Impact of Servo Press Motion on Hole Flanging of High Strength Steels (submitted to SAE – Sept. 2016)

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The capabilities of the servo press for varying the ram speed during stroke and for adjusting the stroke length are well known. Also during the blanking operation, the servo can help to slow down the press at the critical moment of blanking without losing overall productivity. Various publications, especially from Japan (Junlapen et al. 2010; Osakada et al. 2011), claim that servo press blanking has the potential to improve the quality of the blanked edge and to reduce noise. However, most of these studies have been conducted on small capacity (50-150 ton) presses. Furthermore, the inertia of the press ram and drive has not been considered when discussing the small variations in the press speed used in conducting stamping or blanking operations.

Various companies installed servo presses for blanking. Some of the considerations may include increase in productivity and flexibility in adjusting the ram stroke, noise reduction and improvement of edge quality of blanked edge.

The overall objective of this study is to determine, for a selected sheet material and hole diameter, the servo press motion that possibly could provide the “Best” possible blanked/sheared edge quality to improve the Hole Expansion Ratio (HER) in hole flanging.
The specific objectives are to determine the effect of ram (blanking) speed upon the edge quality, and the effect of multiple step blanking (as much as possible with the servo press available) using several punch motions, during one blanking stroke.

1. **Blanking Experiments**

The blanking tests were conducted at Aida-America using an Aida 300-ton Servo Drive Press.

![AIDA press used in the experiments](image)

Figure 1: AIDA press used in the experiments

The material provided by KTH for these studies was 1.4mm thick 780MPa TRIP steel and the blanked hole had a diameter of 75mm, as shown schematically in Figure 2. The schematic of the blanking tool, provided by KTH, is seen in Figure 3.
Figure 2: Sketch of the samples used in blanking (blank thickness = 1.4mm, material 780MPa TRIP steel, hole diameter = 75mm)
Figure 3: Schematic of tooling, provided by KTH, used for the blanking (Hole diameter = 75mm and Average Punch/Die clearance 15% of the sheet thickness)

An attempt was made to measure the punch/die clearance using lead wires at 4 different positions. However, this attempt was not successful because the lead wires were sheared during the stroke. Therefore, it was assumed that the clearance is the same around the 75mm hole and equals to 15% (value provided by KTH) of the sheet thickness.
The blanking tests were divided into several groups as follows, it should be noted that the speeds chosen were restricted by the maximum allowable speed (30 SPM) of the AIDA press used in this study:

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Single Blanking (SB)(^1) at 20SPM (70mm/s)</td>
<td>1.1 to 1.5</td>
</tr>
<tr>
<td>2</td>
<td>Double Blanking (DB)(^2) at 20SPM (70mm/s)</td>
<td>2.1 to 2.5</td>
</tr>
<tr>
<td>3</td>
<td>Single Blanking (SB)(^1) at 2SPM (7mm/s)</td>
<td>3.1 to 3.5</td>
</tr>
<tr>
<td>4</td>
<td>Double Blanking (DB)(^2) at 2SPM (7mm/s)</td>
<td>4.1 to 4.5</td>
</tr>
<tr>
<td>5</td>
<td>Two Step Blanking (TSB)(^3) at 0.1mm penetration 2SPM (7mm/s)</td>
<td>5.1 to 5.3</td>
</tr>
<tr>
<td>6</td>
<td>Two Step Blanking (TSB)(^3) at 0.3mm penetration 2SPM (7mm/s)</td>
<td>6.1 to 6.3</td>
</tr>
<tr>
<td>7</td>
<td>Two Step Blanking (TSB)(^3) at 0.8mm penetration 2SPM (7mm/s)</td>
<td>7.1 to 7.3</td>
</tr>
</tbody>
</table>

Table 1: Experimental Matrix

\(^1\)Single Blanking (SB) consists of conventional blanking

\(^2\)Double Blanking (DB) consists of conventional blanking, followed by the retraction of the punch and iron/shave with a second stroke

\(^3\)Two Step Blanking (TSB) consists of a stroke in which the punch penetrates the sheet a certain amount (shown in the table), the punch retracts and finally the punch fully blanks the sheet.
2. Hole Flanging

Hole Flanging tests were conducted at EWI, using their 160 ton hydraulic press and tooling. The geometry of the EWI tooling that was used in the test can be seen in Figure 4. Round samples were cut from the blanked sheets (Figure 2) using water jet. The blanked holes were centered on top of the spherical hole flanging punch.

![Figure 4: Sketch of the EWI tooling used for hole flanging (The punch is stationary and the die moves down)](image)

The hole flanging experiments were conducted with burr down, burr in contact with the punch, the punch was lubricated before each experiment and the ram velocity was set to 12.5mm/s.

The dome height and the flange diameter where edge fracture occurred were taken as a measure of edge quality. The different conditions of edge fracture (for samples blanked at different speeds) were compared using Hole Expansion Ratio (HER) which is given by:
\[ HER = \frac{D_f - D_i}{D_i} \times 100, \]

Where:  
\( D_f = \) final flange diameter, where edge fracture occurred  
\( D_i = \) initial hole diameter (75 mm)

There are many studies on blanking and hole flanging using a 10mm hole, according to the ISO standard 16630. However, results with ISO, in Europe as well as in U.S, indicate that the results of these studies show very large scatter to be useful for industrial use (Atzema et al. 2013). Variations in these results are attributed to variations in punch/die concentricity, and/or measurement errors in identifying edge fracture during hole flanging. In addition, a 10-mm hole is not large enough to clearly differentiate the local ductility change of different materials by considering the statistical deviations of the data. On the other hand, FE simulations showed that a 75-mm hole diameter can improve the sensitivity of the hole edge quality and material properties in the hole expansion ratio. The new 75 mm hole expansion test procedure developed through a Joint Industrial Project (JIP) conducted with support from the state of Ohio, Ohio Development of Services Agency (ODSA) on Advanced Manufacturing Program (Grant No. TECG20141159) (Ohio,2014) was found to be more effective than standard testing methods to evaluate the edge cracking by considering the effects of material properties and trimming methods.

From the test set up it was possible to obtain the load stroke displacement coupled with pictures taken throughout the test. It was then possible to determine at which stroke the first crack appeared, Figure 5. The HER was then calculated with the help of simulation using DEFORM 2D software.
The calculated HER values can be seen in Figure 6. It is observed that:

a. SB (Single Blanking) and DB (Double Blanking) at 2SPM increases the average HER values when compared to 20SPM, from 23 to 26.4% for Single Blanking and from 24 to 27.6% for Double Blanking (DB).

b. Double Blanking (DB) when compared to Single Blanking (SB) condition gives a negligible increase of in the HER, around 1%.

c. Two Step Blanking (TSB) gives lowest HER values: 24.7, 23.2 and 22.6% for 0.1, 0.3 and 0.8mm initial penetration, respectively.
Figure 6: HER values for the different blanking conditions (Please see Table 1 for the explanation of blanking conditions, given in the horizontal axis) – The tops of the bars represent the average HER values while the error bars represent the maximum and minimum HER values

3-Edge quality of the Blanked Holes

For the tests conditions in which 5 samples were tested, one of them was used to prepare edge samples for the analysis of the sheared edge quality under the microscope. For this to be done, small samples were cut from the blanked sheets as shown in Figure 7.
Figure 7: Locations where the samples were taken for edge analysis – The arrows represent the rolling direction

From the edge analysis it was possible to measure the length of Rollover, Burnishing/Shear and Fracture zones. An example is shown in Figure 8.
Figure 8: Measurement of the different zones in the sheared edge (Single Blanking at 20SPM)

Figure 9 illustrates that the change in speed or press motion did not have significant influence in the length of the zones for Position 3. The same result was found for the other positions seen in Figure 7.

Figure 9: Effect of speed and press motion on the zone length
Figure 10: Micrographs of edges obtained in Single Blanking at 2SPM (positions are seen in Figure 6)

It is believed that the difference in the edge geometry shown in Figure 10 is due to a difference in the punch/die clearance at the positions 1 and 3. It is clear that there are two distinct fractures in Position 1, this can be explained by insufficient punch/die clearance which causes that the cracks, initiated at the punch and die corners, do not meet as the blanking stroke proceeds (Altan & Tekkaya 2012).

If there is sufficient clearance, such as in Position 3, the cracks do meet and the actual clearance can be measured by the horizontal distance of the shear zone to the burr, as shown in Figure 10. The calculated clearance for Position 3 was 0.32mm or about 23% of the sheet clearance and as consequence the Clearance at Position 1 was 7%.
The locations (in the blanked sample) of the first crack during the hole flanging experiments were also analyzed and are shown in Figure 11. During hole flanging the majority of the cracks initiated at the rolling direction, as expected, since the hoop stresses are tensile at the edge of the hole, as seen in Figure 12. The majority of the cracks start at Position 1 which is may be due to differences in punch/die clearance around the circumference of the tool, as explained above.

Figure 11: Locations of Crack initiation in Hole Flanging – The underlined numbers represent the positions in blanking (Figure 6) while the numbers show how many times the crack initiated at that location during hole flanging.
Figure 12: Hoop stress calculated in hole flanging by FE simulation using DEFORM 2D

3. Conclusions

Blanking at 2SPM (7mm/s) when compared to 20SPM (70mm/s) results in an increase in HER values: from 23 to 26.4% for Single Blanking (SB) and from 24 to 27.6% for Double Blanking (DB).

Using Double Blanking could slightly improve HER (increase of around 1%) when compared to Single Blanking. However, this improvement is negligible and is within the margins of experimental errors.

This study illustrates that various blanking speeds, within the range considered, (7 mm/sec and 70 mm/sec) do not significantly change the quality of the blanked edge. In this study, the results of hole flanging tests indicated that most fractures occurred near the location 1 of the blanked hole, Figure 11. This observation indicates that during hole punching the punch/die clearance may not have been uniform along the hole circumference. The micrographs, shown in Figure 10 also support this observation. Hence it is very important that punch and die ring are
assembled in a concentric manner (as best as possible). Observations made in industrial practice also indicate that worn blanking tools contribute to increase in pre-damage of the blanked surfaces. This results in reducing the HER.

Using a servo press in blanking, the ram speed could be slowed down near BDC, thus improving the blanking edge condition and HER, without reducing the cycle time (and lowering productivity) in blanking. However it should be noted that blanks for mass production in the automotive industry are typically run at SPMs greater than 20. However the maximum possible speed on the AIDA press used in these studies was only 30 SPM. Hence further studies need to be conducted to see the impact of higher SPM on blank edge quality and HER.

4. Acknowledgements
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5. References
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