Edge fracture in hole extrusion and flanging, Part I

The effect of process variables

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Hole extrusion, or collar forming, is widely used in stamping (see **Figure 1**). In this process, the blanked hole with a small diameter is extruded to a collar with a larger diameter. The characteristics of the blanked edge, the ratio between these two diameters, and the radius of the die affect the height of the collar that can be extruded. During extrusion, the metal thins from stretching, which causes the flange thickness to vary. The thinnest part of the extrusion is at the top of the flange. When a higher flange is desired, the thickness in the flange is reduced and determined by the punch/die clearance during collar extrusion. However, in extrusion, the required flanging or extrusion force also is increased.

Hole extruded features, or formed collars, often are used to provide mechanical attachments or threads necessary for assembly. Edge fracture in hole extrusion is a problem when forming and flanging advanced high-strength steels (AHSS) that exhibit considerable strain hardening and low ductility (see **Figure 2**).

Common Process Variables

Research indicates that many variables affect both the quality of the blanked edge and the extrusion height that can be achieved without fracture.

Blanked edge quality is affected by:

- Material properties (strain hardening behavior, microstructure, inclusions).
- Material thickness.
- Punch/die clearance and its uniformity around the part periphery.
- Tool wear.

The height of the collar that can be extruded depends on:

- The quality of the blanked edge.
- Tool geometry including die diameter and die corner radius.
- Punch geometry.

Often the objective is to estimate the diameter of the initial, smaller blanked hole, provided that the material type and thickness, extruded collar diameter, die corner radius, and desired extruded collar height are known for the given blank.

For low-carbon steels, such as AISI 1008 and AISI 1010, the blanked hole diameter can be estimated using this formula:

$$d = D - (2H - 0.86R_d - 1.43T)$$

Where: d = Initial hole diameter
D = Extruded collar diameter
T = Material thickness
R_d = Die corner radius
H = Desired extruded collar height

However, for AHSS, such as DP600 and DP780, this formula does not give reliable results, so a new method for estimating the diameter (d) is needed.

Effect of Punch/Die Clearance in Blanking

The quality of the blanked edge affects edge cracking when tensile stresses and strains are imposed on the edge during hole extrusion. The blanked edge is divided into five zones (see **Figure 3**):

1. The rollover zone, where the edge of the sheet is bent by elastic and plastic deformation.
2. The shear or burnish zone, a smooth and shiny area obtained by shearing.
3. The main fracture zone, where fracture causes the material to separate.
4. The burr zone caused by fracture.
5. The depth of crack penetration that often is equal to punch/die clearance.

The load-stroke curve of blanking is shown in **Figure 4**. When the punch contacts the sheet, the blanking force increases suddenly, while the tool and the press are elastically deformed and stretched. When the fracture zone is reached, the blanking force sinks abruptly. The rapid increase of the punch force at the start of blanking and the sudden

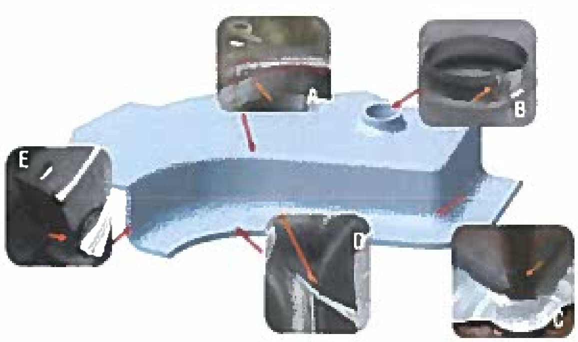

Figure 1

Edge cracking can manifest as a surface crack on the radius (A), edge cracking after hole flanging or collar forming (B), shearing crack at the deep-drawn edge (C), edge cracking at the flange (D), and edge cracking at the open head (E).

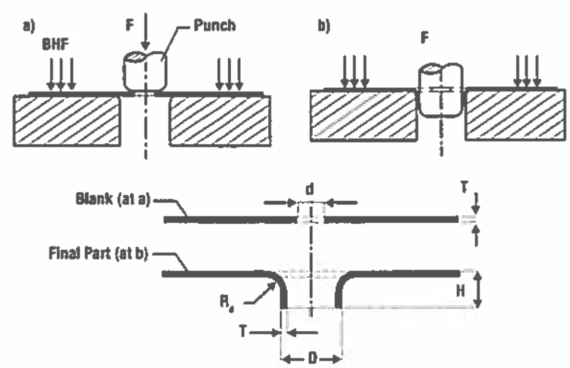

Figure 2

Shown here are details of the hole extrusion (collar forming) process. R_d = die corner radius, T= sheet thickness before extrusion, T' = sheet thickness after extrusion, D = extrusion or collar diameter, d = initial hole diameter, and H = extrusion or collar height.

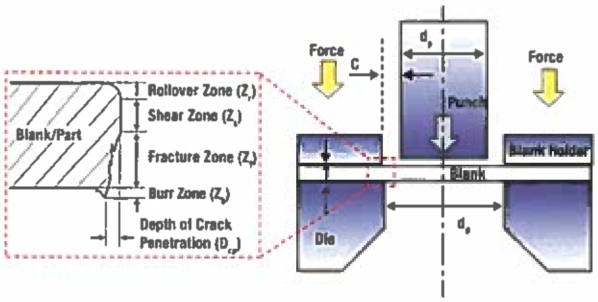

Figure 3

The different zones of deformation in a blanked/pierced edge are shown on the left, while a schematic of blanking and the punch/die clearance (c) appears on the right.

drop in the force when the sheet fractures may cause vibrations and excessive loading of the press and tooling. These excessive vibrations can damage the press and tooling in repetitive operations, especially in blanking AHSS or 8- to 10-millimeter-thick blanks.

Researchers at The Ohio State University's Center for Precision Forming recently investigated the effect of blanking speed on edge quality, as well as the effect of multiple-step blanking using several punch motions during one blanking stroke. They used a 300-ton AIDA servo press and a blanking tool provided by KTH to blank TRIP780 sheets (see **Figure 5**).

The punch/die clearance of the blanking tool (see **Figure 6**) did not seem to be uniform around the tool's circumference. The rolling direction in the blanked samples was well indicated. To determine the quality of the blanked edge and to estimate the punch/die clearance at various locations of the blanked hole, the researchers obtained micrographs of the edges and compared them with finite element simulations (see **Figure 7**) for positions 1 and 3. The hole flanging tests indicated that more fractures occurred near position 1. This observation can be explained by the difference in the punch/die clearance between positions 1 and 3. ⓢ

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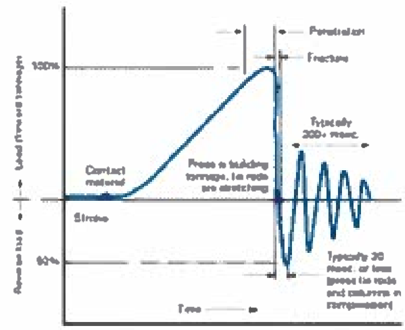

Figure 4

Shown here is a typical load versus stroke curve in a blanking/piercing process. In most practical operations, the reverse load (tonnage) should not exceed 10 percent of the maximum nominal press capacity.

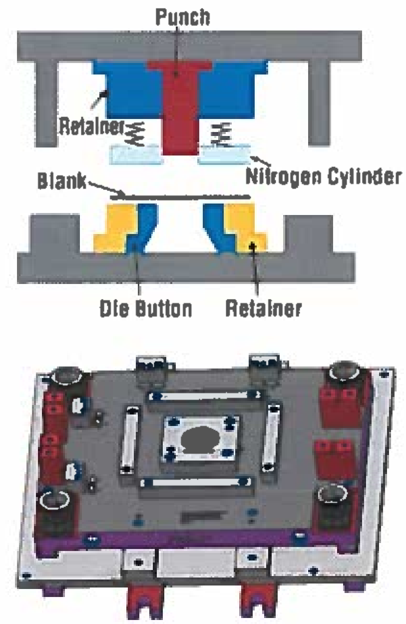

Figure 5

This schematic shows the tooling provided by KTH for the blanking studies in a 300-ton AIDA servo press.

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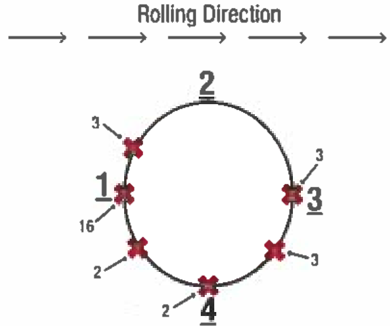

Figure 6

The locations of crack initiation in hole flanging are shown here. The underlined numbers represent the positions in blanking, while the other numbers show how many times the crack initiated at that location during hole flanging during hole expansion tests.

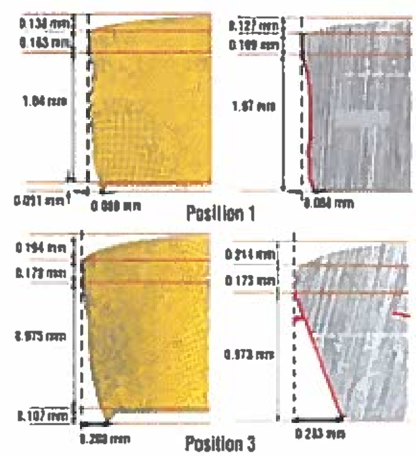

Figure 7

These are the simulations and micrographs of blanked edges on 1.36-mm TRIP780. Positions are shown in Figure 6.