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The Research on Precision Forging of Spur Gears

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Abstract

The cold precision forging of spur gears has been researched, and the effects of relief-hole shape and forging process on the spur gears forming has been analyzed. The results present that the forging load decreases when a suitability diameter of relief-hole is chosen, but the function is not obvious. The spur gears precision forging method with an adjustable movement of concave mould can benefit both the top and the bottom corners forming of the spur gears, full fill the tooth cavity, and decrease the forging load.

Keywords: spur gears; cold precision forging; forging process

1. Introduction

The gears which act as one of the most basic parts in transmitting action and power have got a very extensive application in engineering. The precision forging process which used to produce spur gears is a kind of new process and new technology with a tempting foreground. Comparing with the traditional machining method, it can not only make the material utilization of forging spur gears increase to 70% above from current approximate 40%, but also increase gear strength 20% above and production efficiency about 40%.[1,2].

Though the precision forging of spur gears has a very big application foreground, the gear tooth filling (especially both the top and the bottom corners) is difficult, the forming load is large, so that the spur gears precision technology is located at lab researched moment at present[3,4]. In this paper, the influence of the specimen shape with relief-hole and forging process on forging gear are systemically analyzed used the research method which combined a finite-element simulation with experiment.

2. Experiment equipment and method

The related parameters of the spur gears are shown in Table.1 and the outline of experiment apparatus is shown as Fig.1.

Table.1 spur gear parameters

Gear tooth number	18
Mould	3mm
Tooth thickness	25mm
Pressure angular	20°

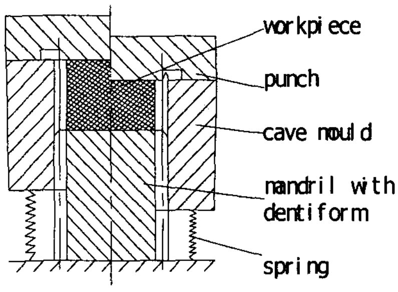
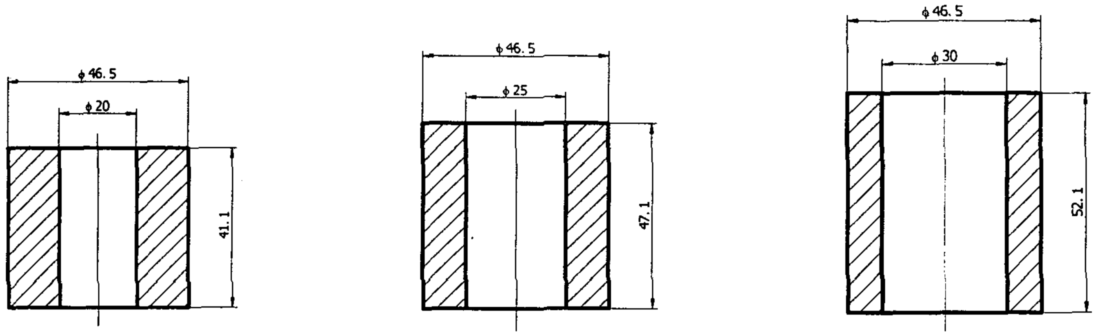


Fig.1 Outline of experiment apparatus

3. Experiment results and analysis

3.1 The influence of the specimen shape with relief-hole on forging gear

Experimental specimen dimension is shown in Fig.2.



(a) relief-hole diameter 20mm (b) relief-hole diameter 25mm (c) relief-hole diameter 30mm

Fig.2 specimen with relief-hole

Using experiment apparatus shown as Fig.1, specimen material which is 15 steel (cold condition), working speed which is 2mm/s, friction coefficient which is 0.3, the forging process is simulated by DEFORM software, and then the results shown as Table. 2 are got.

Table.2 Numerical simulation results of specimen with relief-hole

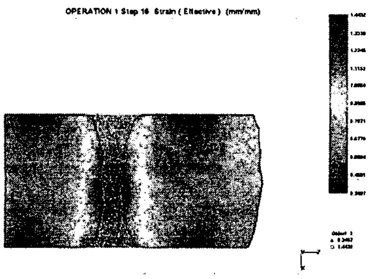
Relief-hole diameter/mm	Working load/KN	Actual stroke/mm	Filling analysis
□20	5079.8*[1]	18	Up angular corner of the spur gear do not been filled enough, relief-hole is vanished
□25	6451	22	Filling is enough, up angular corner is round, relief-hole is just vanished
□30	4122*[2]	27	Filling is not enough, relief-hole does not been vanished

*1Relief-hole is closed in advance, inside metal overlaps to cause mesh distortion, the part is inferior.

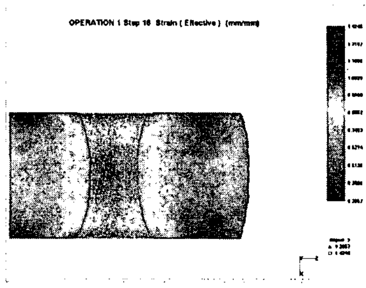
*2 Double-bulge is appeared, metal overlaps to cause mesh distort, the part is inferior.

It can observed from the table.2 that the relief-hole which diameter is 20mm has already been closed before the tooth cavity filled in the course of simulation, which cause inside metal overlaps and mesh distort, simulation is withdraw before the up corner of spur gear filled enough. The fact proves that the relief-hole has not realized function divided flow for the specimen which relief-hole diameter is 20mm. But comparing with relief-hole diameter is 25mm, the relief-hole is closed until the gear tooth filling stage finished, the divided flow function can be embodied out. Comparing with relief-hole diameter is 30mm, because the wall is too thin, double-bulge is appeared, metal overlaps to cause mesh distort, and the simulation failed to be finished.

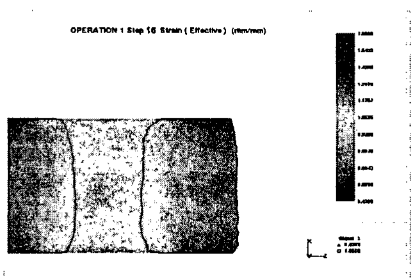
The effective strain distribution of the forgings is shown in Fig.3. It is shown that the effective strain distribution of relief-hole diameter 20mm is similar to what of relief-hole diameter 25mm and the outside effective strain is slightly greater than inside one. This proves the trend that the metal of these two kinds of specimens flows inwards and outwards is relatively consistent. The inside effective strain of the specimen which relief-hole diameter is 30mm is greater than outside one. This proves that filling the tooth cavity is not enough. Interior holes shrink of these three kind specimen is different in forging process. The diameter 20mm relief-hole has already been closed before the tooth cavity were filled enough, the specimen relief-hole shrinking of the relief-hole diameter 30mm is fast than filling in the tooth cavity, but the specimen relief-hole shrinking of the relief-hole diameter 25 is synchronized with filling in the tooth cavity outwards.



(a) relief-hole diameter 20mm



(b) relief-hole diameter is 25mm



(c) relief-hole diameter is 30mm

Fig.3 effective strain distribution

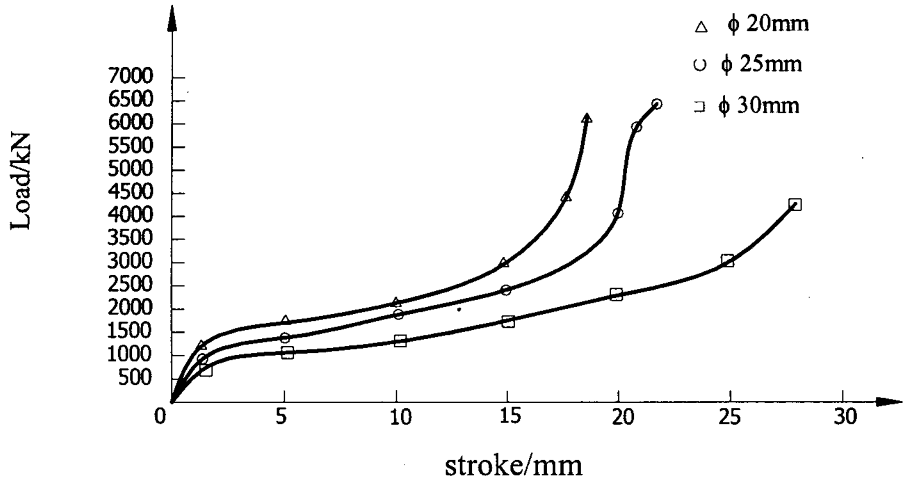


Fig.4 the load-stroke curves of different relief-hole diameter

It can be observed from Fig.4 that the tendencies of these three curves are the same basically. Just the curves rise relatively fast at the beginning stage, the curves rise gently when the strokes are greater than 3mm, and then the curves begin to rise sharply after the working load is higher than 3000kN. But these curves are different with each other on the detail. Because the relief-hole shrinks comparatively fast, the load curve of specimen with diameter 20mm rises sharply in the relatively little stroke. Because the relief-hole shrinks relatively slowly, the load curve of specimen with diameter 30mm has not entered steep stage of rising even after stalling for a long time. The load curve of specimen with diameter 25mm lays between other two a pair of curves. At the last stage on the curves, because the relief-hole which diameter is 20mm has already been closed before the tooth cavity is filled and the relief-hole which diameter is 30mm, the wall is too thin, double-bulge is appeared, metal overlaps to cause mesh distort, the simulation failed to be finished, then the curves aren't complete. But the specimen relief-hole shrinking of the relief-hole diameter 25 is synchronized with filling in the tooth cavity outwards, the simulation is finished. The curve begins to make gently at the last stage of rising steeply, divided flow function has been embodied, but the function is not very obvious, comparing with no relief-hole, the load has only been reduced by 2%.

The copper specimen is taken to carry on process experiment, the animal fat is adopted to lubricate on the specimen surface, and a spur gear is got as Fig.5 when the working load reaches 2800KN.

The relief-hole is just closed. Tooth filling situation has the typical characteristic of forging with force float concave moulds. It is completer that the specimen down corner is filled with, and the big burr is appeared under the drove of concave mould. It is complete to fill in the middle part, but the corner is slightly round. The round of upper corner of the spur gear is relatively big.

Above mentioned characteristics and numerical simulation results are identical, it proves that the result of the numerical simulation is relatively reliable.

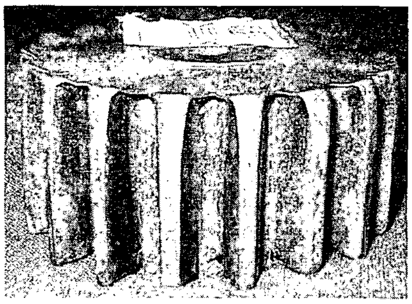


Fig.5 the specimen of relief-hole diameter 25mm

3.2 Forging with an adjustable float concave mould

When forging with a float concave mould, because of the friction, the tooth can not be filled with evenly, it is better to be filled with one side, and filling in another side is relatively weak. If concave mould can be adjusted in the whole forging process, it moves down at the beginning, moves up at the certain point, then upper and lower corner of the specimen can be filled enough, and because the tooth is evenly filled, the working load will be reduced.

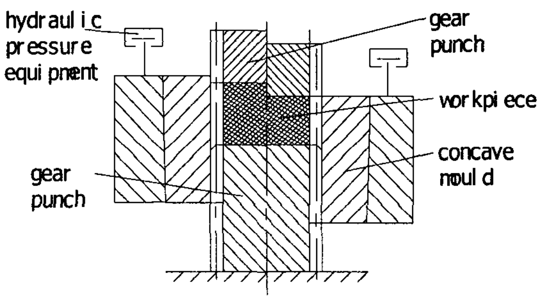


Fig.6 Outline of experiment apparatus

Experiment apparatus is shown as Fig.6, specimen material which is 15 steel (cold condition), working speed which is 2mm/s, friction coefficient which is 0.3, and a complete spur gear is got when the working load is 5691kN, and the stroke is 15mm.

From the load-stroke curve shown in Fig.7, it can be found out that the whole curve rises steeply at the end, and the ascendant trend is relatively mild. The working load reduces by 12.8% than that of adopting common float concave mould.

The experimental condition is shown as 2.1, the concave mould movement can be adjusted, first it moves down 8.6mm, then moves up 0.6mm, a copper spur gear shown as Fig.8 is got when the working load reaches 2800KN.

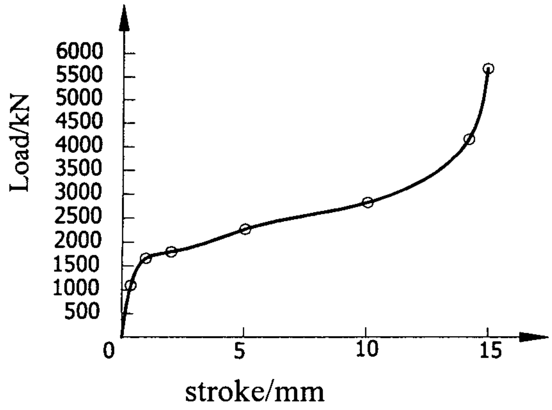


Fig.7 Load-stroke curve

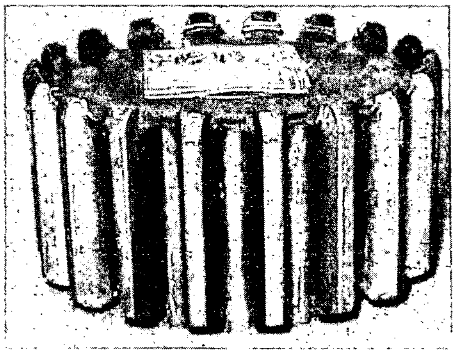


Fig.8 the copper spur gear forged with an adjustable float concave mould

It can be observed from Fig.8 that the tooth shape is very complete. Comparing with common float mould forging process when the working load is 2800KN, the result can not be got, and the tooth shape of upper corner has not been full filled as shown as Fig.5.

4. Conclusion

a. Choosing a suitable relief-hole diameter, the working load can be reduced, but the function is not very obvious, and the working load is reduced by about nearly 2%.

b. Adopting the precision forging method of adjustable float concave mould, the tooth cavity is relatively even filled, and a complete spur gear can be got at relatively low load.

Reference

[1] 林治平、陶泽球等，直齿圆柱齿轮精锻工艺方案的研究，锻压技术，1999.NO.2:9

[2] K.Kondo and K.Ohga, Precision cold die forging of a ring gear by divided flow method, Int. J. Mach. Tools.Manu. fact., 1995.35(8): 1105

[3] N.R. Chitkara and M.A. Bhuttr, Near-net shape forging of spur gear forms: an analysis and some experiments, Int. J. Mech. Sci., 1996.39(8-9): 891

[4] 陈泽中、包忠诩等，直齿圆柱齿轮精锻技术的研究进展，金属成形工艺，1999.17(5):

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