial to the nearest grounded surface or opposite charge. The magnitude and direction of the force acting on a square unit area of the web is given by Eq. 2 (in a very simplified form for discussion):

$$E = \sigma \times \varepsilon \qquad (2)$$

where

σ = charge per unit area (charge density)

ε = electric field acting upon a unit square area of the web.

Charge density on the web is a function of the charging current. The charge density on the web's surface is affected in accordance with Eq. 3:

$$\Sigma = i/v \qquad (3)$$

where

i = charging current per unit width

v = linear web speed.

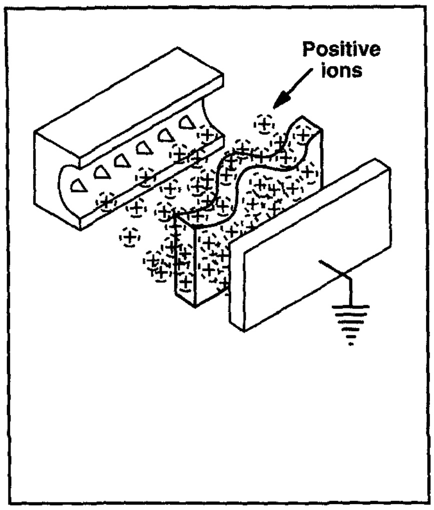
From these relationships, the direct impact of charging current to the holddown force can be seen.

The objective of a successful roll changeover is to ensure that the resultant vector in the x direction given by Eq. 4, $R(x)$, is large enough to make attraction to the web possible:

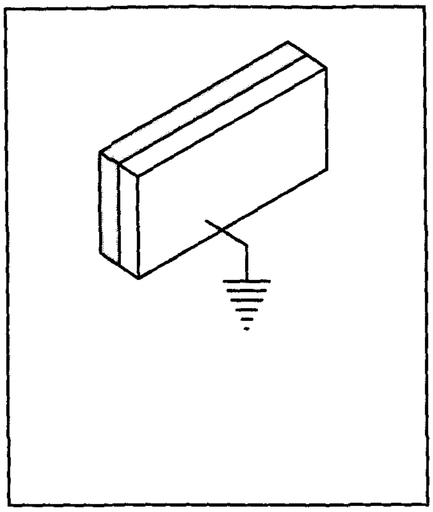
$$R(x) = R \cos \alpha \qquad (4)$$

The knowledge of what parameters affect this result is important to understanding the requirements of a successful electrostatically assisted core start.

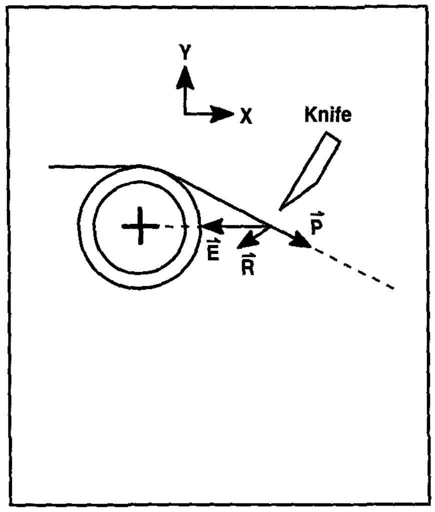
4. Charges trapped on insulating surface



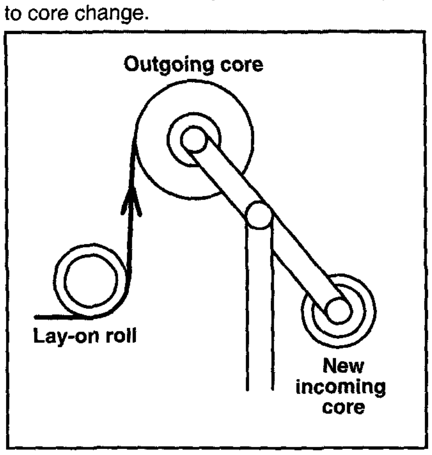
5. Charged surface sets up field to ground and is attracted.



6. Force diagram for leading edge of web the moment after the knife cuts the web



7. Roll size reaches specified diameter prior to core change.



Several parameters affect the proper installation of electrostatic charging equipment for electrostatically assisted roll starts. Factors affecting the successful use of electrostatics for adhesion of the web to the core include:

- The use of a proper ground reference
- Charging current
- Linear web speed
- Material
- Gauge of the web
- Wrap angle of the film on the new core
- Type of core used
- Position of the knife.

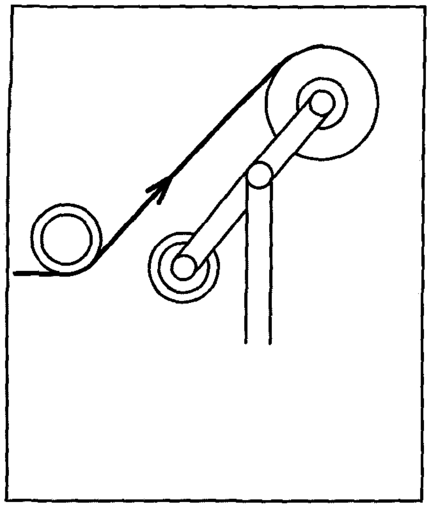
The existence of a ground reference opposite to the charging bar is a requirement for the proper use of electrostatic charging for core starts. One of the two elements supporting the incoming core structure can act as this ground reference. A mandrel supporting the core is the element most widely used for this purpose. The mandrel must run the complete length of the core. Shaftless winding, where air shafts chuck the core at the ends, will not suffice. Metal cores also can provide the ground reference needed for charging. In both scenarios, the ground reference through the bearings of the mandrel to the machine frame is sufficient for proper system grounding. The mandrels or the metal core should be made of a highly conductive, nonpainted or noncoated conductor. Simple continuity checks between the mandrel and the grounding stud on the charging generator will confirm the presence of a good ground.

From the link between charge density and the electrostatic force explained previously by Eq. 3, the charging current is clearly an important factor on the holddown force. Electrostatic charging generators should have a current generation of at least 600 uA of charging current available at 0.5 in. Charging current receives a direct impact by the distance between the electrodes and ground. This can be dramatically noted by the plot of charging currents available as a function of distance to ground and output voltage from the generator (**Fig. 12**). Note that the different voltage output levels are required for the same charging current at different distances from the ground. Keep in mind that current is the parameter that affects the holddown force on the web.

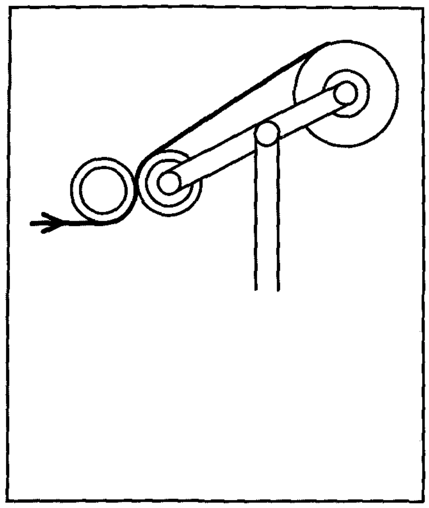
Another variable affecting the electrostatic attraction of the web to the core is the linear web speed. Charge density (coulombs per m^2) decreases as more material passes beneath the charging electrodes per unit time. For a known electrode–ground distance, the current (current is charge per unit time in units of coulombs per second) is fixed. As more web surface area passes beneath the electrodes per unit time, less charge per unit length is trapped by the web. The momentum of the cut web also increases with increasing film speeds. What follows is a resultant force acting less on the web in the direction of the core than a slow-moving web.

The material itself affects the degree to which it can retain charges and be held to the incoming core. In general, plain paper stocks, which are porous and tend to retain moisture, are conductive. This leads to relatively weak attraction of the web to the core when compared to insulating polymer-

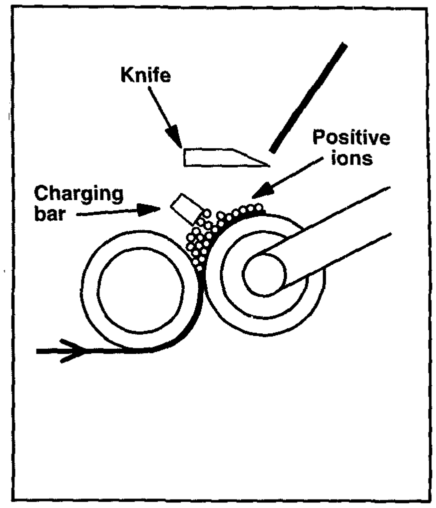
8. Turret begins to rotate.



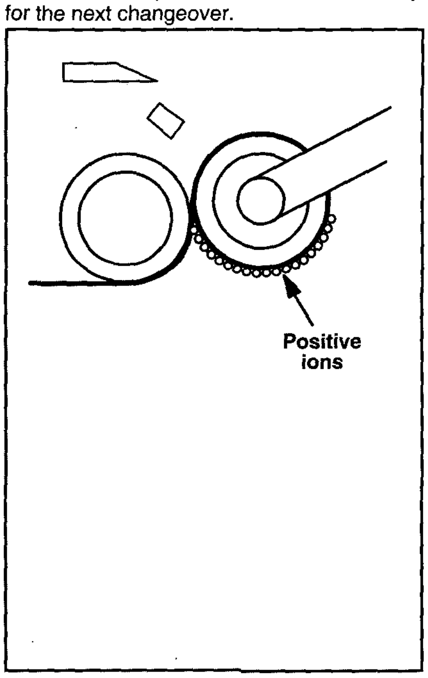
9. The new incoming core moves into position to begin accepting film.



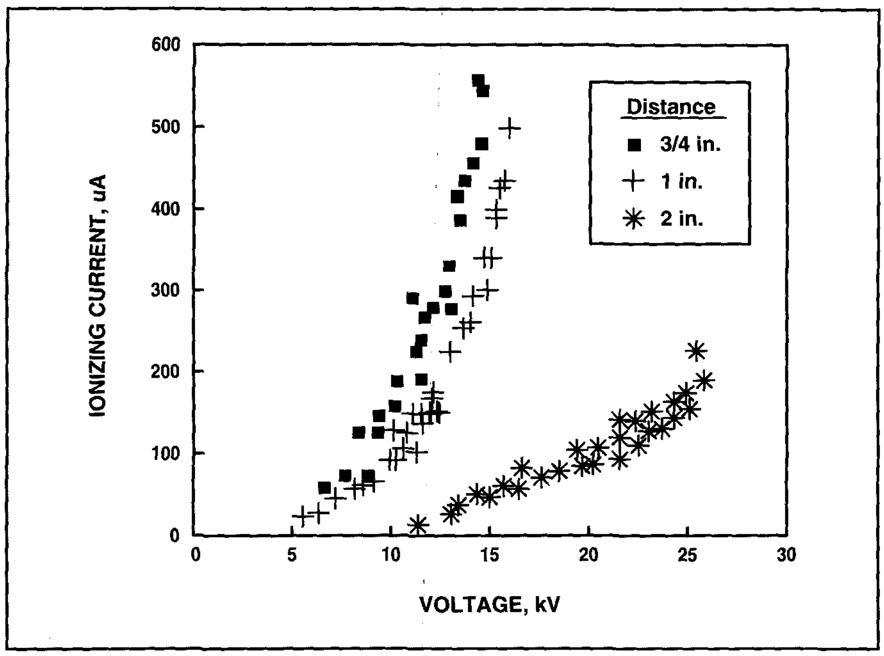
10. Knife fires, and charged web is adhered to core.



11. Film winds up on the new core until ready for the next changeover.



12. Typical charging current as a function of electrode-to-ground distance

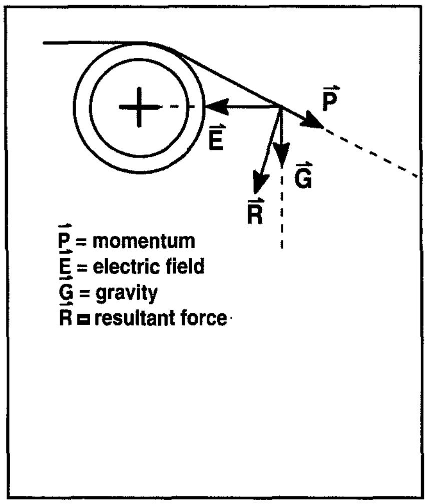


based materials. Insulators such as polymer films, fabric sheets, and nonwovens retain charges easily and allow the web to set up a strong force of attraction to the core. As the surface resistivity increases, the material takes on a greater ability to have charges retained on its surface, and subsequently is easier to hold to the core.

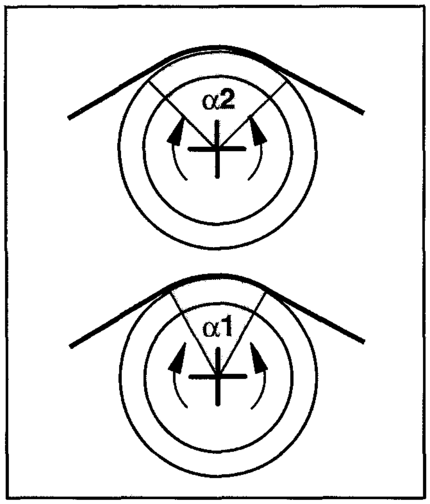
The web's gauge plays a role in how well suited it will be for electrostatically assisted roll starts. In practice, this means that thicker materials (e.g., gusseted bags) require higher charging currents. For heavier-gauge materials, the force that up to now has been ignored—gravity—begins to play a greater roll on web dynamics during core starts. Its effect becomes noticeable when gravity counteracts the electrostatic force after the web is cut (**Fig. 13**). Finally, the momentum of a thicker-gauge web is greater than that of thinner gauges. This resultant force counteracts the electrostatically generated force of attraction. The forces of gravity and film momentum, both of which counteract the electrostatically generated force, are impacted by the thickness of the film.

Another parameter that needs to be considered when dealing with electrostatically assisted roll starts is the

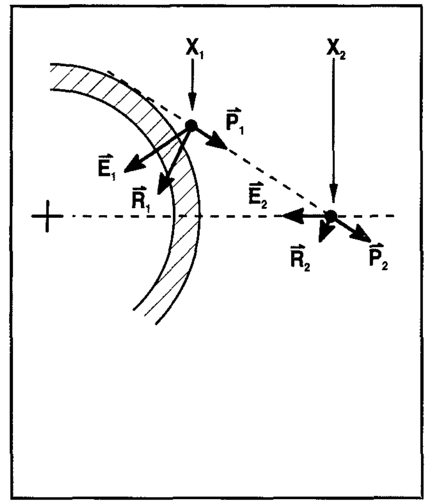
13. For thicker-gauge materials, gravity becomes an important relative force acting on the web.



14. At larger wrap angles (α2 > α1), the length of the web already pulled to the core is greater prior to cut off, making it easier to hold down the film.



15. Size and direction of resultant vector for differing knife positions



wrap angle of the web on the new incoming core. As seen in **Fig. 14**, at greater wrap angles (α2) a larger portion of the web is already electrostatically attached to the core prior to knife cut-off. Upon firing of the knife, this larger surface area, already held in place, requires only the consideration of how to hold the web "tail" for minimal foldback. Practically speaking, the wrap angle should be at least 45°.

The position of the knife relative to the incoming core is important in the electrostatic core-start technique. As seen in **Fig. 15**, the resultant vector is affected by where the knife severs the web. When the knife cuts the web closer to the core (X_1), the charged film's electric field acting on the leading edge is stronger due to the shorter distance to the ground reference than a point further downstream (X_2).

Various types of cores affect the success of using the electrostatic core-starting technique. One key variable affecting the outcome is core thickness. Thicker cores move ground (mandrel) and electrode further apart, thereby reducing the ion current. Successful electrostatically assisted roll starts have occurred with up to 5/8-in.-thick paper cores. Practically speaking, thicker cores reduce the ability to make electrostatic starts at higher speeds for thicker-gauge films and for more conductive materials. The core material also has an impact on the amount of holding force obtained in a given electrostatically assisted roll changeover scheme. Core materials, in order of preference, are: metal, plastic, and paper.

For metal cores, the distance between electrodes and ground has been shrunk by the core thickness, thereby increasing the potentially available ion current. Insulating plastic cores easily maintain charges of the opposite polarity on their surfaces to hold webs in place. Paper cores can easily hold insulating webs to their surface. When conductive materials are to be held to the paper or metal core, problems of charge leakage and minimal web holddown forces arise **(Fig. 16)**. This reduces the potential holding force of the web to the core. In practice, moving from the most preferred to the least preferred core materials requires an increase in field strength by moving the electrodes closer to the core (ground). In addition, moving from metal to paper cores reduces the ability to charge more conductive materials and reduces the top-end running speeds of the winder.

In addition to these parameters affecting the success of electrostatically assisted roll starts, there are several guidelines that apply to charging the leading edge of the film to the core. These guidelines include: placement of the knife with respect to the charging bar, other roller interactions with the web once it has been charged, and the interactions of the various components during the roll changeover.

First, always charge the web prior to being cut. When the knife fires, the newly-cut tail must be attracted to the core. Second, 100% control over the charges being sent to the web is imperative for proper core starting. Any further interactions with the web surface downstream of the charging point will tend to recharge the film to a degree that is unpredictable. In practice, this requires direct charging of the film to the new incoming core without any interactions with lay-on or idler rollers.

Timing of all the key components of the winder with the electrostatic charging system is another issue that must be understood. A generic timing diagram **(Fig. 17)** indicates the interaction between the knife and the charging system. Note that the generator must come up to full voltage to obtain the proper charging-current level prior to firing of the knife. This ensures that maximum charging effectiveness is available at the point at which the new web tail needs to be attracted to the incoming core. Also note the short duration that the charging generator is on after the knife fires. This ensures little charging of the web, which can cause dust attraction and operator shocking at the unwind. Quick switching of the charging generator can have the added benefit of reducing the time that film tension is lowered during the rewind. These guidelines, if followed, will eliminate many potential problems associated with electrostatically assisted core starts.

Core-start techniques

The problems faced by converters and their customers, including adhesive or tape costs, an inability to recycle cores 100%, and the inability to maintain process speeds, are caused in part by the type of core-start technique used. A quick review of the available techniques is useful.

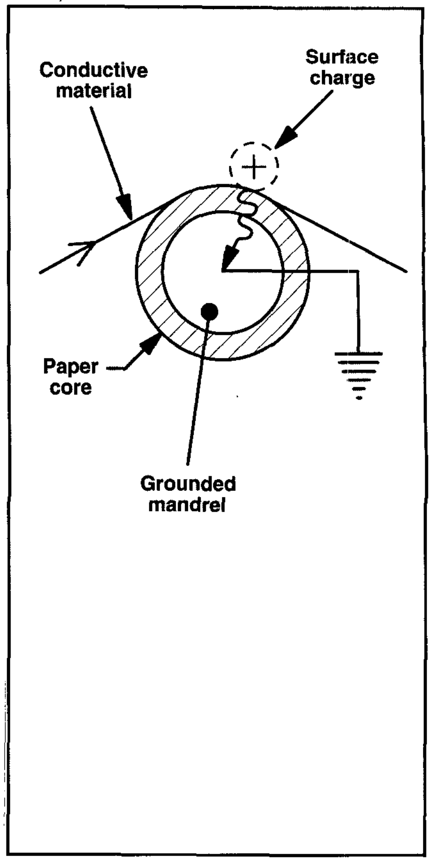
Techniques currently in place for facilitating core starts during film transfers on automatic film winders include: double-sided tapes, adhesives, and electrostatic or liquid assist. Double-sided tapes are placed along one or more faces of the core. The tape is cut to length, applied to the core, and the release liner is removed. When adhesives are used, the operator swabs glue onto the core with an applicator (brush, rag). The electrostatic assist method has been thoroughly explained in this paper. As for liquid assist, water or glycerol can be misted to the core to start the web. The adhesion between the cores and the film is accomplished by the liquid's surface tension and tackiness. Currently, double-sided tape is the most commonly used core-start technique, followed by adhesives, with the electrostatic- and liquid-assist techniques being the least common.

The operating costs for standard tape core starts are considerably greater than those for an electrostatic system. A comparison of operating costs between the two transfer techniques clearly points out this difference. As seen in **Table I**, the operating costs for the most common core-start technique, double-sided tape, is projected for two different types of tape. An inexpensive multiple-purpose tape is compared to a higher-end "clean" pull-off type. A simple payback analysis, less the cost of capital, is made in **Fig. 18** for an electrostatic core-start system. At higher frequencies of roll changes, wider webs, and at greater numbers of shifts, the payback period declines. For example, assuming a continuous three-shift operation with core starts every 30 min, the payback for a 72-in.-wide web is five months. The operating costs of the electrostatic-assist system are negligible; power consumption is less than 75 W for the few seconds of changeover.

Another problem converters have with adhesive-based core-start techniques is the residue remaining on the core once the web is removed. Debris in the form of adhesive or double-sided tape left on the core affects the converter's ability to recycle them. In addition, when operators use knives on the core to remove the remaining debris, the surface will inevitably be cut. This can lead to telescoping through the defect. In addition, direct labor costs involved in removing the debris can be from 5 min to 15 min per core. Both the electrostatic and liquid techniques overcome these problems and allow for 100% core recyclability.

A further difficulty experienced by end users with the tape or adhesive transfer system is the inability to run the unwind stand at full machine speeds. At the moment the core of the roll is approached, the unwind must be slowed down to allow the tape to be threaded through the machine. This is especially true of diaper lines, where the backing and nonwoven materials are joined at operating speeds except when the core-start portion of the web is reached. With nonadhesive core-start systems, the film can be spliced at full operating speeds. An added benefit of the electrostatic or water-based transfer technique is the ability to use a greater portion of the film by running the material closer to the end of the core. Adhesives or tapes tend to "bleed through," causing discoloration, staining, or other defects in the web. Product damage and the inability to run the machinery at full production speeds are overcome with the nonadhesive core-start techniques.

16. Path to ground of surface charges when conductive materials are placed on paper (or metal) cores



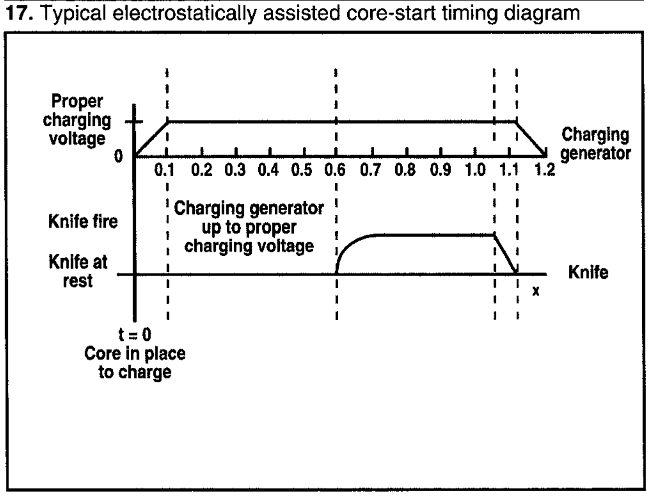
Conclusion

Electrostatic core starts can replace glue or tape to provide the holddown force required for core starts on automatic film winders. By examining the force diagram, with the cut edge of the film as the reference point, the dynamics required for this electrostatic-assist technique can be understood. This understanding, coupled with the background knowledge of how system parameters affect the changeover in an electrostatically assisted core start,

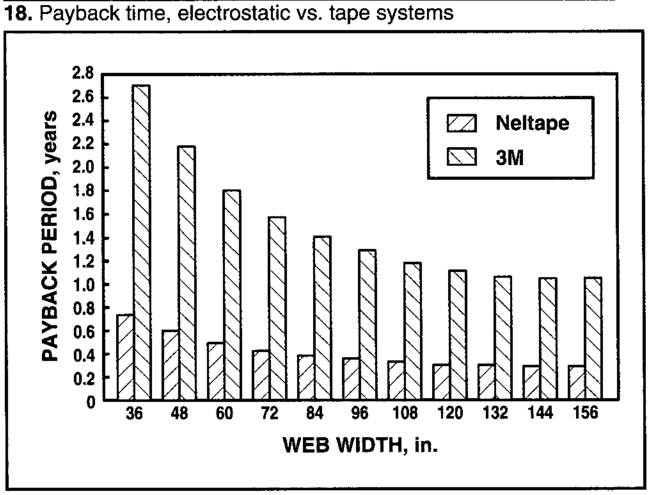
I. Tape costs for various core starts, US$

	Web width, in.	One shift: Roll change every 15 min	One shift: Roll change every 30 min	One shift: Roll change every 60 min	Two shifts: Roll change every 15 min	Two shifts: Roll change every 30 min	Two shifts: Roll change every 60 min	Three shifts: Roll change every 15 min	Three shifts: Roll change every 30 min	Three shifts: Roll change every 60 min
3M tape	12	3.072	1.536	0.768	6.144	3.072	1.536	9.216	4.608	2.304
cost per	24	6.144	3.072	1.536	12.288	6.144	3.072	18.432	9.216	4.608
day	36	9.216	4.608	2.304	18.432	9.216	4.608	27.648	13.824	6.912
per line.	48	12.288	6.144	3.072	24.576	12.288	6.144	36.864	18.432	9.216
Assumes two	60	15.36	7.68	3.84	30.72	15.36	7.68	46.08	23.04	11.52
pieces of	72	18.432	9.216	4.608	36.764	18.432	9.216	55.296	27.648	13.824
tape/roll	84	21.504	10.752	5.376	43.008	21.504	10.752	64.512	32.256	16.128
	96	24.576	12.288	6.144	49.152	24.576	12.288	73.728	36.864	18.432
	108	27.648	13.824	6.912	55.296	27.648	13.824	82.944	41.472	20.736
	120	30.72	15.36	7.68	61.44	30.72	15.36	92.16	46.08	23.04
	132	33.792	16.896	8.448	67.584	33.792	16.896	101.376	50.688	25.344
	144	36.864	18.432	9.216	73.728	36.864	18.432	110.592	55.296	27.648
	156	39.936	19.968	9.984	79.872	39.936	19.968	119.808	59.904	29.952
Neltape	12	0.8448	0.4224	0.2112	1.6896	0.8448	0.4224	2.5344	1.2672	0.6336
cost per	24	1.6896	0.8448	0.4224	3.3792	1.6896	0.8448	5.0688	2.5344	1.2672
day	36	2.5344	1.2672	0.6336	5.0688	2.5344	1.2672	7.6032	3.8016	1.9008
per line.	48	3.3792	1.6892	0.8448	6.7584	3.3792	1.6896	10.1376	5.0688	2.5344
Assumes two	60	4.224	2.112	1.056	8.448	4.224	2.112	12.672	6.336	3.168
pieces of	72	5.0688	2.5344	1.2672	10.1376	5.0688	2.5344	15.2064	7.6032	3.8016
tape/roll	84	5.9136	2.9568	1.4784	11.8272	5.9136	2.9568	17.7408	8.8704	4.4352
	96	6.7584	3.3792	1.6896	13.5168	6.7584	3.3792	20.2752	10.137	5.0688
	108	7.6032	3.8016	1.9008	15.2064	7.6032	3.8016	22.8096	11.4048	5.7024
	120	8.448	4.224	2.112	16.896	8.448	4.224	25.344	12.672	6.336
	132	9.2928	4.6464	2.3232	18.5856	9.2928	4.6464	27.8784	13.9392	6.9696
	144	10.1376	5.0688	2.5344	20.2752	10.1376	5.0688	30.4128	15.2064	7.6032
	156	10.9824	5.4912	2.7456	21.9648	10.9824	5.4912	32.9472	16.4736	8.2368

17. Typical electrostatically assisted core-start timing diagram



18. Payback time, electrostatic vs. tape systems



leads to a good background of the process. The most significant parameters include: a proper ground reference, the charging current, and the placement of the knife. This technique has shown to provide a quick payback, increased core recyclability, and increased machine speeds. ■

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