Examining edge cracking in hole flanging of AHSS

Part II: Modeling of blanking

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Editor's Note: In flanging of advanced high-strength steels (AHSS), edge cracking may occur. This series examines the relationship between sheared edge quality and edge cracking in flanging.

This article is the second in a series of four and discusses the significance of modeling the blanking process to predict the sheared edge quality and its influence on subsequent edge forming.

Stamping of AHSS can present several challenges, such as springback, fracture in stretch bending, and edge cracking. The hole expansion test is commonly used to evaluate edge cracking or edge stretchability. Failure by edge cracking can occur at significantly lower strains than those predicted by the forming limit curve (FLC), which is used to evaluate formability.

A number of studies have shown that the edge quality of the punched hole has a significant influence on hole stretchability. For example, holes made by wire EDM have a better stretchability than drilled or sheared holes.[1] Another study showed that blanking, which is the most practical method of producing holes or cutouts, generates a shear-affected zone (SAZ) and a burr, and if these are removed, hole stretchability increases.[2]

It is useful to characterize the sheared edge quality, produced by blanking, through experiments and computer simulations.

Ultimately, the aim is to be able to quantify how deep a flange can be achieved, or how much a hole can be expanded, for a given blanked or sheared edge quality.

The sheared edge (see **Figure 1**) consists of:

- The shear zone, which is smooth and shiny and created by shearing the material.
- The fracture zone, where fracture causes the part to separate from the blank sheet.
- The depth of crack penetration, which is a deviation from a straight part edge.
- The burr, which is a protrusion at the part edge.
- The rollover zone, where the edge of the sheet surface is bent by plastic deformation.

In addition to the geometric features, the sheared edge quality also includes the SAZ, which extends from the sheared surface into the adjacent material. The SAZ is the volume of metal that has been subjected to a very high plastic deformation and high temperature during shearing. Thus, the sheared edge quality (geometry and SAZ) is affected by the punch-die clearance, material properties, material thickness, cutting speed, and tool wear.

Effects of Punch-Die Clearance on Sheared Edge Geometry

Blanking experiments conducted at the CPF with AISI 1050 sheet are shown schematically in **Figure 2**. Different die diameters were used

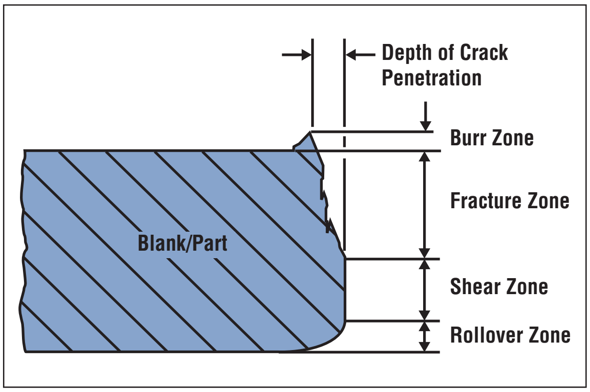

Figure 1

The sheared edge has several geometric features.

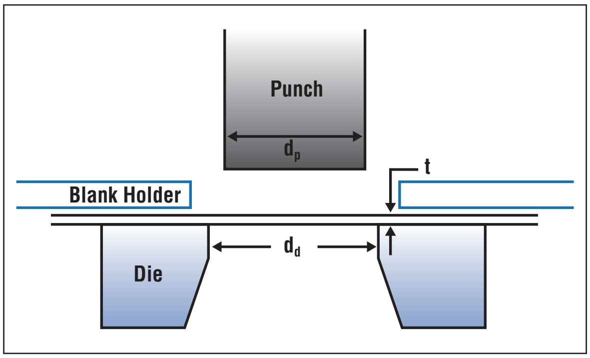

Figure 2

Blanking experiments were conducted at the CPF with AISI 1050 sheet.[3]

% Clearance	5	10	15	Tendency
Rollover (mm)	0.085	0.128	0.156	Increases
Shear (mm)	0.390	0.333	0.285	Decreases
Fracture (mm)	0.795	0.809	0.829	Increases

Figure 3

These shear edge geometries were obtained for different punch-die clearances in blanking AISI 1050 steel at a punch velocity of 2,678 mm/sec. [4]

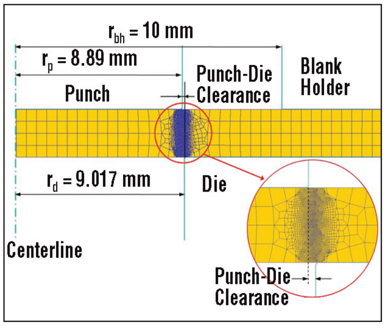

Figure 4

Finite element simulations of blanking were conducted to predict the shear edge geometries and the SAZ more accurately. This shows the blanking simulation at the initial step for 1.27-mm AISI 1050 sheet.

for setting different punch-die clearances, such as 5 percent, 10 percent, and 15 percent of the sheet thickness. The edge of the blanked sheet, obtained from the tests, was sectioned and put under an optical microscope to measure the sheared edge geometries.

Experimental results are summarized in **Figure 3**. As the punch-die clearance increases within the range investigated:

- The rollover zone (plastic deformation of the sheet before separation) increases.
- The shear zone decreases.
- The fracture zone increases slightly.
- The burr height remains approximately unchanged.

FE Simulation of Blanking

Finite element (FE) simulations of blanking were conducted to predict the shear edge geometries and the SAZ more accurately. The initial setup of the FE model is illustrated in **Figure 4**. Calculated steps of blanking are shown in **Figure 5**, which illustrates that strains in the shearing zone kept increasing until cracks initiated, causing fracture. FE modeling of blanking is improved by including a fracture criterion that indicates when the crack initiates in the simulation. **Figure 6** shows the sheared edge obtained from blanking tests and simulation at a punch-die clearance of 15 percent.

The effect of temperature needs to be considered in the FE model, since a very large plastic deformation and temperature increase occurs in a localized deformation zone. Simulation shows that local temperature increases up to 440 degrees C can occur in blanking of AISI 1050 sheet (see Figure 6b). This temperature could be higher in blanking AHSS because these steels have a higher strength and lower thermal conductivity than AISI 1050.

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Notes

1. *A. Karelova, et al., "Influence of the Edge Conditions of the Hole Expansion Property of Dual-Phase and Complex-Phase Steels," in proceedings from Material Science and Technology Conference (MS&T), Detroit, 2007.*

2. *B.S. Levy, C.J. Van Tyne, "Failure During Sheared Edge Stretching,"* Journal of Materials Engineering and Performance *(online), March 2008.*

3. *I. Al-Zkeri, P. Baroncini, T. Altan, "Determination of the Critical Damage Value at High Strength Rate Using a Blanking Process," ERC/NSM Report No. HPM/ERC/NSM-02-R-02, The Ohio State University, 2002.*

4. *Ibid.*

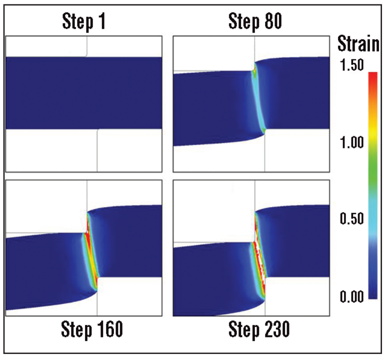

Figure 5

These strain distributions were obtained by simulation, at different steps of blanking, for 1.27-mm AISI 1050 sheet.

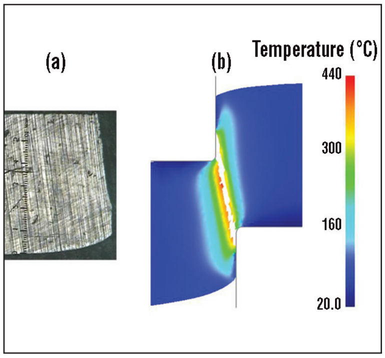

Figure 6

Shown here are the experimental sheared edge geometry for 15 percent clearance (a) and the sheared edge from the FE simulation with temperature distribution (b).