

Effects of Punch Configuration on the AHSS Edge Stretchability

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ABSTRACT

The hole piercing process is a simple but important task in manufacturing processes. The quality requirement of the pierced hole varies between different applications. It can be either the size or the edge quality of the hole. Furthermore, the pierced hole is often subject to a secondary forming process, in which the edge stretchability is of a main concern. The recently developed advanced high strength steels (AHSS) and ultra high strength steels (UHSS) have been widely used for vehicle weight reduction and safety performance improvements. Due to the higher strength nature of these specially developed sheet steels, the hole piercing conditions are more extreme and challenging, and the quality of the pierced hole can be critical due to their relatively lower edge stretching limits than those for the conventional low and medium strength steels. The stretchability of the as-sheared edge inside the hole can be influenced by the material property, die condition and processing parameters. Previous studies showed that the as-pierced edge stretchability can be improved by implementing the bevel shape punch head with an optimal die clearance. In this study, production punches are fabricated with different configurations and surface treatments to study the as-pierced edge stretchability of AHSS. The hole piercing experiments are conducted on DP600, DP780 and DP980 steels using a computer controlled punching system. The hole expansion test is used to evaluate the effect of pierced edge conditions on the edge stretchability. Results indicate that a selection of the 15% die clearance (per side) and a conical shape punch results in a less damaged edge, which significantly delays edge fracture in the forming process and increases the edge stretchability of AHSS.

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INTRODUCTION

Conventional automotive mild and high strength steels are being replaced by advanced high strength steels (AHSS) due to the demands for vehicle weight reduction and safety performance improvement. However, several local formability issues have been raised in stamping processes such as edge cracking and shear fracture in small radius stretch bending. It has been found that the edge cracking issue is related to sheet metal shearing processes such as blanking, trimming and piercing. Nakata et al. [1] has studied the shear deformation properties and the damage behavior on both low and high strength steels using the conventional shearing die. They found that the thickness clearance is critical in trimming high strength steels. The experimental comparison of the edge stretchability of AHSS between standard punched hole, drilled hole and laser cutting hole were conducted by Konieczny [2] and Karelova [3] et al. at different punching clearances. Results showed a better edge stretchability was directly associated with a better shearing process. Golovashchenko [4] modified the conventional shearing process by adding an elastic pad underneath the blank, which would reduce burrs

in a wide variety of clearances without deteriorating the total elongation or edge stretchability. However, the value of the elongation was lower than that observed from the conventional shearing process. The shearing process was also modeled using different Finite Element Analysis (FEA) models [1,5,6], but the simulation results were in limited agreement with experiments. Although some limited data or guidelines might be available on the optimal shearing variables set up, they are often based on conventional lower strength, higher ductility sheet steels. They may not be applicable for shearing AHSS. To optimize the shearing variables for AHSS, Shih et al. [7,8] developed a bevel shear hole piercing process to improve the quality of the sheared edge based on the stretchability or flangeability of the sheared edge. The purpose of this study is to further investigate the effects of punch configurations on the AHSS sheared edge stretchability. Punches with different geometries and surface treatments are fabricated to a production piercing condition to study the as-pierced edge stretchability of AHSS

in this study. The computer controlled punch system was used for the hole piercing test and hole expansion test was used to evaluate the edge stretchability.

HOLE PIERCING TEST

A computer controlled hole piercing process was developed on a lab hydraulic press and the setup is shown in Figure 1-1. A general-purpose punch die set was inverted and mounted to the computer controlled hydraulic press. A schematic diagram of the punch die set is shown in Figure 1-2. The punch diameter (P_d) was 10 mm, and various die with different inner diameters (D_d) were used to achieve different die clearances (CL). The punch speed was kept at 1 mm/sec and the die clearance per side was fixed at 15% of metal thickness (Shih et al. [7,8]) regardless of the test materials. For each material, five specimens were tested on each punch condition.

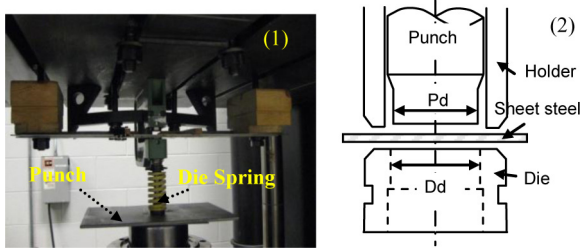


Figure 1. Schematic illustration of hole piercing die set.

Punch Configuration

There are a total of seven different punch configurations included in this study. The conventional flat punch (FP), flat punch with in-line grinding (ILG), 4 micron fine polish (4M), flat punch with radius on the corner (Edge Hone, EH), edge hone punch with 4 micron fine polish (4MEH), 6 degrees conical shear and 6 degrees bevel shear (6D). All punches are made of M2 steel except for the flat punch (FP) and 6 degrees bevel shear (6D) are made of D2 steel with hardness of 60 HRC for all punches. The 6 degrees bevel shear punch was developed from previous studies [7,8] for optimal piercing AHSS with combining 15% die clearance and the shearing direction parallel to the material rolling direction. The 6 degrees is also implemented to make the conical shear punch, and the detail of each punch is discussed below.

6 degrees Bevel Shear (6D)

The 6 degrees bevel shear punch was previously developed to achieve optimal piercing condition for AHSS as shown in Figure 2. Due to the beveled angle, the tip of the punch will first contact and pierce the material at one side of the hole, and the trailing edge will eventually contact with the material and complete the piercing.

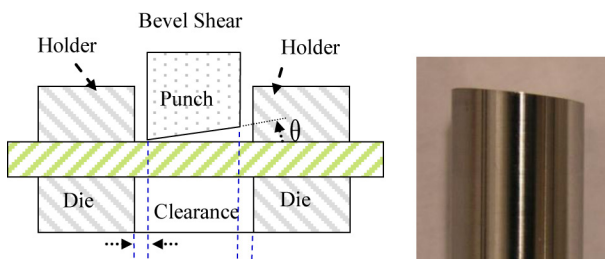


Figure 2. Schematic and photograph of bevel shear die set.

In the production piercing condition, it is a challenge to ensure the material rolling direction is aligned parallel as the bevel shearing and the horizontal force against the beveling shear face could deflect the punch tip when high speed piercing AHSS. This could lead to an unbalanced die clearance condition. To prevent these situations, a 6 degrees fully symmetrical conical shear punch, as shown in Figure 3, was fabricated for this study.

Conical Shear

The tip of the conical shear (Figure 3) can be used to locate the center of the hole on the sample to ensure the even die clearance condition throughout the piercing process regardless of the gauge and strength of the material. The sheet metal within the punch hole area is pre-bent and stretched before the edge of the punch begins to contact and shear off the material, which is different from that of the bevel shear.

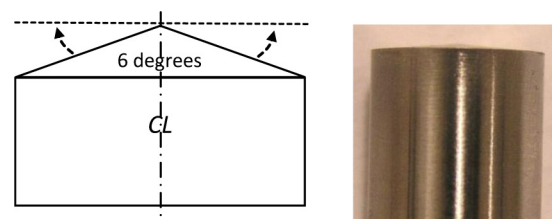


Figure 3. Conical shear punch.

Flat Punch (FP), In-Line Grinding Punch (ILG) and 4 Micron Polish Punch (4M)

In addition to the geometry and shear angle altering, different surface polishing conditions were applied to the conventional flat punch. Figures 4-1 through 4-3 show the conventional flat punch (FP) with typical tangential direction polish, in-line (axial direction) grinding and 4 micron 45 degrees fine polish. The differences among these three punches are the polish direction and surface smoothness.

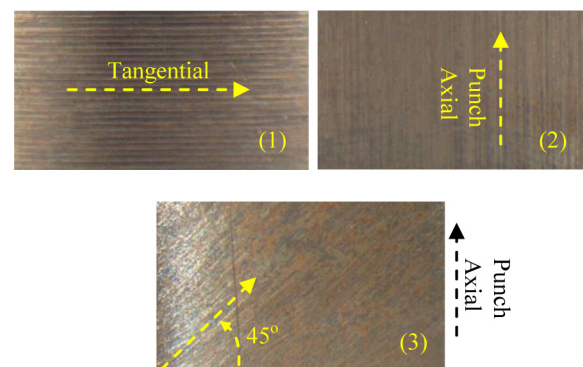


Figure 4. 1) FP tangential direction polish 2) FP in-line (axial direction) grinding 3) FP 4 micron 45 degrees fine polish.

Edge Hone (EH) and Edge Hone with 4 Micron Polish (4MEH)

The sharpness of a fresh built punch would be slowly reduced after production break-in. For the application of the AHSS, the pierced hole edge quality could be affected by the reduced sharpness of the punch. To address the concern, a 0.14 mm die corner radius was applied to the flat punch, usually called edge hone, and the