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Research Article

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Finite element simulation on rolling-extrusion forming of variable wall thickness cylinder parts

Zhao Xi[1,2], Zhang Zhimin[3*] and Zhang Baohong[3]

[1]*College of Mechanical and Electrical Engineering, North University of China, Taiyuan, China*
[2]*Taiyuan University of Science and Technology, Taiyuan, China*
[3]*Engineering Technology Research Center for Integrated Precision Forming of Shanxi Province, Taiyuan, China*

ABSTRACT

In order to reduce the machining time and increase the material utilization, the rolling-extrusion technique for the mass production of variable wall thickness cylinder parts were put forward. In this process material is formed by means of three passive rotational tools. The charge is provided by means of a pusher pushing the billet in a working space between the profiled rolls. A FEM model for rolling-extrusion was developed based on the DEFORM-3D software. Then coupled heat transferring and material flow were simulated and the effects of process parameters on them were analyzed. The results show that the deformation nonuniformity of billet increases with the increase of the punch speed and friction factor or the decrease of initial temperature of billet. In order to verify results of simulation, tests of forming were made. The results of these tests confirmed the rightness of the FEM model.

Key words: variable wall thickness cylinder; rolling-extrusion; FEM

INTRODUCTION

Variable wall thickness cylinder parts are widely used in the production of projectile bodies, and the production is very big. The traditional production methods of this part are cutting to realize wall thickness decrease. The deficiencies of the traditional method [1] is as follows: 1) low material utilization;2) big consumption of cutting tools;3) high Production costs. The newer solutions concern spin extrusion [2, 3]. But the productivity is very low, and the cylinder is difficult to stripping from the punch.

To address these issues, in this work, the rolling-extrusion technique was presented. In this process a cylinder part is pushed into a working space between three profiled rolls [8, 9] by a punch. At the meantime, the rolls will rotate and compress the metal under the action of friction, and then the wall thickness of this billet will decrease. The required shape of this part can be got, without mechanical cutting, by reasonably design of working space. Compared with traditional processes, the proposed method can reduce the machining time and increase the material utilization.

In this paper, the authors focused on determining the process parameters of rolling-extrusion process for variable wall thickness cylinder parts. In numerical simulations the Deform-3D software was used. This software based on the finite element method. The effects of process parameters on material flow were simulated. Serve nonuniformity of deformation as the objective function, the process parameters will be optimized, and results of numerical research will be verified in a simple machine for rolling-extrusion.

2 NUMERICAL SIMULATION AND ANALYSIS OF RESULTS

2.1 Establishment of geometrical element model

The DEFORM-3D software was used for the numerical simulation. The process geometrical model (Figure1), worked out for the calculations needs, consists of three rotating tools – profiled rolls (moving in the same direction with the same velocity of the punch), pusher pushing the charge with constant velocity, and charge modeled by means of hexahedral elements.

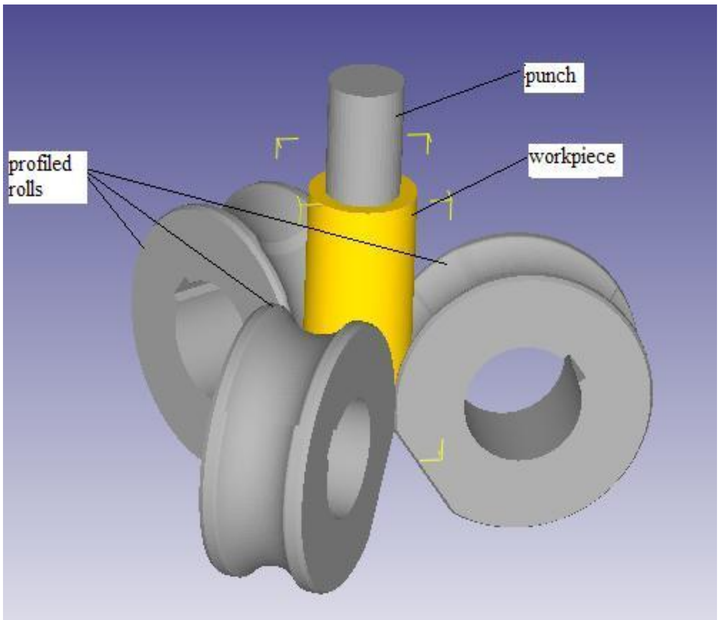


Fig.1 Finite element geometric model

2.2 Simulation conditions

The rigid viscoplastic finite element method was used [5, 6]. The deformation material used for the simulation is 45Cr, and its size is showed in Fig.2. The tool and die materials are all AISI-H13. In this work, the friction coefficient between the roller and the billet used the shear friction driving model [4]. Contact and heat boundary conditions: contact heat conductor coefficient: $11 W \cdot m^{-2} \cdot K^{-1}$; heat exchange coefficient: $0.02 W \cdot m^{-2} \cdot K^{-1}$ [7]. And the initial temperatures of the roller and die were set at 120 ℃, and the surroundings temperature is 20 ℃. The billet is divided to 65844 tetrahedron elements with 14782 nodes. The time increment is set as 0.0 5 s for each FEM iteration step.

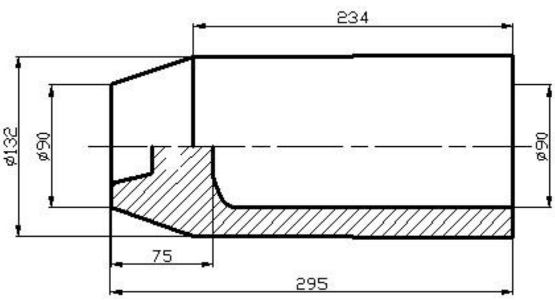


Fig.2 Extrusion blanks

In this work, three parameters are considered: the punch speed v (equal to the linear speed of the roller); initial temperature of billet t; and friction factor m. The calculation conditions for simulation ale divided into three groups as follows：

Case 1: v= (8, 16, 24, 32, 40) mm/s, t=1050 ℃, m=0.3;

Case 2: v= 16 mm/s, t= (960, 1010, 1030, 1040, 1050) ℃, m=0.3;

Case 3: v= 16 mm/s, t= 1050 ℃, m= (0.2, 0.3, 0.4, 0.5, 0.6).

2.3 Simulation results and analysis

Based on the FE model established, the process was thoroughly simulated and analyzed, then the material flow and the effects of process parameters on them were investigated.

Here, the standard deviation D is adopted to describe the nonuniformity of deformation, defined as:

$$D = \sqrt{\sum_{i=1}^{N}(x_i - \overline{x})^2 / N - 1} \qquad (1)$$

Where $\overline{x}$ the average of variable, N is is magnitude of variable. The larger the value of D, the more nonuniform the variable.

2.3.1 Effect of punch speed

Under simulation Case 1, effects of punch speed on the process and distributions of field-variables were discussed.

The results show that with the punch speed increasing, the maximum equivalent strain, and the nonuniformity of deformation D increases, the deformation of billet becomes more no uniform. While for further increasing of v, nonuniformity of deformation changes a little, as shown in Fig.3. Because with v increasing, the plastic deformation just concentrates in outer of billet and is hard to extend into inner layers. On the other hand, with v increasing. rotational speed of rolls increases too, thus the contacting time of under forming zone and environment is shortened and billet temperature is enhanced. So the billet has the better plasticity, and the deformation tends to be uniform. Considering the production efficiency, 16mm/s will be a better choice of bunch speed.

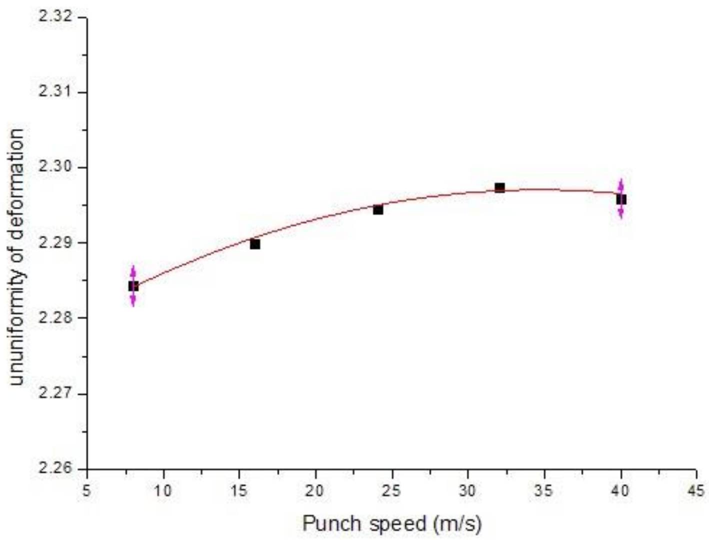


Fig.3 Effect of v on nonuniformity of deformation

2.3.2 Effect of initial temperature of billet

Under simulation Case 2, effects of initial temperature of billet on the process and distributions of field-variables were discussed.

Under different initial billet temperatures, the maximum and minimum equivalent strains appear on the outer-plane of billet. Respectively, with the initial temperature increasing, the maximum equivalent strain decreases while the minimum one increases. Fig.4 shows that with temperature increasing, the nonuniformity of deformation D decreases. which means the larger the initial ring temperature, the more uniform the deformation. When temperature increases, material plasticity becomes better, and more metals are involved in plastic deformation. The deformation zone is easy to penetrate towards the thickness of the part. Obviously, 1050 ℃ is the best selection.

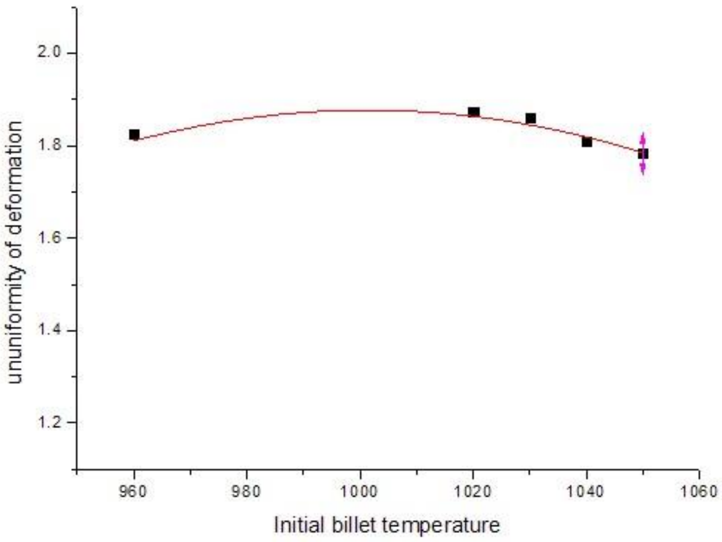


Fig.4 Effect of t on nonuniformity of deformation

2.3.3 Effect of friction factor

Under simulation Case 3，effects of friction factor on the process and distributions of field-variables were discussed. With friction of contact surface increasing, the maximum and minimum values of equivalent strain ate enhanced. The nonuniformity of deformation D augments with the increase of fiction factor. Large friction prevents metal in outer and inner layers from flowing along axial, which result in more nonuniform distribution of deformation. But small friction is not conducive to the biting of billet; a better selection of friction factor should be 0.3.

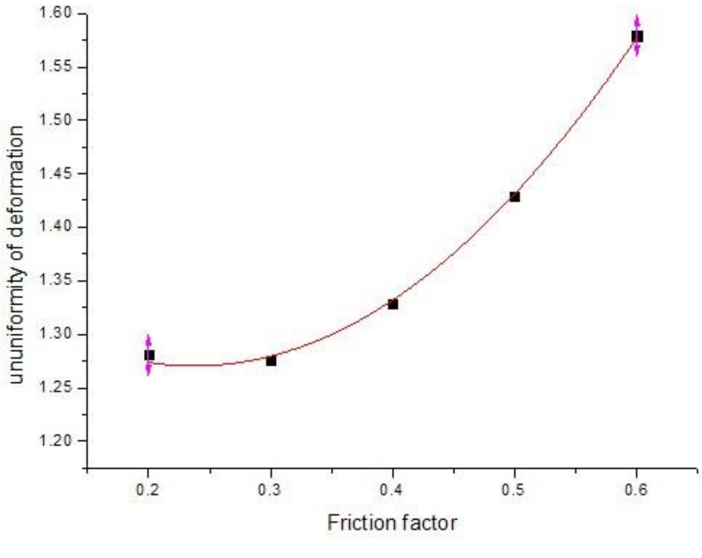
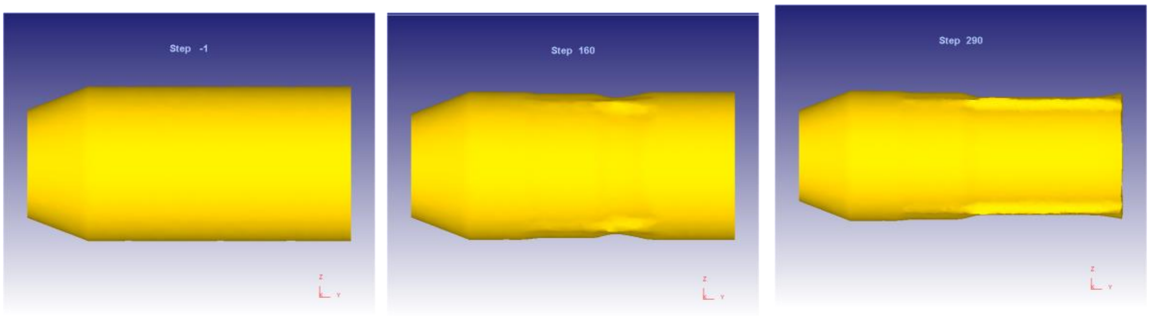


Fig.5 Effect of m on nonuniformity of deformation

2.4 Metal Flow of Forming Process

During the forming of a variable wall thickness cylinder parts，the wall thickness can be decreased orderly by controlling metal flow. Fig.6 shows that the billet obtains the expected shape, with the process parameters selected above.



(a) (b) (c)

Fig.6 Simulation process of forming
(a) Initial step; (b) 50% step forming; (c) Final step

3 EXPERIMENT VALIDATIONS

In this work, use press machine of 630 tons, and a simple equipment of rolling-extrusion to do the physical experiment(see Fig.7). Water-based graphite was used as a lubricant. Basing on the results of numerical simulations, the process parameters of rolling-extrusion process was set as: v=16mm/s; t=1050 ℃, m=0.3. The result showed the size of parts basically meet the requirements, and the material utilization increased by 19%, compared with traditional methods.

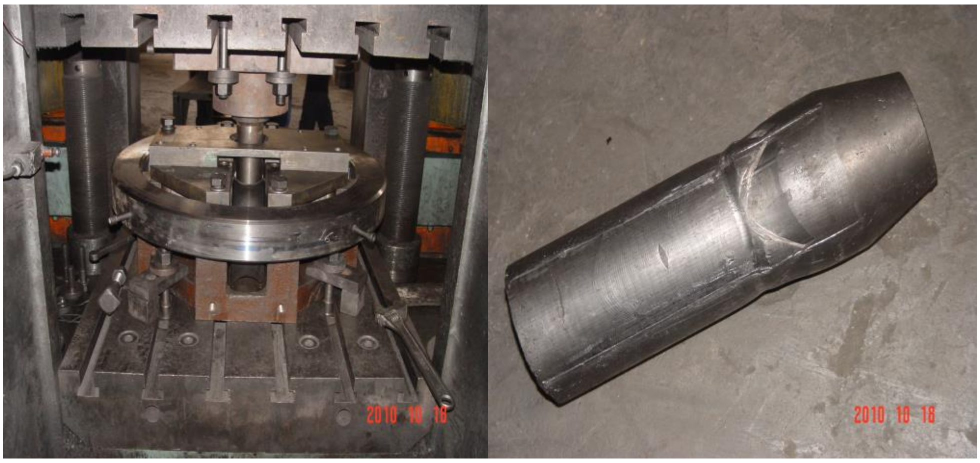


Fig.7 Forming equipment and experimental part

CONCLUSION

（1）The variable wall thickness cylinders parts can be worked out, by using the way of rolling-extrusion, and the material utilization increased by 19%.
(2) The Simulation results show that the deformation nonuniformity of billet increases with the increase of the punch speed and friction factor or the decrease of initial temperature of billet.
（3）The FEM model was verified by the physical experiment. The results of these works will be useful for determining guidelines for designing of technological process of rolling-extrusion of variable wall thickness cylinder parts.

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