

Analysis of Tool Wear for Trimming of DP980 Sheet Metal Blanks

Saeid Nasheralahkami, Sergey Golovashchenko, and Scott Dawson
Oakland University

Raj Sohmshetty
Ford Motor Company

ABSTRACT

In recent years, implementation of dual phase (DP) Advanced High Strength Steels (AHSS) and Ultra High Strength Steels (UHSS) is increasing in automotive components due to their superior structural performance and vehicle weight reduction capabilities. However, these materials are often sensitive to trimmed edge cracking if stretching along sheared edge occurs in such processes as stretch flanging. Tool wear is another major issue in the trimming of UHSS because of higher contact pressures at the interface between cutting tools and sheet metal blank caused by UHSS's higher flow stresses and the presence of a hard martensitic in the microstructure. The objective of the present paper is to discuss the methodology of analyzing die wear for trimming operations of UHSS components and illustrate it with some examples of tool wear analysis for trimming 1.5mm thick DP980 steel. The results of die wear of D2 cutting inserts will be reported based upon measurements of the surface of the die and measuring of the burr height of the samples. Strong correlation between local chipping of the trim die and the local burr height of the trimmed sample will be discussed in the paper. This correlation serves as a guidance that die wear of the cutting edges of the trim die can be monitored off line by observing the shape of the trimmed edges.

CITATION: Nasheralahkami, S., Golovashchenko, S., Dawson, S., and Sohmshetty, R., "Analysis of Tool Wear for Trimming of DP980 Sheet Metal Blanks," *SAE Int. J. Engines* 10(2):2017, doi:10.4271/2017-01-0302.

INTRODUCTION

As automakers are challenged to improve safety and fuel economy, they search for new materials to meet higher standards. Advanced High Strength Steels (AHSS) and Ultra High Strength Steels (UHSS) help engineers meet requirements for safety, efficiency, emissions, manufacturability, durability, and quality at a low cost. AHSS and UHSS are a newer generation of steel grades that provide extremely high-strength and other advantageous properties, while maintaining the high formability required for manufacturing [1, 2, 3]. Among UHSS, dual phase DP980 has been representatively applied to the automotive structural parts requiring crash performance such as B-pillar, B-pillar reinforcement, bumper, rear side member and impact beam. However, there are some difficulties due to its limited formability, weldability, dimensional accuracy after stamping, wear of the stamping tool, and scratches on the tool and product [4, 5, 6].

The process of stamping parts from sheet metal frequently includes shearing operations such as blanking, piercing, and trimming. The typical sheared edge on sheet metal has four basic features called rollover, burnish, fracture, and burr as shown in Figure 1. These features are found on both the edge of the cut off piece and the clamped piece but in alternate orientations. Rollover represents the plastic deformation at the sheared edge caused by the bending. With a sharp cutting edge, the blade creates a vertical, rubbed edge known as the burnish. The angular fractured surface is rough and occurs as an

abrupt transition from the smooth burnish area. The burr is usually caused by the excessive clearance, dullness of the cutting tools or a combination of both factors. In general, many factors could affect the configuration of the sheared edge, such as the clearance between the upper and lower cutting blades, cutting angle, the degree of sharpness of the cutting blades, cutting speed, lubrication, sheet material parameters, tooling conditions, tool wear, strain rate, etc. [4, 7, 8, 9, 10, 11, 12, 13, 14, 15].

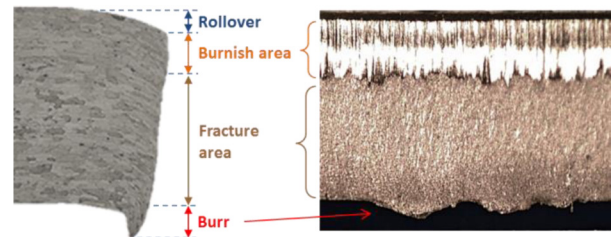


Figure 1. Characteristic Features of a Sheared Edge.

The quality of shearing operations is an important factor that affects the subsequent stamping operations, especially where sheared edge stretching occurs in such cases as stretch flanging, stretch hemming, or drawing with preliminary pierced windows. Severe deformation occurring in the shearing process deteriorates stretchability of the sheared edges.

Many studies were conducted on shearing processes and characterization of sheared edge. Weaver and Weinmann [16] studied the sheared edge formation stages as well as the effect of clearance and tool dullness. Li [17] conducted an experimental study on the trimmed surface and burr with respect to the clearance, sharpness of the tool and inclined angle, which demonstrated the micro-mechanisms of deformation and fracture in the trimming of aluminum alloys. In last decade significant effort has been made on developing trimming of AHSS and UHSS and their characterization. According to Chintamani and Sriram [18], limited quality of sheared edge surface is one of the obstacles on the way of broader implementation of AHSS in automotive industry due to formation of burrs and splits from sheared surface. The experimental comparison in the edge stretchability of AHSS among standard punched hole, drilled hole and laser cut hole was conducted by Konieczny et al. [19] and Karellova et al. [20]. They showed that improved edge stretchability could be achieved applying a better shearing process. Mori et al. [21] used local resistance heating to increase the effective sheared zone and to reduce the punching load when trimming UHSS. In order to eliminate slivers and burrs, Golovashchenko [9, 10] and Ilinich et al. [13] modified the conventional shearing process by using a scrap support underneath the blank together with a dull upper trimming tool. As a result, higher quality sheared edge have been achieved and burrs have been reduced in a wide variety of clearances without deteriorating the total elongation or edge. Chiriac and Shi [22] studied the effect of the prior deformation on the edge stretching limit and performance of DP980. Golovashchenko and Ilinich [23] introduced edge formability in the form of total elongation of sheet metal under stretching conditions, and they conducted the tension tests for DP500 and DP600. The sheared edge tension test was also successfully utilized later by Wang et al. [24] to investigate the edge formability among different grades of AHSS.

Forming of AHSS involves higher contact pressures and temperatures at the tool-sheet interface compared to forming mild steel, due to the higher strength and higher strain-hardening behavior of AHSS. These conditions lead to galling, chipping, abrasive and adhesive wear in the tool, and significantly reduce tool life. Furthermore, the effect of tool wear on part edge quality is significant. Tool wear leads to the formation of burrs. Burr height is generally an important criterion in industry to evaluate part quality and indicates when the tool should be reground to obtain the sharp die-and-punch radius. It has also been observed that the effect of tool wear is more pronounced at higher blanking clearances [8]. Despite all published works on trimming of AHSS, few researches have been carried out in the case of trimming die wear and its effect on the shear edge quality of AHSS. Nasheralahkami et al. [25] studied the influence of trimming conditions and tool wear on quality of trimmed edge of DP980 steel sheet. Husson et al. [7] showed that tool wear leads to the formation of burrs and increases burr height where the effect of tool wear was simulated by assuming different punch corner radii in simulations. Makich et al. [26] proposed a method based on the use of 3D topographical images to measure volume of a burr in blanking operation and its correlation with punch wear. Luo [27-28] investigated the worn behaviors of the punch in piercing a hole on a

larger thickness plate of AISI 52100 steels using two kinds of the convex double shear angles. Hernandez et al. [29] presented theoretical modelling of the effects of tool wear on the shearing mechanism and resulting form errors as well as an experimental study of edge draw-in, depth of crack propagation and burr height for AISI 304 stainless steel sheet.

In the current paper, the effect of tool wear on quality of trimmed edge of ultra-high strength DP980 steel is discussed and results are compared with mild steel based on the experimental examinations.

EXPERIMENTAL PROCEDURE

Trimming experimentations were carried using an experimental trimming die set shown in the Figure 2. Both upper and lower trimming tools are made of D2 high-carbon, high chromium cold work steel. Both tools have a sharp trimming edge with zero degree trimming angle.

The clearance is the horizontal distance between the upper trimming and the lower trimming tools. In our wear study, clearance was precisely controlled and adjusted around 10%t for all materials as recommended in industry. Significant attention was paid to provide a substantial stiffness of the experimental die to avoid significant clearance variation during the cutting process.

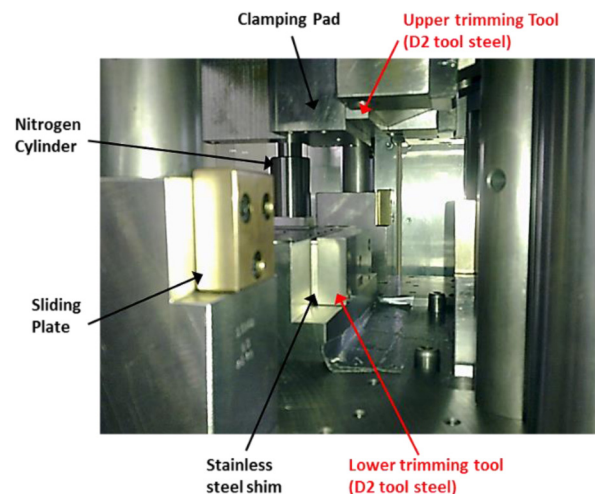


Figure 2. The experimental tooling.

All trimming processes were performed transverse to the rolling direction of the sheet materials. Trimming line for cutting specimens included decoiler, straightener, automatic feeder and 65 ton Minster mechanical press as shown in Figure 3. The specimens were 5-inch wide and trimmed at the speed of 45 strokes per minute.

Two different Ultra high strength steel (DP980) were used in this study: DP980-1 sheet was 1.4mm thick and DP980-2 was 1.5mm thick. Both DP sheet materials were non-coated. In addition to DP980 sheets, Interstitial Free (IF) mild steel with nominal thickness of 1.4mm was examined for comparison.