SHEAR SLITTING OF ALUMINUM WEBS USING BLOCK KNIVES

by

Hongbing Lu[1], Jin Ma[2], Ming Li[3] and Bernie Becker[3]
[1]Oklahoma State University
[2]Third Wave Systems, Inc.
[3]Alcoa Inc.
USA

ABSTRACT

C Shear slitting of two aluminum webs, namely 1050 H18 of 0.28 mm thick and 5182 H19 of 0.20 mm thick, using block knives are investigated through experiments using a laboratory slitter. This investigation focused on two aspects of shear slitting using block knives, appropriate for relatively thick webs. They are: (1) tangential shear slitting at zero rake angle, i.e., traditional shear slitting with a pair of block knives. In this aspect, the effects of major slitting parameters on the burr height at the slit edge were investigated. These include the clearance, overlap, overdrive and cant angle. The critical clearances for both webs have been determined; and (2) slitting at a rake angle, a new method for edge trimming when the two blades are not necessarily in contact. The top blade geometry was modified for slitting with a rake angle of -15^o to allow slitting of an aluminum web, up to 1 mm thick in this investigation. This new method of edge trimming using block knives was found to be very effective and robust over a (relatively) very wide range of slitting parameters. Very good slit edge was produced, and the burr height was found to be independent of slitting parameters over a relatively large range of slitting parameters. Because two blades do not have to be in contact in slitting so that the blade wear is much less than in the case of traditional shear slitting, this new method is expected to extend significantly the block knife service life while producing consistently high quality slit edges.

INTRODUCTION

Shear slitting of aluminum webs with disk knives have been studied recently, [1-5]. The relationship between the slitting parameters and slitting qualities, primarily the slit edge quality indicative of burr height, has been established. Two types of setups were investigated. The first setup was the conventional setup at zero rake angle. Three major slitting parameters, namely the clearance, blade overlap and cant angle, were investigated systematically through a testing matrix for an aluminum web. It was found that the clearance is the most important parameter affecting the burr height. There exists a critical clearance for each slitting configuration. The burr height is at its minimum if the clearance is below the critical clearance. But the burr height increases abruptly when the clearance is larger than the critical clearance [1, 3, 4].

Rake angle was introduced into shear slitting in the second setup. Through experimental investigation and FEA analysis [2], an optimum slitting configuration was determined. A combination of -18^o rake angle and modified top blade geometry was able to produce one slit edge with good quality (zero or very small burr). There is no critical clearance for this setup as long as the web can be slit into two. In other words, this setup is robust for a wide range of clearances [1, 5].

This research is a continuation of the previous work to determine the effect of slitting parameters on the burr height when block knives are used. Block knives are generally used for thick sheets because their rigidity is high. However, their blade tip geometry is different from disk knives. In this research, the conventional setup, i.e., slitting using block knives at zero rake angle, was investigated first. The slitting parameters studied include the clearance, overlap and blade overdrive. The cant angle and rake angle are fixed at half or zero degree. Nonzero rake angle was then introduced into the setup based on previous research.

EXPERIMENTAL SETUP

We adopt the definitions of burrs on two slit edges from the setup with disk knives as shown in Figure 1 (a). The lower blade is at the front side of the top blade. The burr on the front slit edge always appears on the bottom web surface. It is named the front bottom burr. The other burr appears on the top surface of the rear slit edge. It is named the rear top burr.

In order to quantify the burr height and profile, two approaches are used to observe the burr profile and measure the burr height. The first approach is to wrap the slit edge with epoxy and polish to reveal the cross section of the edge to observe the profile under a microscope. This approach is very accurate, but is also very time consuming. The second approach is to use a profilometer to scan the burr height. Figure 1 (b) shows a setup for the measurement of burr height using a profilometer (Mutitoyo Surftest 402) with a resolution of 1 μm. The profilometer can measure the surface topology when the stylus needle passes on the web surface and edge. The analog output from the profilometer is connected to a computer with A/D board and a data acquisition system. Data representing the slit edge profile are recorded by the computer.

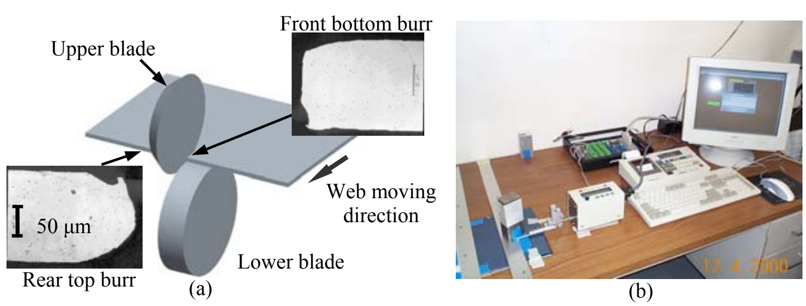


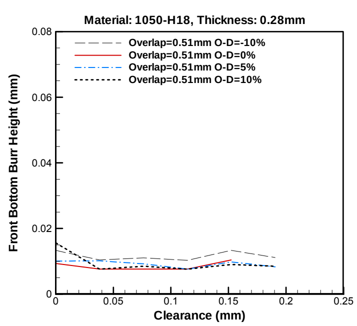
Figure 1 – Definition of two slit edge burrs and the setup for the measurement of burr height.

Two aluminum webs, 1050 H18 of 0.28 mm thick and 5182 H19 of 0.20 mm thick respectively, are used in this investigation. They are thinner than the common webs for block knives due to the limitation of the slitter power. In plant, the lower blade is usually driving by a different motor from the main web line. Hence, overdrive occurs when the speeds of the web and the lower blade at the cutting point are different. The lower blade of the laboratory slitter used in this work is also driven by a DC motor whose speed can be adjusted to control the amount of overdrive. In this paper, negative overdrive indicates that the speed of the lower blade is faster than the web speed. The web speed during slitting is 35±0.5 ft/min. The web tension is 10.3 MPa and it has been shown that both webs remain in the elastic range under this tension [1].

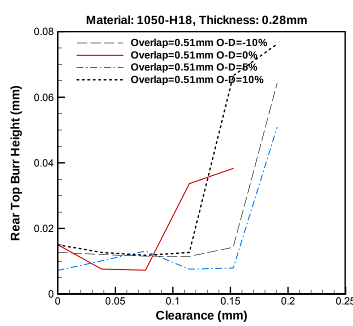
SLITTING AT ZERO RAKE ANGLE

Since the web used in experiments are 0.28 and 0.20 mm thick, the clearance was tested up to 0.25 mm, which is larger than the critical clearance based on previous studies [1,4]. For these two aluminum webs, an overlap of 0.25 mm was too small to convert a web into two webs using the laboratory slitter. Hence, the overlap was tested at 0.51 mm and 0.76 mm.

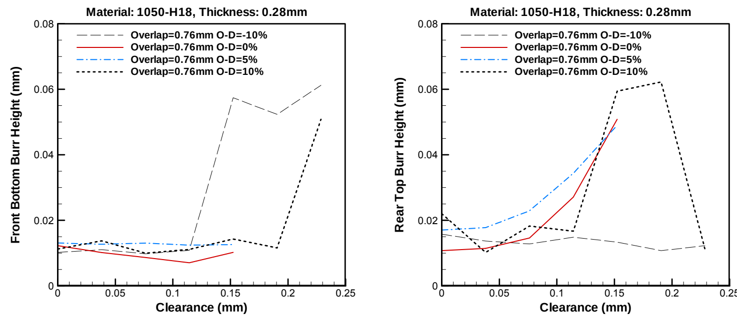
For shear slitting with disk knives at zero rake angles, one observation is that when the clearance is larger than the critical clearance, the front bottom burr increases drastically. For shear slitting with block knives at zero rake angles, due to the symmetry of the knives with respect to the web plane, either front or rear slit edge may have high burrs when the clearance increases to a certain value. The blade edges of both top and bottom block knives are at 90^o. These blade edges are symmetric with respect to the web plane. We call this blade symmetry. It was found the burr formation has no preference to either slit edge. This is a distinct feature for shear slitting with block knives. It is reflected in the plots of the front bottom burr heights and rear top burr heights.



(a)



(b)

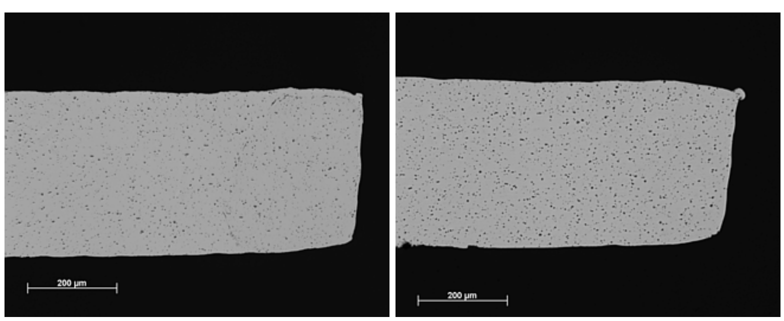


(c) (d)

Figure 2 – Burr height for the 1050 web at zero rake angles.

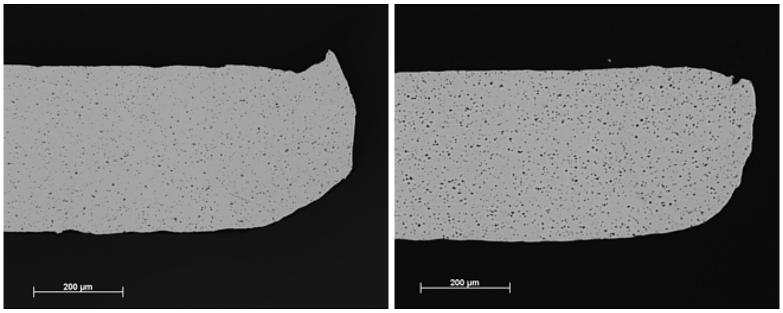
Figure 2 shows the burr height of the 1050 web as a function of clearance at zero rake angles. It may be noted that the data in Figure 2 represent the average burr height over five measurements. The variation is approximately 10% of the average value. Both the front bottom burr and the rear top burr can be very high at large clearances. Experiments showed that the burr increases abruptly and is not predictable at large clearances. When the clearance is less than 0.076 mm, both burr heights are 0.01 to 0.02 mm. It is noted that for slitting with disk knives, the rear top burr height is higher than the front bottom burr height when the clearance is less than the critical clearance. But due to blade symmetry, the rear top burr height and the front bottom burr height are about the same when block knives are used. The four curves in each plot indicate four different overdrives. The burr height and critical clearance are not consistently dependent on the overdrive. Hence, the effect of overdrive is not evident.

It is observed from Figure 2 (b) and (d) that the critical clearance for the 1050 web of 0.28 mm thick is about 0.06 mm. The micrographs of the cross sections of one sample of 1050 material obtained at zero clearance are shown in Figure 3. Small burrs are seen in these micrographs. The micrographs of a sample obtained at 0.15 mm clearance are shown in Figure 4. For this sample, the front bottom burr is about 0.05 mm, which is unacceptable. As mentioned earlier, high burr can occur on either side due to blade symmetry. In this case, the front slit edge happens to have a high burr.



(a) Front slit edge (b) Rear slit edge

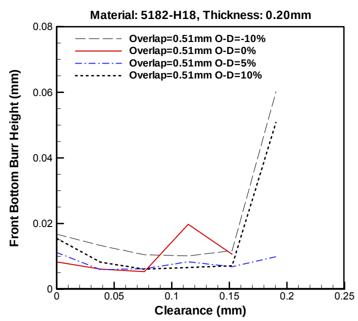
Figure 3 – Micrographs of the 1050 web at zero clearance.
Rake angle=0^{o}, overlap=0.51 mm, cant angle =0.25^{o}, overdrive=10%.



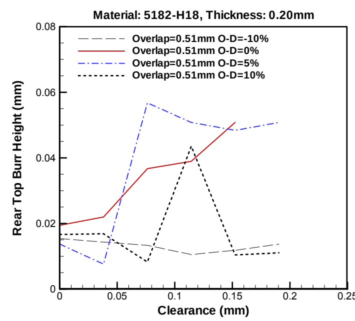
(a) Front slit edge (b) Rear slit edge

Figure 4 – Micrographs of the 1050 web at 0.15 mm clearance.
Rake angle=0^o, overlap=0.51 in, cant angle =0.25^o, overdrive=10%.

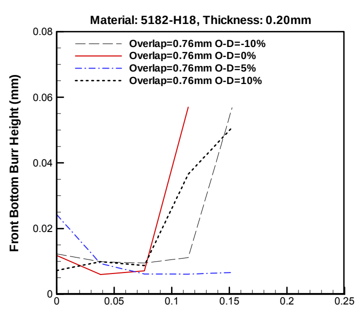
For the 5182 web, the rear top burr height appears to be random. At the zero clearance, the burr height can be up to 0.025 mm. This is generally unacceptable. The effect of overdrive on burr height is not significant in these experiments for the 5182 web. The critical clearance for this web is about 0.05 mm.



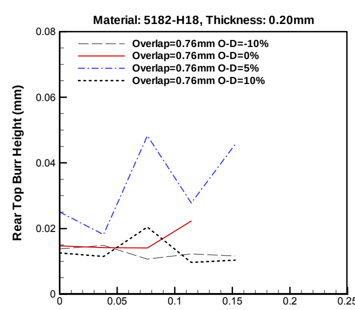
(a)



(b)



(c)



(d)

Figure 5 – Burr height for 5182 web at zero rake angles.

SLITTING WITH A RAKE ANGLE

Previous experiments [1, 5] showed that at a rake angle of -15^{o} to -20^{o} using disk knives, the rear top slit edge has the minimum burr. In this research, a smaller rake angle is used for block knives in order to reduce the blade wear in slitting of thick webs. Hence, the rake angle is set to -15^{o}. Similar to disk knives, the top block knife will be ground and the bottom knife is intact.

Configuration I

The as-received blade has geometry as shown in Figure 6 (a). The first tested blade geometry is shown in Figure 6 (b). Three angles, angle α, angle β and angle θ related to the new blade geometry are shown in Figure 6 (b). From geometry consideration, the relation between these three angles is $\theta=90^{o}+\alpha-\beta$ for the block knife. For the original block knife, $\alpha=\beta=0^{o}$, $\theta=90^{o}$.

Previous experiments showed that the slit edge quality is better if the top and bottom slit edges are parallel to each other [5]. Hence, the top blade is ground to $\alpha=15^{o}$ for the rake angle of -15^{o}. The two slitting faces of the blades are parallel to each other, as indicated in Figure 7.

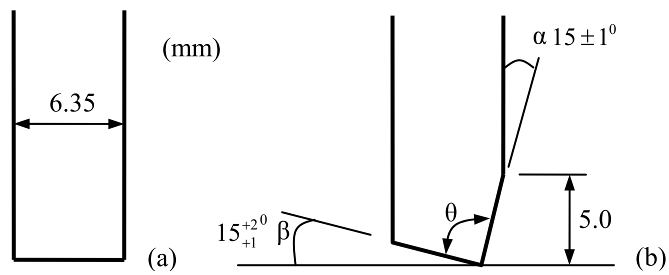


Figure 6 – Top blade geometry for slitting with a rake angle.

To avoid the top blade to penetrate into the web surface during slitting to cause surface damage of a web, angle β has to be at least 15^{o}. As angle β becomes larger, angle θ becomes smaller and the blade will contain smaller volume of material, leading to higher rate of blade wear. It is desirable to increase θ, and when $\beta=15^{o}$, θ is 90^{o}.

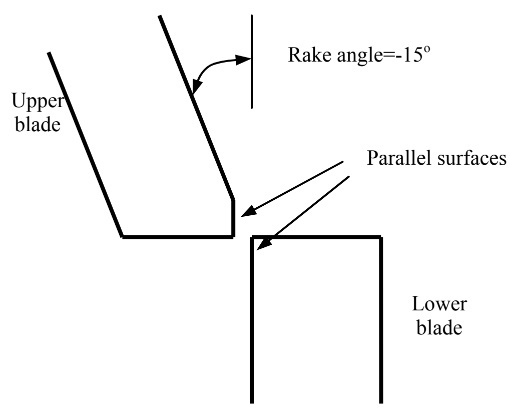


Figure 7 – Slitting configuration with a rake angle of -15^{o}.

The rear top burr height under this configuration is 0.05±0.01 mm, which is not acceptable. Another problem with this setup is that the top and bottom cutting edges are locally symmetric with respect to the web plane, so that the web does not have a preference to produce burrs on either side. As a result, the burrs could be formed on either side of the slit edges. Therefore, this configuration did not produce good edge at the rear side consistently. As slitting with a rake angle can create one edge with good quality, it is intended for trimming operation in which the good edge must be produced consistently at one edge. Hence, this configuration is not suitable for plant operation.

Configuration II

In order to produce a predictable good slit edge, it is necessary to change the blade geometry so that the blade local symmetry is broken and there is a preference for the formation of a good slit edge on one side consistently. Since the lower blade is kept unchanged, the option is to modify the top blade, specifically, to increase the angle β. In this configuration, the angle β is increased to 30^o and the angle θ is 75^o. It is noted that in previous experiments with disk knives [5], the angle θ was 60^o. With the use of this blade geometry, a good rear slit edge was produced when the clearance is less than 0.13 mm. However, when the clearance is larger than 0.13 mm, the burr formation becomes unpredictable. Either the rear slit edge or the front slit edge may have high burrs while the other edge has a minimum burr.

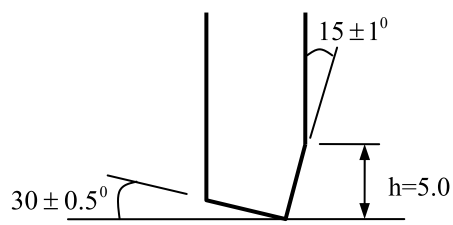


Figure 8 – Top blade geometry with a rake angle of -15^o.

Another problem with this setup is that the front slit edge with high burr is bended excessively. This bended height is estimated to be close to the web thickness. This bending deformation during slitting would result in unnecessary consumption of energy, moreover, it induces high noise. Occasionally, bending will stay in the converted web, leading to defective webs. The excessive deformation was believed to be related to the chamfer height h, which is 5.0 mm as shown in Figure 8.

Configuration III

A new block knife was ground with reduced chamfer height h shown in Figure 9. The chamfer height h is now 0.5 mm, 10% of the value used previously. This value is the same as used in the previous experiments with disk knives [1, 5]. Good slit edge results were obtained consistently with this configuration.

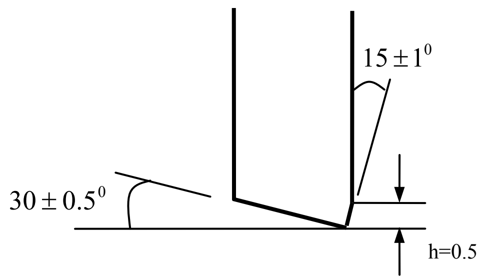
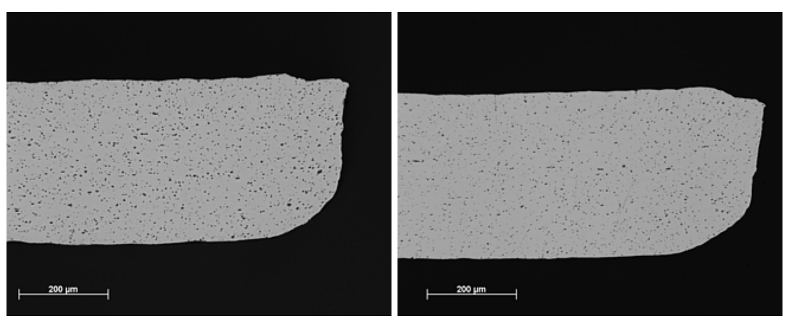


Figure 9 – Top blade geometry with a rake angle of -15^{o}.

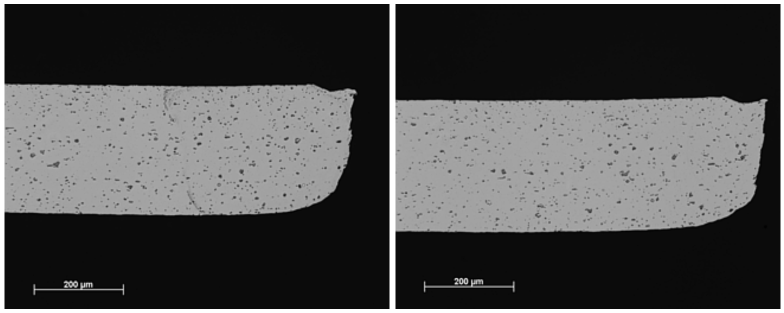
One test matrix was performed for each material under this configuration. Three clearances, i.e., 0, 0.13 and 0.25 mm, two overlaps, i.e., 0.51 and 0.76 mm, and three overdrives, -10%, 0% and 10%, were tested. Slitting with a clearance of more than 0.25 mm at an overlap of 0.51 mm can hardly be performed because the web cannot be slit apart. The rear top burrs are consistently good with a burr height of 0.005 to 0.008 mm based on the profilometer measurement. The front bottom burr height is large except at zero clearance.

Two samples from each material were sectioned to observe the burr profile. Figure 10 shows the section of a rear slit edge of 1050 material of 0.28 mm thick. Very gradual burr can be seen at the slit edge. However, the burrs are lower than the web surface. Figure 11 shows the section of a rear slit edge of 5182 material of 0.20 mm thick. These burrs appear more evident. However, the burr peak is still leveled with, or below the web surface.



(a) (b)

Figure 10 – Micrograph of a slit edge of 1050 material (a) clearance=0 (b) clearance=0.25 mm; Overlap=0.76 mm, cant angle=0.25^{o}, overdrive=0%, rake angle=15^{o}.



(a) (b)

Figure 11 – Micrograph of a slit edge of 5182 material (a) clearance=0 (b) clearance=0.010 in; Overlap=0.76 mm, cant angle=0.25^{o}, overdrive=0%, rake angle=15^{o}.

An aluminum web of 3040 H18 of 0.50 mm thick was used to test this configuration. Figure 12 shows the micrograph of the rear slit edge when the clearance is 0.25 mm, the overlap is 0.76 mm and the overdrive is 0%. It is seen the burr peak is lower than the undeformed web surface. Very good and consistent results were obtained for this thicker web.

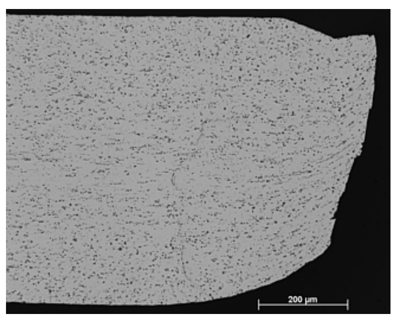


Figure 12 – Micrograph of a slit edge of 0.50 mm thick

SUMMARY

Tangential shear slitting with block knives was conducted on two aluminum webs, 1050 H18 of 0.28 mm thick and 5182 H19 of 0.20 mm thick. Four slitting parameters, i.e., the clearance, overlap, overdrive and rake angle, were investigated for both webs. For shear slitting with block knives at zero rake angle it was determined that the critical clearance for the 1050 web of 0.28 mm thick is about 0.06 mm. For the 5182 web of 0.20 mm thick, the critical clearance is 0.05 mm. The web speed at the cutting point on the lower blade is 35 ft/min. At this speed, the effect of the overdrive up to ±10% of the web speed on the burr height was negligible.

Shear slitting with the rake angle of -15^{o} was conducted. Appropriate blade geometry and rake angle were identified. The rear top burr height was less than 0.008 mm when the clearance was up to 0.25 mm for both webs. Slitting at a rake angle of -15^{o} with a modified top knife can produce consistently very good slit edges over a wide range slitting parameters, indicating that the new method of slitting using block knives at a rake angle is very robust. The clearance can be as high as 0.25 mm, so that the blades do not need to be in contact during slitting. With this configuration, it is expected that the blade service life can be extended significantly while producing consistently high quality slit edges.

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Shear Slitting of Aluminum Webs Using Block Knives

H. Lu[1], J. Ma[2], M. Li[3] & B. Becker[3], [1]Oklahoma State University, [2]Third Wave Systems, Inc., and [3]Alcoa, Inc., USA

Name & Affiliation	**Question**
Unknown	Was all the work done on H-18 fully work hardened or did you use softer material?
Name & Affiliation	**Answer**
H. Lu, Oklahoma State University	We used annealed aluminum and hard aluminum. It worked out consistently well.
Name & Affiliation	**Question**
Unknown	On the examples with the rake angle where the axis of the male upper blade support was always tilted. You were varying the grind angle on the upper male blade. Did you try any of these different rake angles where the angle of the shaft was not tilted? Or did all of that rake angle work have the tilted axis?
Name & Affiliation	**Answer**
H. Lu, Oklahoma State University	In the case of rake angle, we tilted the blade all the time. If we used a new geometry, we basically had a chamfer in the blade tip. If we used a non-zero rake angle, we did not get a good quality – sometimes we couldn't even cut it. We had to use the rake angle with the new blade geometry.
Name & Affiliation	**Question**
S. Hikita, Fujifilm	Did you try changing the overlap between the blades and the over-speed of the blades? Was it robust enough not to be sensitive to that as well?
Name & Affiliation	**Answer**
H. Lu, Oklahoma State University	Yes we varied overlap. We found out for this setup, it is not sensitive to blade overlap. Some overlap is required to make a cut correctly. Once the overlap is greater than that value, it is not sensitive any more. So you can set a huge overlap.
Name & Affiliation	**Question**
S. Hikita, Fujifilm	Was there any sensitivity to the speed between top and bottom blades?
Name & Affiliation	**Answer**
H. Lu, Oklahoma State University	It is not sensitive as well. We tried overdriving with a speed differential between 0-10%. Basically, we don't see any difference.
Name & Affiliation	**Question**
S. Hikita, Fujifilm	You saw the benefit from getting the tension effect in the TD. Did you do any experiments changing the tension in the MD of the web? Did you get any additional tearing action from that?

Name & Affiliation	**Answer**
H. Lu, Oklahoma State University	We actually changed the MD tension from a very low value up to 10 MPa. We found out again that we need some tension, but the tension can be very low. After we achieved a threshold value of tension we found the slitting is not sensitive to tension variation. We used a constant tension which was 10.5 MPa in later investigations.