Optimizing the Shear Slitting Process

Summary
Presenter: Peter Wood, Product Manager – Slitting
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Shear slitting is the most versatile and commonly used method to slit flexible web materials. It is also the most demanding, requiring careful attention to control specific operating variables, for high quality slitting. These variables and their influences are identified, and guidelines for optimizing each variable to refine the slitting process are presented. These variables include:

- blade sharpness/profile
- cant angle
- overlap
- side force
- nip velocity vs. web velocity
- slitter geometry
- trim removal

Blade Sharpness / Profile

In rotary shear process, materials are slit in the nip between two overlapping, hardened metal disks which create stress in the shear mode sufficient to sever the product. This is in contrast to compressive stress when crush/score slitting, or tensile stress when razor slitting. The characteristics of the blades extreme edges determine the “sharpness,” and should not be confused with the grind angle or cross-sectional “profile” of the slitting blades. All slitting blades must have sharp edges, but profiles can vary widely and still meet the criteria for “sharp” blades.

Cant Angle

The cant angle (shear angle) assures a closed nip. Like a pair of scissors, the blades must be in contact at the nip or “cut Point” in order to cleanly shear the web. Certain materials are very sensitive to cant angle settings, whereas other materials seem to slit well with almost no thought given to the question
Optimizing the Shear Slitting Process

Presented by:
Peter Wood
Slitting Product Manager
Tidland Corporation
Large, Complex Slitter

...Shear slitting can involve a large, complex machine, or.......
...Shear slitting can involve a simple “old timer”.
Variables to Control

- Consistency in slit quality is within reach
- Control the variables in slitting
Variables to Control

- Achieving and maintaining a quality cut is directly impacted by factors that can be controlled
  - blade sharpness/profile
  - cant angle
  - overlap
  - side force
  - nip velocity vs. web velocity
  - slitter geometry
  - trim removal
Shear Blade Profile
Terminology

COMPOUND BEVEL, FLAT BLADE, with UNDERCUT.
4 Shear blade profiles…
Blade Profile

Strongest blade edge: for slitting metals, low elongation plastics, tissue, newsprint, coated products

0°-5°

Very weak blade edge: typically used on sheeters and wrap configured slitting machines to reduce distortion of product at slit edge.

60°

25°-30°

Good general purpose edge: for slitting paper, films, laminates, non-wovens, boards.

Extremely fragile edge: rarely used today, except when wrap slitting light metal foils. Light sideload req’d.

45°-60°

Compromise between blade edge strength and distortion of product at slit edge.

45°
Blade Profile

Traditional, Narrow Rim Blades

Low Grind Angle, Wide Rim Blades

0.030" OVERLAP

0.12" 0.18" 0.37"

WEB LINE
The Wrap System

Web speed and lower slitter speed is synchronous
Profiles for Wrap Slitting

...Wrap slitters confine the shear strain into a narrow groove,
...Blades must be very thin (and fragile) to minimize edge damage.
4 Shear Blade Profiles

...#1 & 2: Wrap slitter blades
...#3 & 4: Tangent slitter blades
The Tangent System
Tangent configured slitters permit a wide variety of blade profiles.  

- 45° x 0.8mm: for High Bulk, Low Density Mat'ls.  
- 5° x 9mm: for High Density, Low Elongation Mat'ls  
- 25° x 2mm: General Tangent Slitting

Profiles for Tangent Slitting
4 Shear Blade Profiles

...#1 & 2: Wrap slitter blades
...#3 & 4: Tangent slitter blades
25° Blade in a Tangent Web
25° Stress in Styrene
Aluminum Litho plate
25° Tangent Shear

Unsupported edge
Coating ridge. 25° blade

Notice ridge of coating from edge of compound bevel blade.
5° Wide Rim Blade in a Tangent Web
5° WR Blade Stress in Styrene
Aluminum Litho plate
5° Wide Rim, Tangent Shear

Unsupported edge
No Coating Ridge, Single Bevel Blade

Notice elimination of coating ridge with single bevel blade.
A Sharp & Dull Edge

...As sharpness is lost, an "open nip" forms between the slitters.
Blade Sharpness

Wear Patterns

Extent of regrind required to correctly resharpen blades

'Wear Band' due to metal-to-metal wear between blades

Tip erosion due to abrasion by the web

Original Profile
Blade Sharpness

Wear Patterns

- Metal worn away from original sharp blade
- Dust forms by impact against blunt blade tip
- Dust forms in "open nip"
Wear Patterns

...As sharpness is lost, an "open nip" forms between the slitters.
Wear Band on Blade
Web-to Blade & Blade-to-Blade Wear
Large Lower Slitters
Lower Slitter Profiles - Steel

Typical Profiles:
Steel Lower Slitter Rings

Typically 3° to 5°
Lower Slitter Profile - Carbide

- Carbide or Ceramic edged Slitter Rings.

Typically 3° to 5°

± 1mm

0° ~ 0.5°
Lower slitters which are significantly larger than upper blades tolerate increased overlap with less "cut point shift".

Increased Overlap:

Large lower slitters tolerate overlap error. (Web is better supported).

Small lower slitters exacerbate overlap error. (Web support is quickly lost).

Benefit of Larger Lower Slitters (Tangent Systems)
Minimizing Post-Slit Web Damage

- Blade Profile Determines the Web’s Path Around the Slitter Blade
- Tangent Systems Deflect the Web with Less Cross-Machine Strain, and Permit more Blade Profile Options
- Wrap Systems Create Compound Bending, Blade Profile Options are Limited
Traditional 25° Compound Bevel Blade in a Tangent Web
Slit Edge: PE Microfilm, Standard Blade
Slit Edge: Clay Coated Board
Standard Blade
5° Wide Rim Blade in a Tangent Web
Slit Edge: Clay Coated Board, Wide Blade
Minimizing Post-Slit Web Damage

- Blade Profile Determines the Web’s Path Around the Slitter Blade
- Tangent Systems Deflect the Web with Less Cross-Machine Strain, and Permit more Blade Profile Options
- Wrap Systems Create Compound Bending, Blade Profile Options are Limited
Compound Bending, Wrap Slit
Aluminum, Wrap Slit
Cant Angle
## Cant Angle

<table>
<thead>
<tr>
<th>Cant Angle</th>
<th>Material</th>
<th>Blade Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0° to 0.25°</td>
<td>Metals. Plastic Sheet. Non-fiberous webs. Hard, Brittle Materials</td>
<td>Best</td>
</tr>
<tr>
<td>0.25° to 0.50</td>
<td>Optimum General Purpose Angle. Paper Products. Laminates. Plastic Films.</td>
<td>Good</td>
</tr>
<tr>
<td>0.50° To 0.75</td>
<td>Synthetic Fiber Products. Materials With Loosely Bonded Fibers. Stretchy Films.</td>
<td>Reduced</td>
</tr>
<tr>
<td>0.75° To 1.0°</td>
<td>Fabrics. Unbonded Non-wovens, Etc.</td>
<td>Poor</td>
</tr>
</tbody>
</table>
Skewing two-shafted slitters produces minimal cant angles between upper & lower blades. High elongation materials may require cant angles of 0.5° or 1.0° to slit effectively. Depending on Hub design, blade damage and increasingly poorer slitting will result as skew is increased.
Cant Angle

Beware of the Cant Angle
Overlap

Effect of Increased Overlap on Blade Cross Section

- 0.030" Penetration
- 0.160" (4mm) Penetration
- WEB LINE
- TOP BLADE GRIND ANGLES
  - 60° TIP
  - 45° TIP
  - 25° TIP
  - 15° TIP

0.03 0"
Increasing Overlap:

- Moves the cut point. (Web is no longer supported).
- And increases blade thickness.
Overlap / Chord Calculations

\[ S = r_1 + r_2 - \text{OL} \]
\[ A = \cos^{-1} \left( \frac{r_2^2 + S^2 - r_1^2}{2r_2S} \right) \]
\[ C = 2r_2 \sin A \]

Where:
- OL = Overlap
- C = Chord
- S = Span, Blade Centers
- \( r_1 \) = Radius, Upper Blade
- \( r_2 \) = Radius, Lower Blade

Note: It is necessary to take thickness of material into consideration when constructing the gauge.

### OVERLAP

<table>
<thead>
<tr>
<th>Product</th>
<th>Inches</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tissue</td>
<td>.015&quot; - .030&quot;</td>
<td>.4 - .8 mm</td>
</tr>
<tr>
<td>Fine Papers</td>
<td>.015&quot; - .030&quot;</td>
<td>.4 - .8 mm</td>
</tr>
<tr>
<td>Heavy Papers</td>
<td>.020&quot; - .040&quot;</td>
<td>.5 - 1.0 mm</td>
</tr>
<tr>
<td>Light Boards</td>
<td>.020&quot; - .040&quot;</td>
<td>.5 - 1.0 mm</td>
</tr>
<tr>
<td>Boards</td>
<td>.030&quot; - .060&quot;</td>
<td>.8 - 1.5 mm</td>
</tr>
</tbody>
</table>
Overlap

Shear Slitter Overlap Gauge

Make from any available plastic (Acrylic, UHMW, etc.) or soft metal.

Upper Blade Radius (maximum)

Overlap

Side View

Ca. 1/2"

Lower Knife Ring Radius

Ca. 3"

End View (Cross Section)

Ca. 1-1/4"
Side Force

Knifeholder Suspension Systems

Simple Suspensions

Precision Blade Alignment

Pneumatic Systems
Side Force

Blade sideload systems which permit the blade to tilt over the rim of the lower knife edge will compromise slit quality, unless dished blades are used. Accuracy of the sideloading force is only as accurate as the active component (spring, air cylinder, etc). System mass and harmonics play a significant role in high speed slitters.
Side Force

Dished or back beveled top blades are required for any knifeholder which tilts the top blade when sideloaded.

Negative Blade tilt
Back bevel

Positive Blade Tilt
Flat Blade

A flat upper blade which has been tilted during sideloading will cause the contact point to move away from the proper cut point, creating an "open nip".
Side Force

Blade Sideloads

- Sideload is necessary to traction drive upper blade.
- Heavier materials stall blades, require more sideload
- Excessive sideloading increases wear & chipping

<table>
<thead>
<tr>
<th>Material</th>
<th>Pounds</th>
<th>KG.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tissue</td>
<td>2 - 3 lbs.</td>
<td>.9 - 1.4 kg.</td>
</tr>
<tr>
<td>Thin Plastic Film</td>
<td>2 - 3 lbs.</td>
<td>.9 - 1.4 kg.</td>
</tr>
<tr>
<td>Communication Papers</td>
<td>3 - 4 lbs.</td>
<td>1.4 - 1.8 kg.</td>
</tr>
<tr>
<td>Packaging Laminates</td>
<td>3 - 5 lbs.</td>
<td>1.4 - 2.3 kg.</td>
</tr>
<tr>
<td>Non-wovens</td>
<td>2 - 5 lbs.</td>
<td>.9 - 2.3 kg.</td>
</tr>
<tr>
<td>Light Boards</td>
<td>4 - 8 lbs.</td>
<td>1.8 - 3.6 kg.</td>
</tr>
<tr>
<td>Heavy Boards</td>
<td>6 - 10 lbs.</td>
<td>2.7 - 4.5 kg.</td>
</tr>
</tbody>
</table>
Overspeed

Underspeed Nip
Overspeed

Synchronized Nip
Overspeed

Example:
4" Diameter, .080" Overlap
= Speed differential of − 5.2% = 1000 fpm − 52 fpm = 948 fpm

Example:
Wrap Slit : No Overspeed
= 1000 fpm
Tangent Slit : + 3% Overspeed
1000 fpm + 30 fpm = 1030 fpm
# Overspeed

<table>
<thead>
<tr>
<th>Blade Dia.</th>
<th>Overlap</th>
<th>% Speed Diff. of Top Blade</th>
<th>Radial Friction of Top Blade.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4&quot;</td>
<td>.040&quot;</td>
<td>-4.0%</td>
<td>29%</td>
</tr>
<tr>
<td></td>
<td>.080&quot;</td>
<td>-7.9%</td>
<td>39%</td>
</tr>
<tr>
<td></td>
<td>.120&quot;</td>
<td>-11.8%</td>
<td>47%</td>
</tr>
<tr>
<td>6&quot;</td>
<td>.040&quot;</td>
<td>-2.6%</td>
<td>23%</td>
</tr>
<tr>
<td></td>
<td>.080&quot;</td>
<td>-5.3%</td>
<td>32%</td>
</tr>
<tr>
<td></td>
<td>.120&quot;</td>
<td>-7.9%</td>
<td>39%</td>
</tr>
<tr>
<td>8&quot;</td>
<td>.040&quot;</td>
<td>-2.0%</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>.080&quot;</td>
<td>-4.0%</td>
<td>28%</td>
</tr>
<tr>
<td></td>
<td>.120&quot;</td>
<td>-6.0%</td>
<td>34%</td>
</tr>
<tr>
<td>10&quot;</td>
<td>.040&quot;</td>
<td>-1.6%</td>
<td>18%</td>
</tr>
<tr>
<td></td>
<td>.080&quot;</td>
<td>-3.2%</td>
<td>25%</td>
</tr>
<tr>
<td></td>
<td>.120&quot;</td>
<td>-4.4%</td>
<td>30%</td>
</tr>
</tbody>
</table>
Overspeed

**Typical Overspeed Guidelines**

- **+1% to +3%**: Foils, Low Elongation Films, Delicate Mat'l.s.
- **+3% to +5%**: General Materials, Papers, Boards
- **+5% to +10%**: High Elongation Films, Loose Fibered Mat'l.
- **+10% to +100%**: Textiles, Unbonded Non-wovens, etc.
Slitter Geometry

Tangent

Arc of “Rub”

Arc of “Overlap”
Slitter Geometry

Wrap

Arc of “Rub”

Arc of “Wrap”

Arc of “Overlap”
Slitter Geometry

True Wrap

Web Deflected Around Top Blade
Slitter Geometry

True Tangent, with Traditional Setback

- Ideal Cut Point
- Web Deflected Around Top Blade
- Web Deflected Under Top Blade
Slitter Geometry

True Tangent, with No Setback

Unsupported Slit

Web Deflected Around Top Blade

Web Deflected Under Top Blade
Slitter Geometry

Modified Tangent. Web Bisects Overlap Chord.

- Web Riding Over Lower Slitter Ring
- Web Deflected Around Top Blade
- Cut Point
- Web Deflected Under Top Blade
- Slitter system repositioned upward so that web path bisects the overlap chord, as shown.
Slitter Geometry

Top Blade
Top-Dead-Center.
Minimum Penetration Into Web Line.

Top Blade Too Far Forward.
Unsupported Slit.

Top Blade Too Far Backward.
Excessive rub area.
Slitter Geometry

Slitter "Table"

Slitting Zone  Bowed Roll  Spreading Zone
Trim Removal

Trim Dynamics

"Bubble" results from skewing trim strip away at angle to web.

Edge cracks, stretching, etc.

Tension differential causes strain at trim cut points.

Total Pull
Untrimmed width = Tension

Total Pull
Trimmed width = Tension

Diagonal wrinkle results from strain due to tension differential between web and trim strip.
Trim Removal

Tension and Support, Wide Trim Strip = OK.

Web Tension

No Tension, No Support, Narrow Trim Strip = Trouble.
Trim Removal

Changing Trim Direction

"Bubble" in trim strip formed by pulling trim away at angle from web path.

Unsupported trim strip puts maximum strain at cut point. Trim breaks most likely to occur.

Upper knife blade

Lower slitter ring

Trim
Unsupported trim removal will cause severe strain at slit point, resulting in frequent trim breaks.

Provide a surface to isolate trim strip flutter and improve stability at cut point.
Trim Removal

Trimming Irregular-caliper Edges

Irregular-caliper trim strip

Trim slitters

Idler roll downstream from slitters

Irregular caliper trim strips may "steer" as they pass over idler rolls after being severed from the main web.
Thank You

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Please remember to turn in your evaluation sheet...
of toe-in. Elongation, elasticity, and fiber or filament orientation are important factors in choosing the optimum cant angle. A general rule of thumb is: “Low elongation = low cant angle, high elongation = high cant angle.”

**Overlap**

In tangent systems, increasing the overlap between the upper and lower blades shifts the cut point ahead of the tangent point. The upper blade strikes the web too soon and the web is severed without benefit of support from the lower slitter. In wrap systems, the cut point has little effect on slit quality, assuming that the wrap angle is great enough to prevent the nip from shifting to where the unsupported web is slit before it is in contact with the lower slitter. However, increasing overlap in both systems increases the amount of deflection the web must take to go around the upper blade which can decrease slit edge quality.

**Side force**

Side force refers to the amount of force applied laterally from the upper blade to the lower anvil blade. This force creates friction between the upper blade and the lower anvil blade driving the rotational speed of the upper blade creating the nip speed at the cut point. Too much side force increases blade wear and can cause deflection in the upper blade which results in opening the nip point. Ideally, the side force should be as light as possible to maintain a closed nip and appropriate nip speed.

**Nip velocity vs. web velocity**

In shear slitting, the nip velocity must be equal or ideally faster than the web velocity. If the nip (cut point) closes at a speed slower than the web, slit quality reduces which promotes dusty, ragged, distorted edges. Any “puckering” of the web immediately in front of the top slitter is a sure sign that the slitters are running slower than the web speed. Factors that influence web nip speed are overlap and overspeed. When two circular blades are overlapped and one blade drives the other, there is an inevitable difference in the rotational speed between the blades, the amount of overlap directly influencing the speed differential. On tangent systems, the remedy is to increase the overspeed to compensate for the speed loss. On wrap
systems, the situation is not as easily resolved, since they cannot be realistically oversped enough to compensate for the speed differential.

Slitter geometry

Shear slitting systems can be configured to either of two basic methods: tangent or wrap. While most paper mill primary winders are configured for tangent slitting, secondary winders and a great many general converting slitters may be wrap configured. An understanding of the specific advantages and disadvantages of each method and its influence in the slitting process will be presented.

Trim removal

As edge trim material is removed from the web the tension across the web is altered. Redirecting the trim material away from the web path and/or using a different force to pull the trim induce stress at the cut point promoting a reduced slit edge quality. To promote good edge quality the supported slit edge (lower anvil) should be on the web side of the edge trim and the trim material should follow the path of the web at the same velocity as it leaves the nip point.

Summary

By paying careful attention to the variables that affect shear slitting, namely blade sharpness/profile, cant angle, overlap, side force, nip velocity vs. web velocity, slitter geometry, and trim removal, shear slitting will produce those perfect edges our customers have come to expect.