Effect of Various Shearing Conditions on the Rod Shearing Quality for Large Nuts

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Abstract

The cold forging dies are usually designed and manufacturing by the practical and experimental (P&E) rules in industries. However, carrying out the dies development and the inspections of work-piece quality based on the P&E rules cannot satisfy the economic benefits to increase the company cost. The dies design cannot be improved to reach the amount of production anticipated. Especially, the processing quality of nuts forging is affected by the quality of rod shearing. Therefore, the geometrical design of shearing dies is evaluated according to the normalized Cockroft and Latham ductile fracture criterion. In this study, the effects of shearing conditions on the shearing quality have been realized by using the Deform-3D FEM commercial software. The assessment engineering technology of rod shearing based on computer aided dies design is established to reach the optimization of rod shearing. A lot of industry application merits can be done.

Keywords: Fasteners, Fracture, Rod Shearing, Nuts

1. Introduction

The rod shearing process is a necessary process for manufacturing nuts. Because the nuts are manufactured by the automation, the nuts can be produced in considerable quantities with high industry value. However the cross section of rod shearing is affected significantly by the process parameters and rod materials such as the geometry of dies, the clearance between cut mold and shearing mold, and the formability of rod. The cold forging dies are usually designed and manufacturing by the practical and experimental (P&E) rules in industries. For reducing the cost, how to evaluate the quality of rod shearing is a very important subject. Recently, many researches regarding to the shearing are sheet piercing and fine blanking. Most simulations used the 2D software to analyze the shearing process, especially 2D-Deform. However, the 2D-Deform software are suitable for the plane strain and axi-symmetrical forming, it can not apply to the rod shearing. Therefore, the 3D-Deform software can be used to simulate the rod shearing process. In this study, firstly using the 3D-Deform software to analyze the effects of shearing conditions on the shearing quality of rod shearing, effective stress, effective strain, velocity field etc.

In 1968, Cockcroft [1] proposed the fracture criterion which indicates the tensile plastic work per unit volume reaches the critical value, the material occur fracture. Latham [2] modified the Cockcroft's fracture criterion to propose the normalized ductile fracture criterion. The tensile stress is a major reason to cause the fracture. Bil [3] used three different softwares to analyze the fine blanking process and obtain the optimum values from the experiment. In DEFORM-2D analysis, Kwak [4] explored the effect of die clearance on shear planes in fine blanking. In 2D piercing process, Hatanaka [5] used 2D FEM simulation to realize the shearing phenomenon in fine blanking process. Hambi[6] applied the fracture criterion to carry out the piercing experiment to realize the effect of the clearance on the piercing process. Ko [7] proposed the isothermal and non-isothermal piercing simulation to obtain the stresses of die and sheet, and the force.

2. FEM Simulation

In this study, using Deform-3D commerical software to perform FEM simulation analysis based on the normalized Cockcroft and Latham ductile fracture criterion to assess the shearing die design, the assembly diagram of shearing dies and rod is shown in Fig.1 and the notation for every symbol is shown in Table 1. The total mesh number is 50000, the shape of element is pyramids, Fig.1 can be drawn by the Solidworks software.

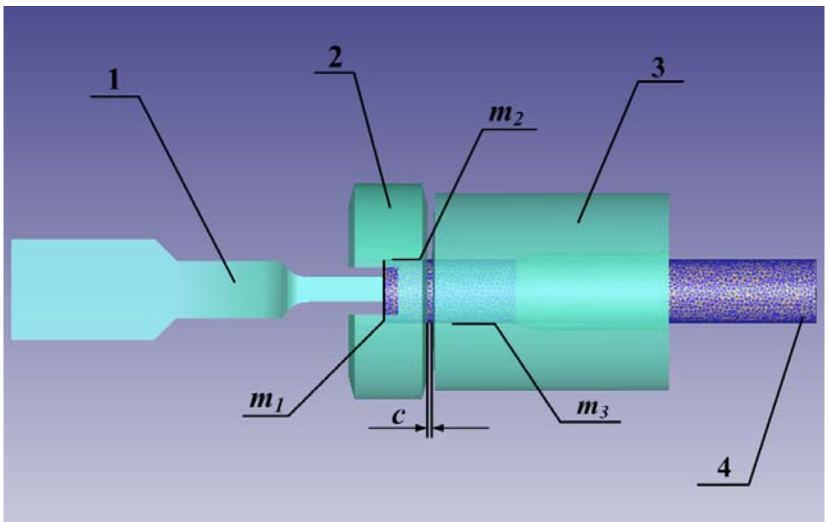

Fig. 1 Assembly diagram of shearing dies and rod.

Table 1 Notations

Symbols	Instruction
1	Stopper
2	Cut mold
3	Shearing mold
4	Rod
c	Clearance
m_1	Frictional factor between stopper and rod
m_2	Frictional factor between cut mold and rod
m_3	Frictional factor between shearing mold and rod

In the simulation, considering the clearance between cut mold and shearing mold and whether dies with fillet or not, the simulation conditions and the results are shown in Table 2. In the Table 2, case 1~case 4 consider the dies have the fillet under various clearances, just only case 4 without fillet. For the case 1 and case 2, the rod shearing process are not successful, just only for c=0.8 mm the rod shearing is successful (case 3 and case 4).

Table 2 Summary of Shearing analysis

	c (mm)	Fillet	Critical damage value	Successful Shearing
Case1	0.4	○	0.25	X
Case2	0.6	○	0.25	X
Case3	0.8	○	0.25	O
Case4	0.8	X	0.25	O

2.1 Fracture criteria

2.1.1 Cockroft's criterion

This fracture criterion indicates the tensile plastic work per unit volume reaches the critical value, the material occurs fracture [1].

The criterion definition is as below：

$$C_1 = \int_0^{\bar{\varepsilon}_f} \sigma^* d\bar{\varepsilon} \qquad \text{Eq. (1)}$$

2.1.2 Cokroft and Lathams' criterion

Latham proposed the normalized ductile fracture criterion according to Cockroft 's criterion , as below：

$$C_2 = \int_0^{\bar{\varepsilon}_f} \frac{\sigma^*}{\bar{\sigma}} d\bar{\varepsilon} \qquad \text{Eq. (2)}$$

where

C_1 and C_2 : Critical damage values, σ^* : maximum tensile stress, $\bar{\varepsilon}$: Effective strain, $\bar{\sigma}$: Effective stress, and $\bar{\varepsilon}_f$: Critical damage effective strain.

2.2 Shearing cross section

Fig. 2 shows the shearing cross section, the shearing fraction is expressed as：

$$\Delta d = d_0 - d_y \qquad \text{Eq. (3)}$$

Where d_0 is initial rod diameter ; d_y is a fracture fraction ; Δd stands for shearing fraction. In Deform-3D software, the above-mentioned dimensions can be measured from the meshed shearing cross session.

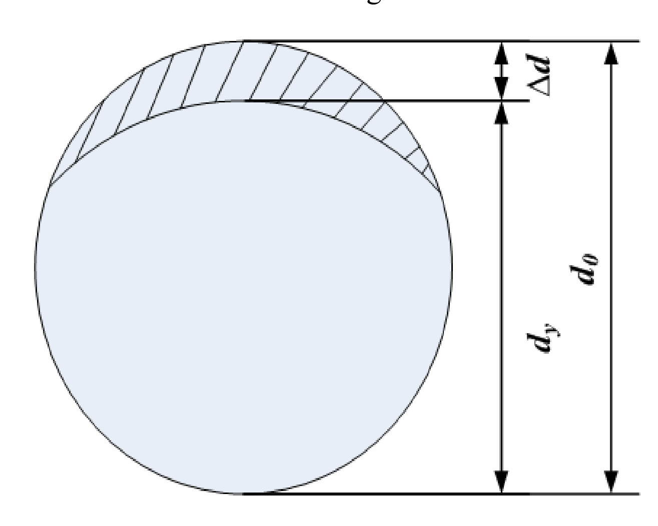

Fig. 2 Schematic diagram of shearing cross section.

3. Results and Discussions

As the rod is too large to cut easily, the quality of rod shearing is not good. The quality of rod shearing affects directly the quality of multi-forging for large dimensional nuts. In the simulation, the critical damage value adopts 0.25 (C_2=0.25). Fillet of dies still affect the burr and shearing fraction. The shearing fraction is more; the quality of multi-stage forging is better. Therefore the fillet of dies takes 0.1 mm to simulate the rod shearing process.

Fig. 3 ~ Fig. 5 shows the effective stress, the effective strain, and the velocity field for the start step considering various clearances. The maximum effective stress occurs on the start step due to the contact between the cut mold and the rod. The maximum effective stress is getting to increase slightly with the increase of clearance, and the maximum effective strain is decreased slightly. As the clearance is small (e.g. c=0.4 mm), the velocity of rod is slow.

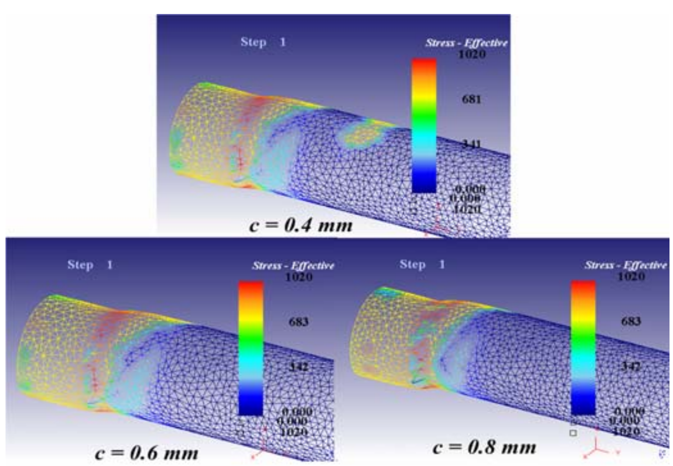

Fig. 3 The effective stress for start step under various clearance (Die with

fillet)

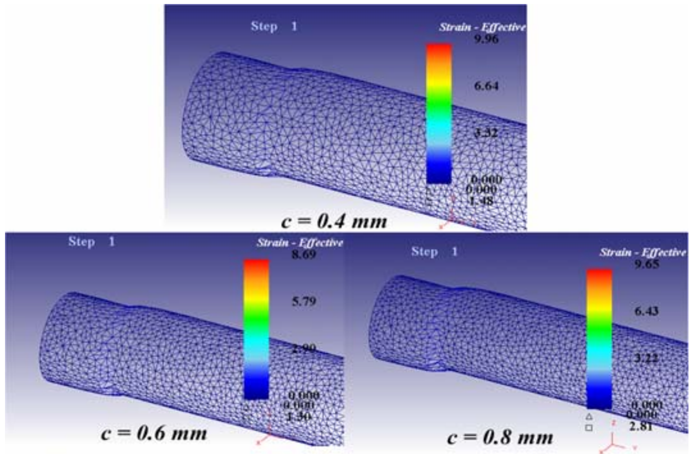

Fig. 4 The effective strain for start step under various clearance (Die with fillet)

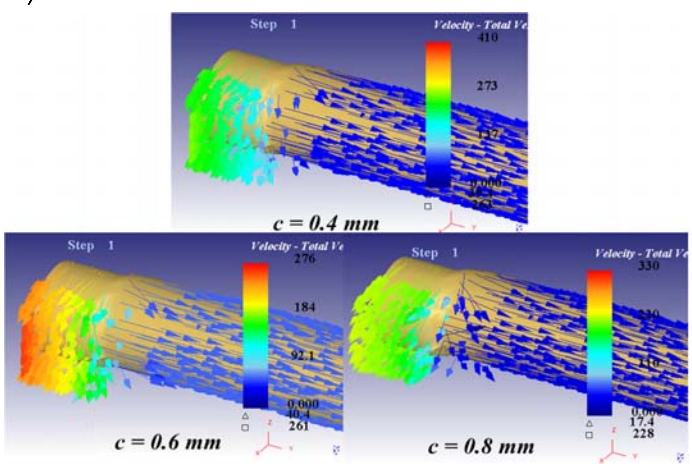

Fig. 5 The velocity for start step under various clearances (Die with fillet)

The maximum effective stress, the maximum effective strain, and velocity field for the final step are demonstrated in Fig. 6, Fig. 7 and Fig. 8.

For the final step, σ_{max} is reduced more than the start step. The larger the clearance is, the larger the σ_{max} is. For the ε_{max}, that for the final step is larger than that for the start step. At $\boldsymbol{c}$ = 0.8 mm, the ε_{max} is smaller, it indicates the burr is smaller.

It is noted that the rod has been cut as the clearance is 0.8 mm. However, for $\boldsymbol{c}$ = 0.4 mm and $\boldsymbol{c}$ = 0.6 mm, that rod has not yet cut from the velocity field in Fig. 8.

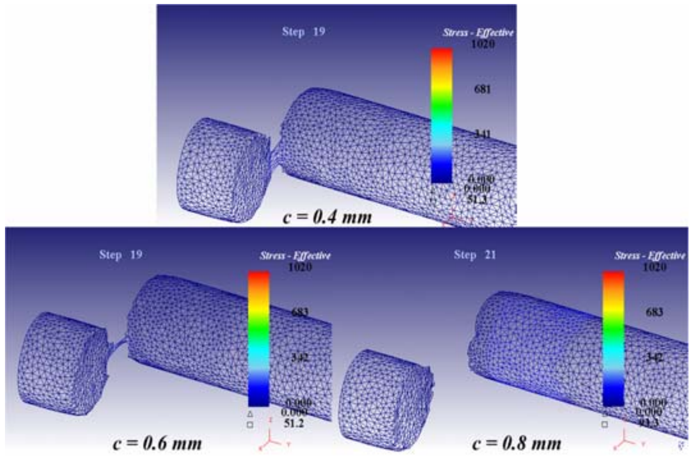

Fig. 6 The effective stress for final step under various clearance (Die with fillet)

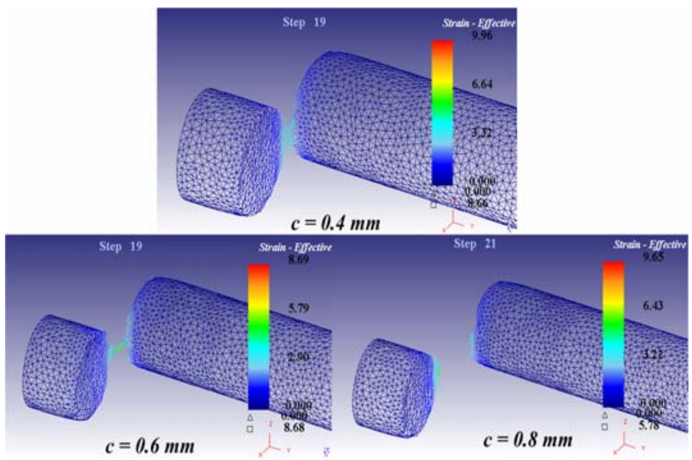

Fig. 7 The effective strain for final step under various clearance (Die with fillet)

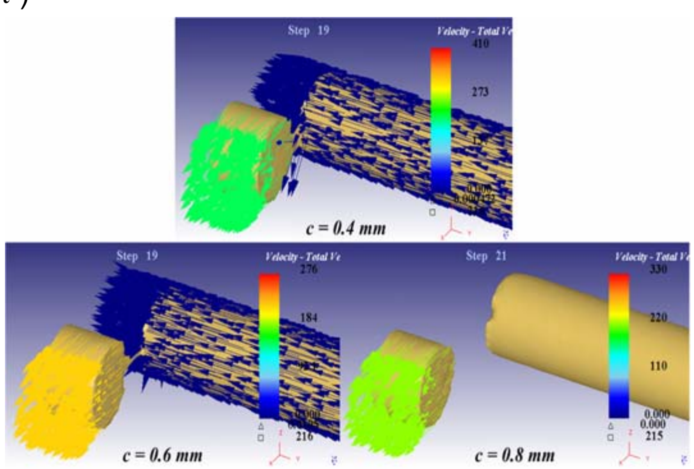

Fig. 8 The velocity for final step under various clearance (Die with fillet)

Table 3 shows the maximum effective stress, the maximum effective strain, and the shearing fraction under various clearances. For the start step, the maximum effective stress is large in all steps. The σ_{max} is increased with the increase of the clearance. The shearing fraction increases with the increase of the clearance. Considering the die with fillet the shearing fraction is smaller than without fillet.

Table 3 Effects of various clearances on the maximum effective stress, strain, and shearing fraction

	c =0.4 (mm) with fillet	***c*** =0.6 (mm) with fillet	***c*** =0.8 (mm) with fillet	***c*** =0.8 (mm) without fillet
Start Step σ_{max} (MPa)	1021.94	1021.253	1019.343	1023.054
Final Step σ_{max} (MPa)	51.2634	51.19554	93.28443	93.04592
Start Step ε_{max} (mm/mm)	1.47926	1.296759	2.810009	3.007164
Final Step ε_{max} (mm/mm)	8.66033	8.684522	5.781156	4.839193
Δd (mm)	3.11	3.38	3.8	3.82

Fig. 9 shows that the burr is decreased with increasing the clearance. Fig. 10 shows that the shearing force is increased with decreasing the clearance.

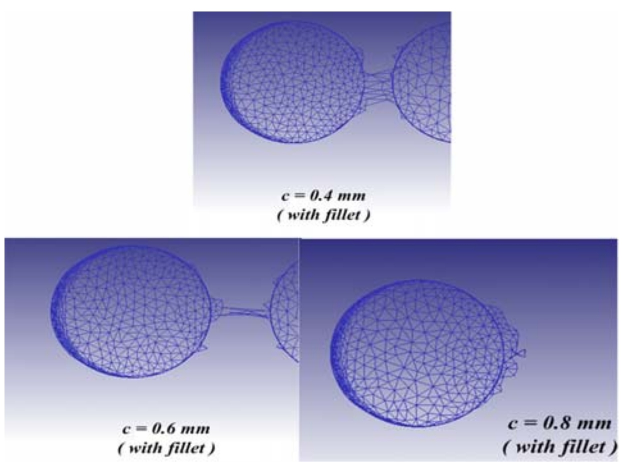

Fig. 9 The shearing cross section under various clearances

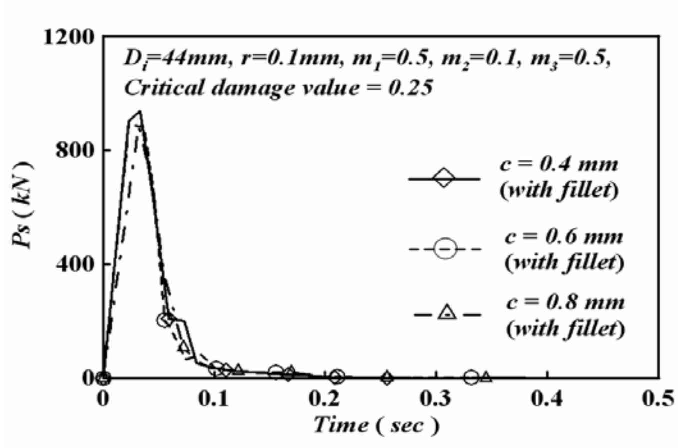

Fig.10 Effect of various gaps on the Shearing force

With a view to realizing the effect of fillet on the shearing fraction and the burr, the Δd is reduced and the burr is more as the fillet doesn't consider, shown in Fig. 11.

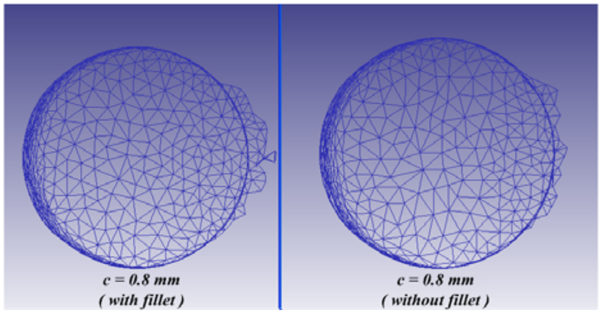

Fig. 11 Comparison of shearing cross sections for die with fillet and without fillet

4. Conclusions

Through a series of FEM Simulation, the major conclusions are summarized as :

1. As the clearance is increased, the shearing force and the maximum effective stress are reduced also; however the maximum strain is increased.
2. As the clearance is increased, shearing fraction is increased, however the burnish is reduced.
3. When ***c*** = 0.8, the die with fillet has more shearing fractions compared to that without fillet, however the burr is more.

5. Acknowledgment

Thanks for THREAD Industrial Company to provide some assistance so as to finish the study.

6. Reference

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