

Numerical simulation and experimental study of 1mm diameter Micro Gear Heat Extrusion

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Abstract. The forward hot-extrusion forming process of micro-gear was simulated by FEM. The deformation process was simulated with finite element software—DEFORM was simulated, the metal flow and filling regularity and stress-strain and load feature were obtained, The deformation mechanism of gear micro-forming was disclosed, The results were analyzed through experiments, providing theoretical basis for production practice.

Introduction

With the rapid development of micro mechanical technology, urgent need for micro parts or slightly type extrusion technology can play an important role in micro mechanical system, so it is very important to study the micro extrusion technology. Analysis and experimental study on Numerical Simulation of this paper, use 1MM diameter micro gear as the research object, the structure of micro gear specific parameters: $m=0.125$ modulus, tooth number $Z=6$, pitch diameter $d=1\text{mm}$, pressure angle $\alpha=20^\circ$.

The simulation conditions and model

The numerical simulation conditions.

In order to simplify the model, convenient operation, the following provisions or assumptions made to simulate conditions: (1) the straight gear parameters: number of teeth modulus $=0.125\text{mm}$, $z=6$, $=20^\circ$ pressure angle. (2) die is simplified as a rigid body, die extrusion process does not occur deformation, damage, do not consider the effects of die thickness. (3) select H62 brass from the custom materials in the library. Calculation of blank of the selected material was H62 brass ($500 \sim 800^\circ\text{C}$). (4) body cell number is 100000, and the mesh distortion larger system automatically remeshing. (5) the extrusion temperature was 650°C . (6) the extrusion speed is 0.1mm/s . (7) in the process of extrusion die and the environmental heat exchange, the heat exchange coefficient is 0.5N/sec/mm/c . (8) friction model with shear friction, the friction factor between blank and die for 0.3.

The simulation conditions and model.

(1) Establish geometric model (blank, extrusion die, extrusion device)

first use proewildfire 4 to model, set the blank diameter of 3.0mm , thickness of 3mm . Mold parts diagram as shown in Figure 1, save as STL file types. And then in the DEFORM-3D software, specify the path to the stored, module for processing before entering, set blank for plastic, temperature 650°C , die temperature is 650°C for rigid. Click the object Geometry introduction to simulated as shown in figure 2. In order to reduce the simulation time, considering the symmetry of the blank extrusion, therefore only simulation model 1/12. The simulation type is set to deforming and heat transfer.

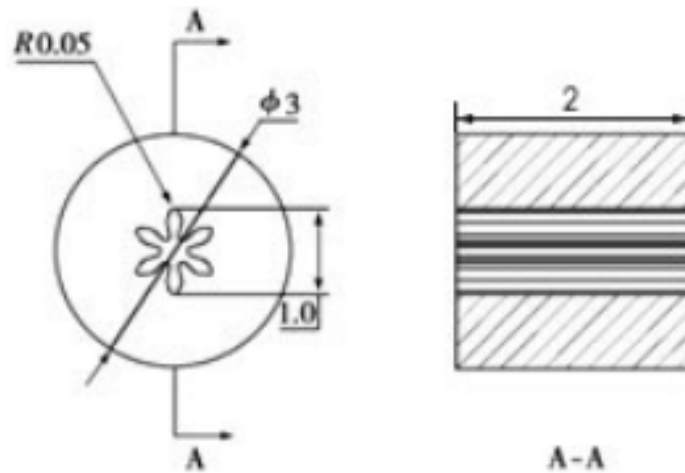
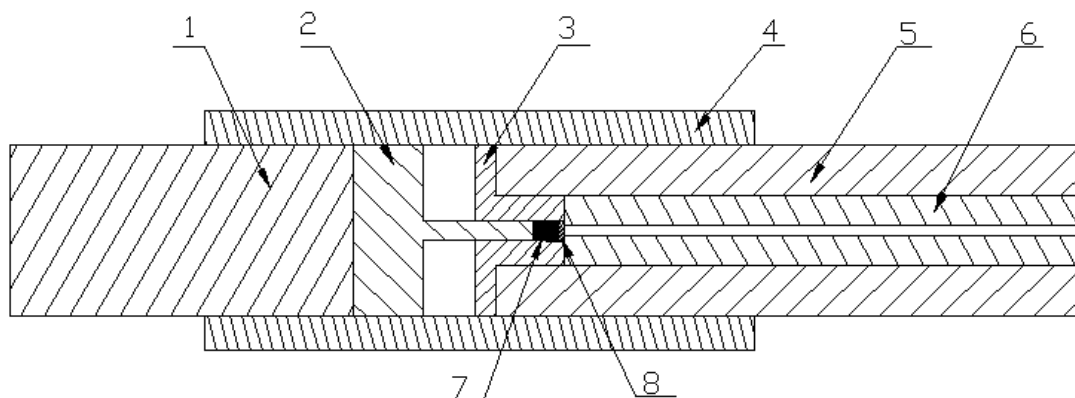


Fig.1 Extrusion die



1 pressing rods 2 extrusion needle 3 extrusion 4 sleeve 5 extrusion cylinder jacket 6 supporting blocks 7 blank 8 extrusion die

Fig.2 Extrusion die assembly drawing

(2) the budget squeeze pressure:

$$P_p = C n \sigma_b$$

P_p is a punch unit pressure; C constraint coefficient; n as the material hardening exponent; tensile strength for hot extrusion temperature material (MPa); P is the total pressure.

Brass H62 estimation of 650 °C, $P_p = 50 \times 4.275 \times 2.3 = 500 \text{ MPa}$, $P = 3.4 \text{ KN}$

Simulation results and analysis

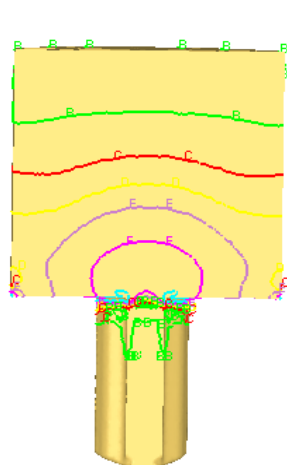
In this paper, direct extrusion simulation process is calculated in 500 steps, but this paper only takes 400 step change chart. Each step represents the formation of intermediate results at a point in time.

Full condition.

The extrusion effect is shown in Figure 3, you can see the forming condition of the last step: micro gear tooth top is most likely not flawed, mainly with the metal fluidity. And this paper extrusion forming good simulation results, cross sectional area, size and shape and cavity cross-sectional area, size, shape of the same. In addition, other parts are the basic full, does not appear in the whole process of folding defect.

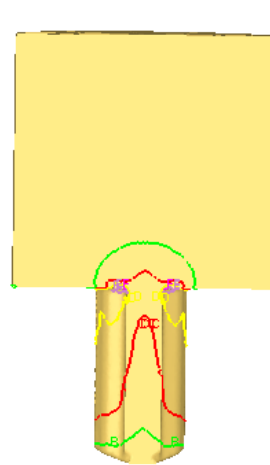


Fig.3 Extrusion effect chart



Stress - Effective

B = 28.5
C = 57.0
D = 85.5
E = 114
F = 143
G = 171
H = 200
I = 228
J = 257



Strain - Effective

B = 0.786
C = 1.57
D = 2.36
E = 3.14
F = 3.93
G = 4.72
H = 5.50
I = 6.29
J = 7.07

Fig.4 The equivalent stress diagram

Fig.5 Strain diagram

Equivalent stress, strain distribution.

Figure 4 shows the equivalent stress distribution, the deformation zone circumferential direction gradually reduced, the deformation zone stress than non deformation zone of high stress, and the ratio of deformation zone stress is small; the strain from the graph display of extruded shim near to die gradually increase to 5, the deformation zone and the sizing junctional strain reached maximum. At the same time, the mold at the entrance to the larger shear deformation and higher working stress.

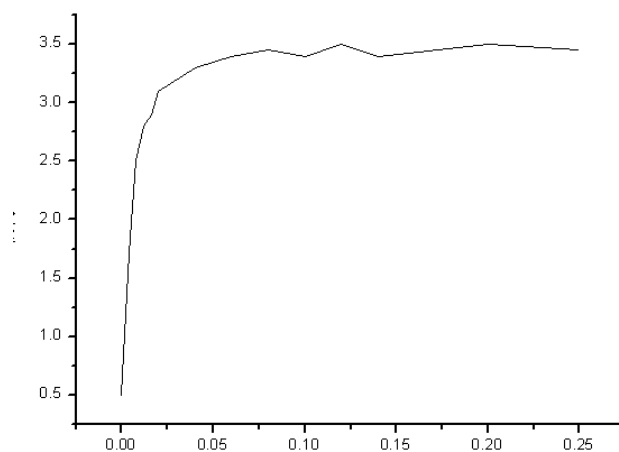


Fig.6 The extrusion load graph model

Stroke load curve.

It can be seen from Figure 6: along with the time change of extrusion pressure extrusion process, and present the stage.

The relationship between extrusion pressure and time.

(1) The first stage (upsetting and filling stage) is the process material fills the cavity, but also a sharp rise in stages, blank head punch contact under the pressure of cutting edge of die gradually yield. The punch to punch down, bottom pressure to the blank, material is first upsetting, produce radial flow and full of the cavity, the pressure is increased.

(2) The second stage (stable extrusion stage): squeeze pressure tends to stable stage, the punch to pressure, material continuously from the steady deformation region to die extrusion, extrusion pressure stability. But this stage crowded with the fluctuation of pressure, this is mainly because in the stable stage of plastic flow, there are still a few inhomogeneous plastic deformation.

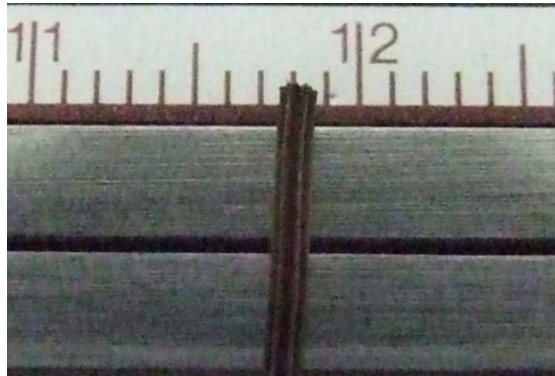


Fig.7 The micro gear column chart (addendum circle diameter of 1mm)

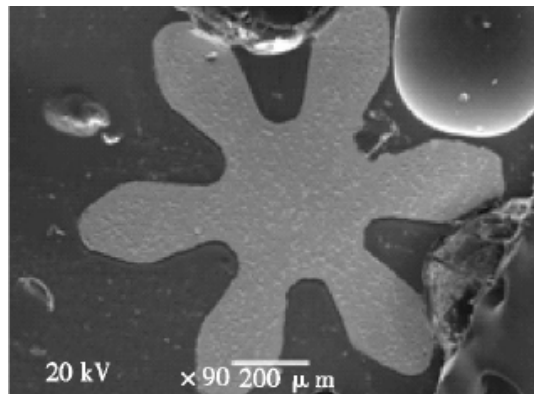


Fig.8 The micro gear section electron micrographs

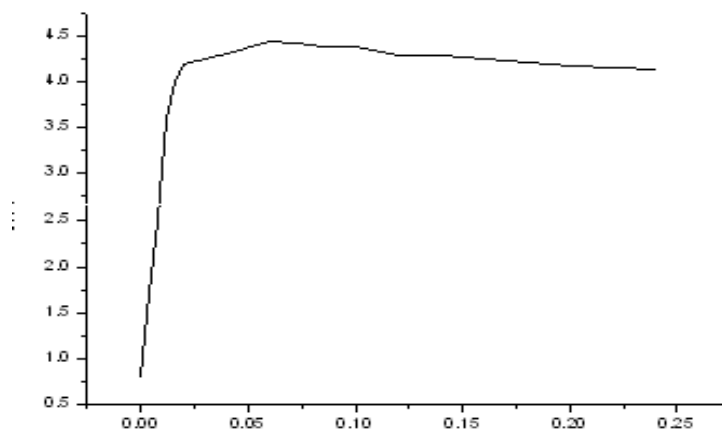


Fig.9 Test the actual load diagram

Test and analysis of hot extrusion of micro gear.

From Fig. 7, 8 can be seen that the micro gear shaping is full, the outline is clear, the test was very successful; from Figure 6 and Figure 9 shows the actual pressure to squeeze pressure larger than the simulation.

Conclusion

Through the micro gear is hot extrusion numerical simulation and experimental study on forming conditions, results show that this method is feasible, for the micro forming has certain guiding function test. At the same time, micro extrusion forming test the actual load simulation should be large and that the micro forming, friction and micro forming mechanism has great relationship, these problems will be the next step in the experimental study.

$l=0.043\text{m}, H=0.0038\text{m}, S_{\text{max}}=4.38\text{ m}.$

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