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Study on Warm Precision Forging of Half Axle Gears

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Abstract

A typical die-set for enclosed-die forging of half axle gears in double action hydraulic press is presented, the important factors those influence on precision forming of half axle gears are analyzed, warm forming process of half axle gears is simulated by FEM software DEFORM_3D. The results show, that proper die structure and dimension, suitable web thickness and position can improve material filling, ensure full filling of tooth cavity.

Keywords Half axle gears Warm precision forging Die structure Web Filling

1. Introduction

Nowadays, precision forging technology of gears becomes more and more popular. Some successes have been made in Germany, America and Japan etc. In Germany, cold precision forging Co. Wezel has forged successfully spur gears with good surface quality, tolerance rank 7~10 and great intensity [1]. In Japan, Co. Nichidai developed a new type die-set for enclosed-die forging in general presses and studied on precision forming process and equipment of bevel gears in three cylinders hydraulic press. Takigi analyzed the effect of speed ratio of upper and lower punches on precision forming of bevel gears [2].

In recent years, with computer-controlled double action hydraulic press developed successfully and FEM simulation software of massive forming carried out, precision forging technology of gears was developed rapidly. This paper presents a typical die-set for enclosed-die forging of half axle gears in double action hydraulic press, and analyzes the factors those influence on precision forming of half axle gears.

There are many factors, such as structure and dimension of die, web thickness and position and so on, which influence on forming load, metal flow and lifetime of die. Until now, reports on studying systemically all of those haven't been seen. In this paper, forming process of half axle gears is simulated by FEM simulation software DEFORM_3D, and various factors those influence on gears forming are studied. It presents the most suitable die structure, web thickness and position to forming of half axle gears. Moreover, it also presents a proper process of warm precise forging and a die based on 800-ton double action hydraulic press.

2. Analysis of process

Former precision forging process of half axle gears is as follows: heating→preforging→clipping→scale removal→heating→precision forging→clipping→cleaning surface→cold-forging tidying→machining inner hole, half axle and big-end→machining the spline of inner hole→heat treatment→shot blasting[3].

There are many disadvantages to the former process. For example, the expenditure of energy sources is excessive, stock utilization and machining efficiency are low, and lifetime of die is short. In order to solve these problems, through FEM simulation, a warm precision forging process without flash is carried out, which is energy-economizing, material-saving and high efficiency.

New process is as follows: heating with little oxygenation or without oxygenation → precision forging → cleaning surface → machining inner hole, half axle and big-end→machining spline of inner hole → heat treatment → shot blasting. Fig1 shows a part drawing of half axle gear; Fig2 reveals a precision forging sketch.

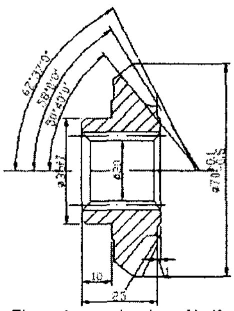


Figure 1: part drawing of half axle gear

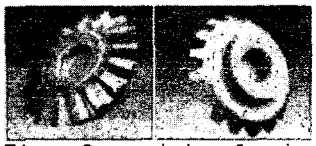


Figure2:precision forging sketch of half axle gear

In contrast to the former process, the new process cuts down six working procedures, such as preforging, heating after preforging, scale removal, twice clipping, and cold-forging tidying, and so on, which reduces greatly energy resources consuming and increases stock utilization to 90.1%. The productivity has been improved one time.

The key of designing die is how to make certain dimension of die with tooth. In order to ensuring final forming precision, heat expansion and springback of forging and die together with oxygenic skin should be taken into account. Assuming that temperature field of forging and die in finish-forging temperature is equal, so the heat expansion of forging and die should be equal and linear. Then dimension of cavity can be ascertained according to the formula below:

$$A=\beta_1 T_1-\beta_2 T_2-\varepsilon$$

In this formula:

A- equivalent weight linear-expansion ratio
β_1- forging material linear-expansion coefficient, mm/℃
β_2- die material linear-expansion coefficient, mm/℃
T_1- finish-forging temperature, ℃
T_2- die operating temperature, ℃
ε - equivalent weight elastic strain .

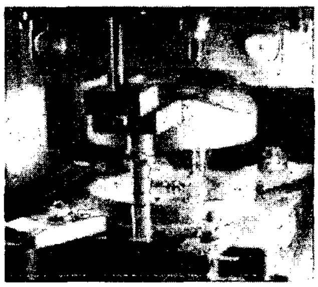


Figure 3: die-set for precision forging of half axle gear

3. Simulation and analysis

This paper expatiates the effect of die structure, web thickness and web position on gear forming, and describes the most suitable technology for gear forming. It also presents a typical die-set for enclosed-die forging of bevel gear in double action hydraulic press (Fig. 3).

3.1 Fundamental parameter setting

(1) Material is 20Cr, the American label is AISI5120; forging temperature is 800 ℃;

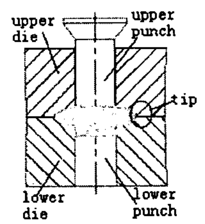
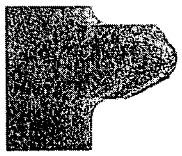
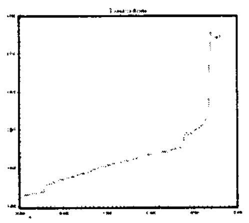
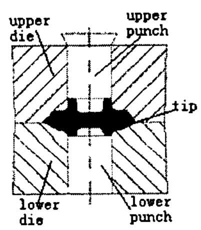
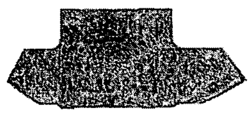
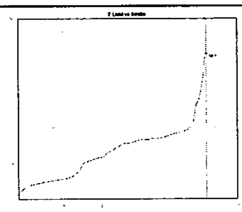
(2) Adopting rigid-plasticity FE model;

(3) Press velocity is 250mm/s;

(4) Friction boundary condition[6]: friction model adopts cutting model, ***m*** is friction shear factor. In this paper, **m**=0.25, ***k*** is the limit of intensity.

3.2 Effect of die structure on gear forming

Table 1: Effect of die structure on gear forming

	male/female die sketch	Mesh deforming sketch	stroke--load curve	stock utilization
project 1 billet Φ 35 × **58**				80.4%
project 2 billet Φ 35 × **52**				90.1%

It can be seen from table 1 that final forming part is at tip of gear big-end. Project 1 is designed according to traditional theory. Hole in forging which diameter is less than 25mm isn't forged[7]. In this project, bottom of upper punch and top of lower punch are flat. Die with tooth is upper, and die with back-cone is lower. Big-end tip of gear isn't forged. In this case, the top of tooth is difficult to fill. And at the end of forming, the load increases along a vertical line. The stress state of die is very severe, thus span-life of die is very short. Whereas in project 2, die with tooth is lower, and die with back-cone is upper. This structure is beneficial to locate billet and push forging out. In this case, big-end tip of gear is forged. Although it adds a removal-process, it brings the advantage, such as containing redundant material and ensuring filling of flank profile. On the other hand, improving the structure of punch as adding a dummy that its size and figure is suitable below the upper punch and above the lower punch can bring some radial force to billet, so it is beneficial to metal flow and improves largely the state of die fill. Finally, the profile of gear is well-rounded, there is no failing on it at all. Because of the rubbing effect between dummy club and billet, the maximal load was not obviously reduced relative to the former, but the status of abrupt change to load is remitted, thus the lifetime of die could be prolonged. At the same time, stock utilization is increased by 9.7percent relative to project 1, and the man-hour of machining hole could be decreased, so economic effect is very remarkable.

Figure 4 shows the experimental result about effect of die structure on gear forming. From it, it can be seen that Pb. check bar formed according to project 1 hasn't been filled up. There is obvious trail along which metal flows to gear big-end at both the top and root of tooth, which looks like ripple going ahead with layer upon layer. However, the profile of Pb. check bar formed according to project 2 is very clear and its tooth is well-rounded.

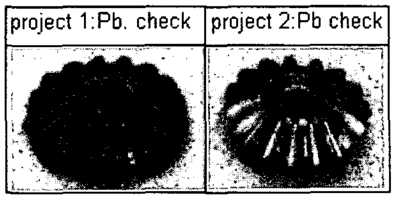


Figure4: experimental result about effect of die structure on gear forming

The experimental result is fit well with the simulative result.

3.3 Effect of web thickness and position on gear forming

1) Effect of different web thickness on gear forming

Figure 5 shows a drawing of web position. In this drawing, d=20mm,H=15mm, t figures web position, h figures distance between web and end surface. The die configuration in table 2 is same as that in the project 2. When h= 0.42H(namely the web central line passes through tooth tip), effect of different web thickness on gear forming is shown in table 2.

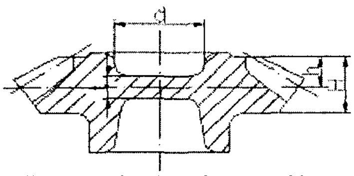


Figure 5: drawing of web position

Table2: effect of web thickness on gear forming

t	Load(ton)	Metal flow	Die fill	Damage factor of material	Overall evaluation
4mm	51.16	fair	good	0.3428	fair
6mm	48.41	good	good	0.2994	good
8mm	51.77	bad	fair	0.2957	bad

2) Effect of web position on gear forming

In table 3: t=0.3d. The die configuration in the table is same as that in the project 2. This table shows effect of web position on gear forming.

Table 3: influence of web position on gear forming

h	Load(ton)	Metal flow	Die fill	Damage factor of material	Overall evaluation
0.4H	48.52	good	good	0.30	good
0.5H	45.43	better	better	0.2957	better
0.6H	45.80	fair	fair	0.3088	fair

From table 3, it can be seen that different web position has different influence on load, metal flow, die fill and the material damage. When h=0.6H, metal flow and die fill are dissatisfied, further more, material damage is big relative to the others; when h=0.4H~0.5H, metal flow is equal and die is easy to fill. Overall evaluating the above factors, when h=0.5H, it is in the most favor of gear forming.

4. Conclusion

(1) The flank profile filled completely is the key of warm forging of half axle gears. Big-end tip of gear is the part where is the most difficult to fill ultimately. The phenomena that load rises rapidly appears at the phase during which the big-end tip of gear is filled.

(2) Improving die structure, big-end tip of gear is forged. This tip can contain redundant material and ensure filling of flank profile.

(3) Improving the structure of punch as adding a dummy club that its size and figure is suitable below the upper punch and above the lower punch can bring some radial force to billet, it is beneficial to metal flow and improves largely the state of die fill.

(4) Suitable web position and thickness plays important role in gear forging too. When t=0.3d, h=0.5H, the state of gear forming is the best.

(5) If only die structure is reasonable, hole in forging whose diameter is less than 25mm should be forged, moreover, it is beneficial to die fill.

References

[1] Neher R. Cold Forging of Gears and Profiles of Couplings. Neuere Entwicklungen in der Massivumformung, in Fellbach bei Stuttgart, 1999：305~311.

[2] Takigi, Precision Forging of Aluminum and Steel, Especially in Enclosed-die Forging. Neuere Entwicklungen in der Massivumformung, in Fellbach bei Stuttgart, 1999：339-351.

[3] Tian Fuxiang. Design and Manufacture of Die Using in Precision Forging of Bevel Gear. Manufacture of Die，2002（12）：28~33.

[4]. Tian Fuxiang. Design of the New-Typed Forging Die for the Planet Gears. Die Industry，2003（2）：35.

[5] Chen Yu, etc. Study on Cold Precision Forging of Spur Gear Forms. Forging skill，2003（2）：11~12.

[6] Peng Yinghong. Simulation Technique of Metal Forming. Shanghai：Shanghai Jiaotong University Publishing Company，1999.

[7] Xia Juchen. Metal Precision Forming Processes. Beijing：Machine Industry Publishing Company，1999.