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RESEARCH ON FORGING FORMING FORCE IN THE COMPOSITE TECHNOLOGY OF CROSS WEDGE ROLLING (CWR) AND FORGING FOR UNIVERSAL JOINT FORK

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In this paper, the forging process of universal joint fork of automobile transmission shaft is simulated and the change of forming force of die forging is studied on the basis of the blank produced by cross wedge rolling (CWR). Temperature / T , friction factor / c and falling speed of upper die / V are the main process parameters affecting the forging forming force / F of universal joint fork. The effects of temperature, friction factor and speed on the forming force were studied respectively by single factor method. The results show that the lower the temperature, the greater the friction factor, the slower the speed, the greater the forming force, the more difficult for forming. The orthogonal test is designed and it obtained the order of process parameters affecting the forming force of die forging that is T > c > V and the best combination of process that the temperature is 1 100 ° C the friction factor is 0,2 and speed of upper die is 150 mm/s.

Key words: CWR; forging; universal joint fork; process parameters; forming force

INTRODUCTION

The universal joint fork of the transmission shaft is a key transmission component in the transmission mechanism of the vehicle, which conveys all the driving forces of the vehicle. The working environment is extremely poor, the load is heavy, and the high using intensity and high toughness are required. The universal joint fork is a kind of fork-type part, the diameter of the big end and the small end varys greatly, and the large end is very difficult to fill. Due to fork parts forming is difficult, the technological feasibility, stability (including fold, tissue defects, underfilling), material utilization, and how to reduce load, improve the service life of the mold are the questions that must be considered during the forming process of the universal joint fork.

In general, researchers do a lot of simulation before experiments to reduce costsand risks during practical production. Wang et al. [1-2] used the finite element method to perform numerical simulation analysis on the precision forming process of the universal joint of the drive shaft, and obtained the variation law of the extrusion force, speed, stress, strain and temperature field in the forming process, which can predict the possible defects in the forming process well. Quan et al. [3-4] established a macroscopic and microscopic coupled simulation model to numerically simulate the forward and reverse extrusion forming process of the universal joint fork. It was found that the universal joint fork reverse extrusion was deformed ahead of the positive extrusion and predicted internal grain size and distribution of the universal joint. Wang et al. [5] improved the structure of the fork size and determine the minimum displacement deformation of the optimal design parameters by using Creo Simulate module of universal joint fork head in 3d complex surface modeling, finite element analysis and structure optimization design.

This paper presents a method of combining forging and rolling to produce the universal joint fork of transmission shaft, that is to say, die forging is carried out on the basis of stepped shaft blank produced by CWR. The effect of process parameters on the forging forming force is studied during the forging of universal joint fork and the orthogonal test is designed to obtain the best combination of process parameters. The process greatly reduces the number of procedure, labor and production costs.

FINITE ELEMENT SIMULATION

Material

In this paper, 45 steel is selected to product universal joint fork of the automobile transmission shaft. 45 steel is a kind of high-quality carbon structural steel with low hardness, high strength and good machinability. After proper heat treatment, it can obtain certain toughness, plasticity and wear resistance, and the source of the material is convenient.It is a kind of common material for shaft-parts. Its chemicalcomposition and mechanical properties are shown in Tables 1, 2.

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Table 1 **Chemical composition of 45 steel / wt. %**

C	Si	Mn	Ni	S	P	Cr	Cu
0,4-0,5	0,2-0,4	0,5-0,8	≤ 0,3	≤ 0,04	≤ 0,04	≤ 0,2	≤ 0,3

Table 2 **Mechanical properties of 45 steel**

R_m / MPa	*Ra* / MPa	*A* / %	Impact Energy / J	Hardness / HB
≥ 600	≥ 355	≥ 16	≥ 39	≤ 229

Fork blank design

The blank adopted in this study is symmetrically rolledby cross wedge rolling. Figure 1 shows a simplified diagram of joint fork forging drawing. Figure 2 (a) and (b) show the size of half the blank obtained by CWR and half of the original blank respectively. The stepped shaft produced by symmetrical CWR provides the blank for the subsequent die forging. Two workpieces can be machined at a time, which greatly improves the production efficiency of the workpiece, improves the material utilization rate, and greatly reduces the manual labor. In the finite element simulation, in order to save the simulation time, we choose half of the cross wedge rolling blank as the research object.

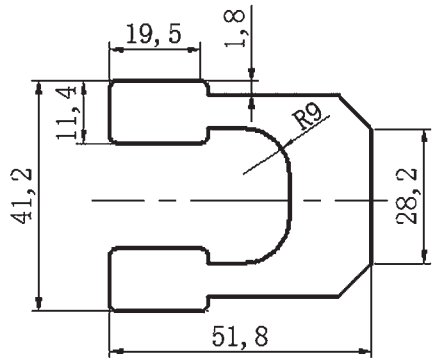

Figure 1 Fork product

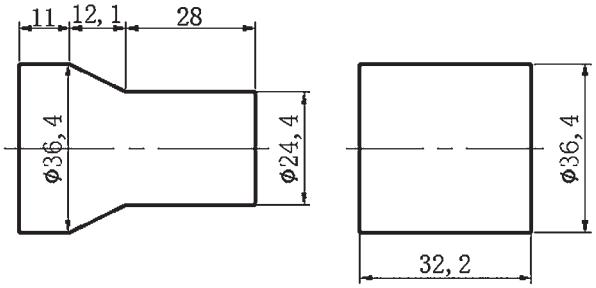

Figure 2 blank: (a)1/2 CWR blank; (b) 1/2 original blank

ESTABLISHMENT OF FINITE ELEMENT MODEL

Figure 3 is the forming process combining CWR and forging for the universal joint fork. The original blank is heated to proper temperature and rolled by CWR, then the stepped shaft is produced which provides the blank for die forging. This is the composite

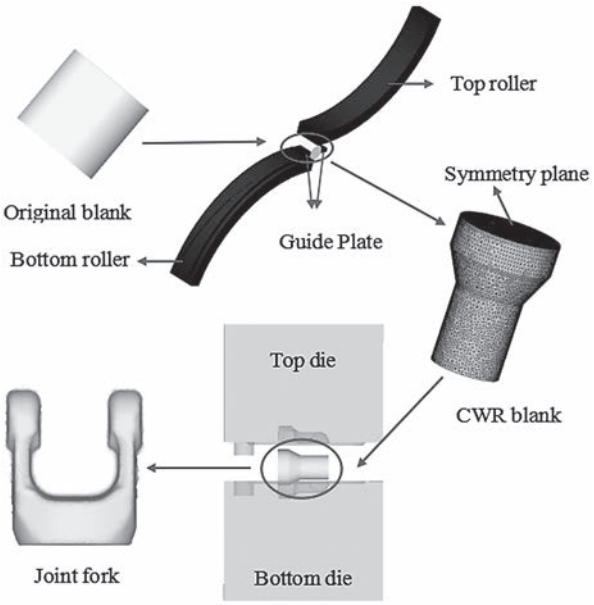

Figure 3 Forming process of the universal joint fork

technology of CWR and die forging. The finite element model is built based on Solideworks and Deform software. In the preprocessing of simulation, the die is defined as rigid body, blank is defined as plastic body. The material is AISI1045(45 steel), environment temperature is 20 °C, preheating temperature of die is 200 °C, convection factor between blank and environment is 0,2 N/(mm·s), heat transfer coefficient of the contact surface between the blank and the die is 11 and initial mesh number of blank is 50 000.

EFFECT OF FORMING PARAMETERS ON FORMING FORCE

Table 3 **Design parameters of single factor test**

N	T / °C	c	V / mm/s
1	1 000	0,3	50
2	1 050	0,3	50
3	1 100	0,3	50
4	1 150	0,3	50
5	1 200	0,3	50
6	1 050	0,2	50
7	1 050	0,25	50
8	1 050	0,35	50
9	1 050	0,4	50
10	1 050	0,3	100
11	1 050	0,3	150
12	1 050	0,3	200
13	1 050	0,3	250

Table 3 shows 13 groups of parameters in the simulation. Generally, the forming force is used to measure the difficult degree of forming process and it has an important influence on the service life of the die. During the forging, tempreture, friction factor and falling speed of the upper die are three key factors that affect the forming force. In this paper, the sing factor method was

adpoted to study the effect of these factors on the forming force.

Effect of temperature on forming force

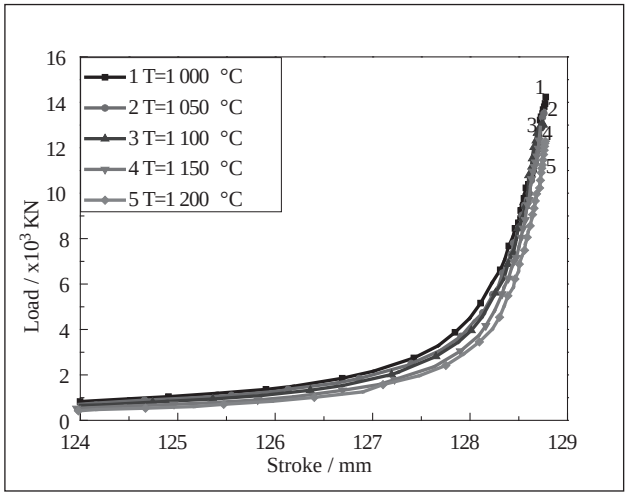

Figure 4 Stroke load curve at different temperatures

Figure 4 shows the stroke load curve at different temperatures. When the die is in contact with the blank, the temperature decreases and the change of the forming force is not obvious. With the further forging, the forming force is gradually increased. It is indicated that the reduction of temperature makes it difficult to form.

Effect of friction factor on forming force

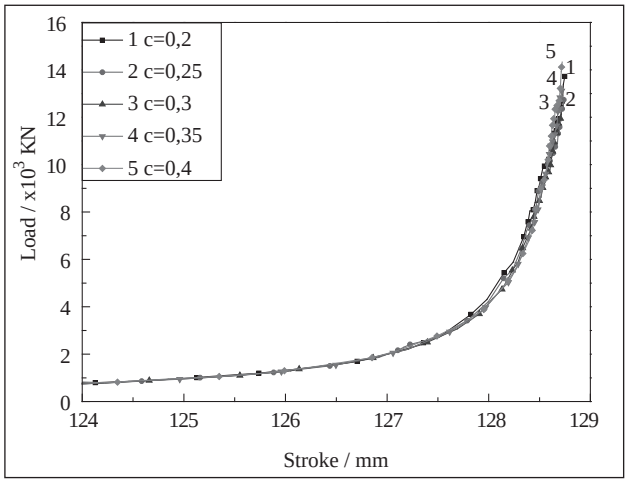

Figure 5 Stroke load curve at different friction factor

Figure 5 shows the stroke load curve at different speeds. Generally speaking, the friction factor has little influence on the forming force. Especially in the initial stage, the influence is very small. With the upper die moving down further, the area of the contacting surface increases, the influence of friction factor on forming force increases. The increase of friction factor makes forming of the fork more difficult. Therefore, good lubrication is beneficial to metal flow and improves die service life.

Effect of velocity on forming force

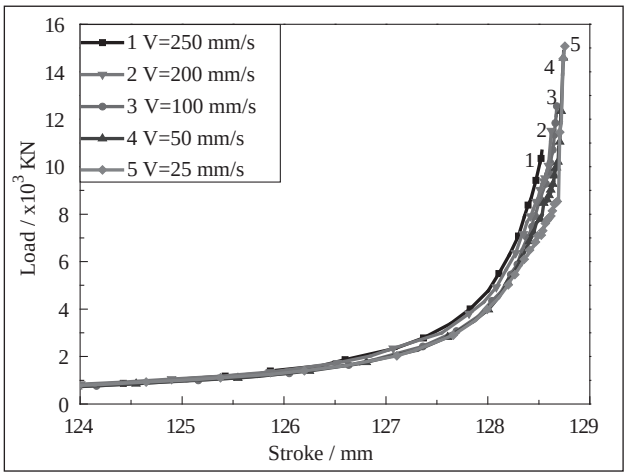

Figure 6 Stroke load curve at different speeds

Figure 6 shows the stroke load curve at different speeds.As the falling speed of the upper die increases, the strain rate increases, the deformation resistance increases, and the forming becomes more difficult. However, when the upper die moves at a high speed, the temperature decreases less and the final forming force decreases. So when the speed of the upper die is larger properly, it is favorable for the fork to form.

OPTIMIZATION OF DIE FORGING PROCESS PARAMETERS

According to the experience in production, the main process parameters affecting the forming force in the forging forming of universal joint fork are: temperature, friction factor, and speed of the upper die. Three-factor and three-level orthogonal test was designed. Table 4 shows the factor level table. Three main factors selected are temperature / A, friction factor / B, and the falling speed of upper mould / C. A, B and C are there factors in the orthogonal test. The orthogonal test scheme and results of range analysis are shown in Table 5.

Table 4 **Orthogonal factor level table of forming force of fork during forging**

Factor / Level	A / T / °C	B / c	C / V / mm/s
1	1 000	0,2	50
2	1 100	0,3	100
3	1 200	0,4	150

The smaller the forming force, the better the forming and the less wear on the die. Therefore, the smallest indicators Ti are selected. The optimal level is $A_1B_1C_3$. The optimal process parameters are temperature of 1 100 °C friction factor of 0,2, speed of the upper die of 150 mm/s. R is the range, which reflects the range of test indicators when the level of various factors change. Therefore, according to the value of R in Table 5, it can be obtained that the order of the factors is C > A > B, which is speed>temprature>friction factor (V > T> c) .

Table 5 **Project designingand range analysis of orthogonal test on forming force of die forging**

Factor	A	B	C	F / N
1	1	1	1	$1{,}46\times10^7$
2	1	2	2	$1{,}68\times10^7$
3	1	3	3	$1{,}35\times10^7$
4	2	1	2	$1{,}49\times10^7$
5	2	2	3	$1{,}34\times10^7$
6	2	3	1	$2{,}16\times10^7$
7	3	1	3	$1{,}62\times10^7$
8	3	2	1	$2{,}13\times10^7$
9	3	3	2	$1{,}68\times10^7$
T_1	4,50	4,57	5,75	44,59
T_2	5,00	5,15	4,86	
T_3	5,43	5,20	4,31	
t_1	1,50	1,52	1,92	
t_2	1,67	2,56	1,62	
t_3	1,81	1,73	1,44	
Optimal level	1	1	3	
Range:R	$9{,}30\times10^6$	$6{,}28\times10^6$	$1{,}45\times10^6$	
Order	C A B			

CONCLUSIONS

In this paper, the influence of process parameters, including temperature, friction factor and falling speed of upper die, on the forming force during the process of die forging for universal joint fork on the basis of the CWR blankis studied by DEFORM software.The following conclusions can be drawn:

(1) It is feasible to produce universal joint fork of automobile transmission shaft by CWR and forging composite process. The stepped shaft produced by CWR can provide the blank which is close to the volume distribution in preforging, and the quality of the material in die forging can be accurately distributed. Therefore, the most prominent feature of the rolling and forging composite process can save materials and reduce the forging procedure.

(2) Temperature, friction factor and stamping speed are the key factors influencing forming force in die forging process. The lower the temperature, the greater the friction factor, and the lower the falling speed, the greater the forming force, the more difficult for the forming. Properly raising the temperature, improving the lubrication conditions, and increasing the falling speed of upper die are beneficial to fork forming and can improve service life of the die.

(3) Orthogonal test was designed and the results show that the order of process parameters affecting the forming force of die forging is V > T > c, and the optimum combination of process parameters is temperature of 1 100 °C the friction factor of 0,2 and velocity of 150 mm/s.

Acknowledgements

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Note: The professional translator for the English language is QianQian Yan, Zhejiang, China