Sensitivity Analysis of Geometric Parameters on the Life of an Automotive Wheel Bearing Unit

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An automotive wheel bearing is one of the most important components to guarantee the service life of a passenger car. The endurance life of a bearing is affected by many parameters such as material properties, heat treatment, lubrication conditions, temperature, loading conditions, bearing geometry, internal clearance and so on. In this paper, we calculate the endurance life of wheel bearing units and analyze the sensitivity of bearing geometric parameters on the life by using Taguchi method.

Keywords : Automotive wheel bearing unit, Endurance life, Geometric parameters, Sensitivity, Taguchi method

1. INTRODUCTION

For a wheel, which is a core part of automotive driving parts, there is an increasing trend to use a bearing unit instead of a taper or ball bearings. The bearing unit is a new concept that provides advantages such as lighter weight, and more convenient and reliable assembly process. A reasonable prediction of endurance life and proper design based on it are essential factors required in effectively designing a bearing unit that can accommodate the current requirement of lighter weight and smaller size. In determining the endurance life of a wheel bearing unit, there are various factors to be considered. They include loading conditions, bearing geometry, assembly conditions, lubrication, internal clearance and operating conditions. These factors are related to each other in a complex way, so that it is important to pay a close attention to the effects of the factors to predict the endurance life [1-6].

In this study, we estimated the endurance life of a wheel bearing unit by analyzing characteristics of various factors related to the life. Based on this, effects of geometrical parameters of the bearing on the life are examined.

2. LIFE OF A BEARING UNIT

In general, a wheel bearing unit uses a double row angular contact bearing like Fig. 1. Fig.2 shows forces applied to the mounted bearing. A vertical and horizontal load V_1, L_1 that work on a tire are calculated from the automotive specifications and cornering acceleration. In order to analyze forces acting on the bearing unit, six parameters have to be known: each bearing's axial displacement, radial displacement and tilt angle. However, since only three equations can be derived under the equilibrium condition of forces and moments, we assume three geometric constraint conditions regarding the wheel shaft as a rigid body (Fig. 3).

With these conditions, we can calculate forces applied on the bearing from the relationship between forces and displacements. Based on this, the total endurance life of a wheel bearing unit can be calculated according to its operating conditions [6].

3. SENSITIVITY ANALYSIS

The endurance life of a wheel bearing unit depends on the geometric parameters of the bearing. To design effectively a wheel bearing unit, it is required to design bearing's internal geometry that maximizes the endurance life based on the given wheel space. In this study, Taguchi method, which evaluates effects of each factor with a minimum number of experiments, was used in order to analyze the effects of factors related to bearing's internal shape on the bearing life. The geometric factors and levels related to the bearing shape are shown in Table 1. For orthogonal arrays, $L_{27}(3^{13})$ type was chosen and we used 6 rows (1,2,5,9,10 and 12) [7]. Table 2 shows the calculated results of the S/N ratio and contributions regarding the larger the better characteristics. From the result, it was determined that the factor that has the biggest effects on the bearing's life is the inner groove radius, the second factor is the ball diameter and next is the number of balls. The distance between ball centers has a little effect and the outer groove radius and contact angle have relatively small effects. Also, looking at the S/N ratio by level, it is found that the endurance life increases as the inner groove radius decreases and the ball diameter increases. However, if the inner groove radius becomes too small, it has a bad effect on the lubrication. Therefore the inner groove radius should be decreased only within the limit that guarantees a smooth lubrication.

4. CONCLUSION

In this paper, the endurance life of a bearing unit was calculated by assuming the boundary conditions that are suitable for an automotive wheel. Based on this, the effects of the bearing's geometric parameters on the endurance life were analyzed by using Taguchi method. As a result, it was determined that the radius of inner groove radius and ball diameter have the greatest effects on the endurance life of the bearing, and the distance between ball centers has a little impact on the endurance life.

7. REFERENCES

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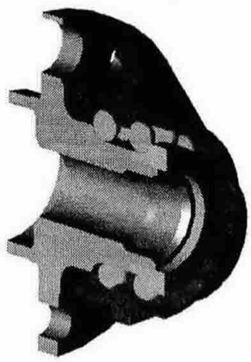

Fig. 1 An automotive wheel bearing unit

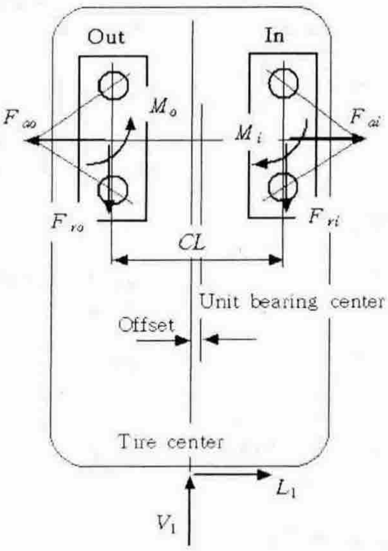

Fig. 2 Forces on the wheel bearing unit

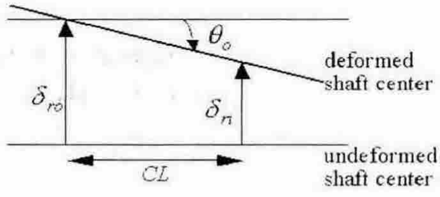

Fig. 3 Wheel shaft model

Table 1 Control factors

Column	Factors	Levels			Remark (ref. to 1)
		0	1	2	
1	Ball diameter (mm)	11.88	12	12.12	±1 %
2	Inner groove radius (mm)	6.18	6.3	6.42	±1.9 %
5	Outer groove radius (mm)	6.18	6.3	6.42	±1.9 %
9	Ball number	14	15	16	±1 no.
10	Ball center distance (mm)	13.5	15	16.5	±10 %
12	Contact angle (deg)	30	35	40	±14 %

Table 2 Signal/Noise(S/N) ratios and contributions

Factors	Levels	S/N ratio	Max. – Min.	Contribution (%)
1	0	27.01	6.01	29.8
	1	29.71		
	2	33.02		
2	0	34.02	7.74	38.4
	1	29.44		
	2	26.28		
5	0	30.79	1.78	8.8
	1	29.94		
	2	29.01		
9	0	28.83	2.24	11.1
	1	29.84		
	2	31.07		
10	0	29.47	0.79	3.9
	1	30.00		
	2	30.27		
12	0	29.08	1.60	7.9
	1	29.98		
	2	30.68		
Sum			20.16	100