Enhancing the Precision of Timing Gear Used in Automobile by Making Use of Azotizing Deformation

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Abstract. Statistic analysis about the effect of heat treatment deformation on tooth profile deviation distribution of the timing gear used in automobile is done with mathematical statistics. Based on the research on the effect of the heat treatment deformation on tooth profile deviation, helical deviation and common normal length etc, the processing measure, tolerance and correcting quantity before and after azotizing treatment can be adjusted to optimize the gear process and to enhance processing precision of the gear.

1 Introduction

The timing gear used in automobile is mostly involute gear. The process of gear made of middle carbon steel or middle carbon alloy steel, hardening and tempering, is generally hobbing or shaping, shaving or extruding, heat treatment, honing[1]..

The high quality and capability of gears not only depend on advanced design method, but also high manufacture technical level. Process of gear modification is developed along fining orientation as the demand for gear accuracy become high. Gear modification is one of key technology among gear design and manufacture. A lot of errors are produced during the process of gear manufacture. The tooth profile is in the range of modification K form chart, but middle dent of tooth profile and addendum thick or dedendum thick of tooth profile appears sometimes[2~3]. A large number of trial and gauging data are demanded to analize the causes of the errors in order to get idea gear modification. The errors are possibly caused by cutters, machine tool, processing errors and heat treatment deformation etc[4]. So the whole process of gear manufacture should be known and the procedures effecting gear modification be studied to get optimized gear modifying effect. In this way, different measures are able to be used aiming at the different causes and optimized process be decided according to theory calculation and adequate error analysis to raise the modifying effect.

Taking a timing gear mounted in crane shaft used in an automobile for example, the effect of heat treatment on the gear process is researched in the present paper.

2 Brief Introduction of Process of the Timing Gear Mounted in the Crane Shaft

The gear made of 40Cr with tempering and azotizing treatment. Its hardness is 26~32 HRC and its surface hardness is 280~740 HV1 with depth 0.2~0.4mm since tooth surface and shaft surface mounting the gear are ion carburized.

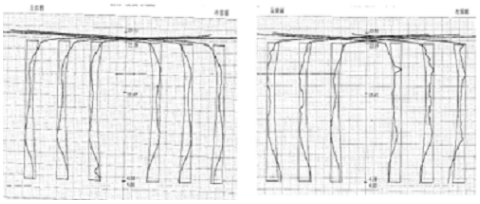
The process flow of the gear is blanking, forging blank, rough turning, tempering, ball blasting, fine turning the ends of the blank, hobbing of teeth, removing rag, marking, drilling of wheel disk holes, grinding of inner diameter hole and front edge surfaces, grinding of tooth profile arris, drilling and boring of pin hole, shaving of teeth, azotizing treatment, sanding of inner diameter hole, cleaning of the gear and inspecting.

The azotizing treatment deformation plays a key role on the effect on last precision of the gear according to the process of the gear. Therefore, a large number of the azotizing treatment deformation of the gear are analized in order to find the basic law of the azotizing treatment deformation and the processing measure, tolerance and correcting quantity before and

after azotizing treatment to be adjusted to enhance processing precision of the gear.

3 Mathematical Statistic Analysis of Gauging Data of the Timing Gear Mounted in the Crane Shaft

To limit the paper length, only one of tooth profile gauging diagrams of ten years before and after azotizing are showed in Fig.1 and only probability density function curves of gauging data of the left profiles of teeth are showed in Fig.2 and Fig.3.



(a) Before (b) after

Fig.1 Gauging tooth profile map before and after azotizing

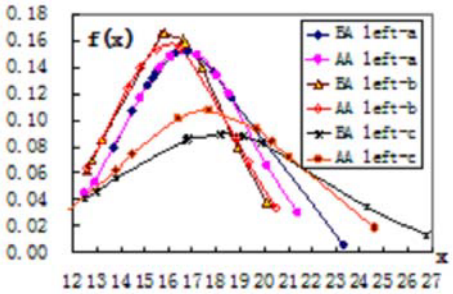


Fig.2. Probability density curves of profile total deviation distribution

Ten gears before and after azotizing are gauged and the gauged data are analyzed with Mathematical Statistics. The data are measured from six points at same diameter circle across right and left profiles of three teeth uniformly distributing and selected randomly. “BA” means before azotizing and “AA” means after azotizing in the table. The points a, b, c before azotizing are corresponding to the points a, b, c after azotizing.

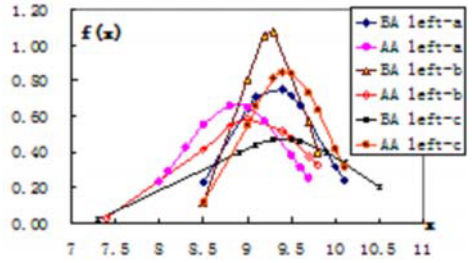


Fig.3 Probability density curves of tooth helical deviation distribution

4 Comparison and Mathematical Statistic Analysis of Tooth Profile Gauging Data before and after Azotizing Treatment.

The gauging data of tooth profile total deviations of ten gears are listed in Tab.1 and Fig.2 is its probability density function curves. The expectation and standard deviation of the tooth profile total deviations are given in the table also.

Tab.1 Gauging Data Of Tooth Profile Total Deviations （Unit：Mm）

Gear number	Left profile						Right Profile						Average
	Point a		Point b		Point c		Point a		Point b		Point c		
	BA	AA	BA	AA	BA	AA	BA	AA	BA	AA	BA	AA	AA-BA
1	23.3	17.2	24.3	14.8	15.8	20.3	16.3	21.5	16.9	19.4	23.3	19.6	-1.18
2	18.6	18.5	13.8	20.5	15.7	17.7	13.9	20.8	13.7	17.7	15	18.9	3.9
3	16.3	12.9	13	19.3	16.6	19.7	13.5	25.8	15.9	15.6	16.1	15.3	2.87
4	15.3	15.6	18.2	12.6	18.9	13.8	12.4	14.7	17.5	21.2	15.5	15.3	-0.77
5	14.5	14.8	16.7	16.5	12.8	24.6	15.2	22	12.7	18.3	14.3	18.3	4.72

6	17.9	20.1	19.9	18.8	20.1	17.6	19.3	17.1	17.3	22.4	16.6	14.4	-0.12
7	15.1	12.5	26.8	14.3	16.7	14.5	15.6	14.2	28.1	14.8	21.6	14.3	-6.55
8	15.5	18	12.5	14.8	12.6	16.4	14.1	15.1	17.8	14.6	14.3	15	1.18
9	16.8	21.4	16.8	13.2	13.2	11.3	14.3	16	15.3	18.2	12.9	17.6	1.4
10	13.7	16.1	19.1	15.5	17.4	21	20	15.2	18.8	16.2	15.3	21.8	0.25
expectation	16.7	16.71	18.11	16.03	15.98	17.69	15.46	18.24	17.4	17.84	16.49	17.05	0.57
standard deviation	2.62	2.76	4.45	2.54	2.40	3.71	2.34	3.78	3.99	2.50	3.16	2.43	3.01

It is found through researching Fig.2 and Tab.1 that before azotizing, the average value of the expectation of the tooth profile total deviations is 16.69μm and the average value of the standard deviation is 3.16μm and after azotizing, the average value of the expectation is 17.26μm and the average value of the standard deviation is 2.95μm. The average value of the expectation after azotizing is 0. 57μm more than that before azotizing and the average value of the standard deviation after azotizing is 0. 21μm less than that before azotizing

5 Comparison and Mathematical Statistic Analysis of Tooth Helical Deviation Gauging Data before and after Azotizing Treatment.

The gauging data of tooth helical deviations of ten gears are listed in Tab.2 and Fig.3 is its probability density function curves. It is found through researching Fig.3 and Tab.2 that before azotizing, the average value of the expectation of the tooth helical deviations is 9.24μm and the average value of the standard deviation is 0.51μm and after azotizing, the average value of the expectation is 9.03μm and the average value of the standard deviation is 0.54μm. The average value of the expectation after azotizing is 0. 21μm less than that before azotizing and the average value of the standard deviation after azotizing is 0. 03μm more than that before azotizing.

Tab.2 Gauging data of tooth helical deviations （unit：μm）

Gear number	Left profile						right profile						average
	Point a		Point b		Point c		Point a		Point b		Point c		
	BA	AA	BA	AA	BA	AA	BA	AA	BA	AA	BA	AA	AA-BA
1	8.5	8.3	9	7.4	7.3	9.4	8.1	7.9	9	8.7	9.2	9	-0.07
2	9.1	8.5	8.5	9	8.9	8.5	9.5	9.1	9.5	9	9.8	9.5	-0.28
3	8.5	8	9.3	8.8	10.1	10	8.4	8.2	8.4	8.2	10	9.5	-0.33
4	10	9.5	9.2	9.4	9.5	9.5	8.6	8.1	8.9	8.5	9.4	9.1	-0.25
5	10.1	9.7	9.3	8.5	9.1	9.8	8	7.8	9.6	9.5	9.4	9.7	-0.08
6	9.4	8.1	9.3	9.8	9.9	9.7	9.6	9.7	9.5	9.6	9.7	9.5	-0.17
7	9	8.8	9.7	9.5	10.5	10.1	8.5	8.3	9.1	8.8	9	8.9	-0.23
8	9.5	9.2	9.8	9.7	9.6	9.1	9.9	9.7	9.6	9.5	9.6	9.3	-0.25
9	9.6	9	9.7	9.5	9.3	9	8	7.8	9.5	9.3	9.1	9.2	-0.23
10	9.4	9.6	9	9	9.9	9.3	8.5	7.6	9.5	9.5	9.6	9.8	-0.18

expectation	9.31	8.87	9.28	9.06	9.41	9.44	8.71	8.42	9.26	9.06	9.48	9.35	-0.21
standard deviation	0.52	0.60	0.37	0.68	0.84	0.47	0.66	0.75	0.38	0.47	0.30	0.28	0.08

6 Comparison and Mathematical Statistic Analysis of Common Normal Length Gauging Data before and after Azotizing Treatment.

The probability density function curves of gauging data of the common normal length are showed in Fig.4. The expectation of the common normal lengths is 42.3297mm and the standard deviation is 4.5μm before azotizing. The expectation is 42.3406 mm and the standard deviation is 4.9μm after azotizing,. The expectation after azotizing is 10. 9μm more than that before azotizing and the standard deviation after azotizing is 0. 7μm more than that before azotizing.

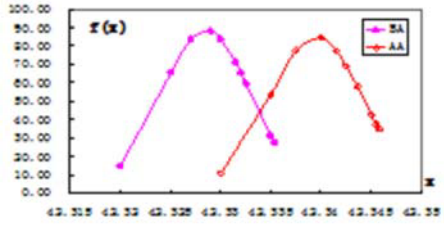


Fig.4 Probability density curves of common normal length distribution

7 Summary

The average value of the standard deviation of the tooth profile deviations is biggest, the average value of standard deviation of tooth helical deviations is smaller than that of the tooth profile deviations and the average value of standard deviation of common normal lengths is smallest. This fact proves that the distribution of tooth profile deviations is the least approaching to standard normal distribution and the distribution of common normal lengths is the most approaching to standard normal distribution.

According to the research of the statistic analysis, modification principle of reverse deformation can be adopted before heat treatment, that is, the tooth profile deviation is reduced by about 0.6μm, the tooth helical deviation is increased by 0.21μm and the common normal length is reduced by 11μm to advance precision of the gear manufacture and to realize design tooth profile during shaving the gears.

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