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# An Investigation of Punch Radius and Clearance Effects on the Sheet Metal Blanking Process

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**Abstract**

In this study, the effects of punch edge radius and blanking clearance on product quality and blanking process in blanking of AISI 304 stainless steel sheet were investigated by using the finite element analysis method. The blanking analyzes were performed at four different punch tip radii (0.01, 0.25, 0.5, 1 mm) and three different blanking clearance (1 %, 5%, 10%). As a result of the analysis, rollover, burr length increased, smooth sheared / fractured surface ratio and blanking force decreased with the increase in blanking clearance. Depending on the increase in the amount of punch tip radius, the blanking force, and burr length also increased, and the smooth sheared / fractured surface ratio decreased compared to the blanking process with flat punches.

Keywords: Sheet metal blanking; Clearance; Punch radius; Blanking force, Burr

**Research Article**

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## 1. Introduction

Today, stainless steel sheet materials are a widely used material type due to their excellent corrosion resistance and superior mechanical properties [1–3]. The die blanking process is widely used in the forming and production of sheet metal parts in areas such as automotive, aerospace, and white goods industries [4]. The blanking process can be defined as blanking the sheet material between the punch and the female die prepared in the appropriate geometry with the movement of the punch into the female die [5]. The factors such as punch speed, punch type, punch tip radius, and clearance can directly affect the product quality and blanking process. [6, 7].

When the studies on the blanking process in the literature in recent years are examined; Han et al. investigated the effect of blanking clearance by using three different clearance values (5%, 10%, 15%) in blanking DP780 dual-phase steel sheet with 1.6 mm thickness using experimental and finite element methods. Depending on the increase in the amount of blanking clearance, the amount of work hardening, burr length, and rollover increased [8]. In the study of Basak et al., the blanking processes of three different (TRIP steel, hot-stamped (HS) steel, and aluminum alloy 5182) automotive sheet metal were investigated through experimental and finite element methods. The blanking force decreased with the increase in the clearance, and the burr length increased [9]. In another study by Basak et al., DP980 dual-phase steel sheet was blanked by the experimental and finite element method. They reported that the quality of the cut product is affected by the punch angle, punch radius, and clearance [10]. Senn and Liewerd investigated the blanking process of DP600 and DC03 sheets with a flat punch and concave punch at different clearances. The smooth sheared region was formed in a higher amount with concave punch in blanked products. With the increase of the clearance, a decreasing trend was observed in general [11]. Gomah and Demiral performed blanking operations with punches with flat edges and a hemispherical ball protrusion in the middle. They obtained a higher quality cut product with the punches with hemispherical protrusion of 2.2 – 2.6 mm compared to the flat punch [12]. Abe et al. on the other hand, compared flat punch and stepped punch blanking operations in the blanking process. They reported that a higher number of punching was made in the stepped punch [13]. Soares et al. investigated the effects of blanking clearance in the range of 0.2% - 15% on product and force in blanking LNE38 steel. With the increase in the clearance, the blanking force decreased and the burr size increased. In addition, fracture angle was observed to occur [14]. Fazily et al. investigated the blanking process of AZ31 magnesium alloy sheet at different temperatures (25 ºC – 250 ºC). With the increase in the clearance, the roll over depth increased, the burnish zone decreased, and the fracture zone increased. [15]. According to Sahli et al., the effects of the clearance on the product when blanking 16MnCr5 material were investigated by experimental and finite element analysis. They reported that they obtained a smoother surface at low blanking clearance values. [16]. Gustafsson et al. investigated the effects of clearance and sheet clamp conditions on the blanking process. When the blanking clearance decreased, the blanking force increased [17]. So et al. investigated the blanking process of 22MnB5 hot forming steel before and after hot forming. With the increase in the blanking clearance, the blanking force, burnish zone decreased, and the amount of rollover and burr increased. Fracture angle formation was also observed [18]. Canales et al. investigated the effects of clearance on blanking process in blanking 1mm thick X30Cr13 stainless steel sheet by finite element analysis method. The blanking force and sheared zone decreased with the increase in the clearance, and the burr size increased [19]. In the literature, it has been seen that studies have been carried out on product quality and blanking process for different blanking clearances and punch types using experimental and finite element methods.

In this study, the effects of clearance and punch tip radius on product quality and blanking process in blanking 304 stainless steel sheet were investigated using the finite element analysis method.

## 2. Material and Finite Element Simulation

In this study, finite element analysis studies were carried out by selecting 1 mm thick 304 stainless steel sheet material. The analyzes were established as an axisymmetric 2D model using Ls-Dyna software. In these analyses, punch, stripper, and die rigid elements were defined, and the sheet was defined as deformable. The analyzes were completed by changing the punch according to the values of four different punch tip radii (0.01, 0.25, 0.5, 1 mm) and three different blanking clearances (1 %, 5%, 10%). The MAT015 Johnson-Cook Material model was chosen. A material card was created by entering Johnson-Cook Hardening and Damage parameters. Johnson-Cook hardening and damage model parameters of 304 stainless steel are given in Table 1. In Figure 1, the schematic view of the tools used in the blanking analysis, and in Figure 2, the punch dimensions used in the analysis are given. Analysis levels are given in Table 2.

Table 1. Johnson-Cook hardening and damage model parameters [20, 21]

| A (MPa) | B (MPa) | n | C | m |
|---|---|---|---|---|
| 205.578 | 1637.984 | 0.811 | 0.014 | 1 |
| D1 | D2 | D3 | D4 | D5 |
| 0.53 | 0.5 | -6.8 | -0.014 | 0 |

Table 2. Input Parameters and their levels

| Parameter | Levels | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Clearance | 0.01 | 0.05 | 0.5 | |
| Punch Edge Radius | No radius | R 0.25 | R 0.5 | R 1 |

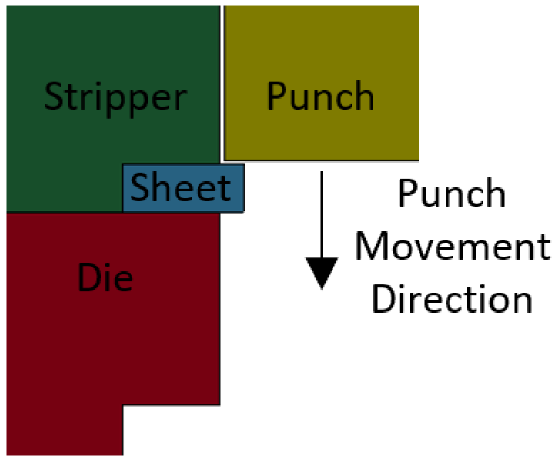


Fig. 1. Schematic view of the finite element analysis model

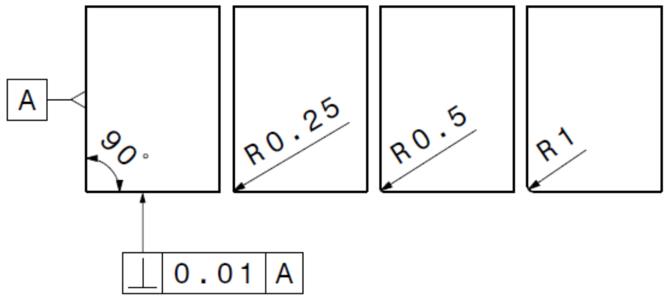


Fig. 2. Punch types

## 3. Results and Discussion

As a result of the finite element analysis, it was seen that different clearance values and punch tip radius affect the blanking process. Figure 3 shows the surface characteristic resulting from the analysis.

In Figure 4, the amount of rollover that occurs on the cut product according to the clearance and punch tip radius is given. The smallest rollover amounts were obtained as a result of the blanking analyzes made with punches without punch tip radius. The rollover amounts increase with the increase in the clearance value in all punch types. The results of other researchers in the literature also support this situation [8, 9, 15]

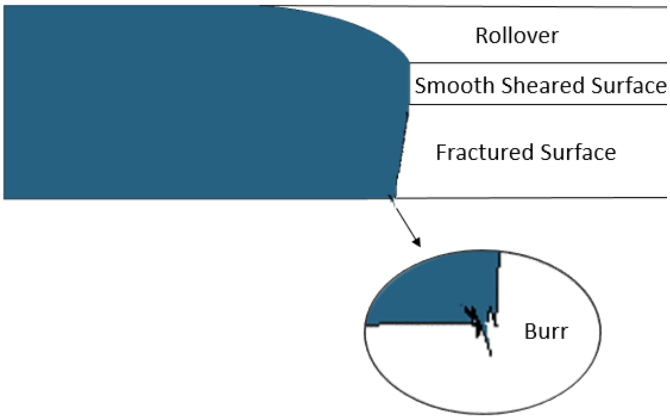


Fig. 3. Blanked product cross-section surface

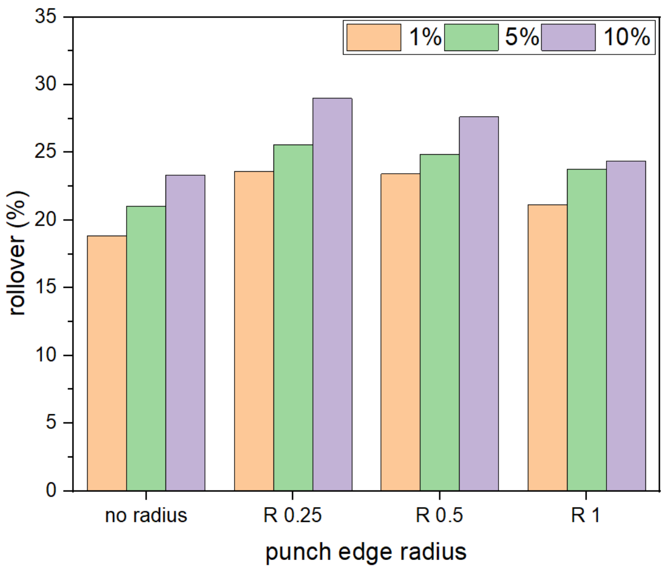


Fig. 4. Rollover - clearance and punch edge radius relation

One of the most important factors affecting the product quality in sheet metal blanking processes is the amount of burrs. The quality of the cut product is usually determined by the size of the burr formed during the blanking [10]. It is desired to minimize the amount of burrs. The amounts of burrs formed as a result of the sheet metal blanking analysis are given in Figure 5. The amount of burr increases with the increase in the clereance. This situation has also been observed in similar studies in the literature [8, 10]. The amount of burr size in blanking operations made with radial punch is approximately 1% or less. An increase in the amount of burrs was also observed in the blanking operations performed with punches with punch edge radius. However, there is no increase in the amount of burr in the blanking process performed with a punch with a tip radius of R 0.25 mm and a clearance of 0.01 mm. This is thought to be the case because the clearance is very low and the fracture process takes place earlier. The amount of burrs occurred in the range of 4-6% in the blanking operations performed with the punches with R 0.5 and R 1 mm punch tip radius and 0.1 mm clearance. In blanking operations with 0.01 mm and 0.05 mm blanking clearance values, the burr size is in the range of 2-3%.

In sheet metal blanking processes, elastic-plastic deformation occurs first in the sheet that is stuck between the die and the punch due to the movement of the punch. Afterwards, some of the sheet is blanked and a smooth surface is obtained. As the punch continues to move, fracture process occurs and a rough surface is obtained [22]. In sheet metal blanking processes, a smoother surface is desired. Smooth sheared / fractured surface ratio is given in Figure 6. The highest smooth sheared / fractured surface ratios were obtained in the range of 1.6 – 1.8 in the blanking process with 1% and 5% blanking clearance values. At a 10% clearance value, the smooth sheared / fractured surface ratio is 0.69, which is higher than the blanking operations performed with all other punch edge radius punches. In blanking operations with punches with punch edge radius, smooth sheared / fractured surface ratios range from 0.5 to 0.68 at 1% clearance. However, this ratio decreases with the increase of the clearance. It is possible to say that the smooth sheared / fractured surface ratio decreases with the increase in the clearance. With the increase in punch edge radius, a linear trend was not observed in this ratio. It is generally seen that the same clearance values are close to each other.

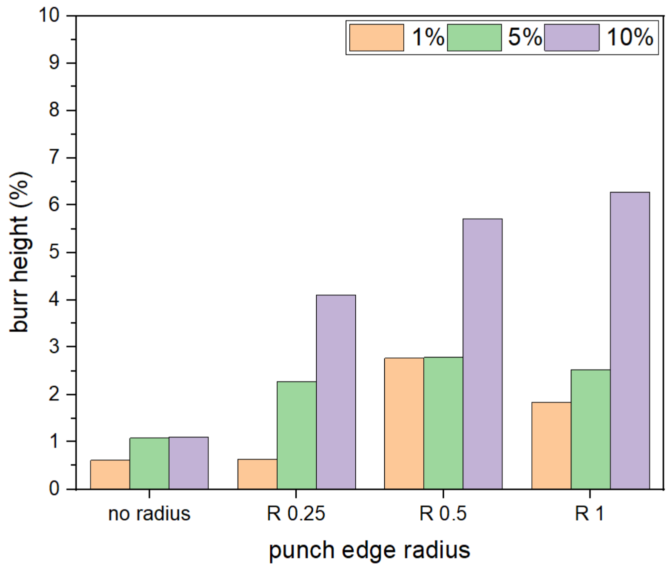


Fig. 5. Burr length - clearance and punch edge radius relation

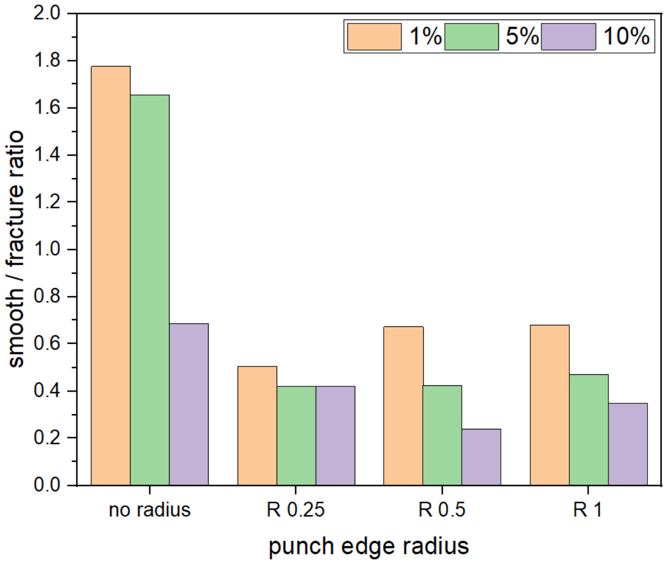


Fig. 6. Smooth sheared / fractured surface ratio - clearance and punch edge radius relation

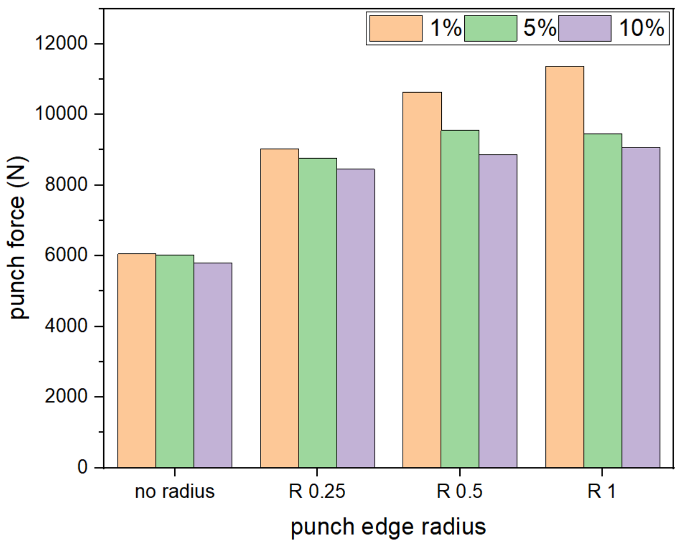


Fig. 7. punch force - clearance and punch edge radius relation

The strength of the sheet metal against blanking with the punch movement creates the blanking force. It can affect the blanking force on many parameters such as clearance, punch type, surface roughness, sheet material type. [6, 13, 14]. According to the blanking force results given in Figure 7, it is seen that the blanking force tends to decrease somewhat depending on the increase in the clearance value in all blanking operations with punches. In the studies in the literature, it is seen that the blanking force decreases with the increase in clearance. [9, 17]. However, in blanking operations made with punches without punch tip radius and punch with 0.25 mm punch tip radius, the reduction in blanking force is small, while in blanking operations with punches with 0.5 mm and 1 mm punch tip radius, the blanking force is more pronounced due to the increase in clearance has decreased.

It is thought that this situation is due to the amount of work hardening formed before blanking. The blanking force occurred in the range of 6059 – 5797 N in the blanking operations made with a punch without a punch tip radius. However, in blanking operations with a punch with tip radius of R 1 mm, a blanking force between 11360 and 9065 N was formed. An increase in the blanking force occurs with an increase in the punch tip radius. The increase in the punch tip radius forces the sheet metal to bend before blanking and causes an increase in the amount of plastic deformation that occurs. At the same time, the increase in the amount of work hardening at any stage of plastic deformation determines the amount of stress required to continue the deformation [23]. In this case, the strength of the sheet for the blanking process increases, and it is thought that the blanking force increases accordingly.

Figure 8 shows the blanking forces generated during the blanking process. It is seen that the blanking process takes the shortest time in the blanking process with a punch without a punch tip radius (Figure 8a). In blanking operations with punches with punch tip radius, it was observed that the blanking process lengthened with the increase in punch tip radius (Figure 8b-d). It is also observed that in blanking operations with punches with a punch tip radius, force generation starts a little later than in blanking with a straight punch. The contact of the punch with the sheet metal in the blanking zone is delayed due to the tip radius. With the increase of the punch tip radius, this process is delayed. With the increase in the punch tip radius, the blanking process lengthens with the late start of the blanking process. In punches with tip radius, the sheet material is forced to bend before blanking. This situation increases the plastic deformation in the sheet metal and causes the need for more force. In addition, the prolongation of the blanking process and the increase in the required blanking force also increase the amount of energy required. In blanking operations with punches with R 0.5 mm and R 1 mm punch tip radius, the force increases linearly with the start of plastic deformation with the contact of the punch and then continues in a certain amount until the end of the punch movement. The reason for this is that the fracture occurs in the sheet at an angle and force is generated due to the friction of the blanked sheet surface to the punch surface.

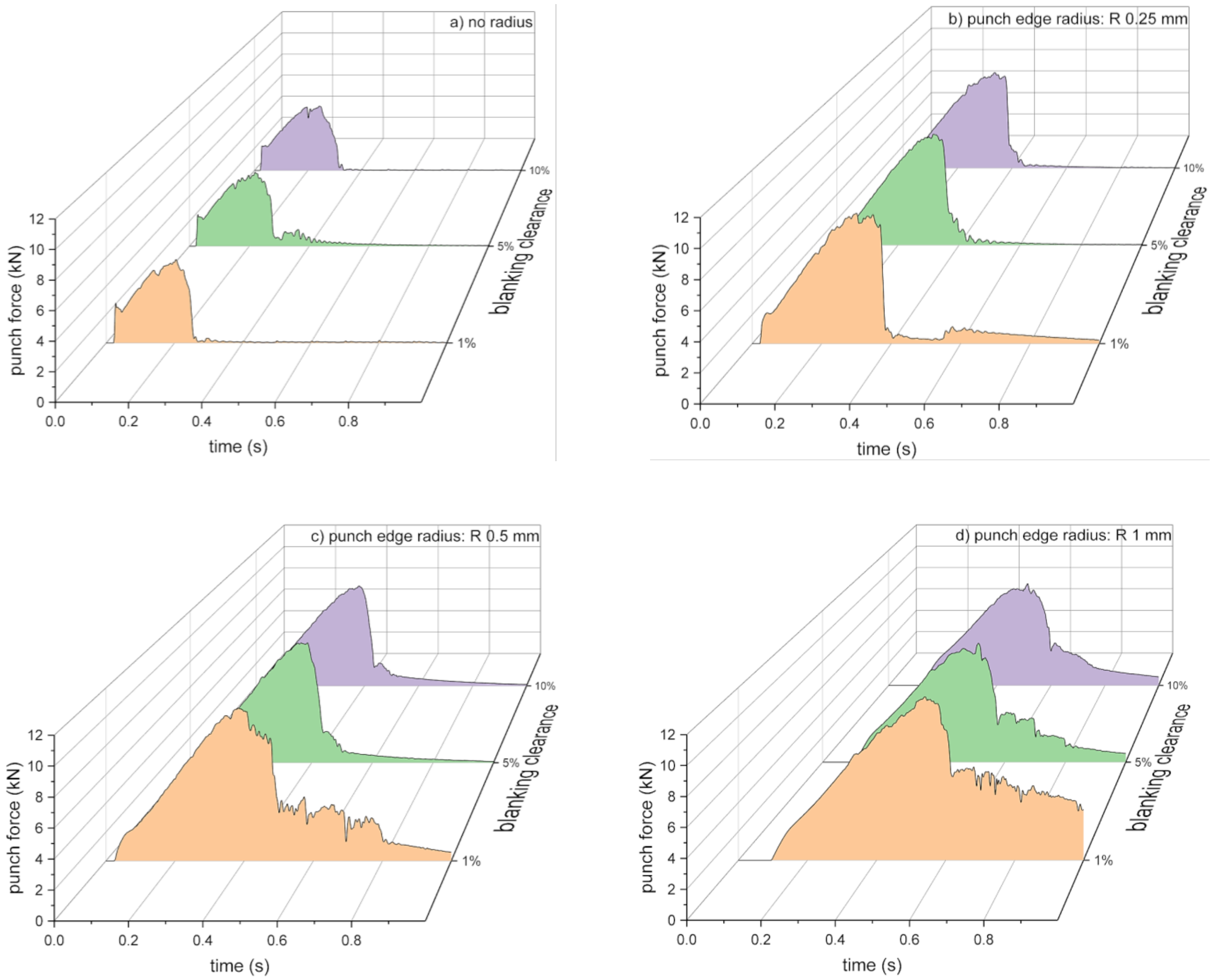


Fig. 8. Punch force at blanking process

When the force formations given in Figure 8 are examined, it is seen that the force increase is later in the operations performed with punches with punch tip radius. Figure 9 shows the deformation and damage conditions that occur in the sheet metal when the punches move 0.68 mm. It is seen that the blanking process has not yet taken place in radius punches while the blanking is completed in the blanking process with flat punches. In the blanking process with a punch with a radius of R 0.25 mm (Figure 9b), it is seen that the stress accumulation in the sheet material is extremely high. However, it is seen that the stress accumulation is at lower levels in the blanking operations performed with punches with a radius of R 0.5 and R1 mm, respectively (Figure 9c-d). This supports the fact that the blanking forces generated during the blanking process with radius punches reach their maximum level later.

In Figure 10, product images are given due to the blanking analyses made with punches with different clearances and radii. It was observed that there was minimum residual stress on the product in the blanking analyses made with straight punches. However, in the blanking analyses performed with radius punches, residual stress is observed due to the increase in punch edge radius around the blanking surface. It can also be said that the residual stress generally decreases with the increase in clearance.

When the plastic deformation distributions given in Figure 11 are examined, results similar to those given in Figure 10 were obtained. Plastic deformation was observed around the blanking surface with the increase in punch tip radius. It is thought to be caused by the radius punch forcing the sheet metal to bend before blanking. In addition, the plastic deformation areas decreased with the increase of the clearance. It has been concluded that this situation is due to the fact that the fracture is easier with the increase in clearance.

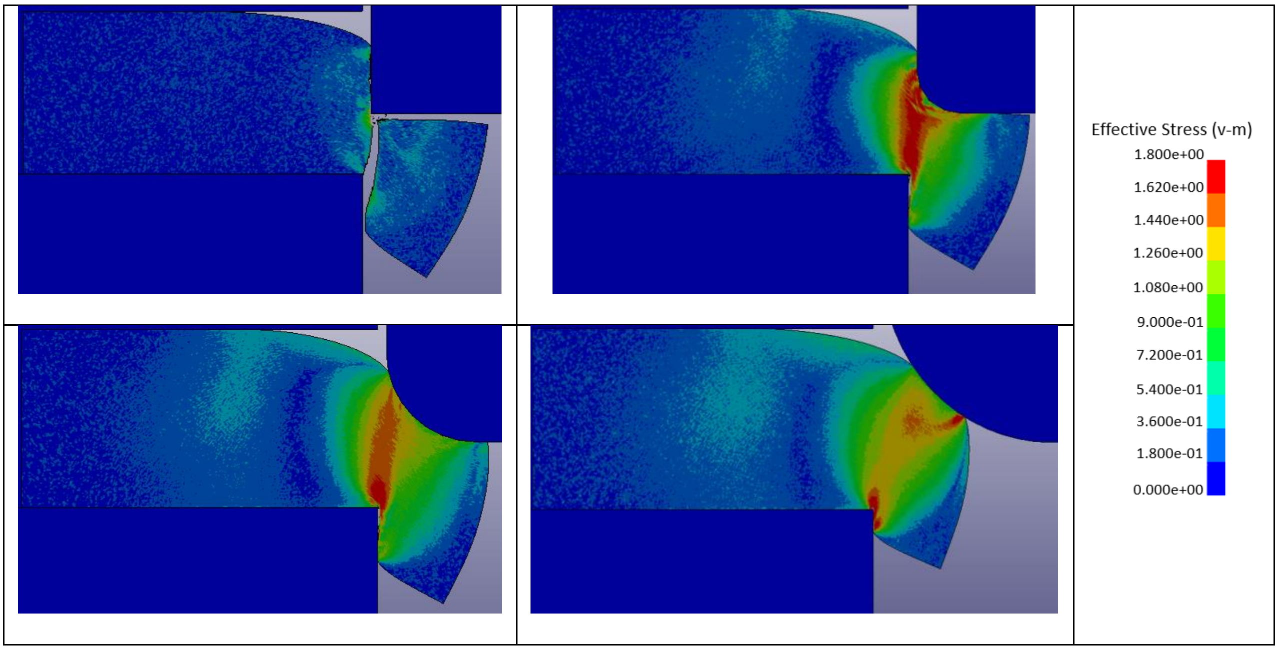


Fig. 9 Blanking states due to punch movement

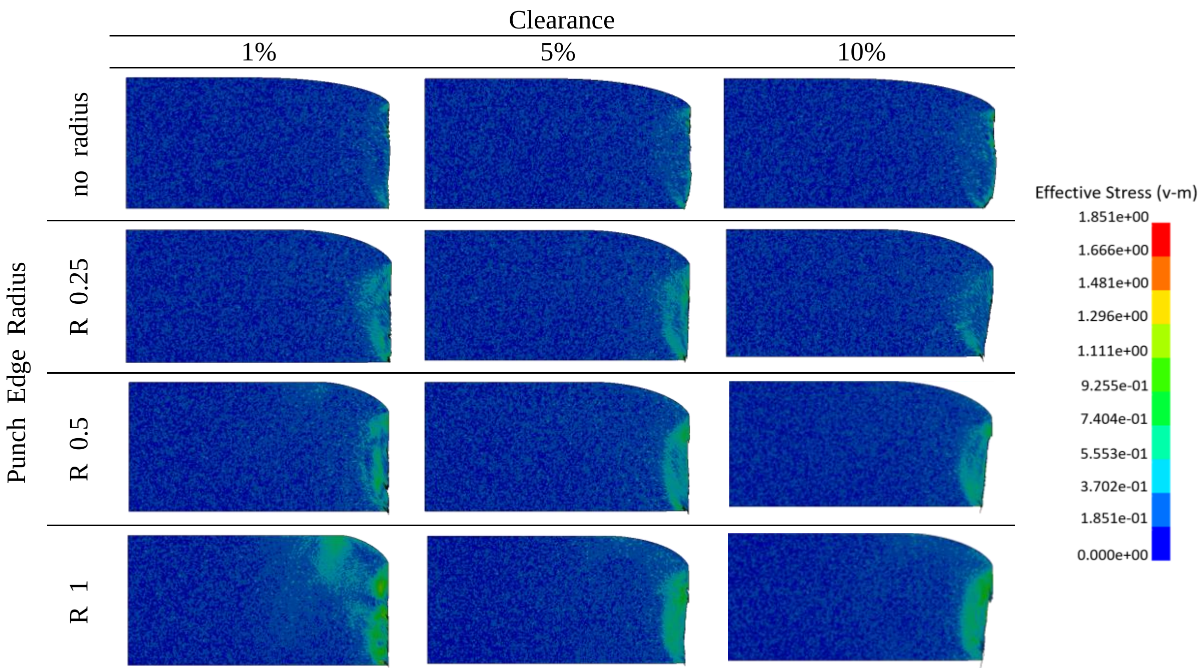


Fig. 10. Stress distributions

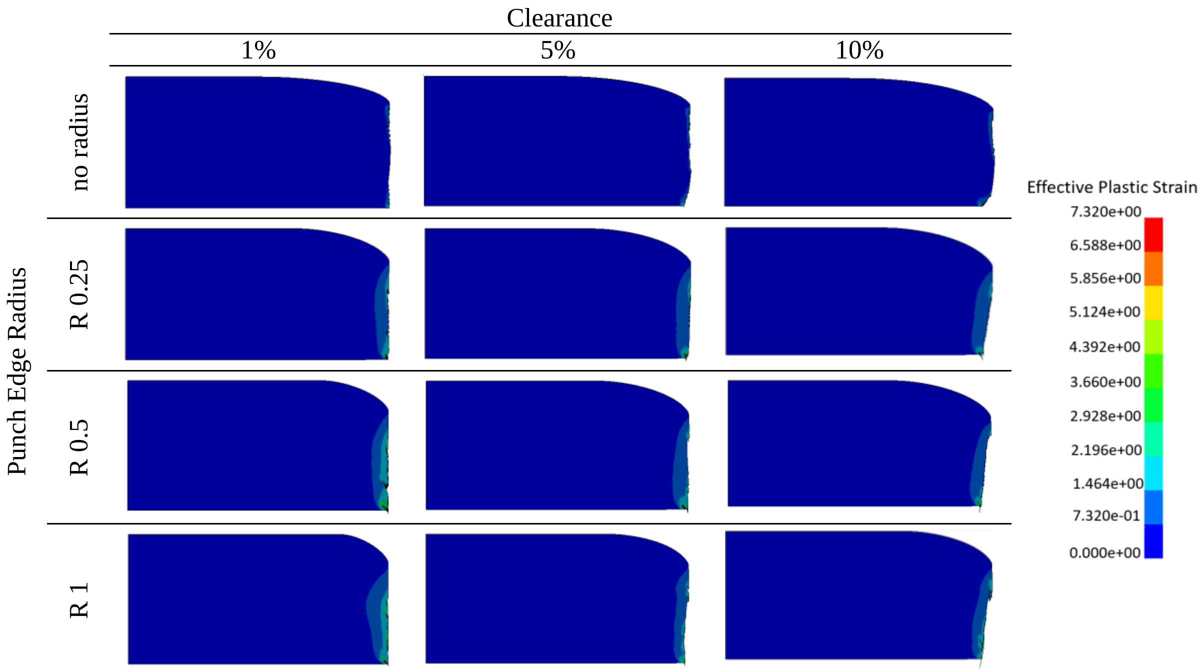


Fig. 11. Plastic deformation distributions

## 4. Conclusions

The findings obtained as a result of the study are given below.

The amount of rollover and burr size increased with the increase in clearance, whereas the smooth sheared surface / fractured surface rate and blanking force decreased. With the increase of the punch tip radius, no significant change was observed in the rollover, but the burr size and blanking force increased. The flat punch obtained the highest smooth sheared surface / fractured surface rate ratio. With the increase in punch tip radius, the blanking time was prolonged. It was determined that there was an increase in the amount of residual stress and plastic deformation on the surface of the blanked product with the increase in the clearance.

## Conflict of Interest Statement

The author declare that there is no conflict of interest in the study.

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