The following serialized technical article documents an independent test by United States Steel (USS) on improving the quality of the shear edge and its corresponding impact on edge stretchability on Advanced High Strength Steel (AHSS). Through a series of tests utilizing different shear angles and punch to die clearances, USS was able to document the delays which occur on the edges of the pierced hole and increase the edge stretchability during forming. This independent testing corroborates the internal testing Dayton Progress has performed and reinforces the clearance recommendations by Dayton.

**An Innovative Shearing Process for AHSS Edge Stretchability Improvements—Part 5**

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**Development of Straight Edge Shearing Test**

Based on the above beveled shearing method for hole piercing, a computer-controlled straight edge precision shearing device was also developed. The shearing device is capable of adjusting the shearing speed, die clearance and shearing rake angles $\theta_1$, $\theta_2$, and $\theta_3$, as shown in Figure 12, where $\theta_1$ is the lower blade rake angle; $\theta_2$ is the upper blade rake angle and $\theta_3$ is the shear rake angle. For the conventional straight edge shearing device, the angles are not stringently controlled and usually very close to zero degrees [4,11]. The photograph of the shearing device is shown in Figure 13a. The load and displacement in the vertical direction of the test can be recorded during the entire shearing process. The test specimen is pre-blanked to 203 mm x 762 mm by a conventional shear. The baseline test was conducted on the specimen shearing in the material rolling direction, and the test specimen was sheared to 203 mm x 25.4 mm. Sheared edge side 1 from the developed shearing conditions was maintained as-sheared and side 2 was then smoothed and polished by fine sanding to prevent the initiation of fracture from this side (side 2) in the sheared edge tension test.

**Figure 12. Schematic illustration of straight edge shearing device**

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**Reader Reply**

This month’s Tool-Tip is an answer to a question submitted by a subscriber.

**Question:** How do I punch through ½” thick multi-layered material? The layers are composed of polyurethane, fiberglass, cardboard, fiberglass, polyurethane, and finally felt.

**Answer:** Piercing through multi-layer materials presents several unique variables and challenges. The actual materials which comprise the overall thickness can cause abrasive or adhesive wear issues on the punch. The materials can adhere onto the punch. The various materials may cause the actual hole size to become undersized. The style of punch, either headed or ball lock will also influence hole dimensions and location. The punch to die clearance determines the amount of shear for fibrous materials to eliminate stringers.

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During straight edge shearing, a 10% die clearance and 1 mm/s shearing speed were used and the specimen was sheared along the material rolling direction. Three shearing rake angles, $\theta_1$, $\theta_2$, and $\theta_3$, are represented by the format of $(\theta_1, \theta_2, \theta_3)$ in the results. In the initial setup, $\theta_3$ varied from 1, 2, 3, 4 and 5 degrees, respectively, while $\theta_1$ and $\theta_2$ were kept at zero degrees (Fig. 14). As shown in Figure 14, the plane surface of the sheared specimen is not flat when the shear rake angle is greater than or equal to 4 degrees. Since the curve shape sample is not acceptable for stamping blanks, only the angles smaller than 4 degrees were considered in the current study.

The comparison in the shear load at various shear rake angles is shown in Figure 15. It is observed that the one degree shear rake angle would result in a peak load as high as 20 KN with a concentrated bell shape-type load profile, which is often observed in conventional straight edge shearing. As the rake angle increases to 2 degrees, the peak load is abruptly reduced to 6.6 KN (67% load drop from the 1 degree rake angle) with a uniform square step load profile. The applied energy in shearing can also be determined from the area under the load-displacement curve and it is 52 joule for the 1 degree rake angle and 41.9 joule for the 2 degrees rake angle. There is about a 19% decrease in the applied energy when the rake angle changes from 1 degree to 2 degrees. At the 3 degree rake angle, the shear load is further reduced to 4.3 KN (78% load drop from 1 degree rake angle) and the applied energy is also reduced to 40.4 joule (22% drop from 1 degree rake angle), which would greatly reduce the resistance shock of the blade and improve the tool life as well as save the energy cost. When the rake angle further increases to 4 degrees, the average shear load decreases slightly while the total applied energy is about the same as that from the 3 degree rake angle. Those results indicate that the 3 degree rake angle is the optimal shear rake angle in this shearing condition (10% CL, 1 mm/s shearing speed).
The optimal shearing angle from the beveled shearing process in hole piercing was directly applied to both lower (θ₁) and upper (θ₂) rake angles in the straight edge shearing test. The comparison in the shear load versus the displacement with shear rake angle θ₃ set to 3 degrees is shown in Figures 16. It is observed that there are two peak loads encountered in shearing with the (0,0,3) setup, which indicates a less uniform shearing process. When the upper rake angle is increased to 3 degrees with the (0,3,3) setup, as shown in Figure 16(a), the first peak load is significantly reduced and the slope of the load profile is also changed. As the upper rake angle increases to 6 degrees with the (0,6,3) setup, the average shear load drops further and the slope of the load profile is also reversed from the (0,3,3) setup. However, a more concentrated peak load is observed at the onset of shearing due to a smaller contact area and sharper blade tip. When increasing the lower rake angle and keeping the upper rake angle at zero with the (3,0,3) setup, the load profile becomes similar to that from the (0,0,3) setup with two peak loads. This indicates that the (3,0,3) setup could be a similar shearing process to the (0,0,3) setup. As shown in Figure 16(b), the shear load distribution is different when both the lower and upper rake angles increase. For rake angles of the (3,3,3) setup, the average load is the lowest among all the tests, while the (3,6,3) setup has the highest initial contact load. The results of different shear load profiles could be associated with different fracture surfaces in shearing, which could result in the different edge stretchability.

Figure 15. Comparison of the shear load between different shear rake angles

Figure 16. Comparison of the shear load between different upper and lower blade rake angles

Concluded in our next issue...

References


