Challenges of High Speed Splicing

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ABSTRACT:
Reliability is a key objective of any continuous web splicing operation, as web speeds increase and parent roll diameters are reduced; the challenge to increase reliability becomes much more difficult.
Accuracy and repeatability of splicing systems become critical when splicing at high web speeds, and failure to consider and solve the obstacles will result in decreased splicing reliability and increased downtime.
The goal of this paper “The challenges of high speed splicing” is to explain what the obstacles are and the solutions required in overcoming these obstacles.

Introduction
Efficiency of a converting process requiring feeding a roll of web material into a process can be improved if the process does not have to stop when the roll of material is depleted. This ability to run at steady state can eliminate waste caused by material that is not within specification due to starting and stopping of the process line.
A web splicer provides a continuous operation by splicing the leading edge of a new roll to the web from the expiring roll, prior to the depletion of the expiring roll.
Patents for web splicing machines have been around for over 70 years and are still being issued today to solve new problems or conditions. There are two basic type of splicers, one uses a web accumulator as a reserve of web material to feed web into the process while the web is spliced at zero speed on the unwind. The second type splices without use of an accumulator device at full line speeds. This presentation will discuss the type of splicer that does not require the use of an accumulator and is used in conjunction with a turret type of unwind as shown in fig. 1.

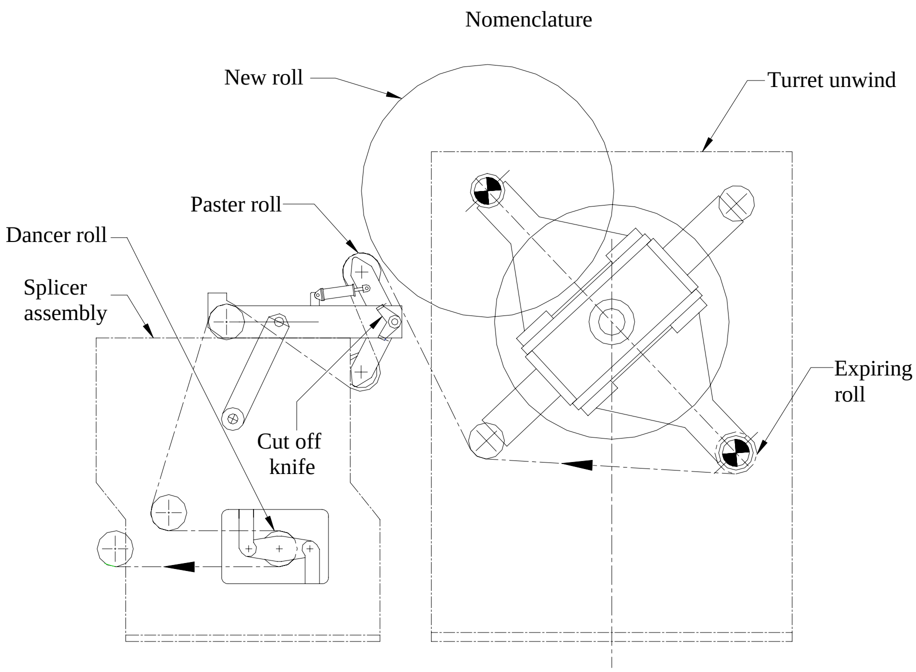


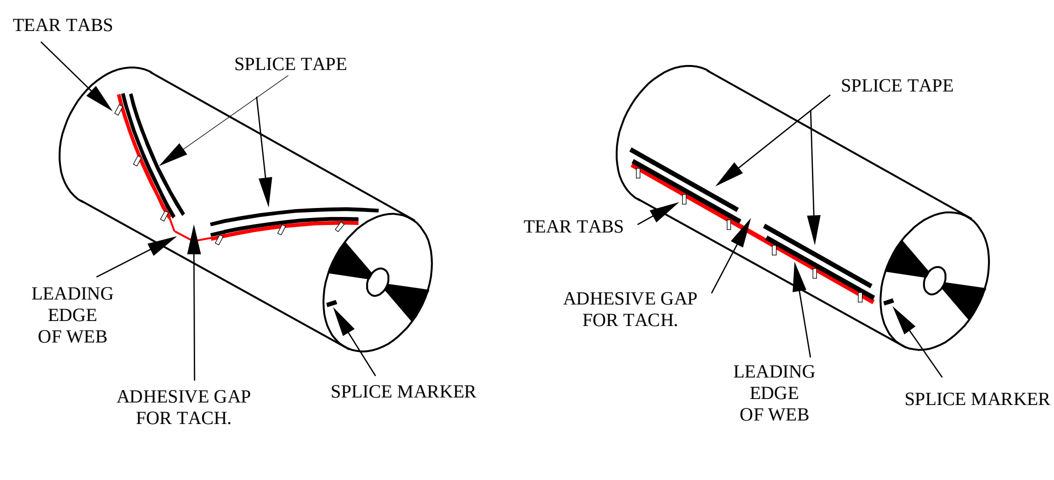
Figure 1.

Regardless of the type of splicer used, reliability is a key objective that must be met for any continuous web splicing operation since the downtime caused by missed splices will ruin the intended efficiency of a continuous operation.
The speeds required for continuous operation are continually increasing and new roll diameters reduced. This combination provides a difficult challenge to increase splicing reliability. Failure to consider and solve the obstacles of high speed splicing will result in decreased splice reliability, wasted product, and increased machine downtime. The intent of this presentation is to explain what the obstacles are and the solution required to overcome these obstacles.

Operation review for typical turret unwind splicer
Before discussing the problems associated with splicing at high line speeds, a basic understanding of the splicing sequence must be understood.

Splice preparation
Prior to splicing, the new roll must be prepared for the splicing operation.
There are many variations for splice preparation; two of them are shown in fig. 2.
One method is to prepare the leading edge with a “V”. This type is useful in some converting process lines to aid in passing the leading edge through the machine, and allows additional adhesive area to hold the splice together.
The second method shown is a straight edge, which is simpler and quicker to prepare.
The tear tabs constrain the leading edge of web against the new roll to prevent the roll from unwinding while the roll is rotated at line speed just prior to forming the splice.
The splice tape attaches the leading edge to the expiring web forming the splice, and in the process breaks the tabs to allow the roll to unwind.
A splice mark is placed on the side or the surface of the roll to indicate the beginning of the prepared roll edge. This mark is electronically sensed during the splice sequence to activate the paster roll during the splice sequence. Other methods to determine the prepared roll edge are also used.

Figure 2.



VEE TAIL SPLICE PREPARATION

SQUARE TAIL SPLICE PREPARATION

Splicing sequence.
The process of making a splice consists of four basic steps, as shown in fig. 3.
After the turret indexes the new roll into a splice position, approximately one-inch away from the paster roll, the first step is to rotate the new roll to match web speed.
Then the paster roll is activated to engage the expiring web against the new roll allowing the splice to be formed.
The knife is activated to sever the expiring web, and the last step is to retract paster roll and place the new roll into tension control for the duration of the unwinding process.
The splice produced consists of the leading edge of the new web adhered to the expiring web, with a tail of some length of expired web. See example in fig. 3a.

Figure 3.

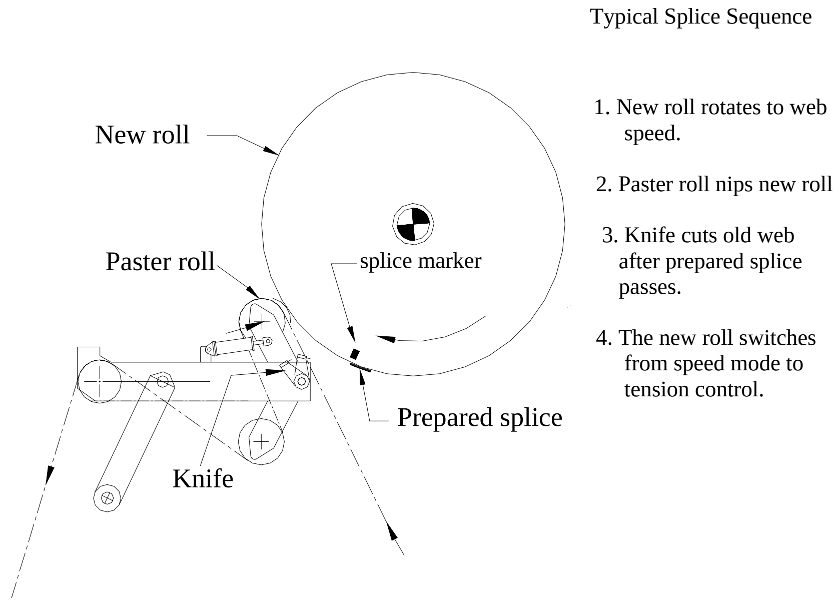
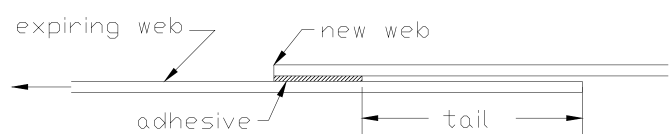


Figure 3a



Important aspects of a splicing operation that contribute to missed splices

Splice preparation of the new roll
Whatever splice preparation design is determined to be best for the product, it must be applied in a consistent manner. This includes the quantity and type of adhesive, the quantity and type of tear tabs, and placement of the splice marker relative to the leading edge of the splice.
The splice preparation may have to be altered for different speed ranges and different types of substrate.
For example, additional tear tabs may be required as the rotational speed of the new roll increases. Increased windage and centrifugal force generated at the higher speed may break the tabs prematurely.
Also, the splice adhesive may not adhere to the web as aggressively at higher speeds.
Once the proper method of splice preparation is found to work for a given product within a particular speed range, then missed splices due to splice preparation at any speed is usually caused by inconsistency in the preparation.

New roll speed up operation
Most rolls that will be spliced will not be round or concentric and because of this, the speed match will not exactly match the line speed when splicing. A modern drive system tuned correctly, with a properly designed dancer control system, leaves some room for typical errors caused by incorrect roll diameter input, and rolls that are not concentric or round. It is not uncommon to be .3% to .5 % over or under web speed even at high web speeds. If the web can tolerate some additional tension over the set point, then the desired target is to keep the new roll speed match error slightly under speed.
Conversely if the web cannot tolerate additional tension then the target is to make the error over speed.

Paster operation

A typical paster assembly consists of a movable rubber covered roller that is displaced by means of pneumatic cylinders. Every effort is made in design to reduce the reaction time, including using air accumulators, oversized ports with quick dump valves on the pneumatic cylinders, and using dc solenoids to reduce valve actuation time. Reaction time from the splice paste initiate signal to contacting the new roll generally ranges from .250 to .350 seconds. Repeatability of the reaction time depends on the mechanical, electrical, and pneumatic design of the paster system. The repeatability of the reaction time for a typical paster assembly will vary from splice to splice as much as .130 seconds and some systems can be as much as .200 seconds.

Actuating the paster roll to nip the new roll is a critical aspect of the splicing operation ***and is the most critical item as splicing speeds increase and or new roll diameters decrease.***

If the paster roll is not nipped against the new roll in the allowed zone in the required time, the splice is likely to be missed.

The allowed zone may be termed the pasting window and is defined as the zone that the paster must nip against the new roll when the prepared splice is 180 +/- 90 degrees away from the nip, as shown in fig. 4.

Should the paster roll contact the new roll when the prepared splice is less than 90 degrees away from the nip, the impact of the paster roll against the new roll may break the tear tabs prematurely, causing a missed splice. If the paster roll contacts the new roll when the prepared splice is greater than 270 degrees away from the nip, the impact of the paster roll and resulting bounce may cause a missed splice due to low or no nip pressure. This is illustrated in fig. 5.

Required repeatability for the paster reaction time to stay within the pasting window with respect to line speed and new roll diameter is shown in chart #1.

Figure 4. Pasting Window

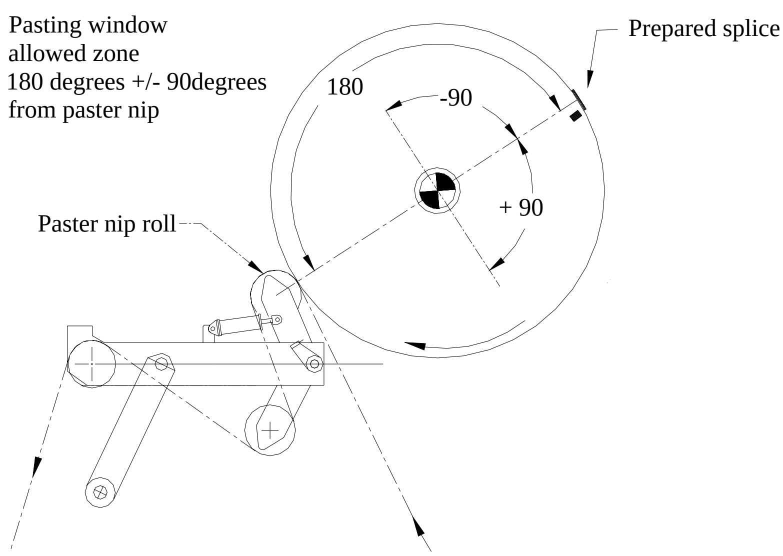


Figure #5

Contact less than 90 degrees from nip   Contact greater than 270 degrees from nip

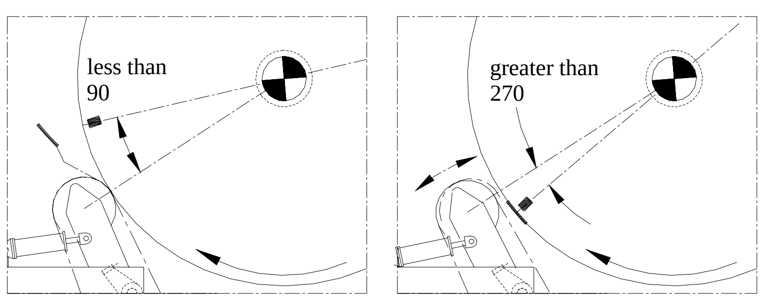
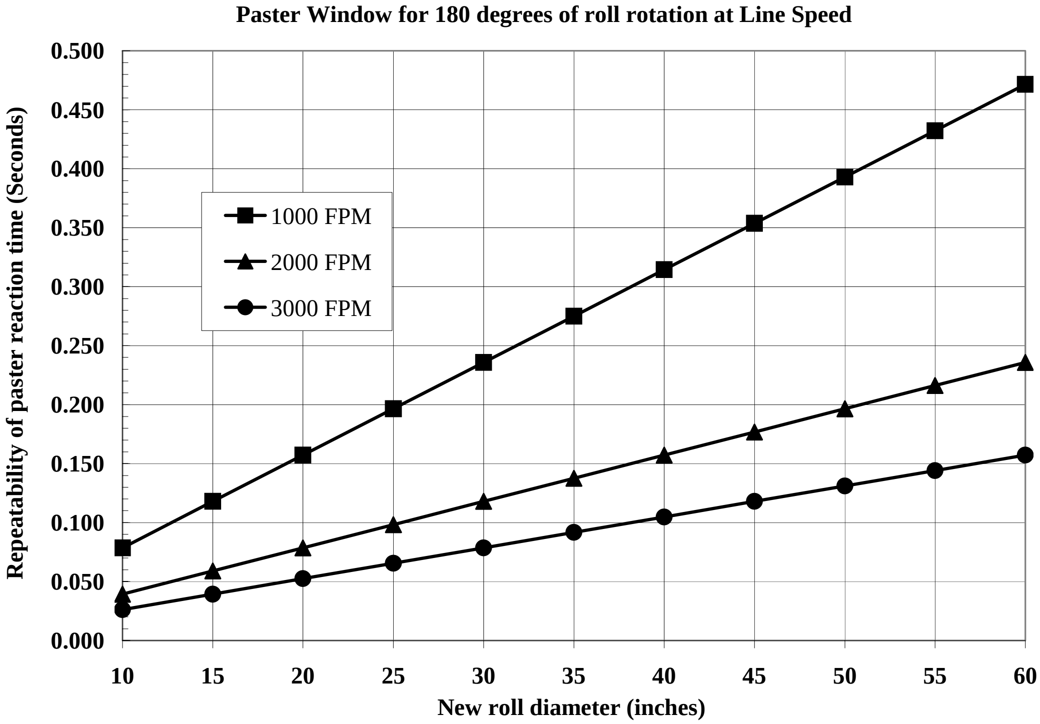


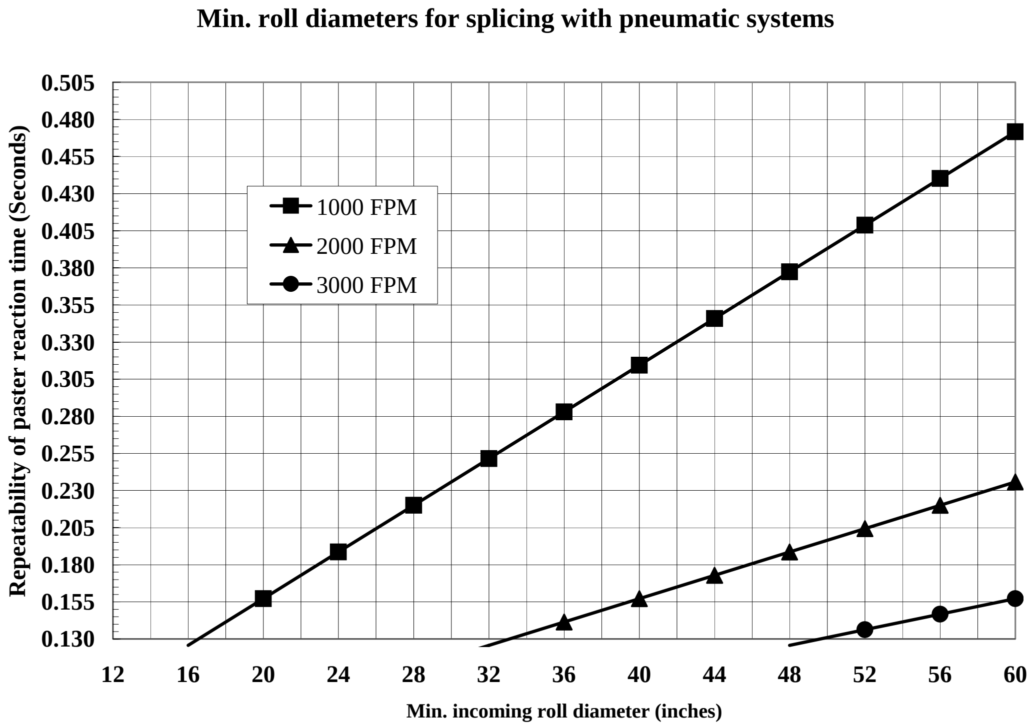
Chart #1



Paster roll repeatability

With a paster roll reaction time variation of .130 seconds, chart #2 below shows the minimum roll diameters that may be spliced reliably at 3000, 2000, and 1000 fpm are 50, 33, and 17 inches respectively. Splicing below these diameters is possible, but not without reducing splicing reliability.

Chart #2



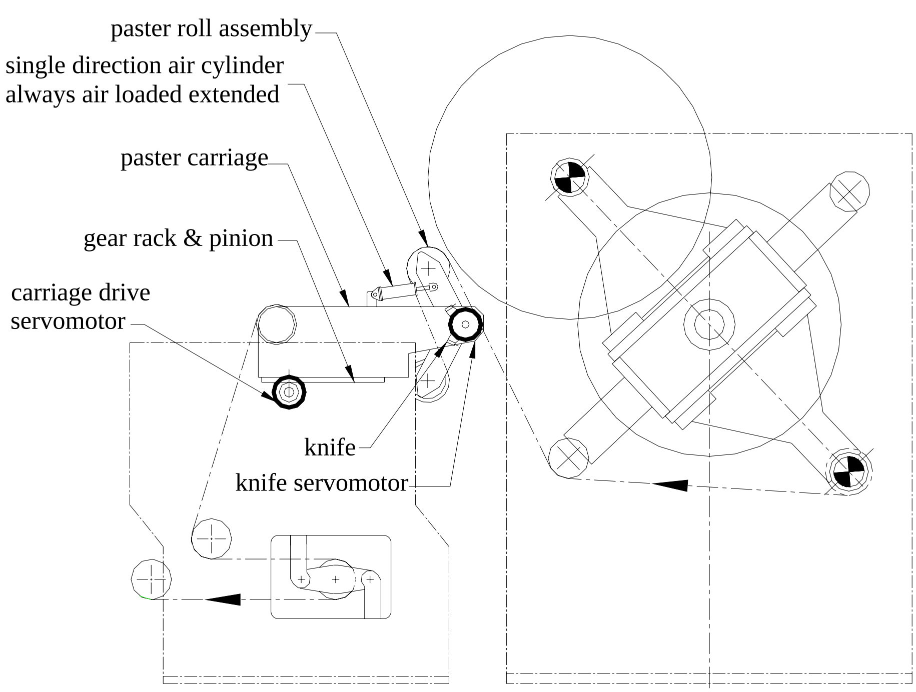
Cut-off knife
A typical cut-off knife consists of a serrated tooth blade attached to a cross member, powered by air cylinders to move either in an arc or straight line to sever the expiring web.
Splices may be missed if the cut is made too early and if the cut is made too late, the lap splice will result with a long tail that could cause a web break as the splice continues downstream. Typical knife reaction repeatability is approximately .080 seconds.
Computerized control systems have been designed and do a good job to keep tail lengths as short as possible. For example, at 3000 fpm with a nominal 34-inch tail set point, a tail of 2 to 51 inches long may be obtained. Splice reliability would be improved if variation in the tail length could be reduced.

Solution to provide increased splice reliability with smaller rolls at high speeds.

To solve the problems associated with splicing at high web speeds, two areas need to be improved; pasting reliability and the ability to reduce tail length variation.
Improvement to both of these areas can be obtained if the repeatability of the reaction time for both devices is improved.
The solution is to replace commonly used pneumatic actuation systems and instead, to apply servomotor systems with properly designed mechanical interfaces.
Servo systems respond much faster and provide much more repeatability than an air systems because unlike air systems, servomotor systems equipped with encoders can be position controlled providing control over acceleration, velocity and de-acceleration during actuation.

Splicer description
A splicer design using servomotors is shown below in fig.6. One servomotor drives the paster carriage forward and reverse by means of a gear rack and pinion, and the second servomotor is mounted on the carriage and is connected to the knife shaft to rotate the knife for cutting the web.
The carriage assembly is mounted to the splicer frame using low friction linear ball bearing slides. Mounted to the carriage is a pivoting paster roll assembly, pneumatically loaded forward against stops by a single direction air cylinder. The pneumatic loading provides the ability to set the desired nip pressure for splicing and does not affect paster reaction time.

Figure #6



Reaction repeatability

Repeatability of the paster reaction time using a servo system as shown on the previous page is one half the time of a pneumatically actuated paster. Repeatability of .065 seconds or less is possible. The servo system acceleration and velocity is controlled as desired for optimum performance, and with encoder feedback the servo determines where the carriage is in the travel providing correction to maintain the firing time. The ability to keep the velocity of the paster actuation as low as possible also reduces the bounce tendency of pneumatic activated systems that accelerate until stopped by either the new roll or some type of shock absorber.

Repeatability of the knife reaction time using a servo system is also much better than a pneumatic system for the same reasons as listed above. Repeatability time of one half or less than that of a pneumatic systems is possible reducing the variation in tail length to at least one half that of the pneumatic systems.

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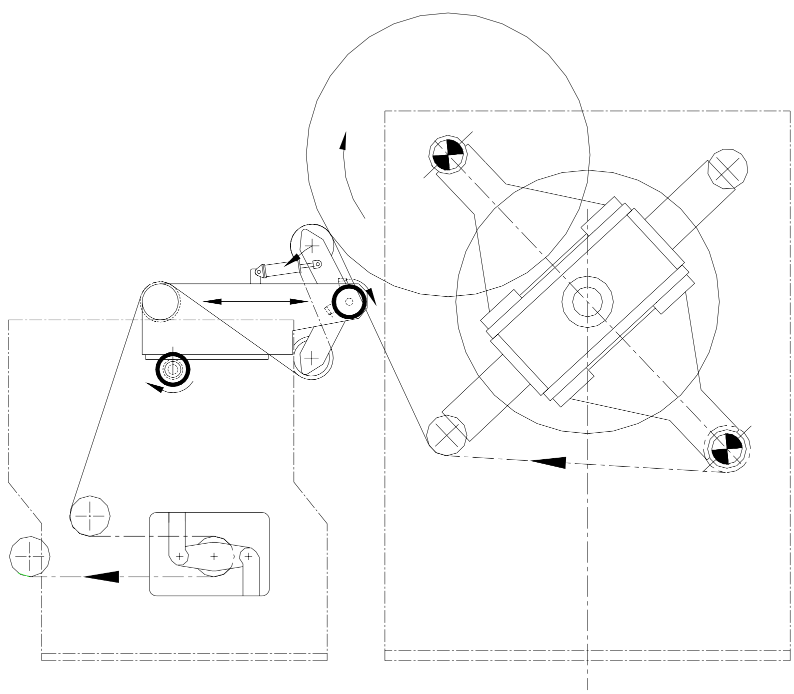
Splicer operation

The splicer in fig. 7 below is shown in splice position. When a splice command is given, the servomotor accelerates to a set velocity, moving the carriage forward, causing the paster roll to contact the new roll. The carriage continues moving forward past the contact point, depressing the pneumatic loaded paster roll, until the carriage reaches a predetermined distance as measured by the servomotor encoder, and then de-accelerates to a stop.

The knife start command calculated by the computer initiates the knife servomotor rotation to insure that the knife will be in the cut position to obtain the desired tail length.

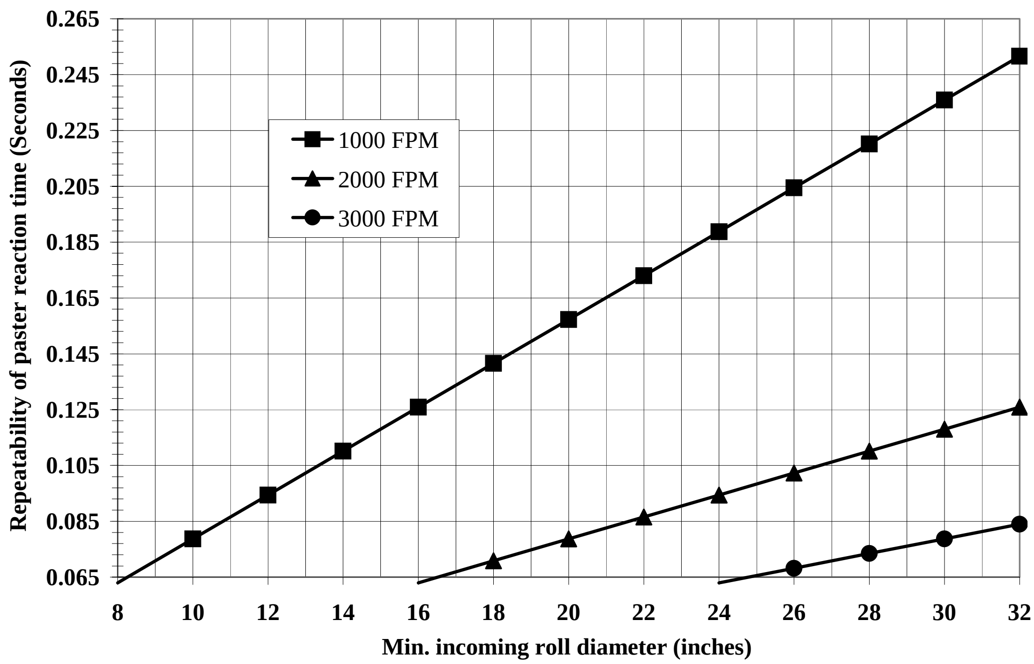
Figure #7



Minimum roll diameters
With a paster roll reaction time variation of .065 seconds, chart #3 below shows the minimum roll diameters that may be spliced reliably at 3000, 2000, and 1000 fpm are 25, 17, and 9 inches respectively. Splicing below these diameters is possible, but not without reducing splicing reliability.

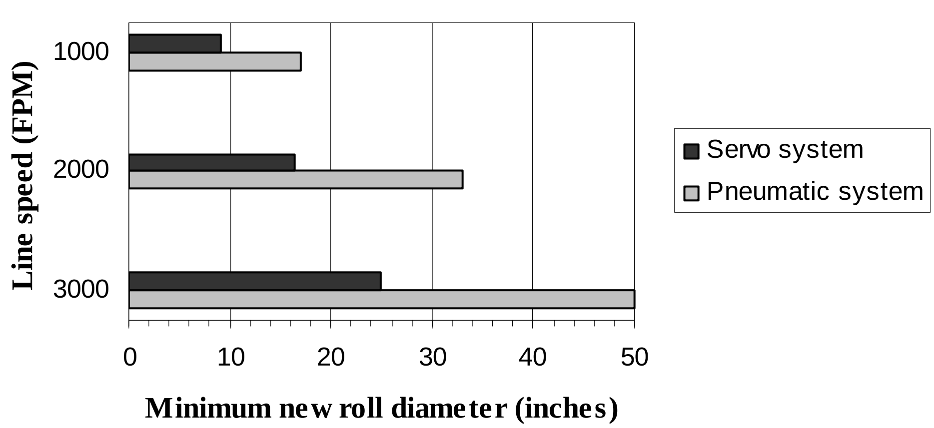
Chart #3

Min. roll diameters for splicing with servomotors



Conclusion
Actuating the paster roll to nip consistently within a pasting window of 180 degrees plus or minus 90 degrees from the pasting nip point will increase splicing reliability. While pneumatic pasting actuation mechanisms are relatively fast, the repeatability is not adequate for higher splicing speeds unless the minimum new roll diameters are kept large enough to stay within the defined pasting window.
Splice reliability is also improved by eliminating missed splices caused by long tail lengths. Improving the repeatability of the knife reaction time provides the reduced tail length variation to produce shorter splice tail lengths.
Replacing pneumatic actuation systems with properly designed servomotor actuation systems will provide the repeatability required for higher splicing speeds and smaller new roll diameters as shown in chart #4 below.

Chart #4 Servomotor versus pneumatic system



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