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The effects of punch angle in noise and force formation for sheet metal blanking process

Onur Cavusoglu[1], Hakan Gurun[1], Fırat Kafkas[1], Saziye Efendioglu[2] and Faruk Mert[3]

Abstract

The paper is concerned with the effect of punch angle (0°, 4°, 8°, 16°), sheet thickness (0.8, 2 mm), and punch speed (25, 37.5 mm / min) on the force formation and noise in the blanking of DP600 dual-phase steel sheet. The blanking experiments were carried out in a modular blanking die. The blanking force and noise variables were obtained simultaneously during the blanking using a load cell and noise measuring device, respectively. It was determined that the blanking force significantly decreased with an increasing punch angle, while noise formation decreased. The increase in the punch speed slightly increased the amount of noise while it did not affect the blanking force significantly.

Keywords

punch angle, punch speed, noise, blanking force, dual-phase steel, DP600, sheet metal

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Introduction

In The automotive industry, advanced high-strength steels (AHSSs) with low sheet thickness are preferred due to reducing vehicle weights while increasing passenger safety. Thanks to the lightening in weight, the energy requirement is reduced. It causes a reduction in fuel consumption and as a result, the carbon footprint decreases. This is also an essential factor in terms of global warming. For this reason, the use of advanced high-strength steel sheets in automobiles has increased considerably in recent years. Among the materials called advanced high-strength steels developed in this context, dual-phase steels have an important place with their superior mechanical properties[1–6].

Blanking is one of the important methods used in sheet metal forming applications. This method is to obtain the product of desired geometry dimensions as a result of blanking of sheet metal which is placed between the punch and die[7,8]. This process starts with the contact of the punch on the sheet. In the meantime, elastic deformation occurs on the sheet first As the punch continues to move, elastic limits are exceeded and plastic deformation starts to occur. With the increment of the punch stroke, the formation of cracks starts on the sheet, and then the blanking occurs. The force applied to perform this operation is called the blanking force[9,10]. Besides, vibration and noise occur during blanking[11].

Considering the sector size of the automotive industry[12], where sheet metal forming processes are intensely needed today and especially advanced high-strength steels are used extensively, detailed research is needed on this subject. The aim in sheet metal production processes is a high-quality production with minimum energy and time[13–15].

When the studies on blanking force and noise formation in literature are examined, Galdos et al. and Gürün et al. examined the blanking force using angled punches in their works. The blanking force was significantly reduced with an increasing punch angle[16,17]. Nothhaft et al. determined the formation of force during blanking with the chamfered punches, there was no significant change in force with a chamfered punch in the range of 0° to 7°, but there was a reduction in the blanking force with 20° chamfered punch, but the product quality was reduced[18]. Mackensen et al. observed that the application of angled punch in the blanking of advanced high strength steels (AHSS) significantly reduces the blanking force[19]. Kutuniva et al. performed the blanking of the DQ960 ultra high strength steel sheet using convex double-sided angled blanking punches in the range of 0° - 14°. By

[1]Faculty of Technology, Department of Manufacturing Engineering, Gazi University, Ankara, Turkey
[2]Turkish Automotive Factory, R&D Center, Bursa, Turkey
[3]Vocational School of Technical Science, Ankara Yıldırım Beyazıt University, Ankara, Turkey

Corresponding author:
Faculty of Technology, Department of Manufacturing Engineering, Gazi University, Ankara, 06560, Turkey.
Email: onurcavusoglu@gazi.edu.tr

increasing the punch angle, the blanking force was reduced by 57%. However, they stated that product quality decreases[20]. In their study, Khleif and Jasim examined the blanking forces by using (0°, 5°, 10°, 15°, and 20°) angled punches. With the increase of the punch angle, the blanking force was reduced by up to 90%[21,22].

Noise formation occurs in sheet metal forming operations where press machines are used. This is one of the main factors affecting the health of the employee. Among sheet metal forming methods, blanking is a process with a higher noise level than others. Tirtharaj et al. examined the effects of noise levels on worker comfort in various tonnage presses and reported that high noise levels caused ear and migraine pain[23]. Xia et al. examined the effect of material type, sheet thickness, and punch speed on noise in sheet metal blanking. They determined that the noise level increases with the increase in material strength, sheet thickness, and speed[24]. Murakawa et al. succeeded to reduce the noise level in the blanking by using hydraulic inertia damper[25]. Otsu et al. controlled the movement of the press ram and realized a two-stage blanking operation, and decreased the noise level[26]. Sano et al. studied noise analysis on a mechanical C-type press and calculated the sound energy to predict noise generation[27]. Wang et al. studied the relationship between noise level and working mechanism in servo presses[28].

It was seen that the blanking force by using the punch angle could be significantly reduced. The noise formation had negative effects on employee health and it was understood that the noise level could be reduced to a small amount by various methods.

In this study, the effects of punch angle, punch speed, and sheet thickness on the blanking force and noise level were determined in the blanking of DP600 advanced high strength dual-phase steel sheet. The experimental results for blanking forces and noise levels were presented and the results were discussed with the related literature.

Materials and experimental procedure

In this study, the DP600 dual-phase steel sheet with a thickness of 0.8 mm and 2 mm was used, which is widely preferred especially in the automotive industry. The chemical composition and mechanical properties of the DP600 dual-phase steel sheet are presented in Table 1 and Figure 1, respectively. Dual-phase steel's microstructure consists of ferrite and martensite phases. Figure 2 shows the microstructure of DP600 dual-phase steel. In the microstructure image, the light-colored regions are seen as the ferrite matrix, while the dark-colored areas are distributed as martensite regions.

Table 1. Chemical composition of DP600 dual-phase steel sheet material (wt, %).

Steel Grade	C	Mn	Ni	Cr	Si	P	S	Cu	Al
DP600	0.07	1.58	–	0.48	0.10	<0.02	<0.01	–	0.03

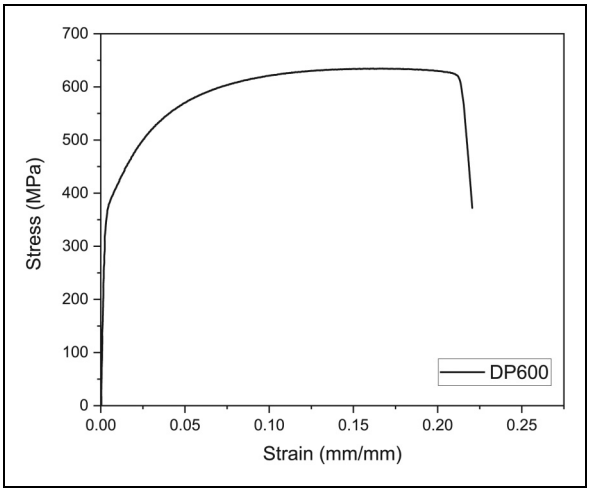


Figure 1. The tensile curve of DP600 dual-phase steel.

Blanking force has a great influence on the product quality and press stiffness[29–33]. In the theoretical calculation of force in blanking operations, ultimate tensile strength, blanking length, and sheet thickness are effective. Generally, in the calculation of the parallel blanking force with a flat punch and die, the length of contact is taken into account and the force is generated depending on this length since all the edges of the punch are in contact. However, in blanking operations using an angled punch, the blanking punch does not touch all sections of the sheet at the same time, so the force is gradually formed depending on the punch angle.

Generally, equation (1) is used for blanking with a flat punch, and equation (2) is used for blanking with angled punches[16].

$$Fc = \tau * S = Kc * UTS * L * t \tag{1}$$

$$Fc = \tau * S = Kc * UTS * \frac{t^2}{2 * \tan\alpha} \tag{2}$$

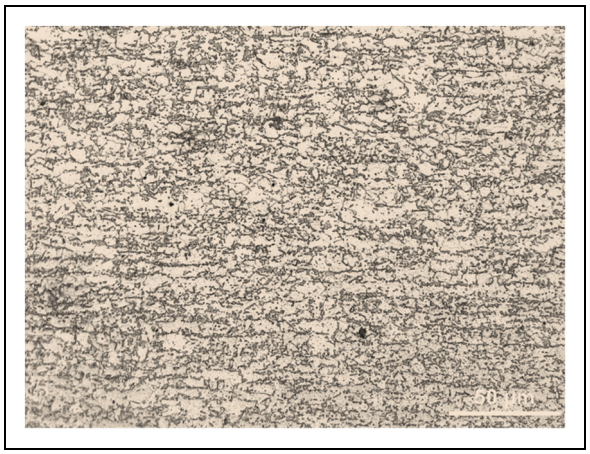


Figure 2. The microstructure of DP600 dual-phase steel.

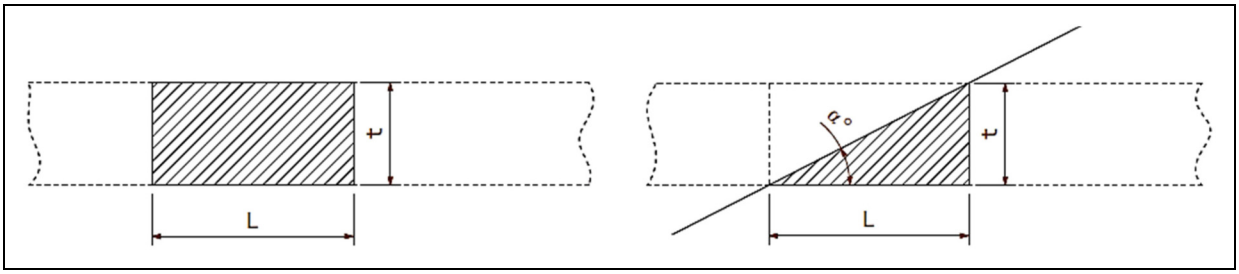


Figure 3. Calculation of the blanking area.[16].

Herein, τ is the shear stress, S is the section zone that is calculated with L is the blanking length and t is the sheet thickness, Kc is the specific blanking factor that relates to the shear stress with the UTS, the Ultimate Tensile Stress. It is needed to calculate the Kc value for specific sheet material with a given thickness and blanked with a known punch angle in the experiments in which the blanking force can be measured[16]. The schematic images of the flat punch and angled punch during the blanking are given in Figure 3.

The experiments were carried out on a speed-controlled hydraulic press. With a load cell connected to the blanking die, the vertical force formed during blanking was measured. A picture of the test setup is shown in Figure 4. The signals coming from the load cell were amplified by an amplifier and transferred to the analog-digital converter and then to the computer. With the calibration, the amount of force corresponding to the voltage changes caused by the load cell was determined:

In the experiments, blanking punches with a diameter of Ø 20 mm were used at 4 different punch angles such as 0°, 4°, 8°, and 16°. The clearance value was kept constant and it was chosen as 0.16 mm and the die diameter is Ø 20.32 mm. To reduce the error margin, the experiments were repeated three times and the average values were taken.

Results and discussion

As a result of the blanking experiments, force and noise formation were examined depending on the punch speed, sheet thickness, and punch angle. Noise formation is an extremely important factor in terms of occupational safety. In this respect, it is desirable to minimize the noise in the industry.

The noise level of the environment was measured before the experiments between 68–70 dB at a blanking

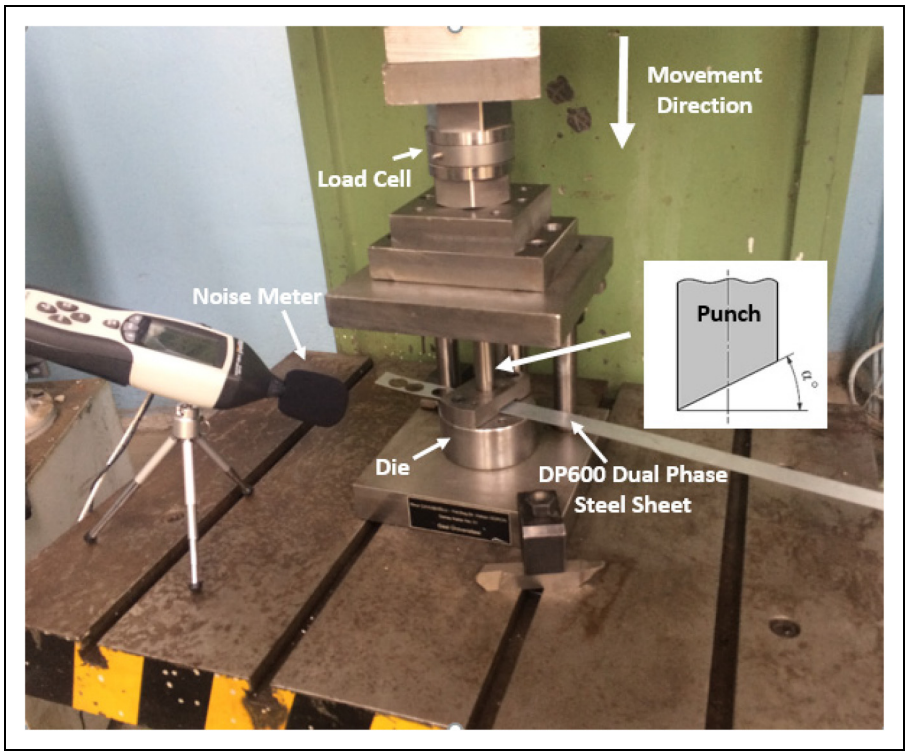


Figure 4. Experiment setup.

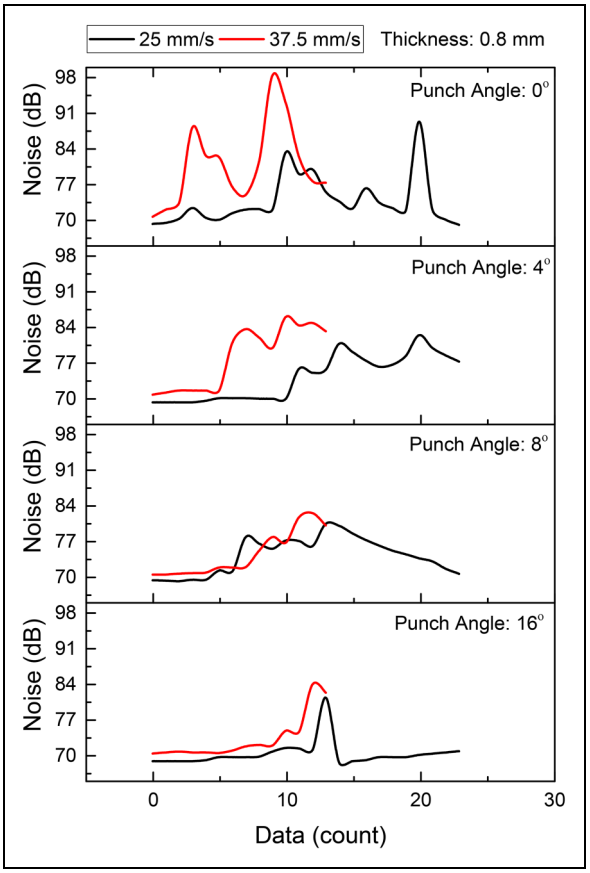


Figure 5. Noise formation for 0.8 mm sheet thickness.

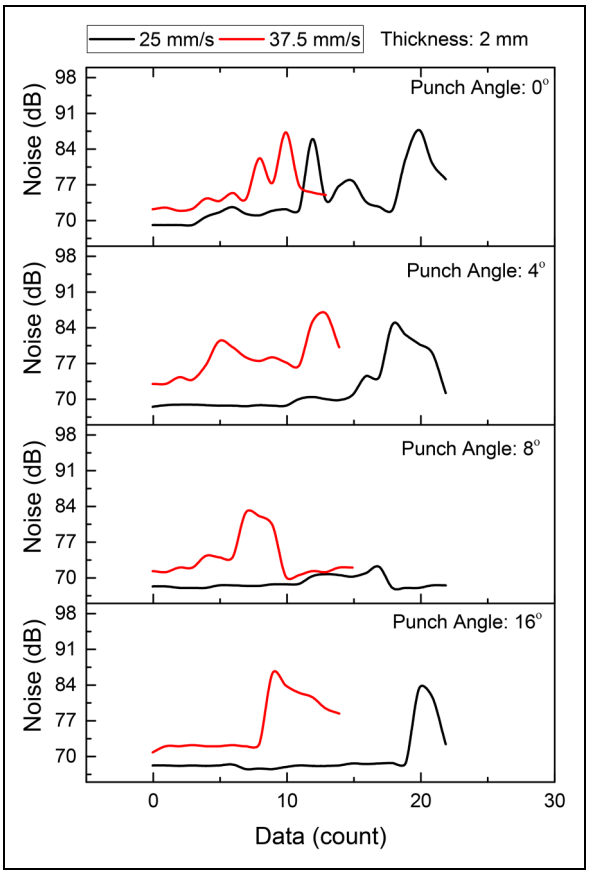


Figure 6. Noise formation for 2 mm sheet thickness.

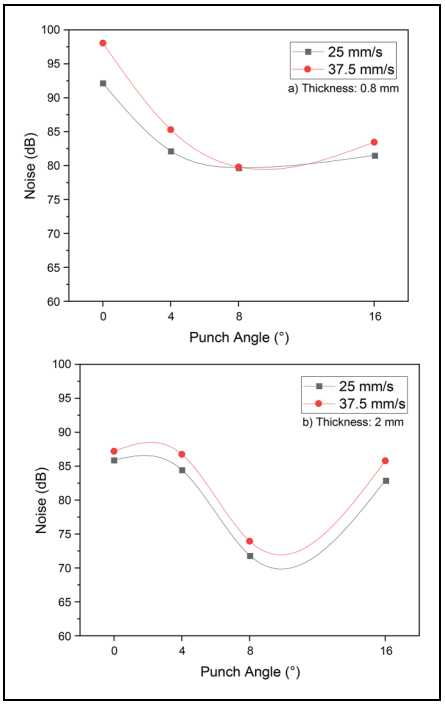


Figure 7. Noise relation with punch angle and speed.

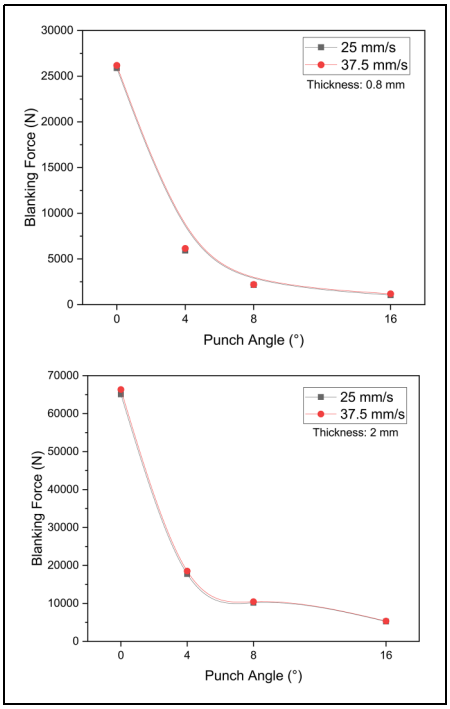


Figure 8. Blanking force relation with punch angle and speed.

speed of 25 mm/min, and 70–72 dB at a blanking speed of 37.5 mm/min, respectively. At higher blanking speeds, the pressure increase in the press hydraulic system leads to an increase in the environmental noise level.

Figures 5 and 6 show noise formation during the blanking. When the noise formation curves are examined, it is seen that in the blanking operations made with 0° and

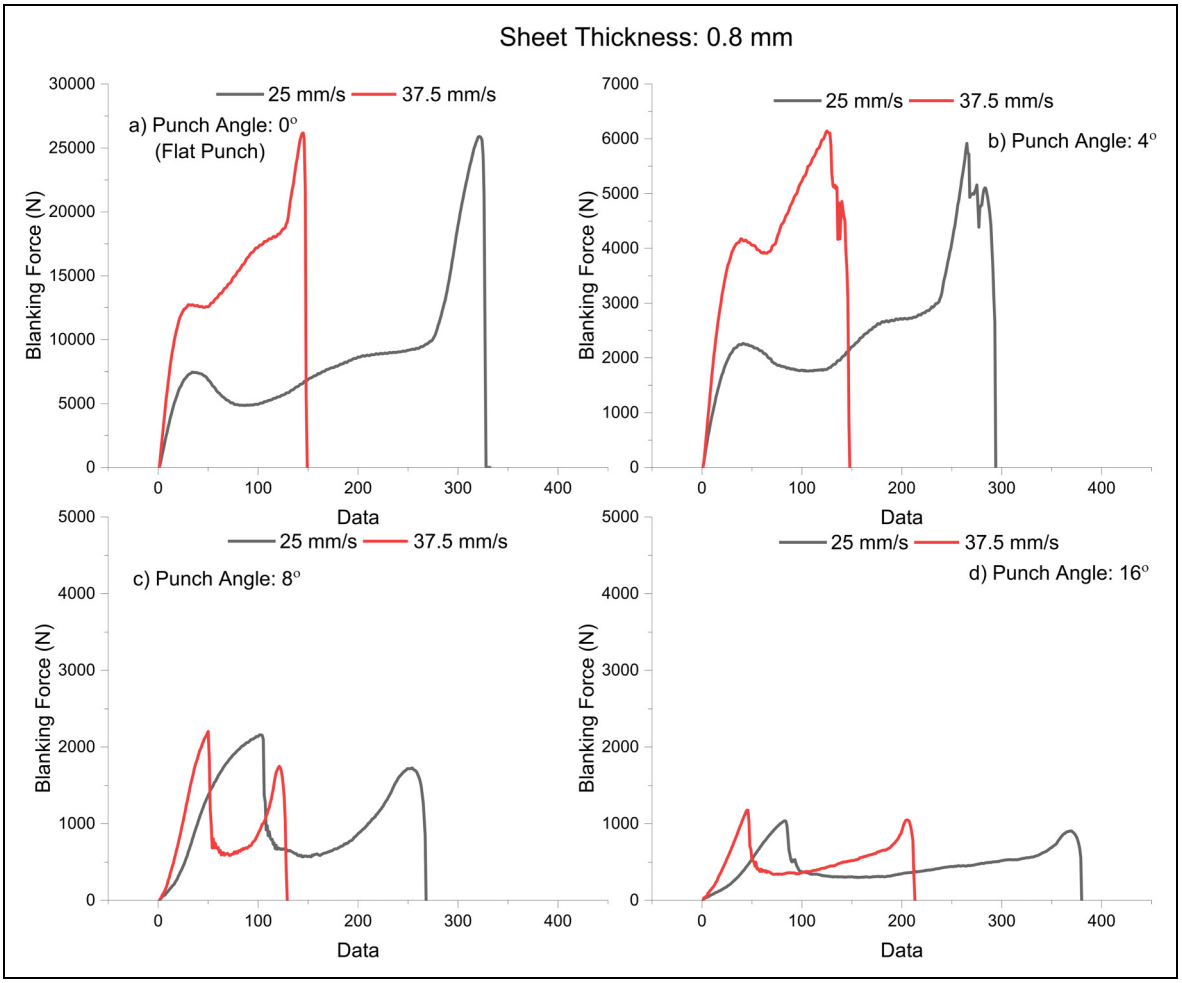


Figure 9. Blanking force formation curves for 0.8 mm sheet thickness.

4° angled punch, the noise first decreases again by reaching a certain amount, and then the increase in the amount of noise continues to reach the maximum level. In this case, the noise that occurred in the first stage is considered as the noise that occurs at the beginning between the crack and the movement of the punch in the guide plate. The noise formed at the next stage was evaluated that the noise occurred during the separation of the sheet by blanking. In the case of blanking with 8° and 16° angled punches, noise formation increased only up to a maximum point. This is thought to be due to fact that the blanking gradually spread to different areas of the sheet in this punch angle range (8°–16°).

Figure 7 shows the relationship between noise, punch angle, and speed. In the blanking experiments performed between 0° and 8° punch angles, it was determined that the amount of noise decreased due to the increase in the punch angle. The lowest noise level was observed in the blanking using a punch angle of 8°. However, no significant change was observed in the amount of noise at the thickness of 0.8 mm in the blanking made with 16° angled punch, but it was determined that there was some tendency to increase for 2 mm sheet thickness. When the change of noise depending on the punch speed is evaluated, it is seen that higher noise occurs at high punch speed. This situation is also described by Xia et al.[24] with the results obtained in their study.

The relationship between the punch angle and speed with the blanking force is presented in Figure 8. It is clearly seen that the blanking force decreases with an increasing punch angle. This case shows that the blanking force can be reduced by using angled punches, in particular for the use of low capacity presses for blanking advanced high strength sheets. However, after the 8° punch angle, it was found that there was no dramatic decrease in the amount of blanking force reduction with increasing punch angle. In the study of Jasim and Kheleif, it was not seen a significant reduction in the blanking force at the increased blanking angle after the 10° punch angle[22].

When the effect of blanking speed on the resulting blanking force is evaluated, in some experiments higher blanking speed has been obtained at increasing blanking force, but increasing blanking speed does not cause a significant increase. For this reason, it is possible to say that blanking at a higher speed has no considerable effect on the formation of force. The results were given in the studies of Slavič et al.[34] and Gaudillière et al.[35] also supported this finding.

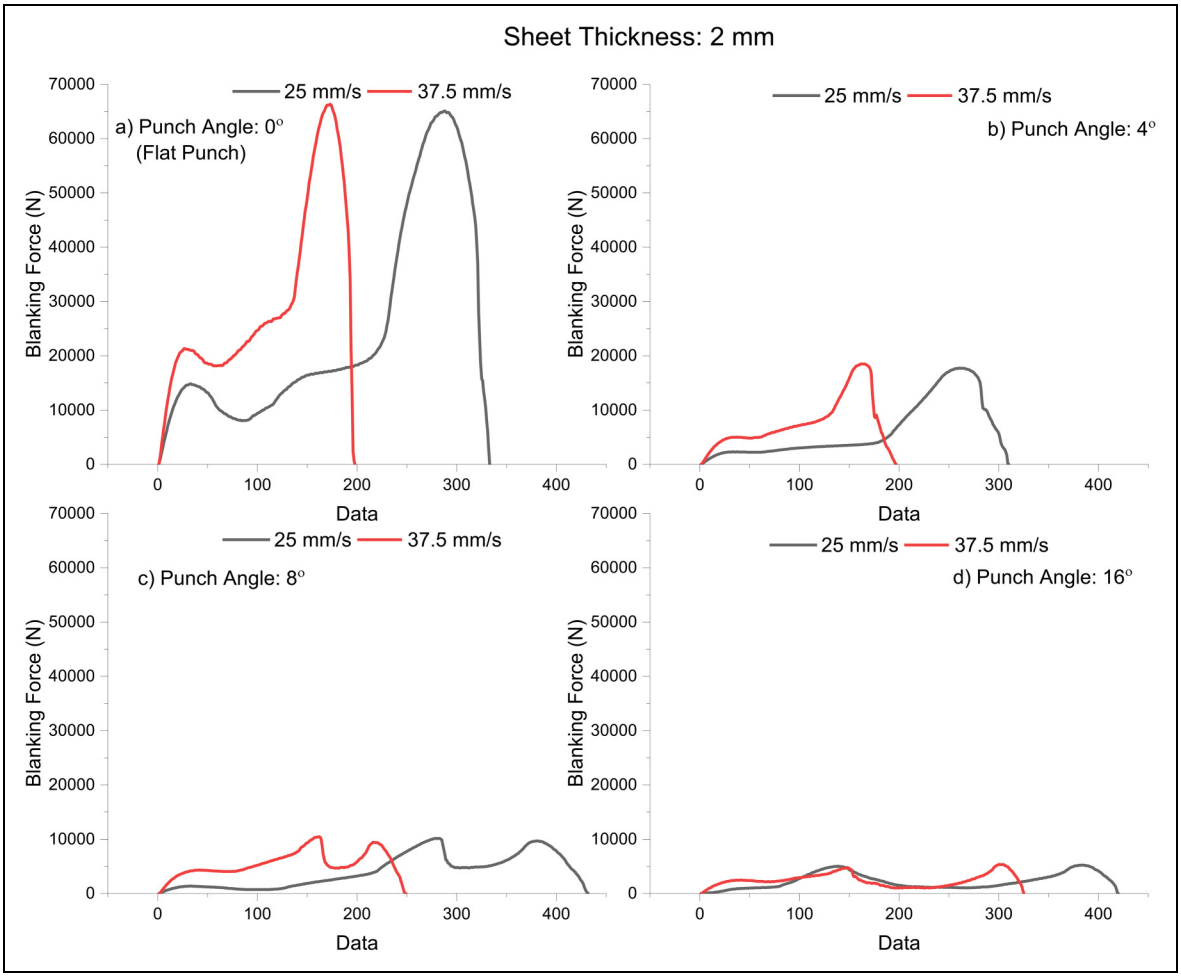


Figure 10. Blanking force formation curves for 2 mm sheet thickness.

The blanking forces that occur during the blanking are measured at different punch angles and speeds. Blanking force formation curves were obtained by collecting data by load cell and they are given in Figure 9 and Figure 10. When the effect of punch speed was analyzed, it was found that the amount of blanking force did not change significantly but the formation of the blanking force was spread to a more extended process due to needing more time interval at the lower speed. It is seen that the blanking forces formed by the 0° blanking punch given in Figure 9a and Figure 10a are higher than the other punch angles and the blanking force reaches the highest point in a much narrower range. In Figure 9b and Figure 10b, it is observed that the blanking force formation range is expanded while the blanking force continues to decrease with the 4° angled punch. It is also clear that the necessary punch stroke length increases due to the increase in the punch angle. When the blanking forces formation is evaluated with the 8° angled punch given in Figure 9c and Figure 10c, a very different blanking force formation is observed compared to the other angled punches. The blanking force first increased and decreased again, and then repeatedly increased and decreased again. The blanking force formation range was seen to expand considerably. With an 8° angled punch, it is possible to say that the blanking takes place in two stages. In this case, the force formation at the punch from the entry stage of the sheet was observed and a certain part of the sheet was blanked at this stage. It was thought that the other side of the sheet was blanked as the punch continued to move. When the blanking made with a 16° angled punch is examined in Figure 9d and Figure 10d, it is seen that the blanking was realized in two stages similar to the 8° angled punch but it is performed with a slightly lower force. Also, the lowest blanking force was obtained at a 16° angled punch. Figure 9 and Figure 10 show that the increase in the punch angle causes the blanking force to decrease significantly. Also, it is understood from the blanking force formation process that the punch speed does not have a significant effect on the blanking force.

Although the use of angled punches has positive effects on noise formation and blanking force, there are also some disadvantages. It generally causes the stroke length to prolong and the blanking time to increase. In addition, some geometric defects were observed on the blanked piece (scrap side).

Conclusions

The Results obtained in this study are summarized below.

- With the increase of punch speed, noise formation increases. However, the punch speed had no significant effect on the formation of the blanking force. Only the slower blanking speed results in a wider range of the blanking force generated in a longer time interval.
- With the increase of the punch angle, noise formation decreased in the range of 0° - 8°, while the decrease in 16° did not continue. It is thought that this situation may be caused by the gradual process in the blanking with 8° - 16° angled punch and the increase of angle due to penetration into the sheet in the form of sinking.
- It has been found that the amount of noise can be reduced by approximately 21% and the blanking force by about 90% with the increase of the punch angle.
- It is generally found that less noise is formed when blanking thick sheets.
- The blanking process can be investigated by using punches with different geometries (concave, convex, etc.) or stepped punches, and the effects of punch movement (such as punching back and forth or waiting at certain intervals) can be investigated as future studies.

Declaration of conflicting interests

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ORCID iD

Onur Cavusoglu https://orcid.org/0000-0002-7239-3902

Supplemental material

Supplemental material for this article is available online.

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