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Gear Shaft Optimization Design

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Abstract: Multi-objective optimization design of gear shaft, first determine the design variables, gear shaft structure size mainly includes length size and radius size, gear shaft shaft diameter as the optimization variable, the equivalent force of gear shaft is an important indicator of static performance, and the gear shaft is optimized with the maximum equivalent force of gear shaft as the optimization goal.

Keywords: Gear shafts, Fatigue, Optimize.

1. Design Variables

There are 6 characteristic parameters of the entire gear shaft structure, if all parameters of the gear shaft are used as design variables, it will lead to a lot of candidate points in the optimization design process, the calculation amount is relatively large, in order to ensure the overall calculation scale, the value of each design variable is relatively small, and the accuracy of the response surface is also very demanding. Therefore, when selecting the design variables, ensure that the original structure of the gear shaft does not change, that is, the length of each section of the gear shaft remains unchanged, and the output shaft structure is optimized by changing the radius of the gear shaft, and the four parameters of R1, R2, R3 and R4, and the experimental design and results are shown in Table 1, and 25 sets of experimental results are obtained through orthogonal experiments.

Table 1. Experimental design and results

serial number	R1/mm	R2/mm	R3/mm	R4/mm	Maximum stress /MPa
1	12	15.5	13	3.2	0.743386
2	10.8	15.5	13	3.2	0.894217
3	13.2	15.5	13	3.2	0.719876
4	12	13.95	13	3.2	0.814058
5	12	17.05	13	3.2	0.852157
6	12	15.5	11.7	3.2	0.841263
7	12	16.5	11.9	3.2	0.850213
8	12.6	15.8	11.7	3.2	0.871261
…	…	…	…	…	…
18	11.15495	1546152	11.61542	3.324561	0.71453
19	12.44505	15.46152	12.08453	3.051524	0.691831
20	11.02391	16.59152	12.08453	3.422524	1.011354
21	11.15495	16.59152	12.08453	3.422524	1.051664
22	12.84505	16.59152	12.08453	3.422524	0.590854
23	11.15495	14.40848	13.91547	3.422524	0.957734
24	12.84505	14.40848	13.91547	3.422524	0.777031
25	11.15495	16.59152	13.91547	3.422524	1.01831

All objective functions will change with the change of design variables, their amount of change is different, the response surface not only gives the sensitivity of a single design variable to the objective function, but also gives the relationship between the cross parameters and the objective function, Figure 1 a is R1, R2 on the gear shaft maximum equivalent force response surface diagram, gear shaft equivalent force changes between 0.67MPa ~ 1 MPa, compared with the original equivalent force 0.74MPa, the change range is between -10% ~ +35%, Figure 1 e is R1, The maximum equivalent force response surface of R3 to the gear shaft, in the response surface determined by R1 and R4, the gear shaft equivalent force varies between 0.65MPa~1 MPa, compared with the original equivalent force of 0.74MPa, the change range is between -12.7%~+35%, indicating that there is room for optimization of the gear shaft structure.

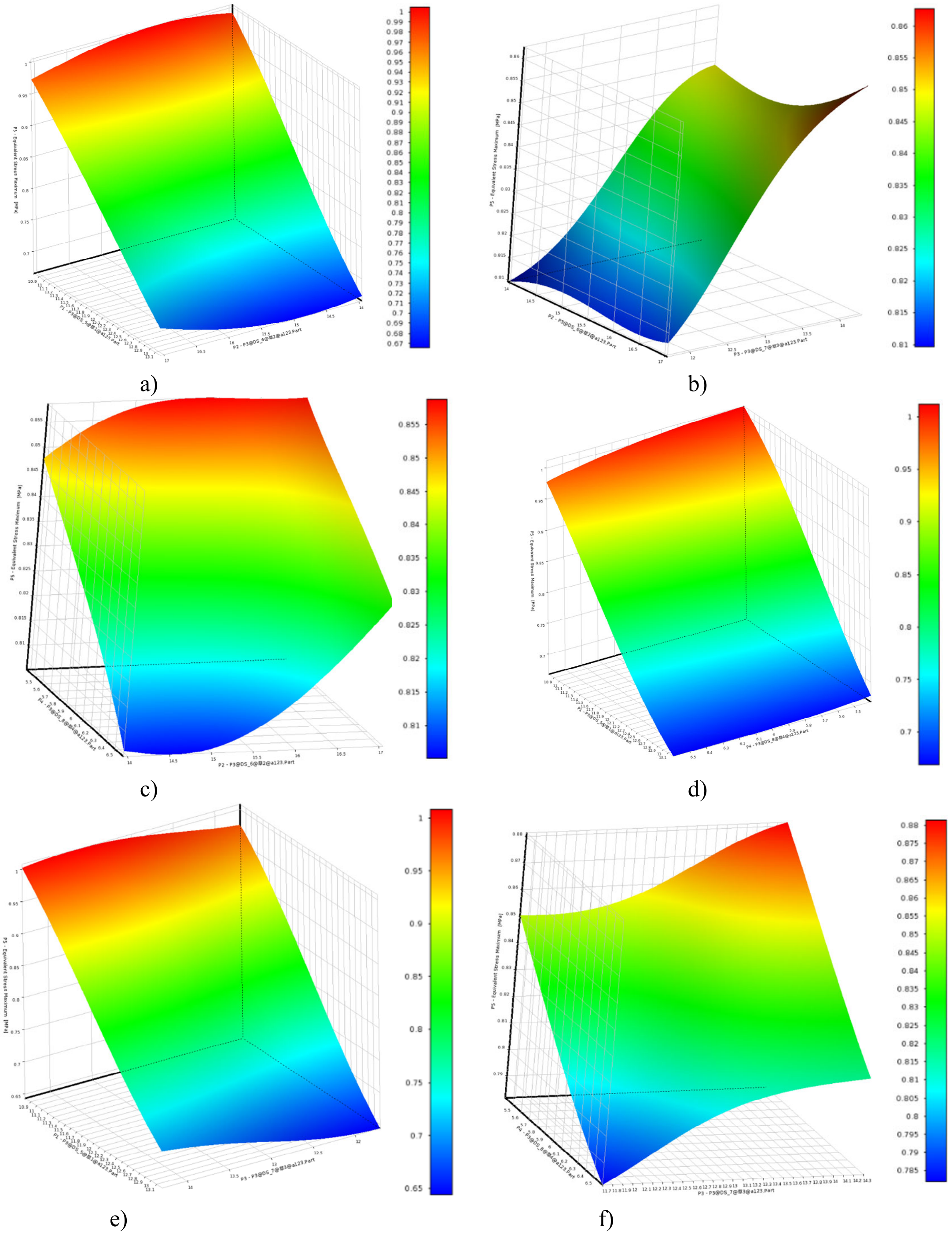


Figure 1. Variables affect the trend on the maximum equivalent force

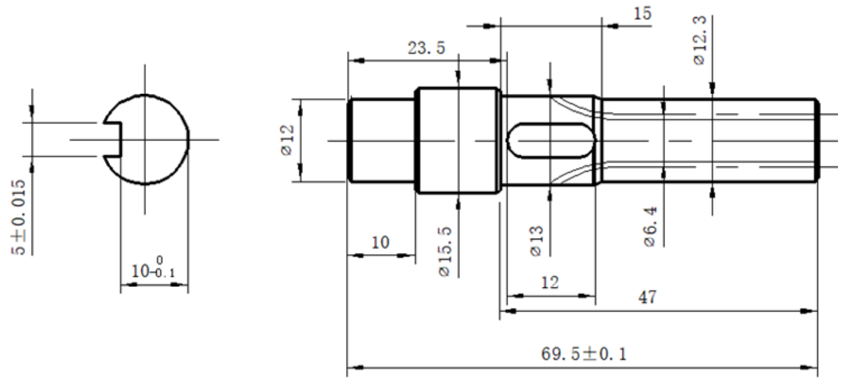
In the optimization results, three sets of optimal data are selected for comparison, the maximum stress difference of the three groups of data is small, and the size change of the gear shaft in group B is the smallest, so the optimal design point of group B is selected.

2. Optimize the Model

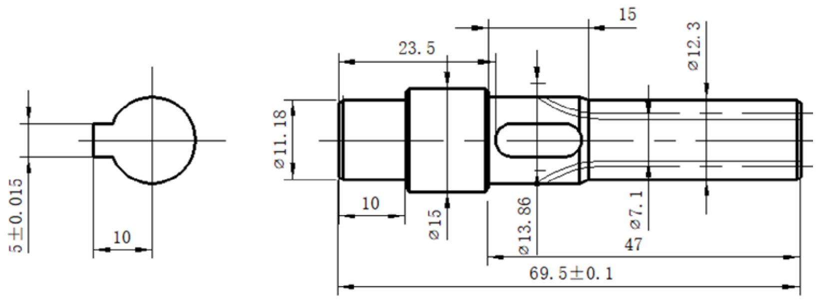
Table 2. Candidate Design Points

Candidate points	R1/mm	R2/mm	R3/mm	R4/mm	Equivalent forces /MPa
A	11.79	15.182	13.83	3.59	0.63109
B	11.18	15	13.86	3.57	0.63287
C	11.19	14.68	13.83	3.59	0.63296

The optimized front gear shaft structure size is shown in Figure 2 a, Figure 2 b is the optimized rear gear shaft parts drawing, the optimized front gear shaft R1, R2, R3, R4 sizes are 6mm, 7.25mm, 6.5mm, 3.15mm, optimized rear gear R1, R2, R3, R4 sizes are 5.59mm, 7.5mm, 6.93mm, 3.52mm, the original gear shaft is modified to a flat key structure.



a)

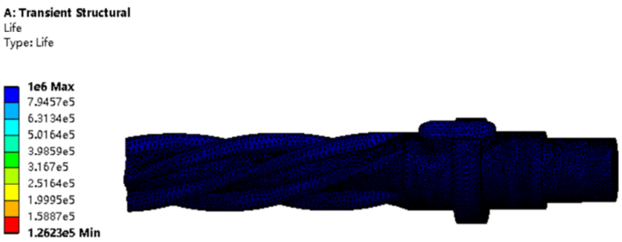


b)

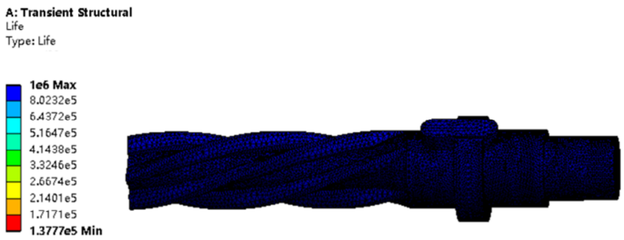
Figure 2. Optimize front and rear gear shaft part drawings

3. Simulation Experiments

Fig. 3 is the gear shaft under different working conditions of the minimum life distribution chart, most of the area of the gear shaft fatigue life is greater than 7.78×105 times, the overall life can also meet the design life of the gear shaft 100,000 times, from the bar chart can be seen, the higher the applied load size, the higher the frequency of direction change gear shaft life is lower, which is consistent with the simulation results.



a)



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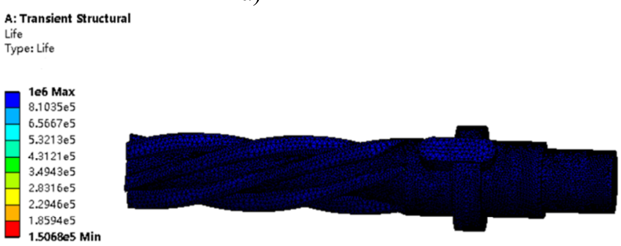

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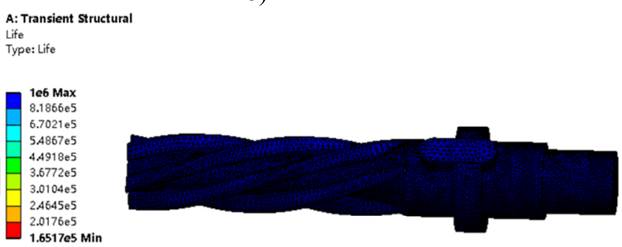

d)

Figure 3. Cloud map of gear shaft fatigue life distribution

4. Load Testing

The test site of the barrier gate is shown in Figure 4, the motor and reducer and other components in the barrier gate chassis, by controlling the speed and rotation direction of the motor, controlling the movement speed and direction of the barrier, testing the performance of the reducer under different working conditions of the barrier gate needs to set the gate rod movement cycle, by setting the parameters in the controller, controlling the lifting rod and falling rod time of the barrier, testing the fatigue life of the gear shaft under 4 different working conditions. The barrier working conditions and the number of test samples are shown in Table 3, and 4 gear shafts are tested for each working condition, and the gear shafts produced by processing are shown in Figure 4.

Figure 4. Load test site

Table 3. The working conditions of the gate and the number of samples

Working conditions	Time	Number of samples
1	4s	4
2	6s	4
3	8s	4
4	10s	4

In the process of testing, there have been no overload, improper operation and other problems, the gear shaft life test results under four different barrier gate conditions are 129400-136400 times, 144300-148600 times, 159600-165800 times and 173500-178550 times, the simulation test results under four different barrier conditions are 126230 times, 137770 times, 150680 times, 165170 times, and the error between the actual test results and the simulation results is within 8%. All have reached the design working life of the gear shaft 100,000 times.

5. Summary

The size of the gear shaft is improved by the response surface optimization, and the keyway of the gear shaft is modified to a flat key structure, and the fatigue life of the optimized gear shaft meets the requirements of use. The optimized gear shaft has interference in the production and processing, so adjust the position of the flat key structure and the size of the shaft section to meet the processing requirements, and the fatigue life of the gear shaft after being improved again also meets the requirements of use, the improved gear shaft is loaded into the reducer for load testing, and the test results show that the gear shaft life meets the requirements of use, and the test results of the reducer barrier load are less different from the simulation results, and all meet the service life of the barrier.

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