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A Guide to Slitting

A compilation of articles contributed by Reinhold Schable.

Converting

September Part 2 of 2

The role of the knifeholder in productive shear slitting

"Hand me the hammer, Harry," is not the best solution to slitter-blade adjustment. Knifeholders are, instead, precision instruments that deserve respect.

By Reinhold Schable, Applications Technology Manager, Tidland Corp.

Gone are the days when a shear-slitting knifeholder was a primitive, cast-iron contraption that required a pocketful of wrenches every time a pattern change was made. It had to have the durability of an anvil because repositioning involved a lot of pounding with a hammer. Lost time, lost product and accidents were a fact of life. This, of course, is no longer acceptable.

Current knifeholders must be thought of as precision instruments, rather than blacksmith tools. As such, we expect more from them, and need to be more discerning about their usability, efficiency, design features and safety. This article will address some of these issues.

Rigidity, compliance, and vibration

The knifeholder must be compliant, that is: it must be able to absorb axial runout and lateral vibration without destructive "chatter." The measure of a knifeholder's susceptibility to vibration is not merely its weight and rigidity, but rather its overall harmonic response to the inevitable vibrations present in any machine system.

A massively heavy unit, without adequate compliance may subject the blade to catastrophic lateral impact against the lower slitter, especially if a critical harmonic develops in response to machine vibration or lateral run-out (wobble) of the lower slitter. However, the same condition can occur to a lightweight, flexible knifeholder, so it's important to consider not just knifeholder weight and rigidity but the total dynamics of the unit — including the support system.

The most critical area in this regard is the method whereby the blade/hub assembly is attached to the knifeholder-support body. The use of spring plates favors the creation of resonances similar to a "tuning fork"— with significant blade to blade damage. On the other hand, an absolutely inflexible connection cannot disconnect the ever-present, lateral-machine vibration or absorb lateral anvil blade run-out.

Photo 1: *The ability to reverse the cant angle is easily accomplished by rotating the cant-control key in this unit. This allows slitting on the opposite edge of the lower slitter ring. No tools are required.*

Cant angle control

A basic law of shear slitting requires that the materials enter a "closed nip." This means that the extreme edges of both upper and lower blade must be in contact where the material enters the nip. Beyond this basic requirement, the amount of cant angle is less critical from the standpoint of slit quality but more critical from the standpoint of blade life. This statement can be verified by the presence of a myriad twin-arbor slitters throughout the world which slit critical products — despite the fact that twin-arbor slitters have no cant angle whatsoever.

Cant-angle control is a two-edged sword. The nip must be closed, as noted above, but excessive angle is very destructive to blade life. In practical reality, if all other slitting parameters are being met, 1 degree of cant angle should be considered maximum.

Especially important is the necessity that the blade be held truly vertical (90 degree) to the plane of the web, otherwise, it is impossible to guarantee a closed nip with such low cant angles. Knifeholder designs which incorporate springs in the blade-retaining hubs, or as a part of a flexible hub-support mechanism itself, allow the blade to tilt over the rim of the lower slitter and are troublesome for this reason.

If a knifeholder is to be used on machines where either edge of the lower slitter can be utilized, the ability to reverse the cant angle is a useful feature (Photo 1). This should be possible without the need to disassemble the unit merely to reverse the angle, and the precision, when reversed, should be unaffected. The use of precision-machined components to fix the angle is not an option; any design that requires operator skill to interpret the cant angle, either by "eyeball" or by stick-on labels, is to be avoided.

Set-up and repositionability

Knifeholder design requirements vary according to frequency of pattern changes, machine accessibility, etc. If pattern changes do not interfere with in-line production, a simple, manual knifeholder, which may require a tool to secure the unit, may be adequate. In most instances, a simple rack-and-pinion system is fully acceptable. Then, there are applications in which time is of the essence, no interruption of the in-line process can be tolerated, and fully automated systems are required.

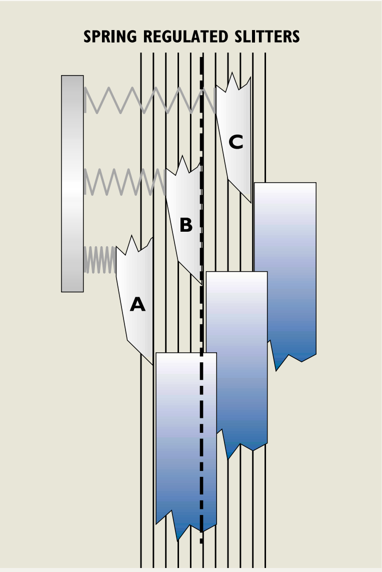


Figure 1: *Spring-regulated slitters are subject to variable side-load forces, depending on initial blade setup. A: Blade set too close — excessive side-load force. B: Blade set too far — inadequate side-load force.*

Since operator skill is a constant variable, the knifeholder must be intuitively simple. Extensive instruction manuals should not be necessary for day-to-day operation. Setting up a knifeholder during a pattern change should require no more than three separate operations ("place," "set-up" and "engage"), preferably no more than two ("place/set-up" and "engage"),otherwise, operator confusion could result.

Engaging or disengaging a slitter, once it has been set up, should not involve more than one operation; ("on" or "off"). The need to "tap it once or twice" with a hammer is sure evidence that the knifeholder design needs improvement.

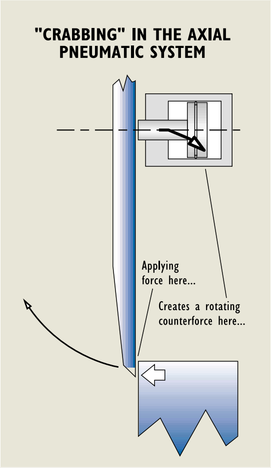


Figure 2: *"Crabbing" — the Axial Pneumatic System is subject to erratic force control, especially at the low side-loads normally required in shear-slitting applications. The rotating counterforce produces "crabbing" or binding at the piston, interfering with smooth movement.*

Set-up cannot be taken lightly, as a fair amount of precision is needed. Most shear-slitting applications require the operator to place the unit within about 1.50-2.0 mm (about 1/16-in.) of the edge of the lower slitter edge. A significant amount of time and productivity is lost as the operator tests and re-tests the blade set-up. False starts because of a missed set-up are particularly wasteful.

Incorporating preset stops, or position locators to facilitate correct placement of the knifeholder, has been an important addition to knifeholder design in recent years. Look for design features that are robust and do not require an extra operation, such as sliding a tab in and out, or locating a reference edge before securing the unit to the guide bar.

Side-load force regulation

When springs are used to regulate sideloading, the preload placement of the blade has a significant impact on the actual sideload force. This means that the operator must place the slitter even more precisely and consistently at a predetermined distance away from the edge of the lower slitter edge during each setup. This may call for the use of shims, spacers or jigs to preset the unit, but because their use is dependent on operator competency, such knifeholders should be avoided wherever possible. Also, spring uniformity between spring-regulated knifeholders may be inconsistent, introducing yet another variable into the slitting equation (Figure 1).

When pneumatics are used to control sideloading, initial blade placement is less critical. Unfortunately, most pneumatically actuated systems have the air cylinder axial to the blade centerline. This means they are subject to "stiction" and "crabbing," which is the tendency of a piston to resist movement at low pressures, and/or bind in the relatively short cylinders typically used in knifeholders (Figure 2).

The use of double-acting cylinders in an attempt to control these problems ignores the fact that it is the pressure differential between the loaded side of the piston and the unloaded side that determines if a system is subject to stiction and crabbing. A simple test of the ability of a knifeholder to respond to side-load force is to apply the desired force (about 2-3 lbs.) against the rim of the blade, instead of against the hub center. The blade should side-load smoothly, with no crabbing or binding.

Diaphragm-actuated slitters are not as vulnerable to binding if the diaphragm is off-axis, and they are more responsive to air-pressure regulation. They are also more compliant to lateral run-out and vibration. Contaminated air supply is also less of a concern with diaphragm-actuated knifeholders.

Finetuning the side-load force must not be dependent upon the need for the operator to adjust the position of the knifeholder body relative to the lower slitter edge. This is equivalent to using a hammer to adjust the side-load — something that is still practiced, sad to say.

Currently, the pneumatic approach is the preferred method of regulating side-load because it's easily controlled and reliable. Increasing or decreasing the side-load force is as simple as changing the air pressure at the control console, in contrast to adjusting the placement of the unit itself (i.e.: "Hand me the hammer, Harry.").

Engage and disengage sequencing

The knifeholder's vertical and lateral strokes must be independent and sequential on both the engage and disengage cycles. The vertical stroke should be fully extended before the lateral stroke begins extension, otherwise a blade "crash" can occur. (Blade "crash" is usually defined by the operator as: "A condition, in which the @!!*&@!! blade has landed on top of the @!!*&@!! anvil ring!!") In the same manner, the lateral stroke must be fully retracted before the vertical stroke begins retraction, otherwise the blade will "drag" over the edge of the lower ring, and chipping may result (Figure 3).

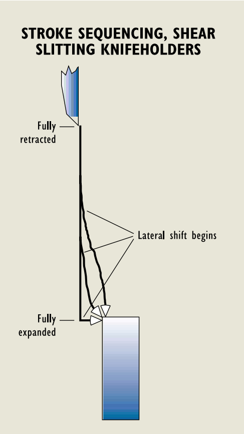


Figure 3: *Stroke Sequencing in Shear-Slitting Knifeholders — the vertical stroke must be fully extended before the lateral stroke is initiated. This can only be done by positive valving of the air supply. The use of sequential pressure chambers or cascading orifices can lead to blade damage.*

This sequencing action must be followed for all shear-slitting systems, regardless of slitter design and is equally applicable to twin-shafted slitter systems, as well as individually mounted, traction-driven slitter systems.

For individual, traction-driven knifeholders, sequencing must be positively valved, rather than relying on a series of cascading orifices or sequential pressure chambers. These designs may become more imprecise and unreliable as blade diameters are reduced during regrinding, creating a condition which requires that the knifeholder must extend further to maintain correct blade overlap.

A good test of the sequencing characteristics of any knifeholder is to set it for maximum vertical stroke and apply air pressure, noting the path the blade takes as it extends. It should fully extend its maximum vertical stroke first, and only then should it begin its lateral extension. If the lateral movement begins before the blade is fully extended vertically, the blade may come to rest on the perimeter of the counter blade, instead of against its side — the condition previously referred to as a blade "jump" or "crash."

Blade changing

Removing a large, heavy knifeholder from the machine to change a blade is cumbersome and dangerous. Being forced to replace a blade while the unit is on the machine is also dangerous, especially if the slitters are in an awkward or inaccessible location. The use of fork wrenches, spanners, or hex wrenches to change blades on the machine should be eliminated for safety and efficiency reasons. Even the ubiquitous Allen key can cause problems if the operator cannot directly approach the blade-retaining screws. Allen keys tend to accumulate under machines, like golf balls accumulate in water holes.

The blade-clamping mechanism should be hassle-free and secure. Especially troublesome is the large rotating retainer nut, commonly used to secure the blade. This design requires an anti-rotation pin, which fits into a notch in the blade's bore. Without this pin, the blade can rotate, which, in turn, can dangerously loosen or

Photo 2: *Replacing a slitter blade is best done off-machine. In this example, the retaining screws are recessed, so the retaining ring or blade cannot be ejected if an operator fails to adequately tighten a screw. This is especially important on high-speed slitters, which require an extra-secure, blade-mounting system. This design is not influenced by blade rotations, as is the case with large-diameter, threaded blade-retaining nuts.*

overly tighten the retaining nut, creating a dangerous condition (Photo 2).

To overcome this problem, some knifeholders fix the blade using multiple screws in conjunction with slots in the blade. This puts extra cost into every blade, places significant strain on the retaining screws, and is not as secure as a physical clamping ring using a similar slotted screw-hole concept.

A related problem is the unintended rotation of the blade hub as the operator loosens or tightens the retaining screws. Designs that require the operator to use a second tool to prevent such rotation should be avoided. The inclusion of an anti-rotation lock for blade changing gives evidence of the manufacturer's concern for safety during the blade-changing sequence.

One of the most important innovations of the last few years is the advent of the tool-free removable blade cartridge, which allows blades to be changed off-machine, in a safer environment. This feature has done much to reduce hazards, machine downtime and improve blade-changing efficiency (Photo 3).

Photo 3: *A tool-free removable cartridge makes off-machine blade changing safer. This is especially important where access is awkward or hazardous. Machine downtime is also reduced.*

Safety

Knifeholder adjustment controls should be away from the rotating nip. The knifeholder's engage and disengage actions should not be sudden, rapid movements which may startle an operator, or be too fast to get a hand out of harm's way during setup.

Is the knifeholder easy to reposition without placing hands close to the blade? Tools, shims, spacers or jigs should not be needed when making pattern changes. Blade guards should be robust and able to tolerate the occasional snarl that occurs during a web break. In some instances, automatic self-retracting, full-coverage blade guards may be required.

Is the air system integrated with the E-stop control, so the slitters will automatically disengage in an emergency? Does the lower slitter shaft have a brake to arrest free-wheeling in an E-stop?

The blade-retaining system must be fail-safe (avoid spin-on blade retaining nuts, as described earlier). Is there any possibility that the operator could install key-slotted blades so they can spin off if a screw works loose? On extremely high-speed machines, do the blade retaining screws have counter-bored sockets to prevent the screw heads from releasing the blade? A blade flying off at 8,500+ fpm is a serious hazard.

Blade changing should be done off-machine, in a safe environment, especially where access to the slitters is precarious. Unfortunately, many machines require the operator to hang from his toenails in half-light to change slitter blades. Blade-mounting systems that require the use of both hands to manipulate spanners, or wrenches to loosen the blade are especially dangerous under such conditions. The tool-free, removable-blade cartridge is a major improvement to safety on these machines.

Blade handling should be minimized and done in a safe environment. The use of wax coatings to protect the blade edge is important, but the coating should be easily removable after the blade has been mounted on the slitter. This means that blade guards should not prohibit access to the blade once it had been mounted, nor interfere with complete removal of the wax coating.

If the guards do interfere with blade changing, then safety gloves should be worn. Large, heavy blades should be supplied as individually wax dipped rather than in a bundle, since separating the bundle itself can be dangerous — not to mention the possibility of nicking a blade's edge.

After all is said and done, the knifeholder is a pivotal instrument in most industries involved with flexible webs. The tendency to think of slitting as an "afterthought," and treat a knifeholder with the attitude that "any old device will do" is being replaced with a greater appreciation of the importance of this seemingly insignificant part of most web-processing equipment.

Four factors to consider in razor slitting

It may be the simplest and cheapest method available, but razor slitting still requires close attention to blade life, edge quality and operator safety.

By Reinhold Schable, Applications Technology Manager, Tidland Corp.

The three most common methods of slitting flexible web materials are shear, crush (score), and razor. Of these three, razor has the lowest installed cost, being the simplest and cheapest method. It can be easily adapted to almost any machine, in almost any location. It is potentially the cleanest method of slitting, assuming the appropriate materials are being slit.

A "cutting" or "slicing" action is created by pulling the material past the stationary blade. The resultant edge depends on the characteristics of the material, its thickness, density, rigidity, plasticity, coating, bonding and other factors. At issue are blade life, slit-edge quality and safety.

1. Safety

While the potential for bodily injury is not as great as with shear or crush (score) slitting equipment where rotating nips are involved, razor-slitting equipment is notorious for cuts and slashes that can be severe. Razors installed in the open span, tangent position are difficult to guard, compared to installations where razors are slitting against grooved rollers. Even with effective guarding, the simple act of changing blades exposes operators to a scalpel-like edge all too frequently. Use of premium blades (hard coated, carbide, or ceramic), to reduce the frequency of blade changes, will also improve safety.

2. Principles of separation

Razor sitting is, in essence, the creation of a "controlled crack" immediately ahead of the blade edge. The mechanical properties of the material and the shape of the edge determine how and where this crack forms. If the crack forms close to the edge, the process is relatively stable, if the crack forms far ahead of the tip, the process may become unstable where edge flaws may develop, and uncontrolled tearing or splitting may occur.

Other factors that influence razor-slit quality are the amount of material displacement by the blade, stretching due to tension problems, web flutter and web temperature, etc. Edge quality for thicker, denser materials may display a typical "raised edge," surface coatings may be disrupted, filaments, dust, or "whiskers" along the slit edge may form.

Figure 1: *Tangent slitting in an open span. A low blade angle is better suited to thin webs that do not deflect under the blade. As webs increase in thickness and strength, the tendency to deflect may be countered by increasing the blade angle.*

When razor slitting plastic materials, the ratio of web tension to the plastic's yield stress must be considered. Since the blade is dragging against the web, its resistance must be added to the tension force and has the potential for exceeding the material's elastic limit immediately adjacent to the slit. Stretched, deformed edges are the result. A general rule of thumb is that the web tension in the slitting zone should not exceed about 10 percent of the material's elastic limit.

What are appropriate flexible-web materials for razor slitting? Razor slitting has found wide acceptance in slitting flexible packaging films, and, paradoxically, for slitting extremely thick polyethylene films. Household aluminum foil is also commonly slit with razor blades. Razor slitting of fiber-based products, however, is usually disappointing due to rapid blade wear. In general, it is usually possible to use razor slitters successfully if the material has low values in caliper, density, elongation, tensile, and abrasiveness.

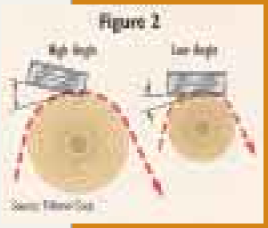


Figure 2: *Wrap slitting using a grooved support roll. Large rolls require that only the blade tip be used for slitting. Oscillating of the blade to distribute wear is not possible. Small rolls permit slitting to be done along the length of the blade edge, making oscillation possible.*

3. Installation parameters

The razor blade may be located in any one of several locations in the web path. The simplest is to slit in the open span between supporting surfaces, as is common on film extruders (Figure 1). Another location is in the valley between two closely spaced rollers. The advantage here is that the web is relatively taut, and does not "flutter" as severely as in a long open span. Both of these locations create a tangent slitting geometry, with little or no support for the web.

The third location is to slit using a grooved roll, which supports the web as it wraps around the roll to

Figure 3: *Without support, low-incident blade angles will deflect thicker webs down, away from the slitting edge. The blade must, therefore, be inserted deeper into the material, causing more edge distortion. Increasing the blade's angle of incidence reduces downward deflection of thicker webs. However, the thicker blade increases slit-edge deformation. The abrupt trailing edge of the blade may also "scrape" along the slit edges, creating dust.*

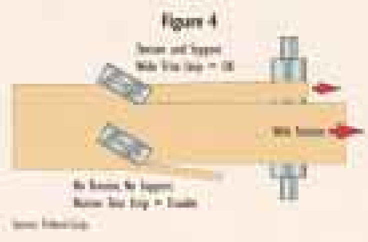


Figure 4: *Trim slitting using razor blades poses a special challenge. Web tension must be balanced on both sides of the slitting blade. The narrower the trim strip, the more critical it is to have tension and support for the strip.*

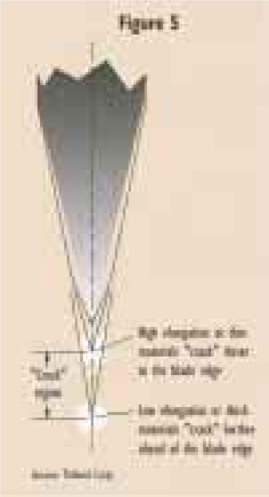


Figure 5: *Razor slitting is, in essence, the creation of a "controlled crack" immediately ahead of the blade edge. The mechanical properties of the material and the shape of the edge determine how and where this crack forms. If the crack forms close to the edge, the process is relatively stable. If the crack forms far ahead of the tip, the process may become unstable.*

some extent (Figure 2). Accuracy is much improved, many multiple narrow slits can be done, and web control is assured because the web wraps around the grooved slitting roll. The diameter of the grooved roll has some bearing on the blade's angle of incidence relative to the web. Larger rolls (over about 150-mm/6-in. diameter) limit the slitting zone to the extreme tip of the razor blade. Thus, the blade must be "tilted" into the roll, creating a relatively high angle of incidence. Small rolls (below about 120-mm/4-in. diameter) permit the blade to be held tangent to the roll, creating a relatively low angle of incidence.

The blade's angle of incidence to the web is dependent on web characteristics, as well as mounting geometry, A low angle relative to the web presents a longer slitting edge, less blade cross-sectional area and less slitting drag on the web (Figure 3). However, there is more tendency to deflect the web away from the blade edge. On the other hand, steep blade angles present a shorter slitting edge, and a thicker blade cross-section. The web is deflected less, but drag resistance is increased, and slit edge deformation is more likely.

It is extremely important to recognize that razor slitting requires equal web tension on both sides of the blade (Figure 4). Otherwise, asymmetrical tension forces can cause problems such as a wavy slit line, film splitting or, in the case of edge trimming, the trim strip may merely turn down under the blade, refusing to slit at all. Razor slitting a narrow waste strip of film without providing adequate tension to the trim strip is a sure recipe for frustration.

4. Blade parameters

Since a very small portion of the razor is engaged in the slitting zone, wear of the extremely thin edge is rapid, and frequently fails at critical times, causing interruptions (downtime) in the process lines (Figure 5). To delay wear, the blade may be mounted on an oscillating blade holder in an attempt to spread the wear over a longer edge zone. The oscillating motion can, however, create "flutter" in some webs, complicating the slitting function.

Another tactic to delay edge wear is to coat the blade with a hard surface, such a TiN or other proprietary ceramic coating. The most durable blades are made of tungsten carbide or ceramic (usually zirconia), and may be the most practical choice when slitting high-abrasive films on extruders, where machine downtime due to a loss of slitting can be extremely costly.

The included angle of the razor-blade edge is a fixed constant, but the "point" at the extreme tip abrades to a constantly increasing radius as wear progresses. It's this blunt tip that determines the end of the blade's useful life. Slowing the rate of tip erosion increases blade life. To spread the wear over a longer edge, many razor-slitting systems incorporate oscillation into the blade holders. This is effective provided the oscillation does not induce web flutter. Obviously, wrap-configured systems are immune to such flutter, but oscillating razors placed in a long open span between rollers have the potential to cause flutter, depending on the extent of the deflecting forces the web encounters at the blade edge.

To delay wear, razor blades may be hard-coated with TiN, ceramic, or a DLC (Diamond-Like Coating) material to significantly extend blade life while reducing friction between the material and the blade. Solid tungsten carbide and ceramic blades are also available for extreme-duty applications.

A typical utility razor blade may have a rather coarse grind finish, which rapidly polishes smoother during slitting. Unfortunately, this also means that the extreme tip is rapidly blunting at the same time. Thus, smoother blades will have a longer service life compared to rough blades. TiN or ceramic edges are the smoothest of all and give better service for the same reason.

Razor slitting is simple; no doubt about it. For many products and applications, it's the best way to get the job done. But like any technology, it's important to understand how it works, what its limitations are, how materials react "under the knife," and what to do to make it function properly when things go wrong.

Five factors to consider in choosing score slitting

The simplicity of score slitting is one of its main attractions, but slit-edge quality is highly dependent on important variables that must be addressed.

By Reinhold Schable, Applications Technology Manager, Tidland Corp.

Score slitting, often referred to as "crush" slitting in international markets, is a common method of separating the web. Basically, a hardened steel disk is pressed against a rotating, hardened steel cylinder, creating a crushing nip into which the material is directed. The resultant nip force exceeds the ultimate yield of the material, and the material is severed along the nip line. Changing slit widths is relatively easy because only the slitter is repositioned over the fixed anvil roll. That's all there is to it. Simple, or so it seems.

Slit-edge quality is variable and depends on the material being slit, the blade-edge profile, blade-edge finish and anvil smoothness. Because slitting is a "crushing" action in the nip between the slitter blade and the anvil surface, it's generally considered the dustiest of the slitting methods, delivering the poorest edge quality. Under a microscope, the resultant edge is ragged and frequently displays a ridge formed by material that has been displaced by the blade tip. Extremely dense or thick materials might require nip forces beyond the yield strength of the blade steel, making score slitting impractical.

Score-slitting variables can be separated into at least five different factors that affect the performance of the process. They include web material characteristics; nip forces (their extent and effect on the blade and anvil roll); blade tip profiles; metallurgy of the slitter blades and anvil rolls; and mounting geometry of the blade relative to the anvil roll.

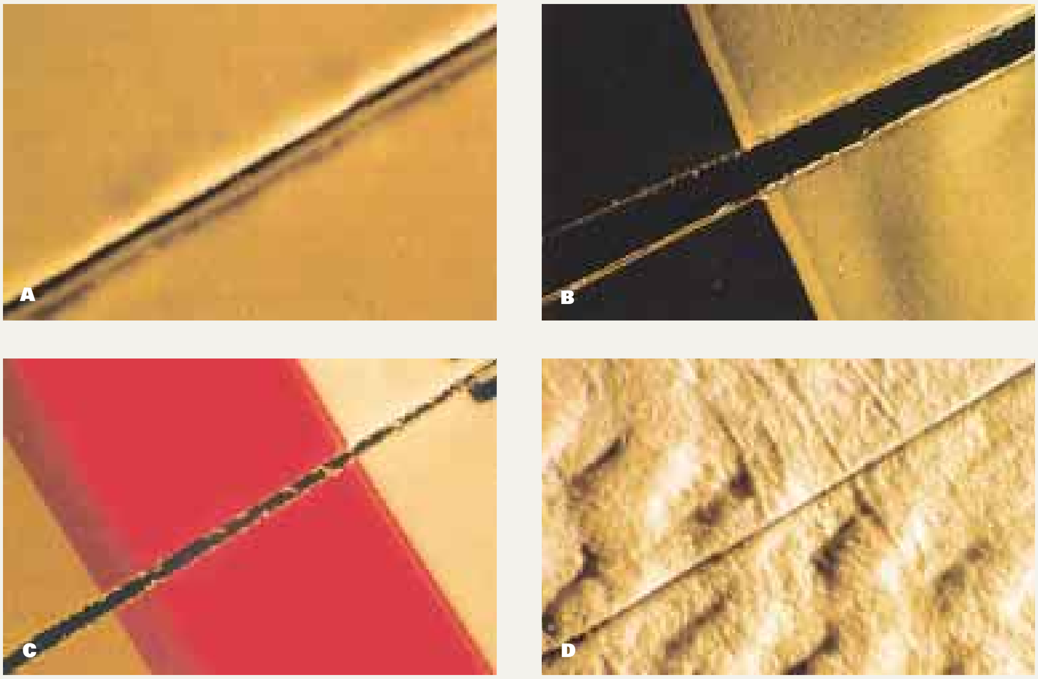
1. The web

Every material has its unique nip force requirements. The density, ductility, hardness, thickness and "grain" of the web determine the force required for plastic deformation to occur to displace the web around the tip of the slitter blade. Depending on the physical characteristics of the web, it might crumble, shatter, extrude or wrinkle. In fact, it might exhibit all of these reactions at various depths along the slit line.

One thing is certain: the web material must be displaced in an amount equaling the volume of the blade tip. This displaced material might be in the form of debris (dust), a ridge along the slit edges,

Source: Tidland Corp.

The score slitting blade profiles should be viewed as starting points in determining the optimum profile for any given web material. Smaller tip radii and acute angles result in rapid tip fracture and anvil-roll grooving. Larger tip radii and included angles require more force to slit, even though durability is improved.



Various web materials score-slit with a 45-deg x 0.005-in. radius blade:

(A upper left) Thick clay-coated, enameled paperboard (0.45 mm thick). The material has been displaced by the blade, forming a prominent ridge along both edges of the slit line.

(B upper right) Polyethylene (100 microns thick). The soft plastic has been extruded by the blade tip radius, leaving thin flakes of polyethylene along the slit edges.

(C lower left) Polypropylene film (70 microns thick). This harder, lower-elongation plastic has crumbled under the blade tip radius, leaving debris as slitter dust.

(D lower right) Paper towel. The cellulose fibers have been effectively crushed, and the porous nature of the web has accommodated the presence of the slitter blade without undue product damage.

a series of cracks, or in the case of laminated products, delamination might occur and laminations might be laterally displaced.

Composite webs, such as paper, textiles and nonwovens, are of relatively low density, with interfiber voids that permit some displacement of the material by the slitter blade tip. Thus, nip forces can be relatively low, ranging from 50,000 psi for tissue to 150,000 psi for lightweight boards.

Laminated webs, such as pressure-sensitive labels, might exhibit interlayer slippage or displacement along the slit edge as each layer struggles to make way for the slitter blade tip. These products tend to be thicker, requiring somewhat higher nip forces, about 150,000 to 200,000 psi, depending on web thickness and composition.

Solid webs, such as extruded or cast plastic films, must be plastically deformed by the blade tip. This means that the tensile strength, elongation and caliper thickness of the web become factors in slitting. High-elongation plastics, such as polyethylene, will extrude easily in the nip, while brittle plastics, such as styrene or acrylic, tend to crumble or shatter in the nip. Typical flexible packaging films can be slit with nip forces of 50,000 to 100,000 psi. Plastic sheet (greater than about 0.2 mm thick) might require very high nip forces of 200,000 psi and higher.

Metals must also be plastically deformed in the same manner, except that the tensile strength, ductility and caliper thickness parameters are even more critical. Usually, only ductile metals such as aluminum or copper can be score-slit and only in a thickness classified as “foil.” Expect to exert nip forces of 50,000 to 200,000 psi, depending on thickness.

2. The nip force

Because the nip induces compressive and tensile stress in the material, it becomes obvious that the nip force must be greater than the strength of the material. It must also be able to continue slitting during "transient events" (hard spots in the web, splices, folds due to wrinkles, etc.). Web speed also influences slitting because a form of "hydroplaning" may result due to the viscoelastic web property. A "bow wave" could form in front of the nip if speeds are high enough. Under such circumstances, the nip force must be increased.

Determining the actual nip force is complex because it is a combination of the air pressure in the knifeholder, the piston area, the blade tip radius and blade tip included angle. If a lever arm is a design feature of the knifeholder, its mechanical advantage component must also be included.

If run-out of the slitter blade or anvil roll is present, or there is vibration in the slitting system, momentary impact forces and stresses could be extremely high, leading to severe chipping or catastrophic blade failure. In the same manner, interrupted slitting imposes a "shock factor" to the blade tip each time the blade drops off of the trailing edge of the sheet and impacts itself against the anvil roll.

Large-diameter blades will not drop as suddenly as small blades, just as larger automobile tires survive potholes easier than smaller tires. Blades that have been slotted to serve as perforating slitters suffer similar shock stresses at each slot in the perfing blade, and the wider the slot, the more abrupt the shock.

Engaging the blade against the anvil roll should be slow and controlled to prevent shock to the blade tip. This is especially important where high nip forces are required to slit the material. For instance, when slitting a heavy plastic sheet, a nip force of 200,000 psi might be required, and without a "soft start" engagement, the blade would "slam" into the anvil roll each time the operator turns on the slitter. Under these conditions, the shock could easily damage the blade.

3. The blade profile

Choosing the best score-blade profile usually involves some compromise between blade life and slit quality. Blade life is strongly determined by tip radius and tip angle as these two factors determine the stress concentration at the blade tip. With very few exceptions, all score-slitting blades must have a small radius at the tip instead of a "sharp" edge that would fracture almost instantly as it is rotated against the hardened anvil shaft. This radius, unfortunately, is the reason slit quality is poorer than with other slitting methods —you are actually slitting with a blunted blade.

Slit quality is also strongly determined by the radius and included angle at the blade tip. A small tip radius displaces the web material easily, so slit quality is better, but tip erosion is severe. A small, included tip angle also displaces the web material easily, but blade chipping is a problem. As the tip radius and included angle are enlarged, blade life increases but slit quality decreases.

While the included angle of the blade tip is a constant, the tip radius continually flattens and enlarges as the blade wears. As the tip enlarges, the tip stress declines, and the rate of wear slows. Unfortunately, the nip force is now distributed over a larger "footprint" area, and slit quality deteriorates. When this occurs, the slitter operator's natural tendency is to increase the nip force, which increases tip stress and accelerates blade wear.

When regrinding score-slit blades, pay particular attention to the tip radius because achieving a precise radius is difficult. Because most grinding equipment does not have accurate profiling capability, operators generally grind the radius by "eye," so operator skill determines the accuracy and surface finish of the radius. Surface finish is important; the tip should be smoothly polished, otherwise, rapid blade wear and dusty slitting will result.

Choosing an optimum blade profile is not always a straightforward process. The blade selection chart suggests typical profiles, but some experimentation might be necessary.

4. Metallurgy

Blade metallurgy determines a blade's hardness vs. toughness. The primary metallurgical requirement for score-slit blades is shock resistance, which is described by the metal's toughness. This is in contrast to shear slitter blades in, which high abrasion-resistance (the metal's hardness) is the dominant requirement. In general, toughness is usually more important than hardness when score slitting because score blades need good shock resistance in order to withstand the internal stress caused by the nip force, especially if run-out, blade bounce or "chattering" is present.

Because the blade exerts considerable cyclical force as it rotates against the anvil roll, the metal suffers repetitive stress-cycle failure. The smaller the slitter blade, the quicker the repetitive stress cycles accumulate. As the number of revolutions accumulate, the slitter blade edge begins to fatigue; it chips, the anvil surface becomes grooved and slit quality deteriorates. Increasing the nip pressure to improve slit quality results in even faster metal failure. Blade life is therefore fixed by the parameters of metal durability, nip stress, and a number of stress cycles (actual number of slitter revolutions at any given nip stress).

At the same time, blades need good abrasion resistance. Some compromise must be made because shock resistance and abrasion resistance usually occupy opposite ends of the steel formula equation. While it is not practical to list all the various steel formulas available for slitter blades, some generalizations are helpful.

A relatively low carbon-content (under 1 percent) and low chromium-content (under 5 percent) steel has better shock resistance than abrasion resistance. Conversely, a high carbon-content (above 1 percent) and high chromium-content (above 5 percent) has better abrasion resistance than shock resistance, especially if the alloy includes significant amounts of tungsten, molybdenum or vanadium. That is an oversimplification of a complex topic, but it conveys the basic concept.

Regarding hardness, the anvil roll must be significantly harder than the slitter blades, otherwise severe grooving occurs. A Rockwell hardness of 64C is usually considered minimum. This suggests that the slitter blade hardness be about 4 to 6 hardness points lower—Rockwell 58C being a typical value. The blade should be hardened throughout, not merely surface-hardened, otherwise the softer core metal cannot support the stresses.

5. Mounting geometry

Score slitting is normally configured for a wrap-slitting mode instead of a tangent web path. Some web materials might become unstable under the influence of the rolling nip of the score blade, especially if there is a tendency for the blade to track to one side. Under these conditions, wrap slitting maintains better control of the web after it leaves the slitting nip. The slitter speed should be synchronized with the web speed.

Occasionally, under light-duty applications, the wrapped web has been used to drive the anvil roll, but web tension must be constant and adequate, or the anvil roll rotation will be erratic. Under these conditions the web must be able to freely rotate the anvil shaft even during acceleration, as well as provide torque for the slitters themselves.

When mounting score slitters, it's important that the centerline of the blade is placed slightly downstream of the centerline of the anvil roll, otherwise the blade might track laterally, creating stress and abrasion at the blade tip. This "crabbing" action can be likened to tire misalignment on an automobile; severe "toe-in" or "toe-out" forces the tire to scrub laterally on the pavement. The same thing can happen if the slitter wheel is not mounted slightly beyond the center of the anvil roll. The goal is to have a slight weather vane action. The actual offset is not critical; a reasonable offset is about $^{1}/_{25}$ of blade diameter.

The diameter of the anvil roll determines the maximum speed of the slitter. The roll should not pass through periods of vibration during acceleration, which is an indication that it's of marginal diameter. Slitter blade wear will be severe under these conditions. As speeds increase, run-out, vibration, and anvil-roll bounce might create a destructive "chatter" between the slitter blade and the anvil roll, which in turn creates extremely high momentary stresses at the blade tip, resulting in rapid metal failure. Increasing the diameters of the anvil roll and slitter wheels — to reduce component rpm and raise critical speed value—is usually a better long-term solution than trying to buy slitter blades made of an exotic steel.

It seems like a low-tech way to slit a flexible web, but as many have found to their chagrin, score slitting has its own set of technological requirements. What's important is to understand the fundamental principles, then take the appropriate steps to get the most from this method of slitting.

Factors to consider in choosing shear blade profiles

Wrap versus tangent slitter geometry has benefits and drawbacks depending on the substrate to be converted. Here's how blade profile impacts shear cut performance.

By Reinhold Schable, Applications Technology Manager, Tidland Corp.

In shear slitting, blade profile is one of the most frequently asked questions. While slit-edge quality is the result of many factors, blade profile is one of the factors most frequently changed in an attempt to improve slit quality. Often, a profile change does not yield the expected results because the shearing mechanism itself is not well understood. This article looks at how profile affects shear slitting.

Profile is defined as the cross-sectional shape of the blade tip, including the region beyond the actual cutting edge. This discussion is, however, limited to the portion of the blade profile that actually engages the web in the slitting process.

Shear slitting, by definition, is the vertical displacement of the material as it enters a shearing nip between two opposing edges. The opposing edges can be two straight blades, as in a guillotine, or two rotating disks, as in the familiar web-slitting machine. These edges are usually in contact, however, some distance, as determined by the web characteristics, may separate them. "Gap slitting" of metals is one example.

Because the upper blade projects through the web during slitting, its profile is of great importance. Any damage to the web along the slit edge is, to a great extent, a result of the upper blade's profile.

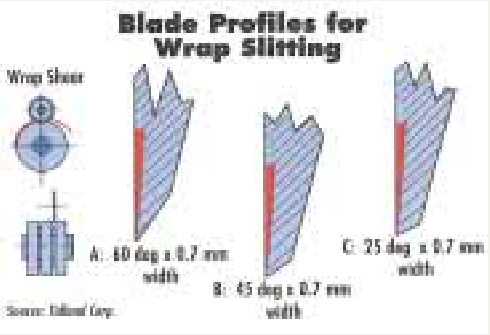
As blade profile angles are gradually increased from "square" to acutely pointed, the material deflection path gradually changes from a vertical (shear stress) displacement to a lateral (tensile stress) displacement. Thus, the shearing mechanism gradually changes from a pure shearing action and merges into a "slicing" or "cutting" action as the blade profile narrows.

Effect of web materials on slitting quality

Web characteristics significantly impact slit-edge quality. Web rigidity, density and extensibility, for instance, may require distinctly different blade profiles for best slit quality. To illustrate: High-density webs are adversely impacted by the "wedging" action of narrow, acutely angled blade profiles; they are better slit using true shearing (vertical displacement) action. Conversely, low-density webs do not always "shear" cleanly, and may benefit from the "slicing" action of an acutely ground blade profile—at the expense of reduced blade life.

Wrap versus tangent slitter geometry is very important in deciding which blade profile to use. While some profiles may serve as "general-

Typical tangent-shear slitting applications include Profile A for high-bulk, low-density materials; Profile B for high-density, low-elongation materials; and Profile C for general tangent slitting.



Typical wrap-slitting applications include Profile A for precision (multiple-web) sheeters; Profile B for general wrap slitting and single-web sheeters; and Profile C for general wrap slitting of thin, supple web materials. Profile C is not recommended for critical wrap applications.

Typical slitter blades:
(Left): A narrow, compound level blade ground to a 25-deg x 0.3-mm width. This rather fragile blade is best suited for wrap slitting applications. (Second blade from left): A general-purpose, compound bevel blade with a 25-deg x 0.7-mm edge. (Third blade from left): A single-bevel blade, which a 45-deg x 4-mm-wide edge. This blade is best suited for tangent slitting of most flexible web products. (Right): A single-bevel, wide-rim blade, with a 5-deg x 10-mm-wide edge. This blade is restricted to tangent slitting of low-elongation materials, and any product sensitive to lateral distortion of the web caused by the slitter blade.

purpose” blades, optimum slitting may require more specific profiles for either wrap or tangent geometry. The concern is how the material reacts to the blade’s presence in the web line; specifically, how the material is deflected as it passes through the slitting nip. Wrap and tangent slitters deflect the web in distinctly different ways, it’s necessary to recognize how blade profile contributes to this deflection and its influence on the slit edge.

Minimizing web damage

The lower slitting grooves in wrap systems limit free deflection of the web, crowding it into the grooves. Compound bending of the web in the slitting zone is a characteristic of wrap slitting; thus blade-tip dimensions should be reduced to minimize this potential source of web damage. Very slender blades, having steep, compound grind angles are designed to keep blade-tip profiles to a minimum in the slitting zone. Hollow grinding is another means of reducing blade profiles, while permitting a somewhat more durable grind angle at the extreme blade tip. It is for these reasons that wrap slitting is best suited for thin, flexible materials.

Tangent slitting does not restrict free deflection of the web as it passes through the slitters, because there is greater available space between adjacent lower slitter rings. Compound bending of the web is not as severe, and may be entirely avoided if the blade is suitably ground. Blade-grind angles can be lower, resulting in more durable edges and longer blade life. Almost any material can be tangent slit, but especially in the case of rigid webs, a tangent slitting system is the method of choice.

Blade-edge durability and slit-edge quality may be at opposite ends of the equation, and some compromise may be required. Sharply pointed blade tips may produce better slit edges, but wear rapidly. At the other extreme, square-edged blades may produce lower slit quality, but are more durable.

Tangent slitting blade profiles

With the above principles in mind, here are suggested profiles for slitting various materials in a wrap or tangent slitter configuration.

For tangent slitting of typical paper-based webs, flexible packaging products, and other similar flexible, relatively thin materials:

- A tip grind angle of 25 deg to 30 deg is durable and relatively immune to chipping. To avoid damaging the web on the unsupported side of the slit, the primary grind face should be wide enough to deflect the web under the blade rim without impacting it against the outer transition corner. With a typical overlap of 0.7 mm, the width of this face should be about 2 mm or wider.
- A tip grind angle of 35 deg to 45 deg is often used as a general-purpose blade, but the tip is not as durable, and is more prone to chipping. An additional problem is that the web cannot avoid aggressive lateral displacement as it passes the slitter blade. Thus, blades with these grind angles are best suited for supple webs that can tolerate rubbing against the blade. When slitting thick, dense webs, it’s important to keep these blades as thin as

possible, because it's very difficult to prevent the outer transition corner from damaging the web.

- A tip grind angle of 0 degree (square) to 15 degree may be used with good results on dense, nonfibrous materials provided the face width of the blade is wide enough to fully deflect the web. With a typical overlap of 0.7 mm, this face width should be about 9 to 10 mm. This profile deflects the sheet under their rim, rather than forcing it laterally, thereby avoiding damaging impact against the outer transition corner. These rather unusual blades have even been found to be useful when slitting newsprint and similar web materials at high speeds.

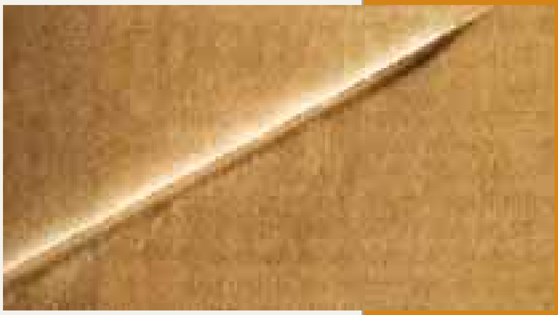
Wrap slitting blade profiles

Wrap slitting is best limited to relatively thin, flexible products that tolerate the compound bending that occurs in the slitting nip. Blade profile choices are limited, and setup is more demanding. Some suggestions:

- A tip grind angle of 35 degree to 45 degree will serve as a general-purpose blade when wrap slitting. Attention must be given to the ability of the material to pass the slitter blade without damage due to crowding in the lower slitter groove. Thus, a blade with these grind angles is best suited for supple webs that can tolerate rubbing against the blade.
- When slitting multiple layers of materials, as in a sheeter, wrap slitting is usually preferred. Two layers slit relatively well, but each additional layer appears to exponentially degrade slit quality. The blade tip must be extremely thin; 45 degree is considered the minimum angle, 60 degree is common.
- When slitting thicker, denser webs, it's important to keep blades as thin as possible, because it's difficult to prevent the outer transition corner from damaging the web. To minimize damage, the grind angle can be increased, the blade can be hollow ground, or the width of the lower slitter groove can be enlarged. Increasing the grind angle much over 60 degree is impractical, as an extremely fragile edge will result. Hollow grinding is costly, and requires complicated secondary regrinding to maintain the narrow blade edge.

Lower slitter ring considerations

The profile of the lower slitter ring, while not as critical as that of the upper blade profile, should also be considered. The majority of lower slitter rings are of a simple cylindrical shape, providing support for the web as the upper blade shears the material. On rare occasions, acutely pointed lower slitters may be designed to project up into the web line in the same manner as upper blades.



Shear slit with 25-deg x 0.7-mm blade. *Damage to the web, caused by the transition corner of a typical 25-deg x 0.7-mm slitter blade is seen as a bevel being formed along the lower edge of the slit line. Increasing the width of the primary grind area will avoid this particular form of damage. This sample is 18-pt clay-coated, #1 enamel paperboard.*

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A bevel, often referred to as a "back bevel" or "undercut," on the contact faces of both the lower and upper slitter blades is important. On the lower slitters, the back bevel acts as a dust-relief angle, preventing an accumulation of slitter debris from forcing the slitter blades apart. Typically, this angle is -3 degree to -5 degree. When slitting very thin, extensible or fibrous materials, this angle may be increased to -6 degree to -8 degree. Rarely is this angle greater than -10 degree. When slitting metals in noncontact applications, this angle may be eliminated entirely for maximum edge durability.

When using carbide lower slitters, the back bevel should include a small facet at the outer perimeter. This facet should be about 1 mm wide and have a very low grind angle (about -0.5 degree); otherwise the carbide edge will aggressively cut metal from the upper slitter blade.

A back bevel on the contact face of the upper blade is important wherever the blades have the potential of being tilted out of vertical alignment with the lower slitter. This vertical relationship between the upper blade and the lower ring is referred to as a rake angle, and can be a source of confusion regarding slitter geometry. As the upper blade tilts over the rim of the lower slitter, the slitting nip is disturbed, resulting in poor slits. The back bevel on the contact face compensates for a small amount of rake angle misalignment. Any knifeholder that cannot accurately maintain a true vertical rake angle must use blades that are either dished (conical shaped) or have an undercut ground into the contact face.

In summary, the profile of the slitter blade has a significant effect on how the material is deflected in the slitting nip. Matching material characteristics with slitting method — wrap versus tangent — is necessary when choosing the appropriate blade profile.