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Die Radius Affecting Sheet Metal Extrusion Quality for Fine Blanking Process

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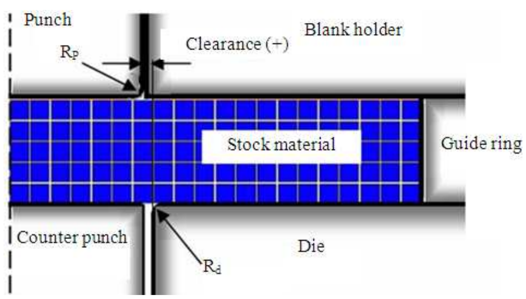
Abstract: Problem statement: Sheet metal extrusion is a process in which the punch penetrates one surface of the sheet metal material to cause it to extrude and flow toward the outlet of the die. Therefore, the process can invent different thickness of sheet metal work piece. From these advantages on the sheet metal extrusion, nowadays, it is generally used in many manufacturing of industrial elements fields. The Sheet Metal Extrusions in Fine Blanking (SME-FB) advantages, over a conventional extrusion, are possible due to a blank holder force, a counterpunch force and a large die radius. However, the selection on those parameter values affects on the material flow and the surface quality on the extrusion parts also. Namely, it causes the crack surface and shrinkage failure which are the general problems in the SME-FB. **Approach:** Objective of this research was to study the effect of die radius on the SME-FB surface which investigated the formation of the failure defection with respect to the several die radiuses by using the Finite Element Method (FEM). **Results:** From the results, it indicated that applying the small die radius caused the material flow difficult resulting in the decreasing of smooth surface. Vice versa, in the case of large die radius, the material flow easy is resulting in the increasing of smooth surface. **Conclusion:** The FEM simulation results of a larger die radius will cause the residual stress at work piece.

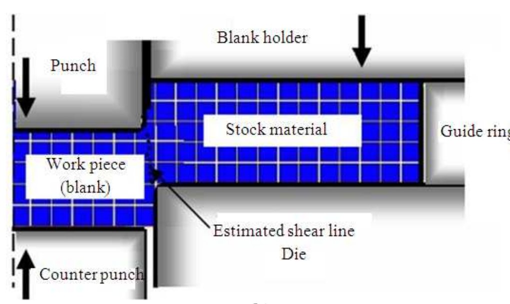
Key words: Die radius, sheet metal extrusion, fine blanking process

INTRODUCTION

The fine-blanking process as shown in Fig. 1 is well known as an effective process to obtain the precision blanked products with a smooth and precision blanked surface. The advantages of the fine blanking technology are as follows: Precision highest in work piece, higher productivity, less material loss and lower cost in finish surface with a press process (Bubphachot, 2009; Thipprakmas *et al*., 2008; Hirota *et al*., 2009; Chen *et al*., 2002; Lange, 1985; George and Maurice, 1997; Michigan Precision Industries, 2007). Fine-blanking process is the most popular one and characterized by three key techniques of extremely narrow clearance, die edge radius and loading compressive stress near the deformation zone with a V-ring and counter punch. This process can produce a fine cut edge without any finishing operations and is used all over the world. These advantages over conventional blanking are possible due to a very special tool design which differentiates itself from that of normal blanking which the outer periphery of the part form on the blank holder, the use of which help to prevent fracture in the part. The extra tooling and machine costs that often accompany this relatively complicated tool design prohibit the economic use of fine blanking for number of applications.



(a)



(b)

Fig. 1: Fine-blanking process with positive clearance (a) Initiation step (b) Press step

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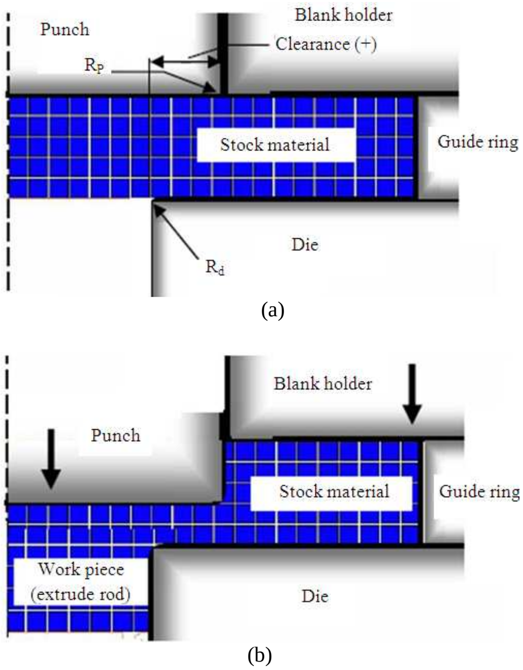


Fig. 2: Fine-blanking process with negative clearance (a) Initiation step (b) Press step

Sheet metal extrusion as shown in Fig. 2 is fine-blanking with tool design in a negative clearance. It is mainly used in producing stepped parts or extrusion rod for assembly process. The economic and efficient design of tools is therefore even more critical for fine blanking. However, with recent improvements in the FEM codes and computer performance, the application of modern simulation techniques can provide a company with a significant competitive advantage, giving important insights into the effects of tool design and process parameters, especially on the appearance of tear or crack surface. In the present study, the effect of die radius on sheet metal extrusion surface in fine blanking process using finite element method was developed to form S45C extruded vary in tool radii.

MATERIALS AND METHODS

Properties of sheet metal: The FEM can be simulation which mathematics computing in mechanical properties equations of each materials. The medium steel S45C (JIS) was used as a stock material model, mechanical properties was determined by tensile and friction testing experiments as shown in Fig. 3. Finally, the FEM results were analytical such as relation graphs, numerical, geometry, behavior flow and behavior color.

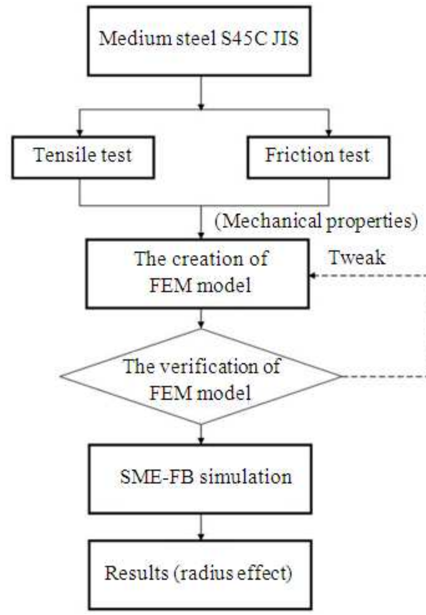


Fig. 3: Procedure of experiment method

Table 1: FEM simulation conditions

Simulation model	Axisymmetric model
Object type	Work piece: Elastic-plastic, Punch/die: Rigid, Blank holder: Rigid, Counterpunch: Rigid
Punch size	$\varnothing_{\Pi}$ 01 μμ R_p = 0.00, 0.05, 0.10, 0.15, 0.20 mm
Die size	$\varnothing_{\Delta}$ μμ 5 R_d = 0.00, 0.05, 0.10, 0.15, 0.20 mm
Blank material	S45C $_{\sigma_B = 530\text{MPa}, \lambda = 26\%}$
Flow curve equation	$\bar{\sigma}=850\bar{\varepsilon}^{0.478}+385$
Fracture criterion equation	Oyane (constant α: 1)
Critical fracture value (C)	0.157
Friction coefficient (m)	0.12

Simulation model: The modeling of the SME-FB process is significant being the ability to model the part as axisymmetric. In this case, only half of the part must be modeled, with the nodes of work piece on its axis of symmetry so defined that they have no movement in the z-direction. In Fig. 6, one such model is shown. One can see the concentration of elements in the area where the shear zone will build up. The finite element method (commercial code MSC.Marc) was used for the FEM simulation. The shape of the elements of the blanked material was rectangular element (4-noded rectangular element type). It was also note that approximate 10000 elements were designed for the blanked material. Calculations were performed by remeshing so that the divergence of the calculations due to excessive deformation of the elements was prevented. The FEM simulation conditions are shown in Table 1.

Medium steel S45C (JIS) was used as a blanked material and a flow curve equation was determined by tensile testing experiments and its mechanical properties are shown in Table 1. The constitutive equation was calculated from the tensile testing experiments results. Therefore, the strength coefficient value 850 and the strain-hardening exponent value 0.478 were obtained.

In order to investigate the fundamental failure and the form of blanked surface by means of the FEM during blanking, the fracture criterion equation and critical fracture value were considered. In this study, Oyane's ductile fracture criterion equations were selected as 0.157, which were investigated and also usually used for the sheet metal extrusion process. A critical fracture value was determined in each fracture criterion equation by using a tensile testing experiment. A critical fracture value was used which agree well with tensile strength and elongation between the FEM simulation results of tensile testing. In this study, the friction coefficient 0.12 was used for the blanking process.

RESULTS

The verification of FEM model: The mechanical parameters of the FEM model was been verified from tensile test and tensile simulation results. A critical fracture value was determined in each fracture criterion equation by using a tensile testing experiment. A critical fracture value was used which agree well with tensile strength and elongation between the FEM simulation results of tensile testing and the results obtained by the experiment. The FEM simulation results of tensile testing showed the tensile strength 530 MPa and the elongation was 26% which were errors of approximate 2.05 and 0.83% compared with the experimental results, respectively as shown in Fig. 4.

As a result of this study, FEM and experimental results substantially agree well with each other, thus the possibility of the FEM approach is indicated for determining the optimal die design and working parameters in the SME-FB process.

Extrusion force: An important field of application for metal forming process is the prediction of forming force which could lead to premature formability of materials in metal forming process. It is possible to formability prediction such as difficulty forming or easy forming with extrusion force, as seen in Fig. 5. In the beginning, the FEM simulation was investigated extrusion force in forming process. The FEM simulation result compared with respect to the die radii 0.00-0.30 mm.

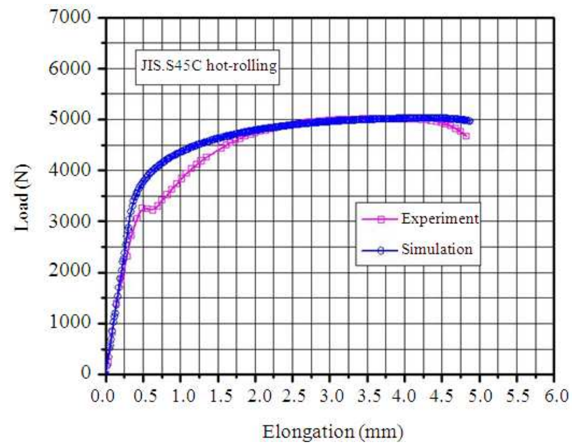


Fig. 4: Comparison of tensile experiment and FEM simulation

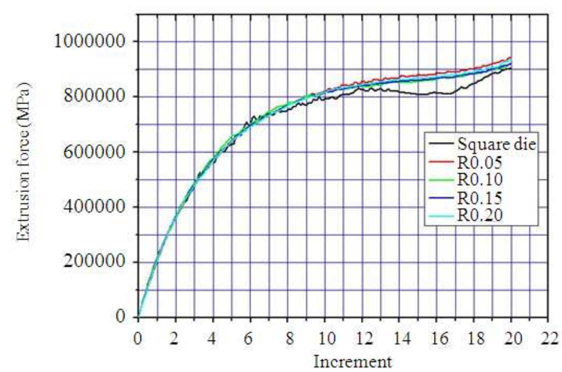


Fig. 5: Relationship between tool radius and extrusion force

The extrusion force, which mostly agreed well with the FEM results, was used and the results are shown in Fig. 5. In every case, the ultimate of extrusion force are 900000 MPa approximately.

The forming force are trend in the same direction, that is gradually increasing force until the end process. On the other hand, square die or die radius 0.00 mm significantly lowest force in process. Particularly, the extrusion force to be decreases in hinder portion and highest in a short time.

The dead metal zone appearing when punch penetration on the stock material. Some material was compress into strip, it form meaning triangular 45° approximately. The dead metal zone, it cause to material compression and flow pass through die orifice. The material flow rapid more than another area. The extrude surface are flow and contact the die orifice with coefficient friction and hold effort, it cause to stretch material and easily to damage on surface, as shown in Fig. 6.

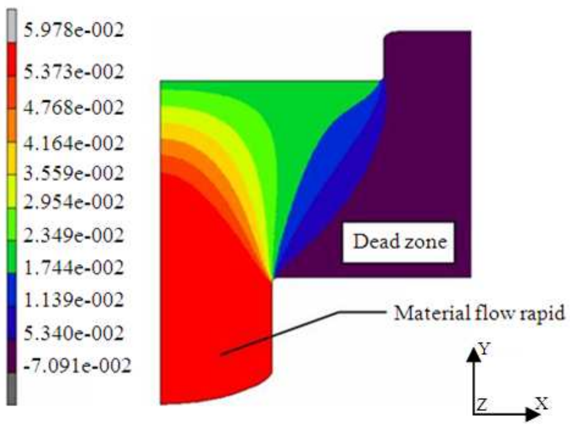


Fig. 6: The Rapid flow in front material

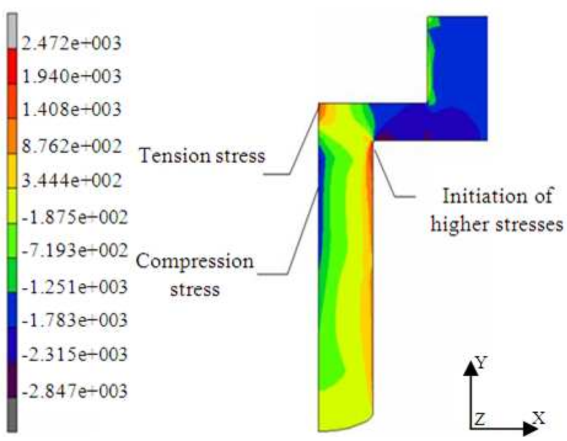


Fig. 7: The stress behavior in extrusion part

Punch penetration into stock material 70% approximately, the negative stress in extrude core and tension stress at the end portion, as shown in Fig. 7. They are cause to velocity difference in material flow, material stretch to flow and product failure in finally.

Surface of extrusion rod: The FEM simulation of extrusion rod surface was investigated using fracture criterion equations with each critical fracture value determined by the tensile testing experiment as aforementioned. The Oyane's fracture criterion equation, which agreed mostly well with the FEM results, was used and the results are shown in Fig. 8.

The FEM result showed an occurrence of cracking surface. In cases square die, the crack formation showed on an extrusion rod surface with increase in punch penetration on stock materials was approximately 10% of thickness as shown in Fig. 8a.

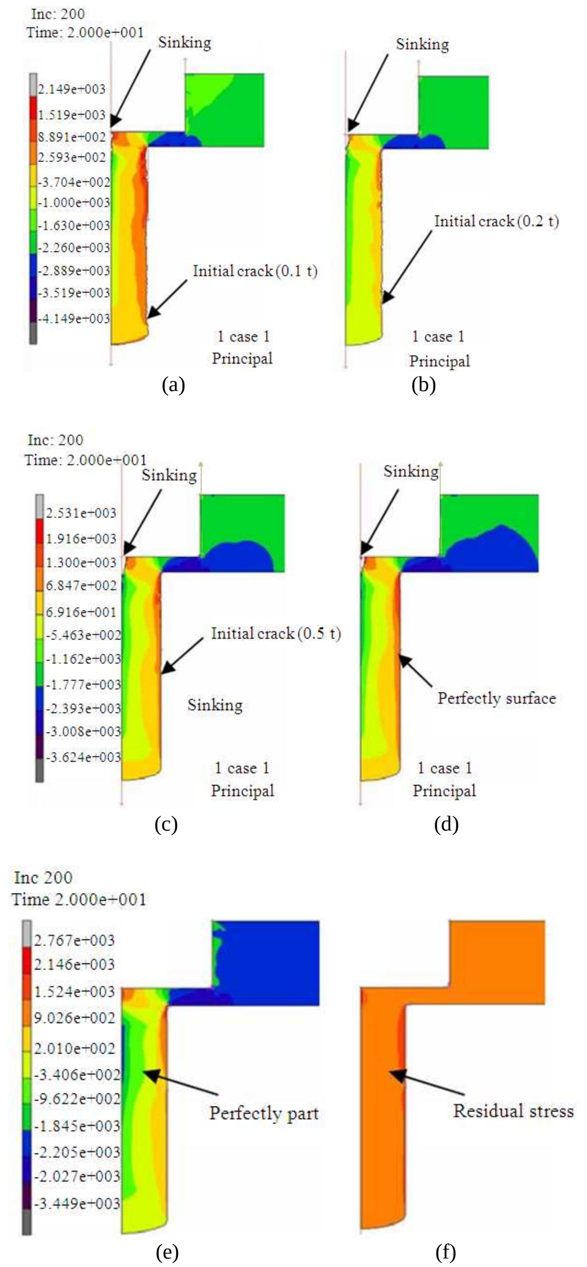


Fig. 8: The study piece are failure in smallest tool radii and perfectly with the optimization of tools radius. (a) R_p, R_d = 0.0; (b) R_p, R_d = 0.05; (c) R_p, R_d = 0.10; (d) R_p, R_d = 0.15; (e) R_p, R_d = 0.20; (f) R_p, R_d = 0.30

On the other hand, decreasing of surface crack in large tool radius. In fact, piping defect and cracking surface was reduces which were increase die radius, but if too large will cause the residual stress at work piece as shown in Fig. 8f.

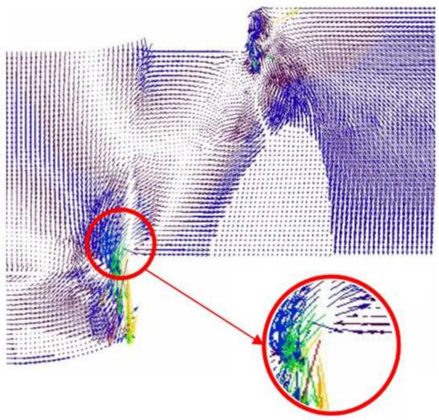
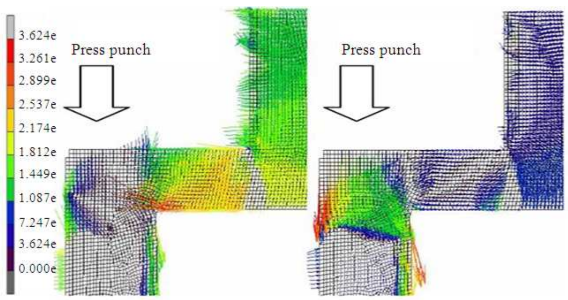


Fig. 9: Principal elastic strain neighbors die edge



(a) (b)

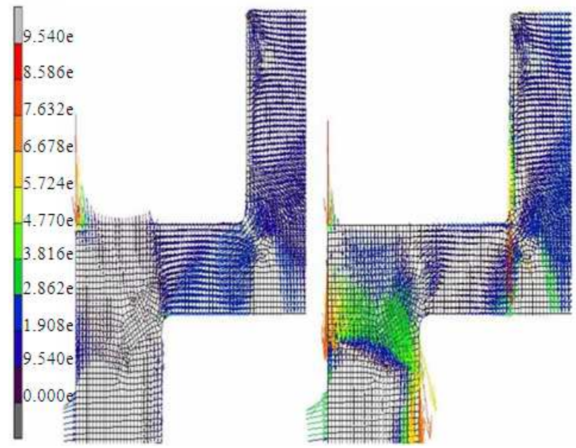
Fig. 10: The comparison of stress-strain neighbors sink bottom rod. (a) Principal stress max; (b) principal elastic strain max

End of extrusion rod: The FEM simulation of 70% punch penetrate on sheet metal surface was investigated effect of tool radii on extrusion end, which were defect prevent and also usually used for sheet metal extrusion in past research (Hirota, 2007). The experiment result showed an occurrence of extrude sinking as shown in Fig. 8a-c. On the other hand, The extrusion sink with decrease and no appearing in large tool radius or optimization radius, as seen in Fig. 8e and f to be similar to surface rod results.

DISCUSSION

In this study, the effect of die radius on extrusion rod of medium steel S45C in fine-blanking process was investigated by using FEM.

The Blank holder force may be too lower, they cause to the material was flow back into the stock sheet and extrusion surface cracked. That is, the material flow easy is resulting in the increasing of strain too high and surface cracking in eventually as shown in Fig. 9.



(a) (b)

Fig. 11: The comparison of stress-strain neighbors smooth bottom rod. (a) Principal stress max; (b) principal elastic strain max

Stress at the end rod not much when compared with the strain. The Strain around work piece surface, cause the flow difficult more than the core rod because the contact friction between the work piece and tools surface, as seen in Fig. 10. The material was flow easy without surface crack and rod sink disappear when tools radius increased as shown in Fig. 11.

The FEM simulation results indicated that applying the small tool radius caused the material flow difficult resulting in the decreasing of the rod shrink and crack surface. In contrast, the width of crack surface is decreased when the tool radii too smallest. Also, there is no crack surface when the tool radii change to optimization. Moreover, the mechanical properties particularly excellence which has high strength value around surface, result in the sheet metal extrusion surface only.

CONCLUSION

In this study, the results of investigation sheet metal extrusion on fine-blanking process with the help of FEM are presented. This includes the identification and elimination of work piece defection, the determination of extrusion effects and the prediction of crack initiation using the fracture criteria. The FEM simulation results indicated that applying the small tool radius caused the material flow difficult resulting in the increasing of the rod shrink and crack surface.

In contrast, the crack surface is decreased when the tool radii too largest. Also, there is no crack surface when the tool radii change to optimization. Moreover, the residual stress particularly excellence which has high value around surface, result in the sheet metal extrusion surface only when the tool radius over largest.

Therefore, the FEM analysis, who are to take into consideration the effecting parameter on process, such as; geometry die design and other process parameters. For example, wide of die land, adjustable of choke and die relief, angle die, extrusion velocity, extrusion ration, blank holder force, counter punch force and material type.

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