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## A STUDY OF THE DIE ROLL HEIGHT OF SHP-1 AND SCP-1 MATERIALS IN THE FINE BLANKING PROCESS

### BADANIE WYSOKOŚCI DEFORMACJI KRAWĘDZI WYCINANYCH ELEMENTÓW ZE STALI SHP-1 I SCP-1 PROCESIE WYKRAWANIA

The height of the die roll, the distance of the V-ring, and the shear rate were varied with the aim of investigating the effects of the applied changes on the fine blanking line in a cold-rolled and a pickled steel sheet, referred to as SCP-1 and SHP-1, respectively. Both materials consisted primarily of a ferrite phase with small amounts of impurities including F, Mn, and Cr. The distance was found to be a very important factor in controlling the shear of the V-ring in the fine blanking process. When the position of the V-ring was set at distances of 1.5 mm and 2 mm, the die roll height increased with increasing shear speeds from 6.4 m/min to 10 and 16 m/min. Analysis of the influence of the shear rate revealed that low rates resulted in the lowest die roll heights since the flow of material was effectively inhibited.

*Keywords:* Die roll, Fine blanking, SCP-1, Shear speed, SHP-1, V-ring

## 1. Introduction

Die processing is a precision processing method used for the mass production of objects, which have the same shape. Fine blanking is a very precise processing method that employs high shear stresses on the processed surface and enables the simultaneous implementation of several processes without requiring further machining. The cross section of a product fabricated using a general shearing process consists of shear droop, shearing surface, fracture surface, and burr. However, the cross-sectional area of the fine blanking process is such that shear surface processing method, An appropriate technique is, therefore, required since the height of the die roll and the shear surface do not coincide. Fig. 1 shows the shape of the die roll.

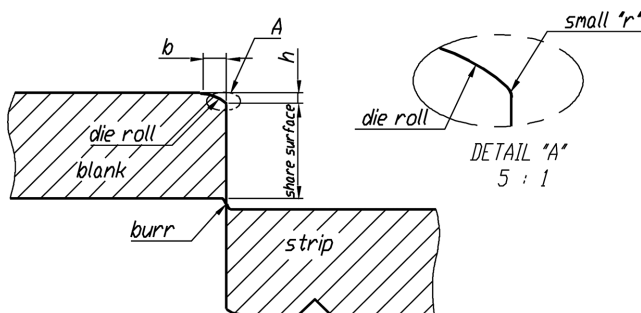


Fig. 1. Fine blanking of die-roll

The height of the die roll is affected by many factors, including the mold that imparts the final shape to the product,

the clearance between the die and the punch, the material properties, the degree of sharpness of the punch and the die, the distance of the V-ring, and the level of indentation of the V-ring. Above all, the distance of the V-ring and the shear rate are very important factors for obtaining the desired shear surface. In the present study, the height of the die roll, the distance of the V-ring, and the shear rate were varied with the aim of investigating the effects of the applied changes on the fine blanking line.

## 2. Fabrication of the fine blanking die

### 2.1. Material analysis and design of the fine blanking product

A cold-rolled and a pickled steel sheet, referred to as SCP-1 and SHP-1, respectively were used as the processing sheets for the experiments. A thickness of 3 mm was chosen in order to facilitate the shear processing, limiting the required hardness of the die and the nominal pressure of the press die. Specimens were obtained in the vertical direction of the sheet. Curable synthetic resins were employed for mounting the specimens. After manual polishing, the specimens were treated in an aqueous solution obtained by mixing 5 cm<sup>3</sup> of strong nitric acid and 100 cm<sup>3</sup> of alcohol as a corrosion treatment.

Photograph 1 shows a specimen and the corresponding metallographic photograph. The materials used in the aforementioned experiments are listed in Table 1. In order to perform the mechanical tests, specific specimens were provided for the plates used in the tension test (KS 5); the tension test

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was carried out as shown in photograph 2. Results of the tests are shown in Fig. 2 and Table 2.

The SCP-1 sheet consisted of a 95.305% ferrite matrix containing some levels of impurities, including F (3.743%), Cr (0.242%), Mn (0.496%), C (0.126%), P (0.043%), and S (0.045%). SHP-1 consisted of a 95.718% ferrite matrix containing different levels of impurities, such as F (3.463%), Mn (0.513%), C (0.168%), P (0.078%), and S (0.063%). SHP-1 is a relatively soft material that transforms quite easily. The maximum tensile load, maximum tensile strength, strain rate, and break rate of the SCP-1 material were found to be 21731.65 N, 289.75 N, 42.16%, and 71.832%, respectively. Similarly, these were 24966.14 N, 337.38 N, 45.03%, and 28.70% in the case of SHP-1.

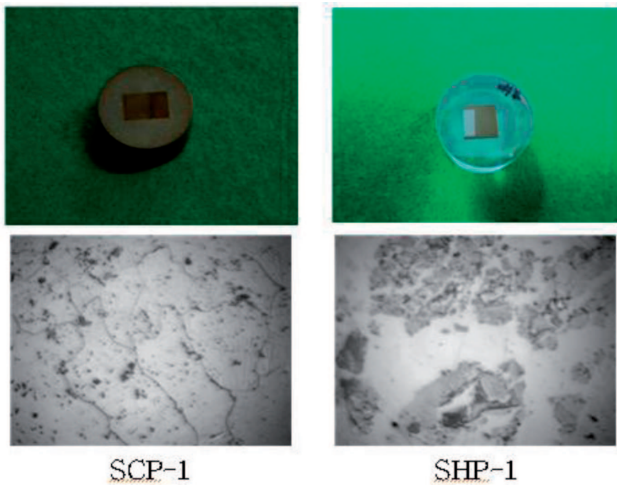


Photo. 1 Example of specimens and organization of the cold strip

TABLE 1

Component analysis for specimens

	Elt.	Line	Intensity (c/s)	/	Conc (%)	Units	
SCP-1 (SPCC)	C	Ka	3.48	0.748	0.126	wt.%	
	P	Ka	5.42	1.402	0.043	wt.%	
	S	Ka	0.22	0.148	0.045	wt.%	
	Cr	Ka	1.36	.0329	0.242	wt.%	
	Mn	Ka	0.87	0.264	0.496	wt.%	
	F	Ka	32.28	1.607	3.743	wt.%	(Containing impurities)
	Fe	Ka	196.30	3.963	95.305	wt.%	
				100	wt.%	Total	
SHP-1 (SPHC)	C	Ka	3.62	0.695	0.168	wt.%	
	P	Ka	6.71	0.946	0.078	wt.%	
	S	Ka	0.29	0.195	0.063	wt.%	
	Mn	Ka	0.68	0.302	0.513	wt.%	
	F	Ka	16.85	1.499	3.460	wt.%	(Containing impurities)
	Fe	Ka	440.42	7.663	95.718	wt.%	
					100	wt.%	Total

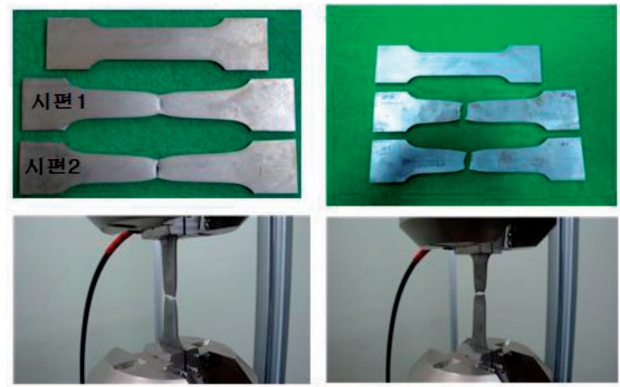


Photo. 2 Specimens after the tensile tests

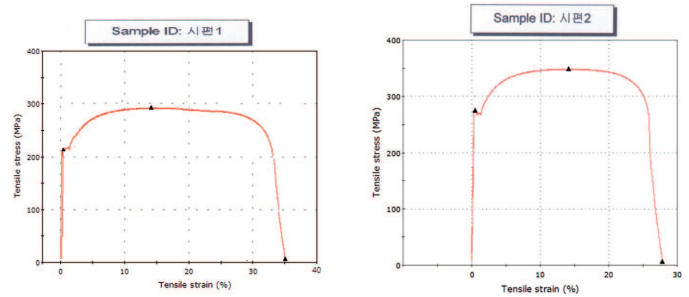


Fig. 2. Results of the tensile tests

TABLE 2

Mechanical test results

	Yield stress	Maximum tensile strength (N/ mm <sup>2</sup> )	Elongation at break (%)	Hardness (Hv)
SCP-1	221.3	294.6	33.26	105.6
SHP-1	275.5	349.2	27.82	114.5

A suitable plate for fine blanking is usually characterized by an evenly distributed spheroidal structure. In the case of SCP-1, the soft material is suitable for fine blanking. In the case of SHP-1, the soft material is expected to account for some of the broken regions in the shear surface. In light of the difficulties associated with forming, four mold sets were used with angles of 30°, 45°, 60°, and 90°. Each set had corner rounds of the type R0.3, R0.5, and R1.0, designed as shown in Fig. 3 and Table 3.

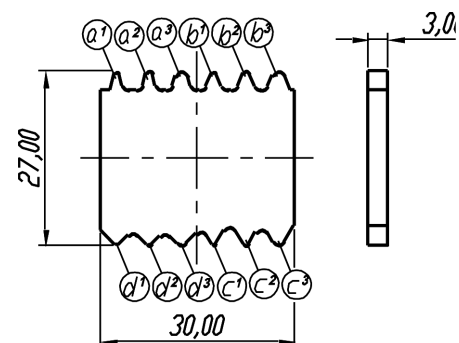


Fig. 3. Part of the fine blanking

TABLE 3 Product shape nine minutes

	Product Shape	Corner R		Product Shape	Corner R
a <sup>1</sup>	30°	0.3	c <sup>1</sup>	60°	0.3
a <sup>2</sup>		0.5	c <sup>2</sup>		0.5
a <sup>3</sup>		1.0	c <sup>3</sup>		1.0
b <sup>1</sup>	45°	0.3	d <sup>1</sup>	90°	0.3
b <sup>2</sup>		0.5	d <sup>2</sup>		0.5
b <sup>3</sup>		1.0	d <sup>3</sup>		1.0

2.2. Fabrication of the fine blanking die

The distance between the shear line of the product and the center of the V-ring was set to 2.0 mm, and the distance to the outside of the material was set to 3.0 mm, equal to the material thickness, in order to guarantee the stability of the shear. The gap of the product was set to 4 mm in order to enhance the shear property and guarantee availability of material. Furthermore, the V-ring line strip layout was designed with a pitch of 34 mm and a material width of 37 mm, as shown in Fig. 4.

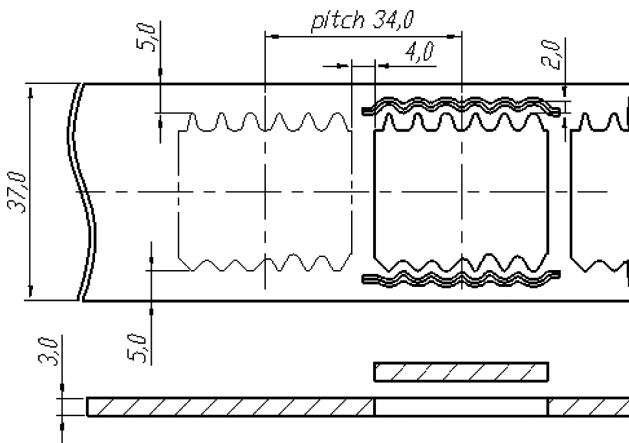


Fig. 4. Strip layout of the fine blanking die

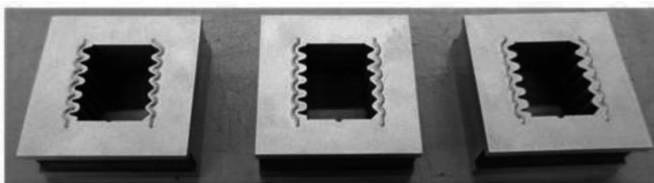


Photo. 3 V-indenter ring

In the Universal Press, the die plate is located above the die plate, in order to carry out the experiments. The counter punch is set in order to prevent deformation of the product during ejection. The blanking punch and V-ring are set on the lower plate of die; the pressure of the V-ring can be adjusted using the die cushion of the press machine. According to the design guidelines for 3 mm thick material sheets, the V-ring should be placed as shown in photograph 3 and Fig. 5, on one side of the guide plate, in order to limit abrasion. the edge of the V-ring was applied to the 0.2 mm round in three places.

Part of the die edge was applied to R0.2 mm inside the rapping process. The cross-section of the product was cleaned at the end of the process.

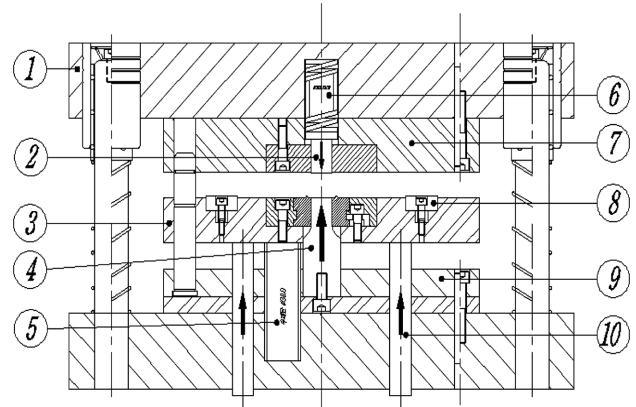


Fig. 5. Fine blanking die-set

3. Experimental and Shear Analysis

3.1. Experimental procedure and conditions

After the die plate was inserted above the die, the resulting clearance was equivalent to 1% of the material thickness. The first experiment was performed with the V-ring mounted at 2.0 mm from the edge of the punch and with a shear speed of 6.4 m/min. In these conditions, the V-ring force was 140 MPa. The material flow was kept constant and shear speeds of 10 m/min and 16 m/min were used subsequent experiments. The die parts are shown in Table 4 as 20-06, 20-10, and 20-16. The numbers (20-06, 20-10, and 20-16) symbol indicate the positions of the V-ring and the shear speeds, respectively.

TABLE 4

Die set for experiments classification

Test order	Test material	V-ring Positions	Blanking speed	Die parts
1	SCP-1	2.0 mm	6 m/min	20-06
			10 m/min	20-10
			16 m/min	20-16
2	SHP-1		6 m/min	20-06
			10 m/min	20-10
			16 m/min	20-16

3.2. Experimental and shear analysis

The shape of the product realized in the present study was analyzed using the DEFORM program by selecting a specific element, since the special gear model with several modules is difficult to analyze. As shown in Fig. 3, b<sup>2</sup> was set at 45°, and R0.5 mm, and the change in the height of the die roll was studied through shear analysis and experiments. The press force was 140 MPa for a clearance of 0.03 mm and a V-ring distance of 2.0 mm. The process parameters used for the analysis are presented in Table 5.

Parameters used in analysis

Parameters		Value	Unit
Average element size		0.01	mm
Element		20000	EA
Damage	SCP-1	1.0	
	SHP-1	1.5	
Tool movement		0.01	mm
V-Ring distance		2	mm
V-Ring angle		45	°
V-Ring radius		0.5	mm
V-Ring high		0.6	mm
Die corner radius		0.2	mm

In accordance with the rolling, the process was assumed to be isotropic and, therefore, anisotropy was not considered in the analysis. The V-ring was fully inserted in order to prevent the material from spreading sideways (X-axis constrain). In addition, the movement of the blanking punch and counter punch along the Y-axis was investigated by measuring the variation of the die roll with changing material thickness. The material thickness (originally 3 mm) was changed in incremental steps of 0.01 mm using a shear speed of 106 mm/sec.

TABLE 5

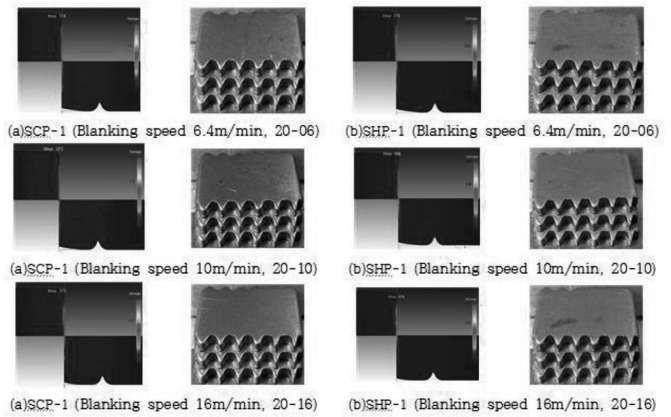


Fig. 6. Die roll shape for V-ring positions of 2.0 mm

## 4. Results and discussion

### 4.1. Results

A non-contact optical microscope (magnification in the range of 30X-210X) was used to characterize the three samples produced in the fine blanking experiment and to measure the height of the die roll. Table 6 shows the measurements of the height of the die roll obtained for each experiment and their average.

TABLE 6

Die roll height by the experiments

Test order	Die parts	V-ring Positions	material	Product Shape											
				a <sup>1</sup>	a <sup>2</sup>	a <sup>3</sup>	b <sup>1</sup>	b <sup>2</sup>	b <sup>3</sup>	c <sup>1</sup>	c <sup>2</sup>	c <sup>3</sup>	d <sup>1</sup>	d <sup>2</sup>	d <sup>3</sup>
1	15-06	1.5 mm	SCP-1	0.807	0.492	0.452	0.649	0.406	0.390	0.645	0.401	0.389	0.642	0.397	0.354
			SHP-1	0.743	0.526	0.445	0.664	0.512	0.414	0.648	0.450	0.402	0.636	0.421	0.394
2	15-10		SCP-1	0.748	0.452	0.436	0.624	0.423	0.385	0.618	0.418	0.366	0.591	0.394	0.352
SHP-1	0.732		0.451	0.436	0.656	0.495	0.427	0.623	0.422	0.395	0.606	0.417	0.359		
3	15-16		SCP-1	0.751	0.454	0.436	0.622	0.424	0.388	0.620	0.420	0.368	0.594	0.397	0.353
SHP-1	0.735		0.453	0.435	0.653	0.495	0.432	0.623	0.426	0.396	0.611	0.420	0.364		
4	20-06	SCP-1	0.743	0.428	0.412	0.611	0.395	0.377	0.607	0.391	0.354	0.584	0.386	0.339	
5	20-10	SHP-1	0.726	0.445	0.427	0.648	0.489	0.398	0.612	0.416	0.387	0.591	0.402	0.347	
		SCP-1	0.745	0.446	0.425	0.619	0.405	0.381	0.611	0.406	0.360	0.586	0.388	0.345	
6	20-16	SHP-1	0.729	0.448	0.433	0.650	0.491	0.407	0.615	0.422	0.390	0.598	0.408	0.350	
		SCP-1	0.746	0.446	0.428	0.624	0.410	0.382	0.616	0.413	0.361	0.589	0.388	0.347	
7	25-06	SHP-1	0.733	0.453	0.433	0.652	0.495	0.411	0.617	0.423	0.394	0.601	0.411	0.355	
		SCP-1	0.740	0.431	0.428	0.623	0.412	0.385	0.612	0.415	0.366	0.587	0.399	0.348	
8	25-10	SHP-1	0.730	0.448	0.431	0.651	0.493	0.411	0.617	0.413	0.392	0.602	0.406	0.359	
		SCP-1	0.747	0.448	0.431	0.635	0.427	0.392	0.624	0.418	0.384	0.607	0.401	0.352	
9	25-16	SHP-1	0.748	0.453	0.446	0.681	0.494	0.415	0.637	0.445	0.396	0.617	0.426	0.364	
		SCP-1	0.750	0.448	0.434	0.635	0.430	0.396	0.625	0.424	0.388	0.610	0.418	0.358	
			SHP-1	0.752	0.455	0.449	0.683	0.495	0.419	0.639	0.449	0.402	0.623	0.431	0.380



## 4.2. Analysis

### 4.2.1. Case 1: 6.4 m/min shear speed

As shown in Fig. 7, the press force of the V-ring was 140 MPa when the shear speed was 6.4 m/min. Changes in the position of the V-ring equivalent to distances of 1.5 mm, 2.0 mm, or 2.5 mm resulted in a similar change in the die roll height for both SCP-1 and SHP-1.

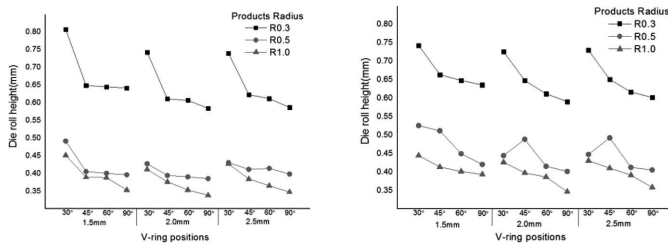


Fig. 7. Blanking speed of 6 m/min

Similarly, in accordance with the shape of the product in the component with the 30° angle, the die roll height for SCP-1 was larger than that of SHP-1. Owing to the low ductility, the SHP-1 specimen did not stretch, and a crack occurred in the material. On the other hand, the SCP-1 specimen allowed for an increase in the die roll height with the applied force.

### 4.2.2. Case 2: 10 m/min shear speed

The experimental conditions are the same as described in Case 1, except for the shear speed, which was 10 m/min. Fig. 8 shows the experimental results of Case 2 for both materials. In case of the SCP-1 specimen, changes in the die roll height resulted in only minor effects on the components that had angles of 45° and 60°.

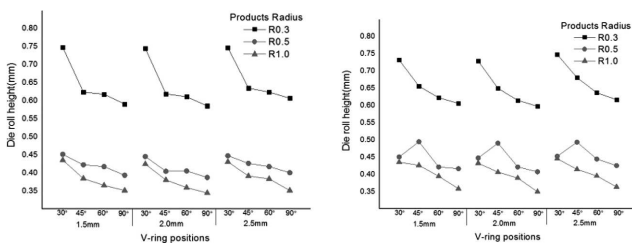


Fig. 8. Blanking speed of 10 m/min

In case of the SHP-1 specimen, the changes in the die roll height resulted in relatively small effects on the component with a 30° angle. This concurs with the results from Case 1, where the influence of the shear speed on the component having an angle of 30° was almost negligible.

### 4.2.3. Case 3: 16m/min shear speed

Experimental conditions were set the same as the first case except for the shear speed, which was increased to 16m/min. Fig. 9 compares the results of the two materials.

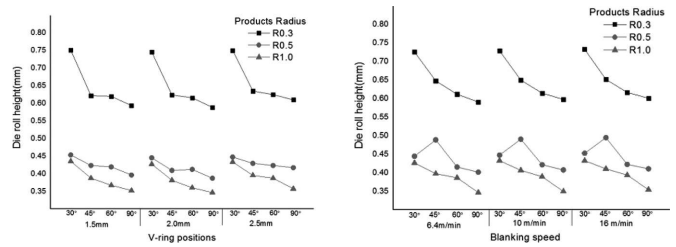


Fig. 9. Blanking speed of 16 m/min

In case of the SCP-1 specimen, the die roll height of the shape of the product all position except for the position 30° cause the low the die roll height change width accordance with The shape of the product is less occurred. on the other hand, in the SHP-1. the 30° of shape of the product was low occurred. Especially in the case of 0.5 mm Round the edges of the product. showed a lot of changes. about the shape Angle of the product.

### 4.2.4. Die roll height changes induced by shear speed

A single graph (Fig. 10) was created in order to compare the results obtained for the three different conditions in the aforementioned experiments. The lowest shear speed was selected in order to analyze the effect of the shear speed on the height of the die roll. It was found that for a V-ring position of 2 mm and a press force of 140 MPa, the shear speed must be increased from 6.4 m/min to 10 m/min and 16 m/min in order to change the height of the die roll of the two materials. Furthermore, the SCP-1 specimen generated a small die roll height when the shear speed was low (6 m/min).

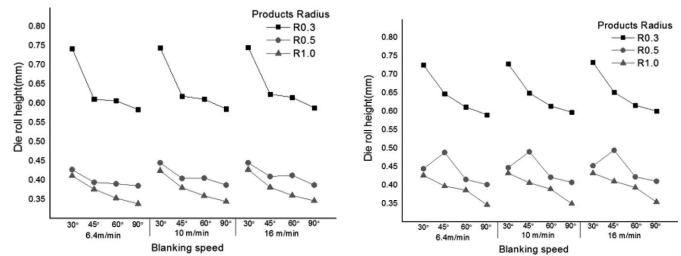


Fig. 10. Change in blanking speed

## 5. Conclusions

A fine blanking die used in the aforementioned experiments. The V-ring distance was set at 1.5 mm, 2.0 mm, or 2.5 mm. Three speeds, 6.4 m/min, 10 m/min, and 16 m/min, were used in order to study the effect of shear speed on the die roll height. The findings revealed that

1. The distance is a very important factor in controlling the shear of the V-ring in the fine blanking process. In the present study, when a distance of 2 mm was used, the material flow effectively inhibited the generation of a low height of the die roll.
2. When the position of the V-ring is set at 1.5 mm, the die roll height increases as the shear speed is increased from 6.4 m/min, to 10 m/min, to 16 m/min.

3. When the position of the V-ring is set at 2 mm, the die roll height increases as the shear speed is increased from 6.4 m/min, to 10 m/min, and to 16 m/min.
4. When the position of the V-ring is set at 2.5 mm, According to change the Shear speed 6.4m/min, 10m/min, 16m/min. as a result of the experiment. when the position of V-ring is 2.0 mm, the die roll height is increased.
5. Analysis of the influence of the shear rate showed that low speed result in the lowest die roll heights the flow of material is effectively inhibited.

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