Blanking and edge fracture in flanging of AHSS, Part I

Test methods for evaluation

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Editor's Note: This is Part I of a two-part series that discusses factors affecting the quality of the blanked edge and its fracture when flanging. Part II, which will appear in the January/February 2018 issue, will discuss methods for blanking that can reduce edge fracture in flanging.

Blanking and shearing are necessary before a sheet blank can be formed into the desired part. Often the quality of the sheared blanked edge affects edge cracking when tensile stresses and strains are imposed on the edge during flanging.

The sheared blanked edge is divided into six zones (see **Figure 1**):

1. The rollover zone, where the edge of the sheet is bent by elastic and plastic deformation.
2. The shear zone, a smooth and shiny area created by shearing.
3. The secondary shear zone.
4. The fracture zone, where fracture causes the material to separate.
5. The burr height.
6. The depth of crack penetration.

Usually the edge quality and the resulting fracture in flanging improve as the length of the shear zone increases and the burr height decreases.

For a given sheet thickness, the factors that affect blank edge quality include material-related variables (composition, microstructure, inclusions, grain size) and process- and tool-related variables (the magnitude and uniformity of punch/die clearance, punch/die wear, blanking speed, blank holder force and design, punch/die corner radii). Recent studies indicate that each group of factors may play a significant role in determining the probability of edge fracture in flanging.

It is well-known that edge fracture in flanging occurs more frequently in blanked or sheared edges than edges that are prepared by milling, electrical discharge machining (EDM), laser cutting, and waterjet cutting. In large production-volume sheet metal forming, edges are blanked or sheared, so edge fracture in flanging is a concern.

A critical task in industrial applications is to find a reliable and simple method that relates the blanking or piercing method to edge stretchability of various materials. Furthermore, it is useful to be able to predict in the design stage whether edge fracture will occur in an edge flanging condition.

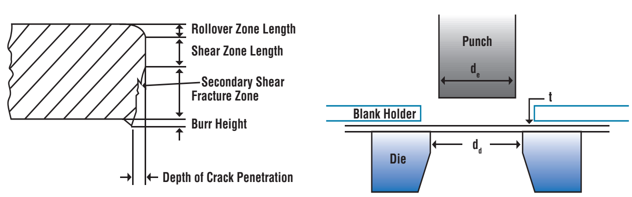


Figure 1

The sheared blanked edge is divided into six zones.

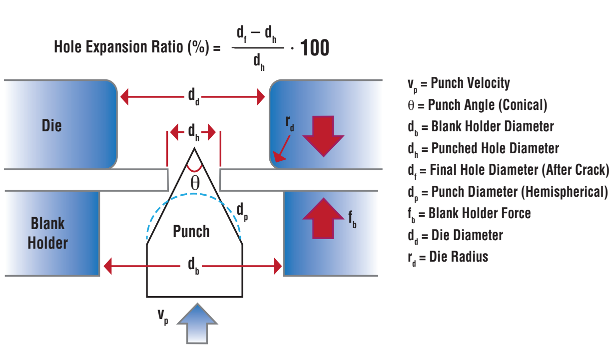


Figure 2

This schematic shows the hole expansion test and the formula to calculate the hole expansion ratio.

Tests to Evaluate Edge Fracture

Edge fracture for a given material and blanking conditions can be evaluated in five ways:

1. Hole Expansion Test (HET)—The principles of the HET and the formula for calculating the hole expansion ratio are shown in **Figure 2**. According to ISO standard 16630, a 10-millimeter circular punched hole produced with 12 percent punch/die clearance is expanded with a 60-degree conical tool at 1-mm-per-second punch speed until a crack at the edge, through the material thickness, is observed. The results of this test show high scatter because it is difficult to maintain a uniform punch/die clearance along the perimeter of the tool. Therefore, larger hole diameters (20 to 75 mm) are used in different variations of this test to reduce punch deflection and improve punch/die concentricity.

2. Half Dome Test—This test uses a rectangular-shaped specimen (see **Figure 3**). The quality of the sheared edge depends on shear tool geometry and punch/die clearance.

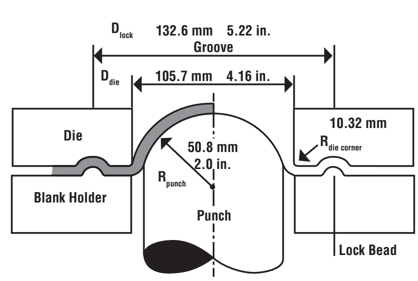


Figure 3

An example of the half dome test is shown here.

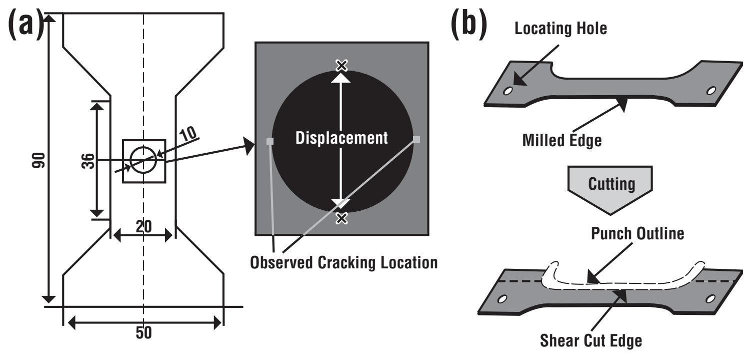
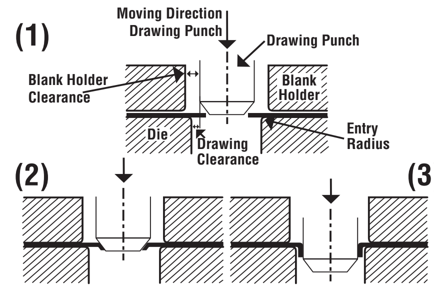


Figure 4

A sample holed tensile test (a) and edge fracture tensile test (b) are shown here.



$$V_A = \frac{D_h - D_o}{D_o} \cdot 100$$

Figure 5

The collar forming test produces parts with a geometry similar to those found in real manufacturing processes.

However, this test is very useful for evaluating the edge fracture characteristics of different alloys. Measuring the strain or thinning at fracture allows a comparison of the edge fracture characteristics of different materials.

3. Holed Tensile Test—This is similar to a typical tensile test, except that a hole is made at the center of a bone specimen (see **Figure 4a**). This hole can be made by machining, EDM, laser cutting, waterjet cutting, or mechanical punching. Test samples measuring 50, 40, and 20 mm wide are used in this type of test. The strains near the fracture area are measured photographically using digital image correlation (DIC) to determine the stretchability of the edge. It also is possible to measure the thinning near the fractured edge. The evaluated edge and the tool do not come into direct contact, so any possible friction effect is avoided.

4. Edge Fracture Tensile Test—This test uses a shape similar to the specimen for the holed tensile test (see **Figure 4b**). However, one side of the specimen is created by a milling operation, while the other side is sheared in a regular blanking operation. This helps to ensure that the crack initiation will start at the sheared edge, where there may be some microcracks. In a similar way to the other methods, the strains or the sheet thickness near the fracture is measured.

5. Collar Forming Test—This test, also known as an extrusion test, produces parts with a geometry similar to those found in real manufacturing processes (see **Figure 5**), so it can be applied directly to practical parts. Often, for a given material type/thickness and tool dimensions, the objective in producing parts with extrusion is to estimate the initial hole diameter to obtain the maximum possible extrusion or collar height without fracture.

General Observations

These five tests are used to determine the effect of material properties and punching conditions on edge fracture in flanging or collar forming (extrusion). In research laboratories, the trend is to use DIC techniques with one or more cameras and the appropriate software to estimate the strains near the edge fracture zone. However, in a practical stamping shop, it is easier to measure the thickness or percentage of thinning at the edge when fracture occurs.

Provided a relationship is established between punched edge quality and the thinning when fracture occurs, it would be possible to predict, at the die and process design stage, when the fracture will occur in the process. As an example, percent thinning values for sheared and laser-cut edges are shown in **Figure 6** for a few materials. In general, thinning at edge fracture decreases as material strength increases. ST

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Reference

D. Diaz, "Edge Fracture in Forming/Flanging AHSS—A State of the Art Review," Report CPF-5.2/17/03 (Columbus, Ohio: Center for Precision Forming, 2017).

Steel Grade	Code	Thickness (mm)	Thinning at Edge Fracture (%)—Shearing	Thinning at Edge Fracture (%)—Laser
DP600EG	A	1.02	7.8	11.3
DP600GI	B	1.2	7.4	10.4
DP600GA	C	1.35	7.4	10
DP600GA	F	1.78	8.9	9.8
T700EG	D	1.75	9.4	9.2
T700EG	E	1.47	11.3	12.7
T700EG	G	1	7.6	7.7

Figure 6

In general, thinning at edge fracture decreases as material strength increases.