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Based on The Robust Design of Gear Die Optimization

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ABSTRUCT: The article is based on the optimization of bevel gear (the modulus is 5.2 and the max diameter is 157mm) preforming Die, then optimizing the final Die. Due to the finished forging is cold sizing, so the load is higher than preforming, and lead to a higher wear depth. This article will through design the final Die to reduce the wear depth and load. Based on the simulation technology and Taguchi to optimize and analysis the Die scheme. At last, get the best optimization final Die, and instruct the reality production.
Keywords: Bevel gear; Die; Taguchi robust design; optimization

I.INTRODUCTION

The optimization design of the final forging die of the bevel gear of this subject is based on the initial die optimization, and further optimizes the final forging die[1,2]. Since the maximum diameter of the straight bevel gear reaches 157mm, the final forging is cold finishing, so the load required during the forming process is larger, and the die wear is much larger than the pre forged die. So this chapter will be the traditional mold design of bevel gear cold forging and the inspection of the relevant literature based on the design of the two bevel gears finishing die, die die that combined combined bridge with diversion hole and bridge with the boss. Then the optimization of the final forging die is carried out by combining Taguchi robust design with the numerical simulation software[3-5], thus reducing the die wear and forming load and determining the optimum die scheme
As shown in Fig. 1.1, the bevel gear is machined in turn, and the corresponding parameters of the bevel gear are shown in table 1.1.

As shown in Figure 1.2, the combination of the flying bridge and the porthole die, as shown in Figure 1.3, is a combination of the flying bridge and the lug type die.

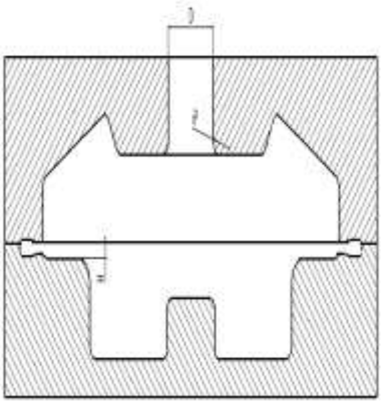



Fig1.1 Bevel gearFig1.2 Flash land and tap hole of final Die section view

II. OPTIMIZATION OF COMBINED DIE OF FLYING BRIDGE AND PORTHOLE HOLE

The die is optimized by using small feature[6-8], and the corresponding signal-to-noise ratio (S/N) is calculated as follows:

$$\eta = -10\log_{10}(\frac{1}{N}\sum_{i=1}^{N}X_i^2) \quad (2\text{-}1)$$

According to the mould shown in Figure three, the 1.2 design variables correspond to the horizontal values, as shown in Table 2.1. The orthogonal table designed according to Taguchi method is shown in table 2,2.

Tab 2.1 The levels of design variance

水平数	D/mm	R/mm	H/mm
1	22	3	1
2	24	4	2
3	26	5	3

Tab 2.2 Experiments scheme

试验序号	D/mm	R/mm	H/mm
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	3
9	3	3	2

UG modeling based on 9 sets of mould design are shown in table 2.2, and then based on the Deform numerical simulation software and based on the simulation results, combined with the analysis of mould wear depth of H and F at small load characteristics, the calculation of each scheme results as shown in table 2.3. According to the signal to noise ratio of each factor in Table 2.3, the average signal-to-noise ratio (SNR) of the die wear depth and the extrusion force under different schemes are calculated as shown in Table 2.4 and table 2.5 respectively.

Tab 2.3 Analysis result and S/N ratio

方案	H/10^{-6}mm	H(S/N)	F(KN)	F(S/N)
1	3.32	109.57	33960	-90.619
2	6.04	104.3	30840	-89.782
3	3.91	108.02	26220	-88.372
4	3.30	109.63	28320	-89.041
5	3.25	109.76	26820	-88.569
6	7.91	102.04	30720	-89.748
7	3.25	109.76	25380	-88.089
8	3.53	109.04	30240	-89.611
9	4.12	107.70	27840	-88.893

Tab 2.4 The average of S/N ratio of the different parameters about the Die wear

水平值	D	R	H
1	107.3	109.7	106.9
2	107.1	107.7	107.4
3	108.8	105.9	109.2

Tab 2.5 The average of S/N ratio of the different parameters about the load

水平值	D	R	H
1	-89.59	-89.25	-89.99
2	-89.12	-89.32	-89.24
3	-88.86	-89.00	-88.34

Based on the principle of small feature, combining the maximum value of the average signal-to-noise ratio in each factor, the optimal process parameters are obtained. The optimum process combination is D3R1H3, and the optimum combination of forming load is D3R3H3.According to the optimum technological scheme of the previous section, the prediction of the signal-to-noise ratio of the process scheme by means of formula (2-2) is carried out:

$$\eta_p = \eta_a + \sum_{v=1}^{q} \left(\overline{\eta_v} - \eta_a \right) \quad (2\text{-}2)$$

D3R1H3 optimal process scheme of bevel gear die wear rate using the formula of the signal-to-noise ratio of the calculated value is 112.4, the depth of die wear the corresponding value of 2.39E-6mm, numerical simulation of die wear depth of D3R1H3 scheme based on 3.25E-6mm is 35.9% and the predicted value, but the 9 groups compared by experimental design of die wear and found the minimum depth the forming load is 25380KN, verifying the accuracy of the test.

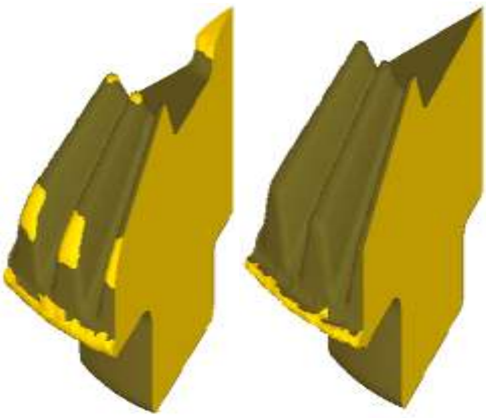
The optimal process scheme for the wear value of bevel gear dies is D3R3H3, the signal-to-noise ratio is -87.82, and the corresponding forming load is 24604. The extrusion force of numerical simulation is 23520KN, and the corresponding signal-to-noise ratio is -87.43, which is 4.4% difference from the predicted value, and the corresponding die wear depth is 9.13E-6mm.
he contrast analysis shows that the load difference between the two groups is small, but the die wear is different, and the scheme D3R1H3 is used as the reference die.

III.OPTIMIZATION OF COMBINED DIE OF FLYING BRIDGE AND LUG

The use of formula (2-2) on the prediction of die wear value to calculate the signal-to-noise ratio is 103.5866, the depth of die wear corresponding to 6.62e-6mm, the wear depth of optimal scheme corresponding to the H2W3D1 value of 6.78e-6mm, predicted that a difference of 2.42%, the forming load is 31149KN.
The prediction of the wear value of bevel gear mold is -88.894, and the corresponding forming load is 27841KN. The load optimal scheme H3W2D1 is modeled and the numerical simulation results show that the forming load is 28820KN, and the difference between the predicted values is 3.52%. At the same time, the maximum depth of die wear is 5.50e-6mm.The comparison shows that the die wear and forming load of the program H3W2D1 are better than the scheme H2W3D1, so the scheme H3W2D1 is used as the reference die.

IV.TWO GROUPS OF THE BEST DIE SCHEME ANALYSIS

From figure 4.1 (a) is shown for bevel gear bridge and fly flow combination die mold sticking rate diagram, the tooth bevel gear on the bottom is not filled, so the scheme of gear forming accuracy; figure 4.1 (b) for bevel gear bridge and convex combination die mold sticking rate, know the tooth filling is complete, high precision.Fig. 4.2 (a) scheme 1, die wear depth is 3.25E-6mm, Figure 4.2 (b) scheme 2, mold wear depth is 5.5E-6mm.



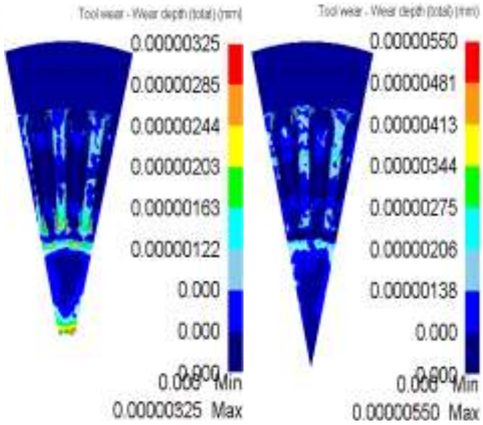
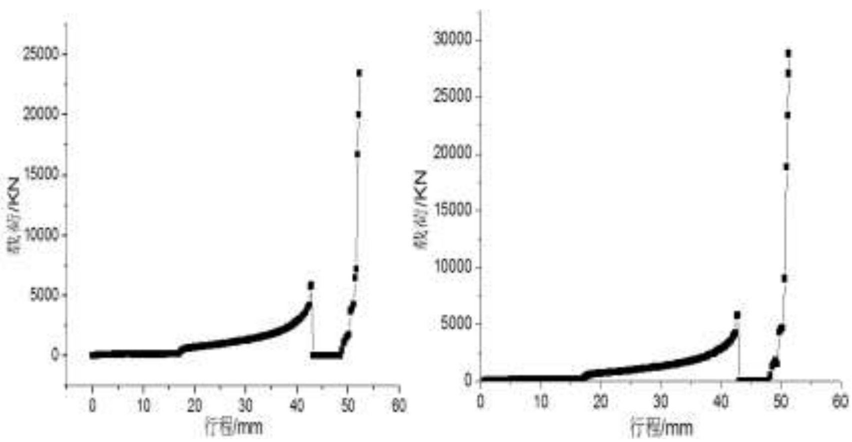


Fig4.1 (a)Scheme1 contact rate (b)Scheme2 contact rateFig4.2 (a)Scheme1 wear depth (b)Scheme2 wear depth

As shown in Fig. 4.3 (a), the maximum forming load of the bevel gear of the scheme 1 is 25380KN, as shown in Fig. 4.3 (b), the maximum forming load of the bevel gear of scheme 2 is 28820KNKN.



(a) (b)

Fig4.3 (a) Scheme1load (b)Scheme2 laod

V.CONCLUSION

According to the two sets of end forging die scheme of bevel gear, based on the contrast analysis of Taguchi's robust design:

In order to ensure the forming quality and accuracy of the bevel gear, the flying edge bridge and the convex platform combined die are adopted;(2) according to the optimization of bridge and the boss combined die results when the bridge height of 3mm and bridge width is 5mm, the boss height is 0, die wear is 5.5E-6mm, the initial plan was reduced by 9.8%, the forming load is 28820KN, reduced by 33.8% compared to the initial program.

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