Managing overspeed in tangent shear-slitting applications to reduce edge defects

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Introduction

At a polystyrene converting plant in the Amazon jungles of Brazil, a slitting system was creating small strands of fibers on the edge of the web, fibers so fine they were labeled with the industry-wide moniker of "angel hairs," hair so fine it cannot be human and so translucent it must come from angels. The strands appeared to glow in the soft light that bathed the converting factory. One could have said they were beautiful were it not for the fact that the converter was watching his profitability go down the drain as he was unable to deliver a quality product to a customer. So with all the critical factors of tangent shear slitting in place, the engineer working on the equipment took the overspeed from the traditional 10% and reduced it to nearly 0%. The angel hairs disappeared. Why was that?

Before you answer, recall that slitting is really just a controlled crack. When you study how things break or why they break you move into the area of science known as Fracture Mechanics, a field of mechanics that focuses on what causes cracks to propagate in different materials or more simply, the forces that separate things. However, while most analysis concentrates on how to prevent fractures, in slitting your emphasis is on how to control and focus the fracture.

Tangent shear slitting is a system in which a round upper blade and lower anvil contact each other at a specific point – called the nip – so as to concentrate the forces on a given material to create a controlled fracture that separates one piece from another piece in such a way that a nice, clean edge remains. This article will briefly review the process by which those forces are concentrated on the web material and then specifically address how to manage overspeed to reduce edge defects and solve some different slitting challenges.

Caliper: *The measured thickness of the web*

Density: *More than the "basis weight" or "gsm"*

Elongation: *How much does it stretch?*

Stiffness: *What happens when it is bent?*

Tensile Strength: *How resistant is it to slitting?*

Abrasiveness: *Will it eat my blades?*

Compressibility: *If it compresses, will it recover?*

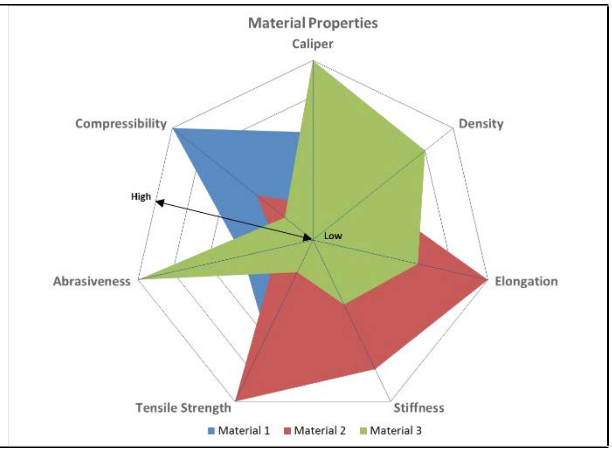

FIGURE 1. *Primary material properties that affect slit quality*

Material properties: The good and bad

To effectively break something you need to first understand its properties. Many of the materials being converted today have very diverse and often challenging material properties that cause one way of slitting to work great for one material, but could be disastrous for another material. Understanding those properties and the effect they have on slit quality is critical. The primary material properties that affect slit quality are described in Figure 1.

All webs possess all of these properties to some degree. Concentrate on the dominant property to establish the basic slitting requirement and then fine-tune as needed based on the other significant properties.

Once you understand your material properties, the next step is to control the critical factors in your tangent shear-slitting system. Those six critical factors are shown and described in Figures 2A-F.

The impact of overspeed

Overspeed is the final variable we want to consider to achieve optimal slit quality (see Figure 3). Simply put, overspeed is ensuring that the lower anvil and upper blade are rotating at a

	Blade profile/sharpness	A. The shape of the blade at the nip or cutting point
	Cant angle	B. The angle at which the upper blade is positioned relative to the lower anvil
	Overlap	C. The distance the upper blade extends below the outer diameter of the lower anvil
	Sideforce	D. The force of the upper blade against the lower anvil
	Slitter geometry	E. The geometric position of the upper-blade centerline relative to the lower-anvil centerline
	Overspeed	F. The percentage increase in rotational speed of the upper blade relative to the web speed

FIGURES 2A-F. *Critical factors in tangent shear slitting*

velocity that is faster than the approaching web that is to be slit. The reason it is required is to prevent the oncoming material from bunching up or slowing at the nip relative to the rest of the web that is outside the slit zone.

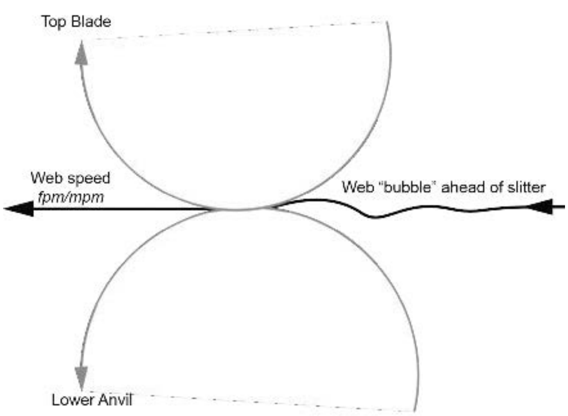

FIGURE 3. *Overspeed diagram showing blade, anvil and web*

As it turns out, the Christmas tradition of gift-giving is the easiest way to illustrate why this is a problem. I hate wrapping presents; I focus on winding and slitting; I don't do folding very well. But sometimes I volunteer for the slitter part when my wife needs paper cut. I grab the paper, grab the scissors and then shove the scissors through the paper only to have it catch and tear about halfway through. But if I give a squeeze on the scissors as I do this, I get a decent slit. If not, I get a ragged slit. Gradually closing the scissors as I shove them through the paper creates the same effect as overspeed.

Overspeed at the slitter is created by accelerating the lower anvil faster than the web speed and ensuring the upper blade is tracking proportionally with the lower anvil. The upper blade comes up to speed due to the traction between it and the lower anvil. This speed relationship is one of the fundamental elements of a tangent shear-slitting process. Without it, there is little to differentiate it from rotary razor slitting. Typical defects associated with an under-speed nip include ragged edges, web breaks and intermittent slits.

What differentiates overspeed is how it is influenced by all of the other variables that influence good slit quality. Because traction is fundamental to overspeed, this means the variables affecting traction are the variables affecting overspeed and they must be managed clearly.

Outside influences on overspeed

In addition to the other variables listed above, overspeed has the added challenge of being affected by elements outside the slitters themselves. These multiple variables must all be managed to ensure we achieve the desired overspeed required to slit a certain material. These variables include:

1. Lower anvil-speed run cycle from acceleration, run speed and deceleration
2. Breakaway torque at acceleration of slitter shaft
3. Upper-knife blade overlap
4. Upper-knife blade wear
5. Slitter geometry
6. Cant angle
7. Sideforce

The first two variables are often overlooked when setting slitter overspeed. It is not enough to simply set the overspeed based on a theoretical web speed. How the machine comes up to speed, how the drives accelerate and decelerate the slitter shaft and several other variables like sloppiness of the motors, effect of accumulators on web speed, caliper variation in the product and differential-shaft overspeed may all influence the actual overspeed you are able to achieve.

Figures 4A-B show how incorrectly timing the acceleration of the winder drives and the anvil-shaft drives creates a disparity between the intended and actual overspeed at the slitter. In this scenario, there is a high risk of under-speed web defects such as jagged edges or simple web breaks. This must be managed for both acceleration and deceleration.

More than any other variable, blade overlap influences overspeed of the upper blade relative to the web speed (see Figure 5). The

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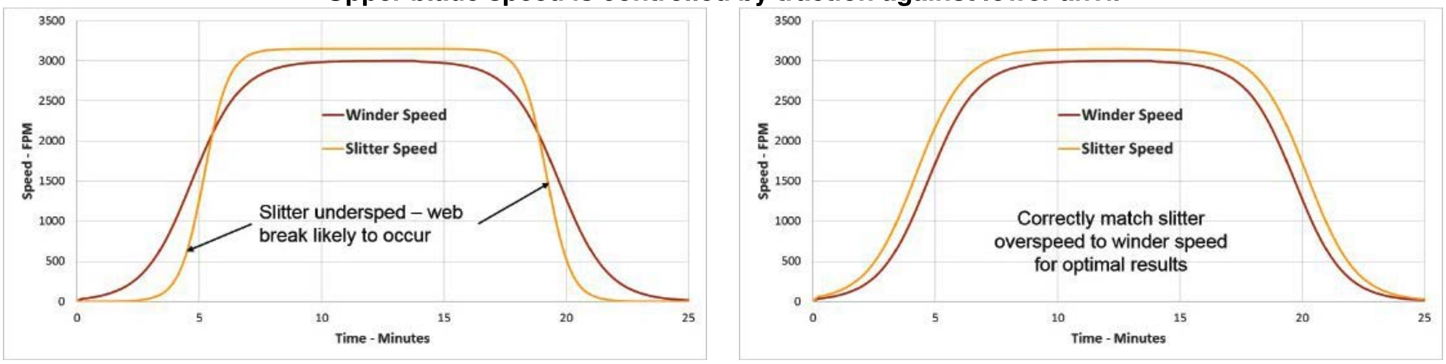
Upper blade speed is controlled by traction against lower anvil



FIGURES 4A-B. *Incorrect timing of winder drive and anvil-shaft drive acceleration (left); correct match of slitter overspeed to winder speed (right)*

upper blade overlaps the lower blade to create the nip point at which the forces are concentrated and shear slitting takes place. This means that the blade contact point at which traction between the blade and anvil takes place is *not* at the outer diameter of the upper blade. Because the upper blade is typically smaller in diameter than the lower anvil, increasing blade overlap means that the lower anvil will need to travel faster to ensure the upper blade is running at the desired overspeed compared to the web.

Overspeed compared to overlap

Note that if you have 0.03 in. of overlap and you want to run at 3% overspeed, you actually need to overspeed the lower anvils 4.9% to achieve this. Otherwise, you are running almost 2% below web speed (see Figure 6). If you increase the overlap to 0.06 in., you need to overspeed the lower anvils 6.9% or you will be running at almost 4% below web speed. This is important to recognize as a common – but often faulty – solution to improving slit quality is to increase overlap. If your operator does this

FIGURE 5. *Blade overlap*

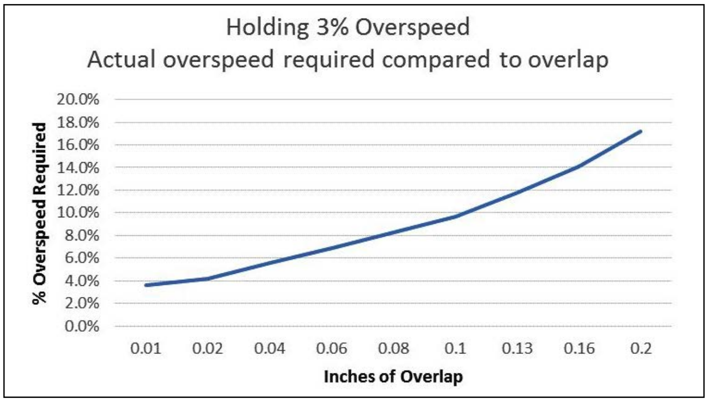


FIGURE 6. *Overspeed compared to overlap*

without adjusting the speed of the anvils, you may very well have an under-speed nip.

Slitter geometry also affects overspeed because of how it influences blade overlap. If the upper blade is not positioned so as to ensure a nip point at the top dead center with minimal overlap, additional overlap may be required to achieve this – carrying with it the challenges associated with excessive overlap.

Blade wear is another variable that affects overspeed. If the upper blades are worn significantly, this will change the point at which traction occurs. Instead of contacting the anvil at the outer-most diameter, blade wear moves that point inward. While there also is a risk of wear opening up the nip point, excessive wear can slow the upper blade – even with the nip closed.

Sideforce affects overspeed because upper-blade overspeed is a function of the traction between the upper blade and the lower anvil. Traction is simply the transfer of friction force; the greater the sideforce the higher the friction between the two and the resultant traction.

continued on page 88 ▶

◀ continued from page 87

Sideforce becomes especially important when dealing with dense or bulky materials that tend to force open the nip. If the nip is open, there is no traction between the upper and lower blades and, therefore, no overspeed.

Similar to sideforce, cant angle impacts the level of traction between the two blades. While increasing the cant angle, too much can lead to premature blade wear – and all of its associated problems – while not enough cant angle can lead to a loss of traction and reduction in overspeed.

Overspeed from minimum to 100%

There are many variables that must be controlled to ensure you are running the overspeed you think you need for the material you are slitting. Some general guidelines are described below. Sometimes, overspeed needs to be changed to reduce edge defects, and when that is the case, managing these variables becomes even more important. Let's examine two examples, one where overspeed needs to be kept to a minimum and one where overspeed needs to run close to 100%.

One common defect in slitting polymers is angel hairs. Often the material is still warm when going through the slitter, so the dynamics of the nip point can have dramatic effects on the overall slit quality. Angel hairs are typically due to the small amounts of the material extruding or plastically deforming as it passes through the nip point. When this is the case, excessive overspeed can often exacerbate the problem.

In one application slitting polystyrene, the converter was creating excessive angel hair on the edge of the roll similar to that shown in Figure 7. By first seeing that all critical variables for good slit quality were under control, the converter was able to manipulate the overspeed to see if it would reduce the presence of angel hairs. By reducing overspeed to nearly zero, the angel hair problem went away. This illustrates that manipulating overspeed helped reduce an edge defect, but keep in mind that this is possible only if you accurately measure that overspeed.

FIGURE 7. *Angel hair from improper overspeed*

FIGURE 8. *Microfiber structure of non-wovens*

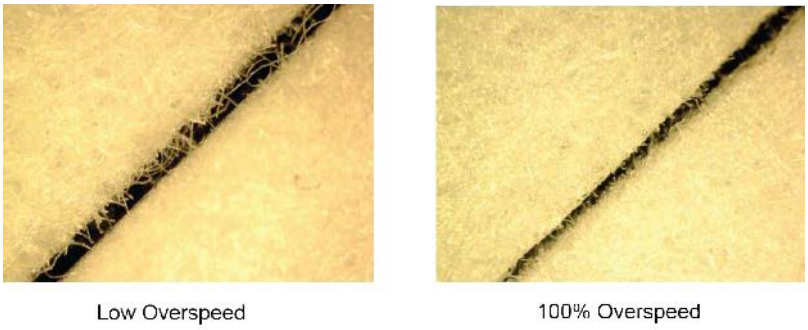


FIGURE 9. *Effect of 100% overspeed on non-woven materials slitting*

Another common application is slitting bulky, dense non-woven materials (see Figure 8). When slitting these products, the knife blade is cutting through hundreds of microfibers to create the slit. If the upper blade is under-speed, two things often occur: 1) The upper blade stalls and the material is torn in two by the slitter, or, 2) the slit occurs but the resulting edge is very fuzzy – from strands that were pulled apart at the last moment, as the material passed by the upper blade rather than being cut apart.

For this reason, many non-wovens need to be run at nearly 100% overspeed or more so the slitter is able to pass through all of the fibers and to overcome the braking effect of the material on the upper blade itself (see Figure 9). In addition, a 1° cant angle often is employed to ensure the nip remains closed and the traction between the upper and lower anvil is maintained. While this much overspeed may seem like a sawing action rather than a slitting action, it is important to remember that the high overspeed is simply facilitating the need for the blade to cut through so many individual fibers.

Conclusion

Concentrating forces at a specific nip point throughout tangent shear slitting often will yield exceptional roll-edge quality that enables converters to provide high-quality products to customers. But as this article described, there are many variables that need to be controlled to achieve this. And while overspeed is one of those variables, what we also see is that the other variables directly affect our ability to control overspeed. ■

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