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Research Paper

Experimental Study of Shearing Dimensional Parameters in the Sheet Metal Blanking Process of StW24 Steel with a Thickness of 12 mm

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Abstract

Blanking is a sheet metal cutting process, which itself is a prerequisite for many other forming processes. Punch and matrix shape and material, punch force and speed, lubricant, corner radius, and punch-matrix clearance are important variables in blanking. Clearance is critical in this process, depending on the material and sheet thickness, and is usually a percentage of the sheet thickness. Too much clearance causes the sheet to press and pull into the clearance area and Low clearance causes misaligned fracture lines and secondary cutting. Producing blanking with high thicknesses is always one of the challenges of the sheet metal blanking process. This study aims to create 57.5 mm diameter StW24 steel blanks with 12 mm thickness and a 38% penetration value. A blanking die was designed and built with different punches based on clearance values of 9, 15, and 21% to match the target drawing. Results show that increasing clearance from 9 to 15% leads to an 11% thicker rollover zone, 5% thicker fracture zone, and 33% thinner shear zone. Increasing clearance from 15 to 21% reduces the thickness of rollover, fracture, and shear zones by 24, 3, and 56% respectively. Increasing clearance from 9 to 21% also leads to a 51% increase in fracture angle and a 34% increase in burr size. Clearance of 15% of sheet thickness is best for producing blank as per the target drawing.

Keywords

Sheet Metal Blanking, Clearance, Rollover Zone, Shear Zone, Fracture Angle, StW24

1. Introduction

Press machines are a popular choice for mass production among industrialists due to their speed and versatility in creating parts from metal sheets with varying thicknesses. The advantages of dies and press machines include mass production, technical control, dimensional accuracy, and complex part production. Metal forming processes are accompanied by plastic deformation. Processes such as blanking, deep drawing, cutting, and bending of metal sheets are examples of metal forming processes at ambient temperature. Some of these operations are associated with failure, such as cutting and blanking, and others, such as deep drawing, must avoid failure[1]. Blanking is a commonly used press-forming process, essential for deep drawing and other methods. The desired piece is made by separating its peripheral lines from the sheet using a blanking die, and it is then taken out of the matrix cavity as a blank. Blanking dies cut metal sheets by pressing a punch against a fixed matrix below it using a press machine's moving part, resulting in the cutting of the workpiece. As the punch enters the sheet, equal opposing forces from the punch and matrix cause the material to flow and deform. This force exceeds the yield strength of the sheet, resulting in plastic deformation. Deformation happens in upper and lower levels causing shear stress in the fixed sheet holder. As the punch penetrates, the sheet moves to the plastic region, and more penetration increases shear stress. The sheet cracks in the plastic area and the rollover zone results in cutting when the applied shear stress exceeds the sheet's strength. Clearance is the difference in size between the matrix cavity and the corresponding punch size, determined by the material and sheet thickness, usually expressed as a percentage. The metal is separated based on the amount of clearance. Figure 1 shows that excessive clearance leads to improper sheet breakage. Increasing thickness by 15-50% maximizes the shearing surface's rollover zone. Small clearance, 0-5% sheet thickness, and misaligned fracture lines, lead to discontinuous fracture which causes secondary cracks. Clearances under 0.3% result in 2-10 secondary cuts on the shear surface. Since the distance between the shear forces changes according to the amount of clearance, it can be said that the distance between the shear forces and, as a result, the failure mechanism depends on the amount of clearance[2].

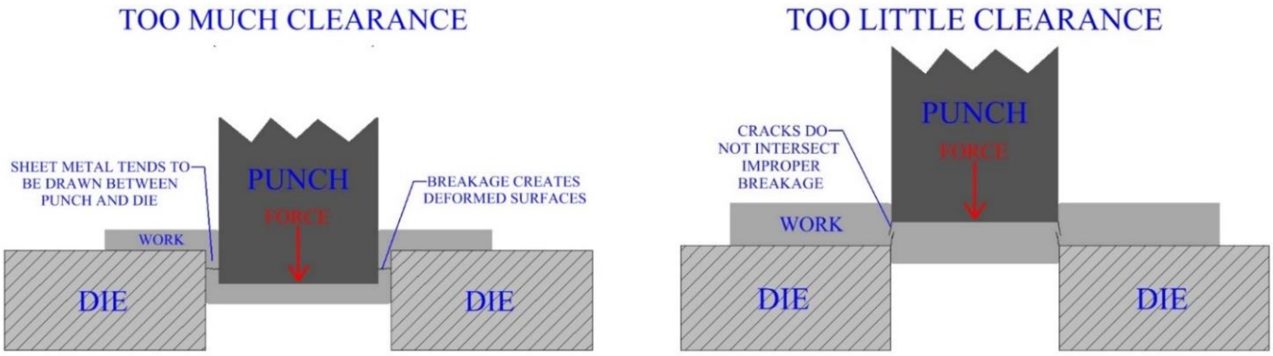


Figure 1. Too much clearance and too little clearance[3]

The actual cutting occurs when the punch penetrates the sheet and creates the shear zone (burnish area). This zone usually occupies between 30 and 60% of the total sheet thickness. Increasing clearance and thickness reduces shear zone percentage. When a certain depth of penetration of the punch is reached, the formation of the shear zone ends with the propagation of the crack[4]. As shown in Figure 2, shearing creates a continuous fracture zone as cracks collide, starting at the shear zone end and occupying most of the cut's thickness, except the burr. More clearance, more sheet thickness, and less ductility of the material increase the ratio of the fracture zone to the total thickness of the sheet. The shear zone is smooth and the fracture zone is angular.

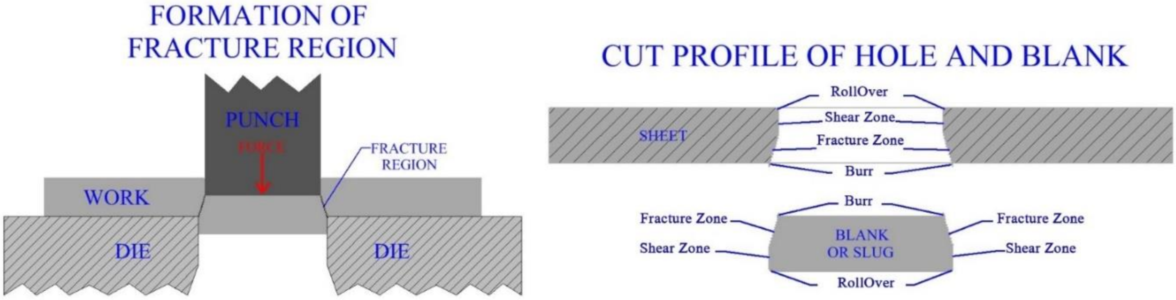


Figure 2. Forming the fracture zone and shearing the sheet[3]

According to Figure 3, four distinct areas including rollover zone, shear zone, fracture zone, and burr are created in the cut section of the produced blanks.

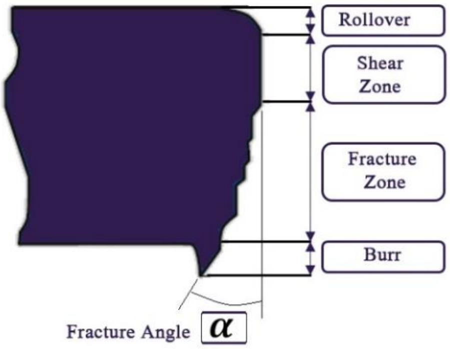


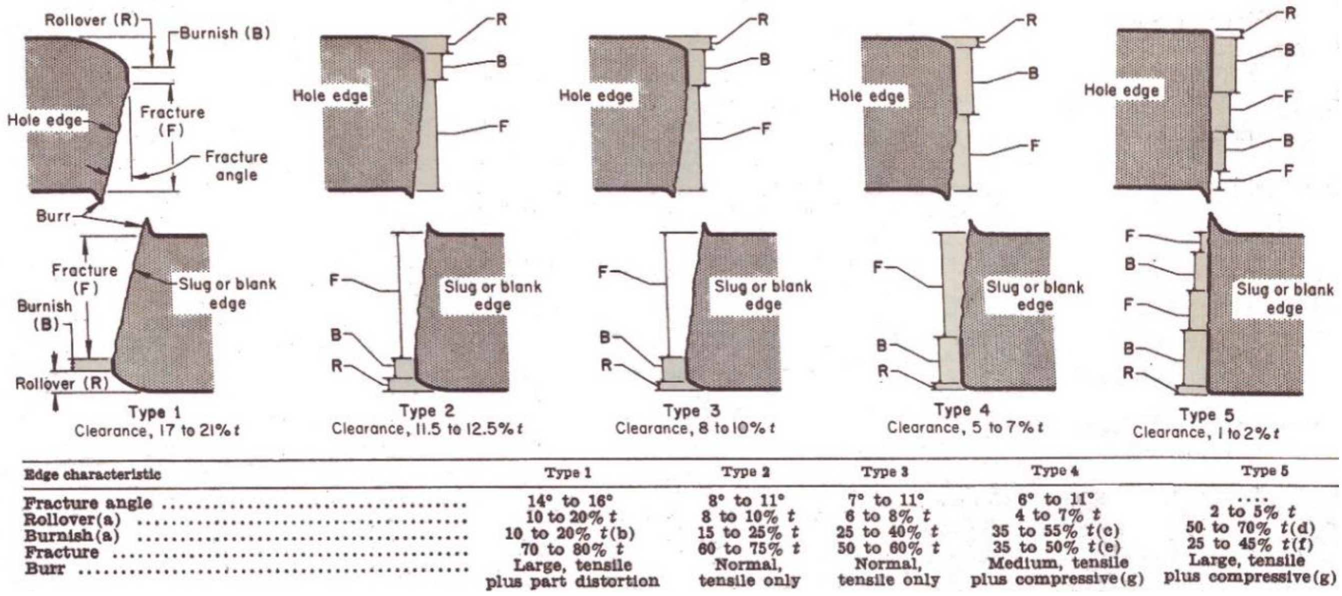
Figure 3. Schematic of the cut section of the blank[3]

Factors that influence the design of the blanking die include workpiece thickness, required force for press tonnage, punch and matrix hardness, clearance amount, and cross-section area. Fan et al. discovered that precise blanking yields better-shearing quality compared to traditional blanking. They investigated AISI-1045 and AISI-1025 steels with negative clearance and matched the computer model with experimental results to reveal damage[5]. Kut used mathematical modeling to guide material failure in the blanking process using finite elements. This research largely simulated the conditions of failure and tearing of a 3.5 mm thick S355R steel sheet[6]. Marouani et al. conducted a numerical analysis of the high-speed blanking process of FeSi ferromagnetic steel with a thickness of 0.65 mm. The study discovered that strain rate, clearance rate, and edge shape impact the punch speed, force, and fracture penetration. Findings indicate that greater clearance leads to decreased punch forces at all speeds[7]. Mackensen et al. studied AHHS steel blanking and discovered punch head angle affects force, with optimal clearance conditions. Fluctuations raise shear force[8]. Falconnet et al. studied punch wear in copper sheet blanking. The punch wear can be predicted and optimized by combining experiment and simulation data[9]. Subramanian et al. researched the optimal selection of punch and matrix clearance to improve the life of punch and matrix in the blanking process for asymmetric shapes. They found that by varying clearance and increasing punch edge radius to 1.5-2 times sheet thickness, die wear is reduced[10]. Murakawa et al. researched the precise blanking of very hard steels. By controlling the clearance and shearing in two stages using modified dies, they were able to produce precise parts of steel with 55 RC[11]. Komori focused on simulating static failure using the node separation method in the blanking process. They found that this simulation can help achieve the best clearance without burrs[12]. Slavič et al. developed a laser-based technique for blanking process control. Increasing punch angle reduces cutting force while deeper penetration decreases it[13]. Demmel discovered that speed and clearance directly affect heat generation during blanking. As the blanking speed increased, the temperature rose to 300 degrees Celsius, a factor to consider in process development[14]. Hou et al. analyzed the hot blanking of HS1500B steel and found that the optimum temperature for dimensional accuracy and die wear reduction is 750-800°C[15]. Maiti et al. analyzed thin low carbon steel sheet blanking using ANSYS software. Force of punch decreases with more clearance and increases with more friction. Sheet thickness has no direct impact, but bigger holder sheet diameter and thickness increase force of punch[16]. Fang et al. simulated the blanking of aluminum 2024 using finite element analysis to optimize clearance. With increased clearance and constant 1 mm thickness, blanking forces decrease. The optimal clearance is 0. 5 mm is accurate[17]. Husson et al. utilized ABAQUS/Explicit software to analyze the impact of factors such as penetration, clearance, tool wear, and friction on the shearing edge in blanking. Tool wear affects die and punch edges. Sharp edges and low clearance increase quality, while slowed edges and high clearance decrease it. Friction doesn't affect the shearing edge, but its efficiency varies. Study used 0.58mm thickness copper sheets[18]. Ghadiri et al. measured crack angle, compression length, and indentation depth in blanking process. Crack growth angle rises with decreased punch speed and clearance. Material's higher shear strength increases angle while less clearance means lower depth. Study on copper sheets' symmetrical blanking process[19]. Farshidian Far et al. created an algorithm for predicting optimal clearance in blanking by reducing burr height. Reducing roughness improves smoothness, but low roughness tears the shear section. More plasticity increases burr height. Study on copper alloy sheet blanking process[20]. Mr. Tambe and his colleague developed a mathematical model and clearance optimization in the sheet metal blanking process for cooper sheets with thicknesses of 0.5, 0.8, and 1.5 mm and clearances of 5, 10, and 15% using Taguchi's experimental design. This study helped to investigate the effect of sheet thickness, clearance, and type of material on the blanking process and to predict an optimal set of parameters to obtain reasonable quality. This investigation showed that to minimize the burrs' height, the clearance should be set at about 5 % with almost no blank holder force[21]. In another research, Mr. Çavuşoğlu discussed the effect of punch edge radius and blanking clearance on product quality and blanking process in blanking of AISI 304 stainless steel sheet using the finite element analysis method. In this study, the blanking analyzes were performed at four different punch tip radiuses (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[22]. Blanking is the first step of the widely used deep drawing process to produce different products. Deep drawing is a type of metalworking process used to form blanks and turn them into cup-shaped products. The desired shape is obtained by pressing the blank into the die utilizing a punch. The final dimensions of the produced part from deep drawing process are a function of the original blank. The flow of material during the deep drawing process must be known to optimize the shape of the blank. Excess material in the work can interfere with metal flow and increase forces acting within the blank while drawing [23-25].

In this research, to produce blanks with a special profile in the cross-section according to the target drawing, a single-stroke blanking die was designed and made from a sheet with a thickness of 12 mm of StW24 steel. The blanking process was done by making three punches, following the design considerations, and taking into account the three values of 9, 15, and 21% of the thickness of the sheet. Then, with the WEDM process, the blanks obtained from the blanking process were cut and after checking the fracture zone, shear zone, burr, and rollover zone with the profile of the target drawing, the optimal clearance value was selected. To check the fracture zone and its compliance with the target drawing, a video dimensional measurement device with 0.5μm display resolution was used.

2. Experimental procedure

In all past research, sheets with a thickness of less than 6 mm have been cut with the blanking process, and to cut blanks with greater thicknesses, more expensive and time-consuming processes are used, including cutting with water, laser and electric discharge, which of course are not suitable for mass production. On the other hand, the production of blanks with high thickness is always one of the challenges of sheet metal blanking. To cut sheets with a thickness higher than 6 mm, it is necessary to apply a high cutting force and as a result, use high-tonnage press machines, and for this reason, the cost of production increases. The factor influencing the cutting force is the amount of clearance. Clearances may range from 1% to 30% of the sheet thickness. The physical properties of the material and its thickness are factors that determine the amount of clearance. In the blanking process, always reduce the clearance from the punch and the size of the punch will be smaller than the size of the matrix. In practice, there is no single table or specific formula that can determine the optimal clearance. But there is a specific guide for choosing the right clearance based on the type of cutting edge needed, with different clearances, which is given in Figure 4 for low-carbon steels[4].



Edge characteristic	Type 1	Type 2	Type 3	Type 4	Type 5
Fracture angle	14° to 16°	8° to 11°	7° to 11°	6° to 11°	....
Rollover(a)	10 to 20% t	8 to 10% t	6 to 8% t	4 to 7% t	2 to 5% t
Burnish(a)	10 to 20% t(b)	15 to 25% t	25 to 40% t	35 to 55% t(c)	50 to 70% t(d)
Fracture	70 to 80% t	60 to 75% t	50 to 60% t	35 to 50% t(e)	25 to 45% t(f)
Burr	Large, tensile plus part distortion	Normal, tensile only	Normal, tensile only	Medium, tensile plus compressive(g)	Large, tensile plus compressive(g)

Figure 4. The effect of mandrel-to-matrix clearance on each side (as a percentage of sheet thickness) on the characteristics of the edges of holes and blanks in low-carbon steel sheets for the production of five types of edges[4]

This study aims to make 57.5 mm diameter blanks from a 12 mm thick sheet of low carbon steel StW24 with a 38% penetration value. Penetration is the thickness of the rollover and shear zones combined. Type 1 conditions require 17-21% clearance, giving a bigger rollover zone and smaller shear zone, lowering cutting force. To create desired blanks, clearances at 9%, 15%, and 21% achieved a 38% penetration value. The clearance for low-carbon steel requires adjustment for other sheet metals. 12 mm thick low carbon steel StW24 (DIN 1.0335) was used. This cold-rolled steel has ideal mechanical properties for forming deep-drawn products like vibration dampers, pistons, pins, etc. See Table 1 for its chemical composition and physical properties.

Table 1. Chemical composition and physical properties of alloy steel StW24 (EU DD13) - DIN 1.0335

Chemical compounds (average weight percentage)				
Elements	Mn	P	S	C
Average percentage by weight	0.4%	0.03%	0.03%	0.08%

Physical properties		
Yield tensile strength (MPa)	Elastic modulus (GPa)	Ultimate tensile strength (MPa)
200	215	400

The target drawing of the desired piece is shown in Figure 5. The piece has geometric and dimensional tolerances and is made of low carbon steel StW24 with a thickness of 12 mm. Part of the piece is a cone with an angle of 8.88 degrees, which should be created by controlling the amount of clearance in the piece.

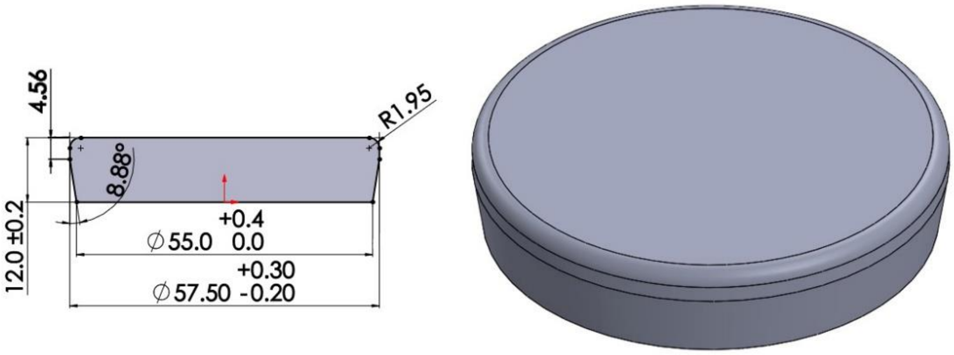


Figure 5. Blank drawing to be produced (Target drawing)

To achieve the intended penetration value of 38%, clearance levels of 9%, 15%, and 21% are selected for a low-carbon steel sheet with a 12 mm thickness. The maximum force of the mandrel, F, is calculated without considering the friction to create a cut according to formula (1), where in this formula C_1, the average constant factor for all materials is 0.70 and UTS is the ultimate tensile strength of the metal sheet, t is the thickness of the sheet and L is the length of the cut edge which is equal to[2]:

$$F = C_1.(UTS).t.L = 0.7 \times 400 \times 10^6 \times \pi \times 57.5 \times 12 \times 10^{-6} = 606938 = 607KN \tag{1}$$

Also, the pressure force F_p is calculated in terms of tons according to formula (2)[2]:

$$F_p = \frac{1.3 \times F}{10000} = \frac{1.3 \times 606938}{10000} = 79\ ton \tag{2}$$

According to formula (3), the cutting stroke force P_b is equal to[2]:

$$P_b = 0.2 \times F = 0.2 \times 606938 = 12138 = 121KN \tag{3}$$

The side force F_H (N) is calculated according to formula (4) where F is the cutting force and C is the maximum clearance (equivalent to 2.52 mm), t is the thickness of the sheet and p is the penetration percentage[2]:

$$F_H = \frac{C \times F}{t - pt} = \frac{2.52 \times 606938}{12 - 0.38 \times 12} = 205575.7N = 206KN \tag{4}$$

In Figure 6, the drawing of the designed strip can be seen. Designing the width of the W sheet strip is based on the production volume, material flow, material thickness, and also the number of rows according to formula (5), based on which, the double-row strip is designed. Material flow for divergent shapes is 0.7 sheet thickness equivalent to 8.4 mm on each side and the distance between two holes is equal to sheet thickness or 12 mm.

$$W = 2 \times 57.5 + 2 \times 0.7 \times 12 + 1 \times 12 = 143.8mm \tag{5}$$

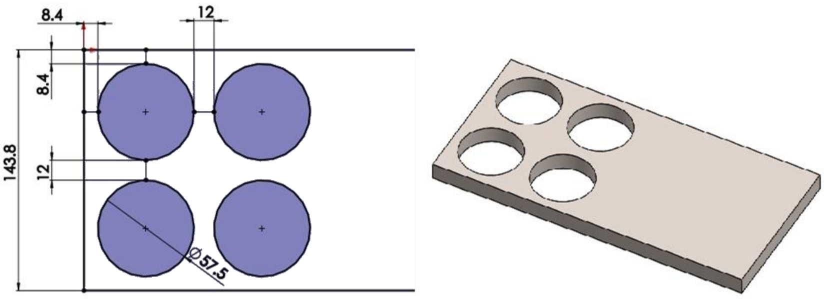


Figure 6. Designed strip

The diameter of the hole of the matrix $D_d$is obtained according to the formula (6) according to the blanking process and the elastic return of the sheet, which $\emptyset$ is the diameter of the blanking in the target drawing[2]:

$$D_d = \emptyset - 2 \times 0.025 = 57.5 - 0.05 = 57.45\ mm \tag{6}$$

Mechanical presses, mainly crank presses, cut sheets and create slope angles in matrixes for sheet expansion. As shown in Figure 7, ignoring this angle results in more burr when pushing the blank through the matrix opening. Thicker parts require a greater angle compared to thinner ones. 2° is the angle for normal thicknesses.

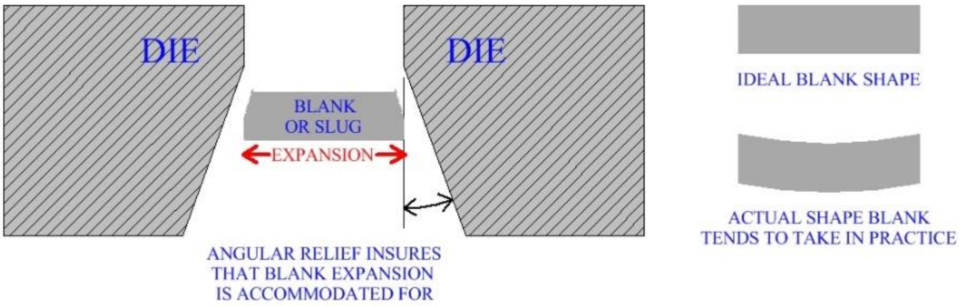
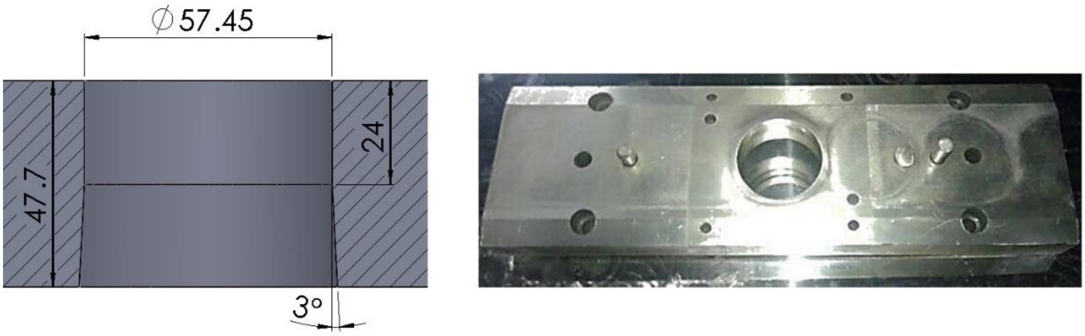


Figure 7. Applying an angle in the matrix to take into account the expansion of the blanks to exit the matrix[3]

The matrix is made of cold-worked steel 1.2379 and is 47.7 mm thick. The hole has a 57.45 mm diameter and is located 53.6 mm from each side. According to Figure 8, the non-angled part of the hole is 24 mm high, twice the thickness of the sheet. The hole has a 3-degree incline and reduces cutting force by 25% for sheets thicker than 6 mm. The matrix undergoes heat treatment after wire electric discharge cutting to create and drill holes. Its surface is hardened to 59 RC and ground down to a thickness of 47.7 mm.



(a) (b)

Figure 8. (a) Matrix cavity drawing (b) Constructed matrix

In the blanking process, clearance is assigned to the punch and is less than the nominal size of the workpiece. Therefore, to test the three clearance values as 9, 15 and 21% of the thickness of the sheet, punch diameters are calculated based on the formulas (7), (8), and (9) in which D_p is the diameter of the punch and $\emptyset$ is the diameter of the blank according to the target drawing[26]. Based on Figure 9, the punch shoulder and holder size are determined using standard tables after selecting punch dimensions from Table 2. The Punch was made of 1.2379 steel and after machining, the punch was heat-treated and hardened to 60 RC. Similarly, the punch holder was made of alloy steel 1.7225 (Mo40) and made via hot forging and machined, then hardened to 40 RC.

$$D_{p_1} = \emptyset - 0.09 \times 12 = 56.42mm \tag{7}$$
$$D_{p_2} = \emptyset - 0.15 \times 12 = 55.65mm \tag{8}$$
$$D_{p_3} = \emptyset - 0.21 \times 12 = 54.9mm \tag{9}$$

Table 2: Clearance values and diameter of punches

Clearance values	Diameter of punch number 3 (mm) (clearance of 21 percent)	Diameter of punch number 2 (mm) (clearance of 15 percent)	Diameter of punch number 1 (mm) (clearance of 9 percent)
9, 15, 21	54.9	55.65	56.42

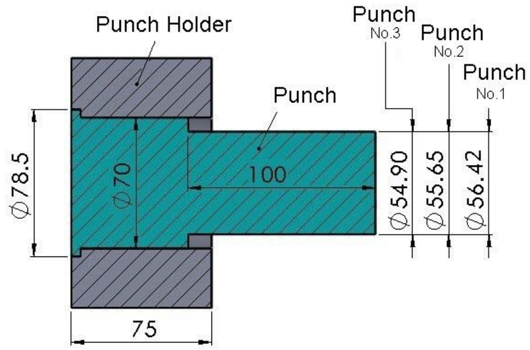


Figure 9. Section of punch holder with three punches with different diameters

Based on the return stroke force and taking into account the allowable tensile stress of the screws, the number and diameter of the screws are obtained, and also by calculating the side force and shear stress of the pins, the number of pins is calculated. The inner width of the feeding channel should be approximately 4 mm more than the width of the strip designed for a sheet with a thickness of 12 mm, so the inner width of the feeding channel was 147.8 mm to save the production of fewer punches. Also, the thickness of the separating plate is found using formula (10) with sheet width (w) and thickness (t)[26].

$$t_s = 2.t + \frac{w}{30} = 28.8\,mm \tag{10}$$

Figure 10 shows that the feeding channel bridges have larger dimensions to connect to the lower shoe and reduce stress concentration in the matrix. The separator plate and bridges are made of 1.7225 steel were machined and heat treated to 45 RC.

Figure 10. The feeding channel is mounted on the matrix and the lower shoe

The thickness of the shoes is obtained from the formula (11) as follows[2]:

$$h_k = \sqrt[3]{\frac{10.F.L_K^3}{E.B_k}} \tag{11}$$

Based on this formula, the thickness of the shoes is 22 mm, and by applying the safety factor, the thickness of the lower shoe is 30 mm and the upper shoe is 25 mm. The shoes were made of 1.7225 steel and after the machining process, they were heat treated and hardened up to 45 RC. The shank is also selected from the standard length of 110 mm with a cylindrical holder of 65 mm, which is installed in line with the axis of the punch and is connected to the upper shoe. The diameter of the guide shaft from formula (12) is equal to 50 mm and its length is 310 mm[2]. The gap between the guide bush and the guide shaft is 0.05 mm and the guide shafts are press-fit in their lower bush.

$$d_r = \sqrt[4]{\frac{64.F_H.L_r^3}{0.0075.E.\pi.N_r}} \tag{12}$$

The guide pines are made of 1.6582 steel (or VCN150 brand) and the guide bush is made of 1.7225 steel[26]. After machining, they were heat treated and hardened to 60 RC and 45 RC, respectively. After all the components were made, the die was assembled with the desired screws and pins, and the initial assembly tests were performed by a 100-ton press machine according to Figure 11. As shown in Figure 12, in this research, by determining three clearance values, three punches were designed and manufactured, and the blanking process was carried out on the StW24 sheet with a thickness of 12 mm.

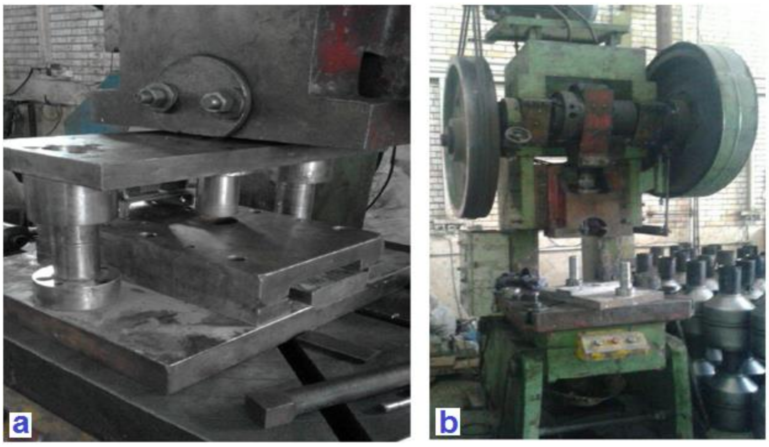


Figure 11. (a) Die on the press table (b) 100-ton impact press

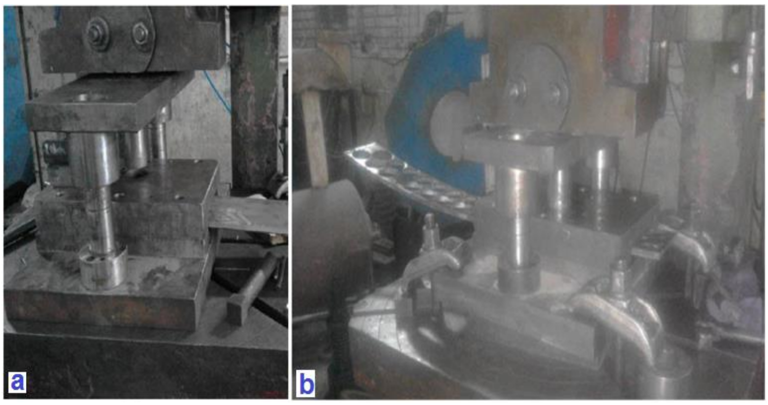


Figure 12. (a) The die is being tested with Three Punches(9, 15, and 21% clearance) (b) The die is undergoing initial testing and passing the sheet

In the next step, blanks according to Figure 13 were cut in half using the WEDM machine. Then, the cross sections according to Figure 14 were photographed by a video dimensional measurement device made by Easson China, model C 2515 which is a precise and effective non-contact optical measuring instrument with 0.5μm display resolution and located in the Mechanics Laboratory, Faculty of Mechanics, and University of Kashan. The obtained images were transferred to AutoCAD, and the zones of rollover, Shear, Fracture, burr, and fracture angle were compared to the target drawing and optimal clearance was selected. Three samples of blanks at 9, 15, and 21% clearance were examined per test step.

Figure 13. Cutting the blank produced by the wire electric discharge process and the cut cross-section of the blank

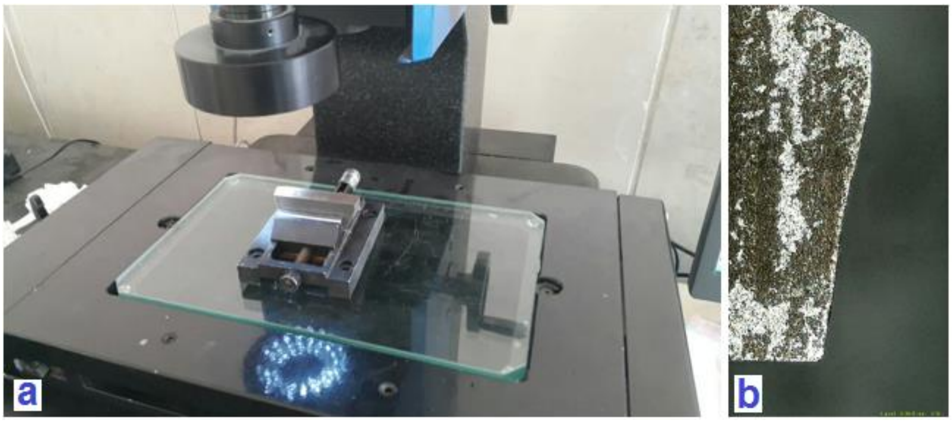


Figure 14. (a) The cut section of the blank produced in the VMM machine (Easson China, model C 2515) (b) The image of the cut section

3. Results and discussion

The target drawing was analyzed for fracture zones, shear zone, rollover zone, fracture angle, diagonal dimensions, and burrs by referring to Figure 15 and Table 3.

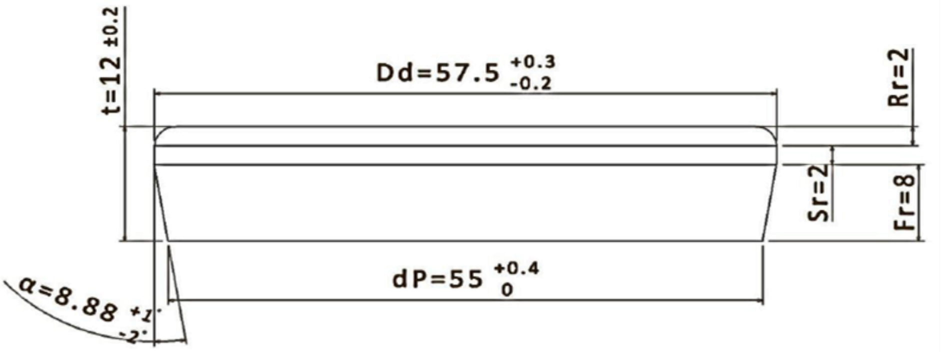


Figure 15. Target Drawing

Table 3. The parameters of the target drawing and the manufactured blank sample

Cross-sectional areas	A sample of blanks produced	Target Drawing
The thickness of the rollover zone	Rt(mm)	Rr(mm)
The thickness of the Shear zone	St(mm)	Sr(mm)
The thickness of the fracture zone	Ft(mm)	Fr(mm)
burr size	Bt(mm)	Br(mm)
Fracture angle	$\alpha t(°)$	$\alpha r(°)$
The diameter of the punch side	Ddt(mm)	Ddr(mm)
The diameter of the matrix side	DPt(mm)	DPr(mm)
Clearance percentage		C%
The thickness difference of the rollover zone of the sample with the target drawing		$\Delta R(mm)$
The difference in the thickness of the shear zone of the sample with the target drawing		$\Delta s(mm)$
The difference in the thickness of the fracture zone of the sample with the target drawing		$\Delta F(mm)$
The difference in the sample burr size with the target drawing		$\Delta B(mm)$
The difference in the size of the fracture angle of the sample with the target drawing		$\Delta \alpha(mm)$

Investigating the variables ΔR, ΔS, ΔF, ΔB, Δα, ΔDd, and ΔDp, which are the difference between the sample size and the target drawing based on the desired tolerances, can make choosing the desired clearance easier. Data was collected from blank samples at 9%, 15%, and 21% clearance values in Table 4 along with target drawing data in Table 5. Differences between the sample sizes and target drawing are listed in Table 6.

Table 4. Extracted data from the manufactured blank sample

Clearance values		Rt(mm)	St(mm)	Ft(mm)	Bt(mm)	Ddt(mm)	DPt(mm)	$\alpha t(°)$
C%	9	1.63	2.80	7.57	0.23	57.49	55.09	5.40
	15	1.91	2.10	7.99	0.45	57.36	55.28	7.80
	21	2.36	1.35	8.73	0.60	57.91	55.57	11.80

Table 5. Extracted data from the target drawing

Clearance values (C %)	Rr(mm)	Sr(mm)	Fr(mm)	Br(mm)	Ddr(mm)	DPr(mm)	$\alpha r(°)$
9, 15, 21	2.00	2.00	8.00	0.50	57.50	55.00	8.88

Table 6. The results of the size difference of the blank sample variables manufactured with the target drawing

Clearance values		ΔR	ΔS	ΔF	ΔB	ΔDd	ΔDp	Δα
C%	9	0.37	0.80	0.43	0.27	0.01	0.09	3.48
	15	0.09	0.10	0.01	0.05	0.14	0.28	1.08
	21	0.36	0.65	0.73	0.10	0.41	0.57	2.92

3.1 Analysis of the Rollover Zone

According to Figure 16, with the increase of slack from 9 to 15, the thickness of the c has increased by 11%, and with the increase of clearance from 15 to 21, the thickness of the rollover zone has increased by 24%. By comparing the thickness changes diagram of the produced blank rollover zone with the target drawing and also checking their difference graph, it can be seen that the data obtained from 15% clearance has the best match with the two graphs of the target drawing and the difference graph. It is also evident that the radius of the rollover zone has become larger with the increase in clearance.

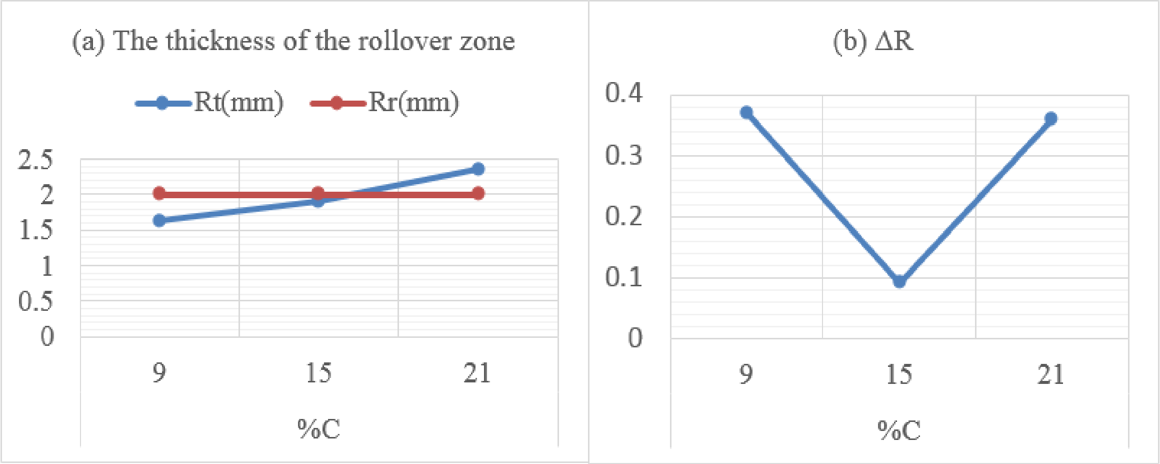


Figure 16. (a) Rollover zone thickness comparison chart (b) The thickness difference diagram of the rollover zone of the manufactured blank sample and the target drawing

3.2 Analysis of the shear zone

As shown in Figure 17, increasing clearance reduces shear zone thickness and thins burnish area. Raising clearance from 9 to 15 decreased shear zone thickness by 33% and from 15 to 21 by 56%. At 9% clearance, multiple cracks indicate secondary cutting and increased friction. A comparison of the shear zone chart with the target drawing shows that data from 15% clearance matches the target and difference graphs best.

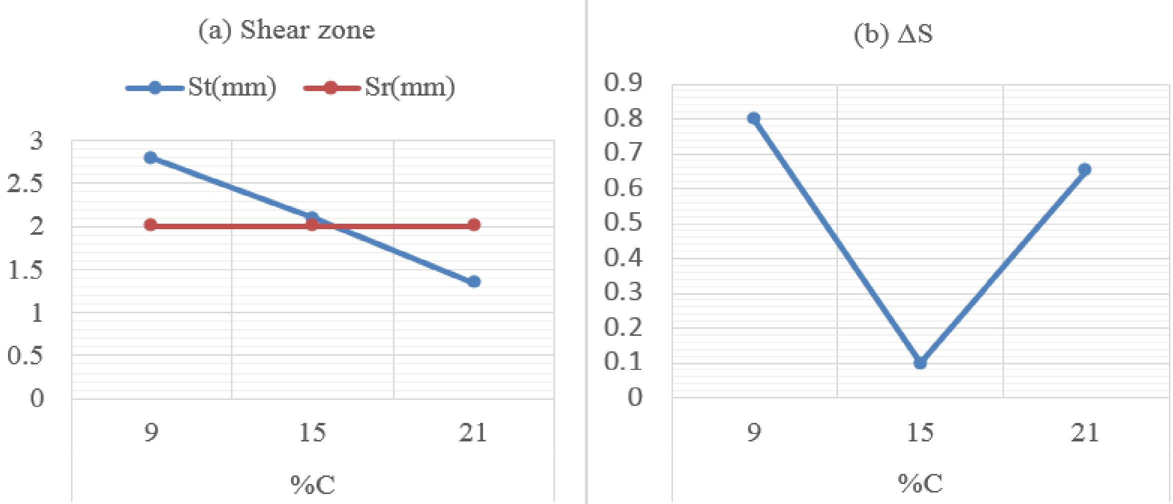


Figure 17. (a) Comparison diagram of shear zone (b) Difference diagram of the shear zone of manufactured blank sample and target drawing

3.3 Analysis of the fracture zone

With greater clearance, the fracture zone thickens, as shown in Figure 18. Increasing clearance led to thicker fracture zones, with a 5% increase when clearance went from 9 to 15, and 3% when it went from 15 to 21. Additionally, larger and deeper cracks formed and their quantity decreased. It can also be seen that the data obtained from a 15% clearance has the best match with the two graphs of the target drawing and the difference graph.

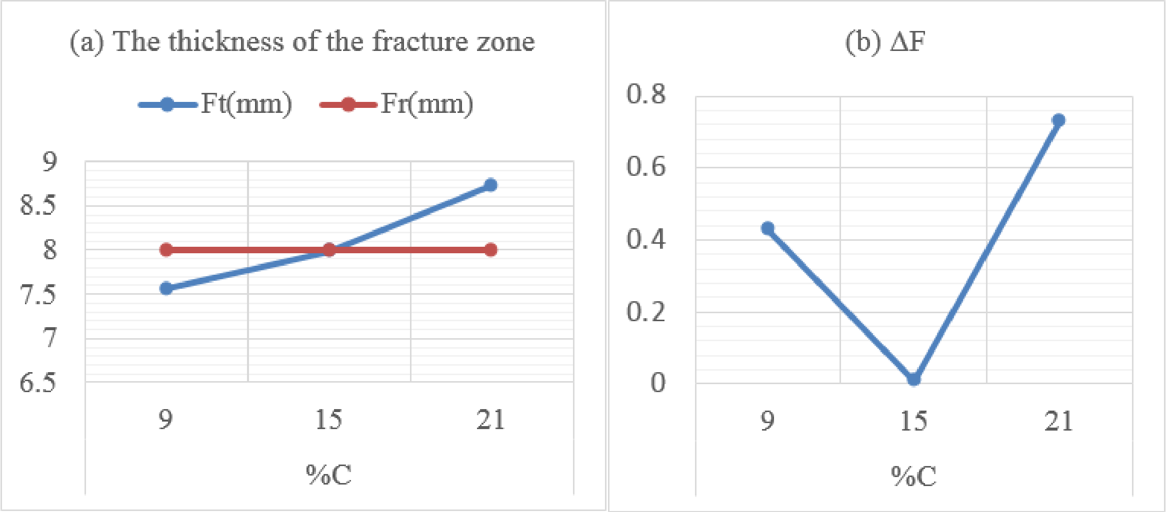


Figure 18. (a) Comparison diagram of the fracture zone (b) Diagram of the difference between the fracture zone of the manufactured blank sample and the target drawing

3.4 Analysis of the burr

Figure 19 shows bigger and more durable burrs with increased clearance. Burr size increased by 96% from 9 to 15 and by 34% from 15 to 21. 15% clearance produces the closest match between the burr size chart and the target drawing.

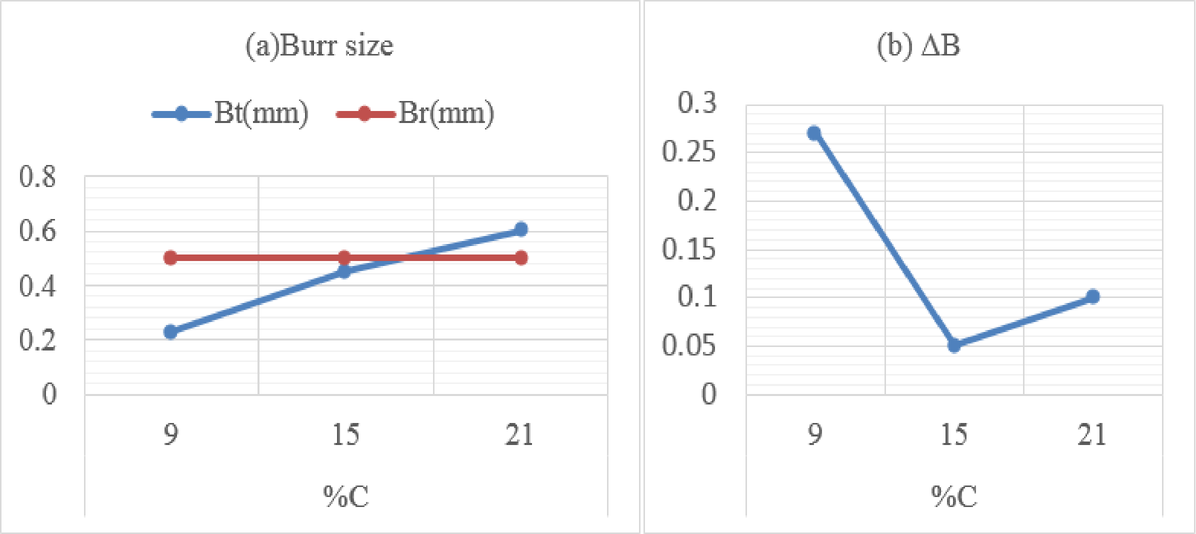


Figure 19. (a) Burr size comparison diagram (b) Difference diagram of the fracture zone of the manufactured blank sample and the target drawing

3.5 Fracture Angle Analysis

Figure 20 shows that as clearance increases, fracture angle rises. Increasing clearance from 9 to 15 increased fracture angle by 45%, and from 15 to 21 by 51%. By comparing the chart of changes in the fracture angle of the produced blanks sample with the target drawing and also examining their different graph, it can be seen that the data obtained from 15% clearance has the best match with the two graphs of the target drawing and the difference graph.

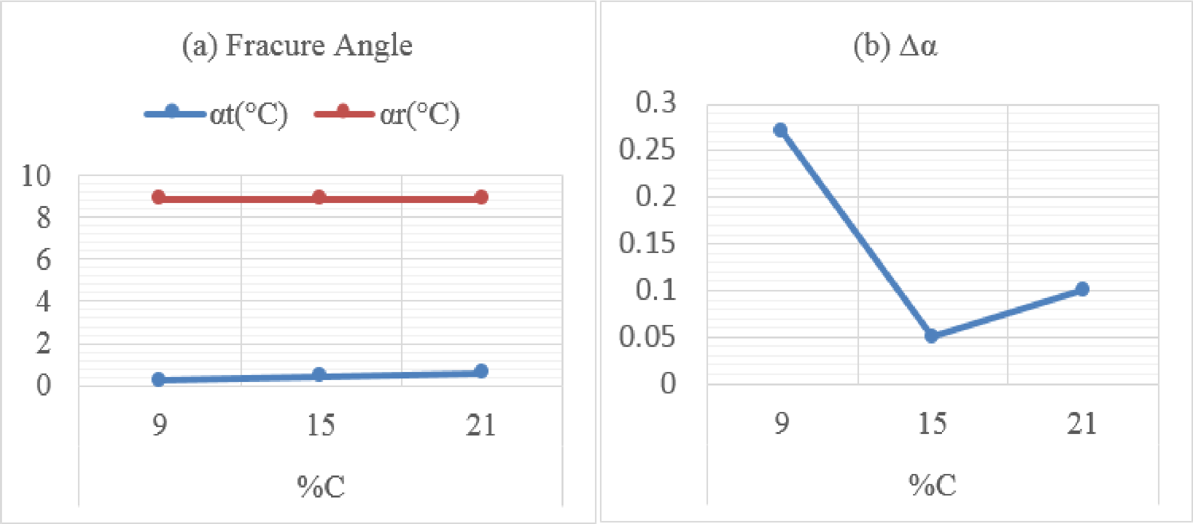


Figure 20:(a) Fracture angle comparison diagram (b) Fracture angle difference diagram of the manufactured blank sample and the target drawing.

4. Conclusion

In this study, a single-stroke blanking die was designed and built to perform the blanking process of a StW24 steel sheet with a thickness of 12 mm, then the blanking process was carried out. The process was completed and measured for rollover zone thickness, shear zone thickness, fracture zone thickness, fracture angle, burr size, and punch/matrix dimensions. Results were obtained in comparison to the target drawing:

- Increasing clearance leads to a thicker rollover zone, with an 11% increase from 9 to 15 and a 24% increase from 15 to 21.
- Clearance increase leads to a thinner shear zone. The thickness of the zone decreased by 33% when clearance increased from 9 to 15, and by 56% when clearance increased from 15 to 21.
- As clearance increases, the fracture zone thickness increases up to 5% for clearance of 9 to 15 and 3% for 15 to 21.
- Increasing clearance leads to larger and more durable burrs. Burr size increases by 96% when clearance is increased from 9 to 15, and by 34% when increased from 15 to 21.
- Increasing clearance leads to higher refraction angles. At clearances of 9 and 15, the fracture angle increases by 45% and 51%, respectively.

Too little or too much clearance leads to defects, and finding an optimal clearance is always one of the challenges of achieving the right quality in the blanking process. Experimental observations indicate that with the increase of clearance, the ejection force of the part and its cutting decreases and the shear zone has become narrower. With the reduction of burnish area, the number of burnish areas is increased, and successive cracks are observed on the surface of the piece. With the increase in clearance, the radius of the edge of the rollover zone has increased. The results of the investigations indicate that the clearance of 15% of the sheet thickness is the most suitable clearance for the production of this blank following the target drawing.

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