Examining edge cracking in hole flanging of AHSS

Part IV: Sheared edge stretching

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Editor's Note: In flanging of advanced high-strength steels (AHSS), edge cracking may occur. This article is the last in a series of four that have discussed the effects of edge quality and how it determines edge stretchability, as well as finite element modeling (FEM) of blanking. Part IV discusses the significance of sheared edge and burr orientation in the hole expansion ratio (HER) of AHSS.

Alex Konieczny conducted experiments at United States Steel Corp. with various advanced high-strength steels (AHSS) to study the influence of punch/die clearance on sheared edge geometries and their hole stretchability.[1] Results from the blanking tests showed that the length of the rollover zone increases almost directly with the increasing die clearance.

Differences in rollover zones, observed among different high-strength steels (HSS) are relatively small. It was found that the sheared zone depth decreases with increasing die clearance, and a very small sheared zone was observed for DP 780 and DP 980 (see **Figure 1**).

Influence of Burr Orientation and Edge Finishing on Hole Flanging

During a hole expansion test, a blanked hole is stretched under tension stresses so that the hole diameter increases (see **Figure 2**). This hole flanging operation stretches the edge material that already has been subjected to large amounts of plastic deformation and temperature changes from the previous blanking operation. Thus, edge cracking during flanging is highly dependent on the material characteristics at the blanked/sheared edge.

Konieczny conducted hole expansion experiments using various edge finishing processes, such as reaming, laser, and blanking, with different die clearances. **Figure 3** compares the hole expansion ratios (HERs) for various sheared edges in HSS. As shown in the figure, HERs are sensitive to sheared edge finishing processes, especially for 50XK, 590R, and DP 590 steels.

Reamed edges showed the highest HER values; however, reaming is expensive and not used in stamping. An interesting observation is that increasing die clearance leads to an increase in HER, indicating high hole stretchability, for DP 590, 590R, and 50XK, while HERs for DP 780, DP 980, and TRIP 780 are less sensitive to the die clearances.

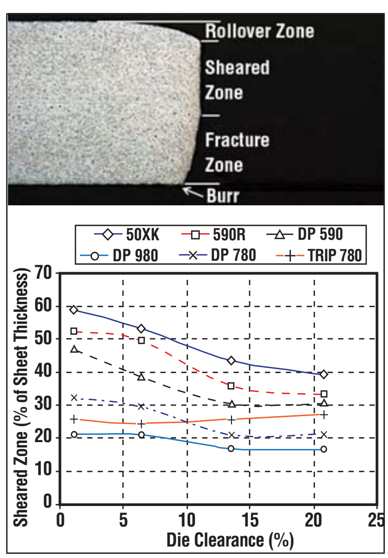

Figure 1

Sheared zone depth was found to decrease with increasing die clearance, and a very small sheared zone was observed for DP 780 and DP 980.[1]

In practical stamping and hole flanging, the burr locations are randomly oriented. The blanked hole can be located so that the burr will be in contact with the hole flanging punch (burr down), similar to the schematic in Figure 2, or so that the burr has no contact with the punch (burr up).

Konieczny also studied the influence of burr location on the HER. Examples of the results for DP 590 using a conical punch are presented in **Figure 4**. The results show that the HER is larger when the burr is placed down and that the increase is greater at lower die clearance values. Similar trends were observed for all other tested steels.

Significance of Sheared-affected Zone in Modeling of Hole Flanging

Most investigators who attempt to model hole flanging using finite element modeling (FEM) ignore the influence of blanked edge geometry and its strain history while assuming a perfect edge without initial strain. At the Center for Precision Forming (CPF), simulations of hole expansion tests with a conical punch were conducted to illustrate the influence of sheared edge deformation resulting from blanking.

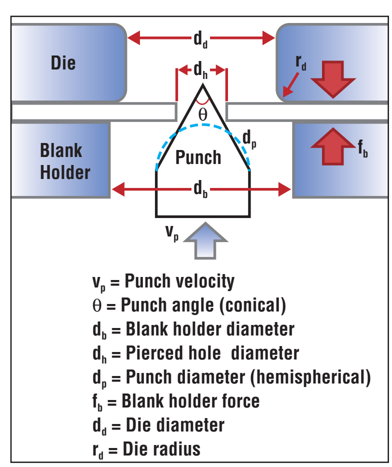

Figure 2

During a hole expansion test, a blanked hole is stretched under tension stresses so that the hole diameter increases.

The sheet material used in the tests was DP 590, burr up. The effect of strain at the blanked edge was considerable (see **Figure 5**). The effective strain at the edge of the flange was quite large, up to 1.6, and increased continuously with the punch stroke. At the same stroke and HER, much larger strains were observed at the blanked edge when modeling hole expansion. Undoubtedly, these large strains affect formability and edge cracking.

Currently the CPF is attempting to develop a methodology to predict edge cracking in hole flanging of AHSS by examining the average strain/stress information at various blanked edges in FEM simulations. Blanking and hole expansion experiments using various blanking conditions also are planned for future studies.

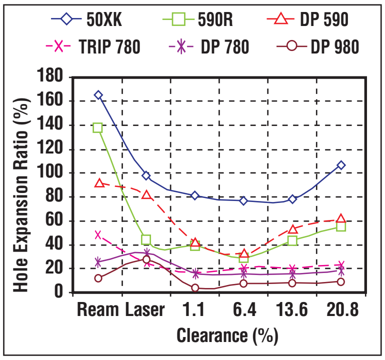

Figure 3

The results of hole expansion experiments show the influence of clearance and sheared edge finishing on HER values for all tested steel stamples with burr up.[1]

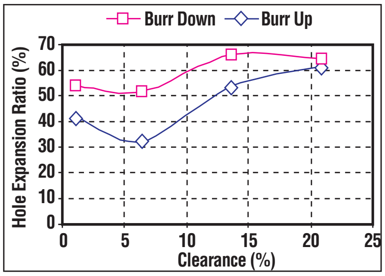

Figure 4

The HER is larger when the burr is placed down, and the increase is greater at lower die clearance values.[1]

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Note

1. A. Konieczny and T. Henderson, "On Formability Limitations in Stamping Involving Sheared Edge Stretching," SAE Technical Paper 2007-01-0340.

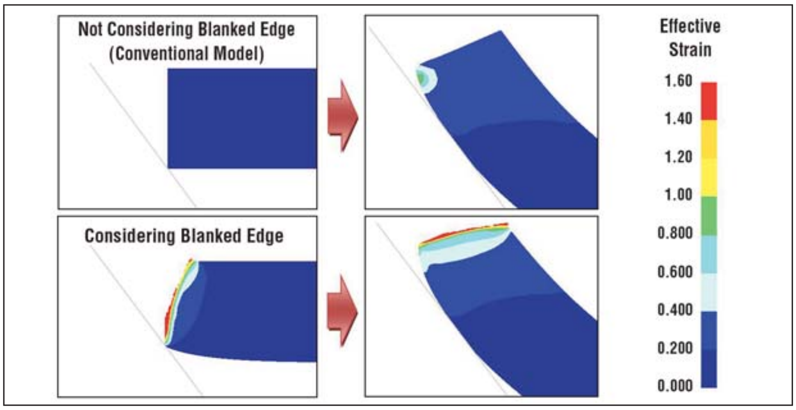

Figure 5

Simulations of hole expansion tests with a conical punch were conducted to illustrate the influence of sheared edge deformation resulting from blanking.