Analysis on the Influence Degree of Processing Quality Parameters on Bearing Vibration (Part II : Experiment)

Xintao Xia[1,a], Xiangfeng Chen[1,b*], Xiaowei Yang[2,c] and Bin Liu[1,d]

[1]Mechatronical Engineering College, Henan University of Science and Technology, Luoyang 471003, China

[2]Luoyang Bearing Science & Technology Co., Ltd., Luoyang 471039, China

[a]xiaxt1957@163.com, [b]black_xfc@163.com, [c]yangxwzys@163.com, [d]lbin1992@foxmail.com

Keywords: Bearing vibration; Fuzzy set theory; Processing quality parameter; Influence degree

Abstract. In order to obtain the main influence factors of bearing vibration, based on correlation analysis of fuzzy set theory, channel radius of curvature, channel shape error and channel surface roughness are selected as processing quality parameters to research the influence degree of different processing quality parameters on bearing vibration. The inner ring channel shape error and the outer ring channel surface roughness as the main factors affecting the bearing vibration are finally drawn.

Introduction

Bearing vibration is a complex mechanical phenomenon [1]. The reason for the vibration is also complicated. Ismail, MAA studied the vibration response characteristics of off-ball bearings [2]. Tse, Peter W studied the state space of the nonlinear vibration response collected by the dynamic rotor bearing system [3]. Prudhom, A analyzes the time-frequency vibrations of motor damage caused by bearing current [4]. Guo, Jun-Feng studied the data compression method of collecting vibration signals of rolling bearings [5]. Although scholars at home and abroad are committed to research in this field and some achievements have been made, the total bearing vibration theory has not yet been established [6]. Considering the difficulty of statistical analysis, this paper adopts the method of correlation analysis in fuzzy set theory.

In this paper, the Average membership degree, Euclidean distance and Closeness degree in fuzzy set theory are combined with qualitative fusion and the main factors affecting the bearing vibration can be effectively filtered out, which provides a new theoretical basis for controlling and improving the quality performance of the bearing. This has a very important practical value.

Experimental Study and Data Analysis

The symbols used in this paper and their meanings are listed in Tab. 1. The data obtained from the experiment is shown in the following figures.

Table 1　Symbols and manings

Serial Number	Symbol	Meanings	Parametric Performance	Unit
1	X_0	Vibration acceleration effective value	Performance	$[dB]$
2	X_1	Inner ring channel radius	Structure size	$[mm]$
3	X_2	Outer ring channel radius	Structure size	$[mm]$
4	X_3	Inner ring channel shape error	Macroscopic shape	$[\mu m]$
5	X_4	Outer ring channel shape error	Macroscopic shape	$[\mu m]$
6	X_5	Inner ring channel surface roughness	Microstructure	$[\mu m]$
7	X_6	Outer ring channel surface roughness	Microstructure	$[\mu m]$

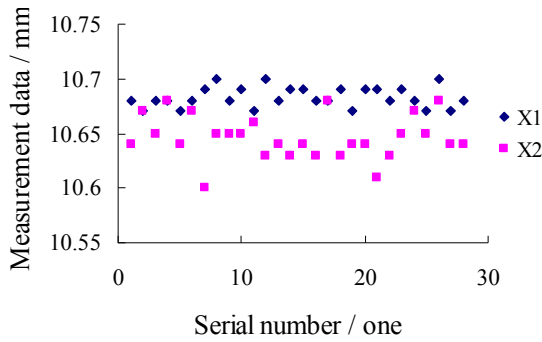The data of baring A is shown as follow.

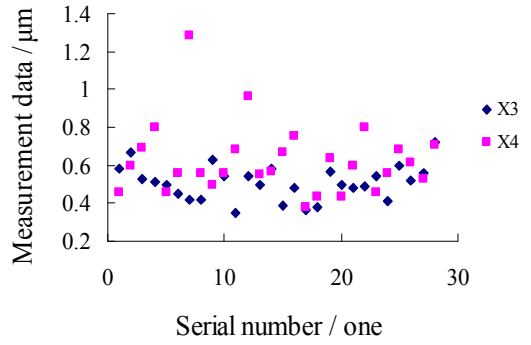Figure 1.   Inner and outer ring channel radius

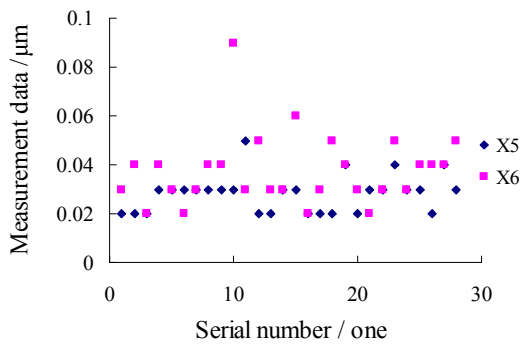Figure 2.   Inner and outer ring channel shape error

Figure 3.   Inner and outer ring channel surface roughness
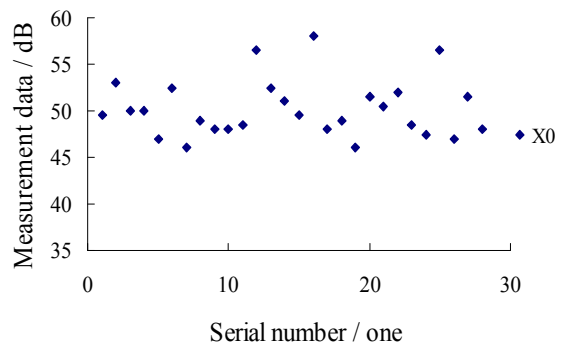

Figure 4.   Effective value of vibration acceleration

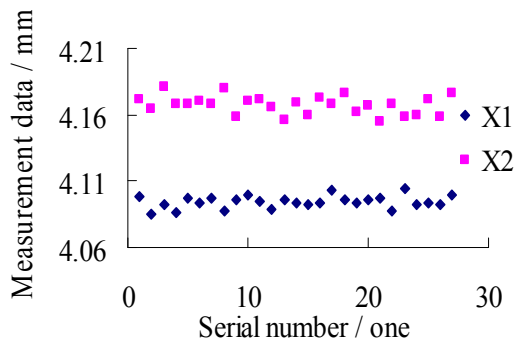The data of baring B is shown as follow.

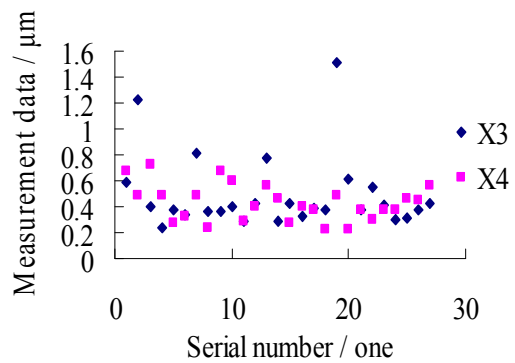Figure 5.   Inner and outer ring channel radius

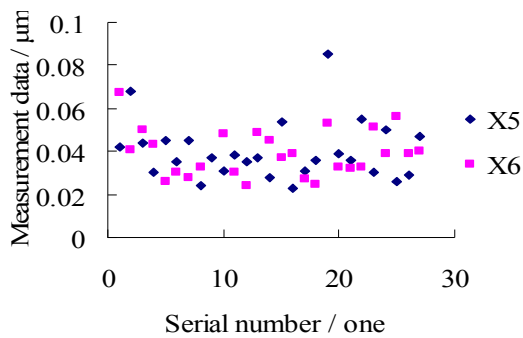Figure 6.   Inner and outer ring channel shape error

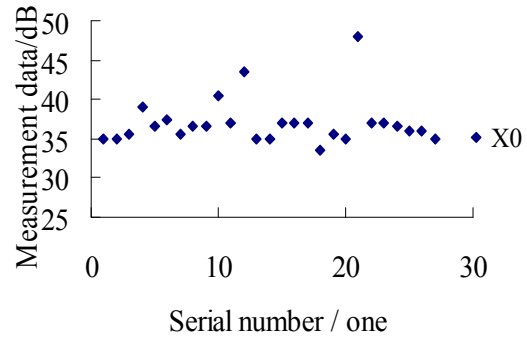Figure 7.   Inner and outer ring channel surface roughness

Figure 8.   Effective value of vibration acceleration

According to the relative size of the Average membership degree μ^*_k[7], the influence degree of the Processing quality parameters X_j on the bearing vibration X_0 is evaluated. The results are shown in Table. 2.

Table 2   Average membership degree μ*k

Bearing Number	μ_1	μ_2	μ_3	μ_4	μ_5	μ_6
A	0.4640	0.4301	0.5557	0.6359	0.4560	0.4891
B	0.3758	0.3827	0.5681	0.4826	0.5378	0.5376

According to the above table, for bearing A and B, these are

$$\mu_4>\mu_3>\mu_6>\mu_1>\mu_5>\mu_2$$
$$\mu_3>\mu_5>\mu_6>\mu_4>\mu_2>\mu_1$$

According to the relative size of Euclidean distance d_p and Base-based Closeness degree N[8-9], the influence degree of the Processing quality parameters X_j on the bearing vibration X_0 is evaluated. The results are shown in Table. 3 and Table. 4.

Table 3   Euclidean distance d_p

Bearing Number	d_{p1}	d_{p2}	d_{p3}	d_{p4}	d_{p5}	d_{p6}
A	0.6489	0.6485	0.5311	0.4593	0.6542	0.6192
B	0.6748	0.7210	0.5377	0.6012	0.5650	0.5797

According to the above table, for bearing A and B, these are

$$d_{p4}<d_{p3}<d_{p6}\approx d_{p2}\approx d_{p1}\approx d_{p5}$$
$$d_{p3}<d_{p5}<d_{p6}<d_{p4}<d_{p1}<d_{p2}$$

Table 4   Base-based Closeness degree N

Bearing Number	N_1	N_2	N_3	N_4	N_5	N_6
A	0.6339	0.6015	0.7143	0.7775	0.6264	0.6569
B	0.5463	0.5536	0.7246	0.6510	0.6995	0.6993

According to the above table, for bearing A and B, there are

$$N_4 > N_3 > N_6 > N_1 > N_5 > N_2$$
$$N_3 > N_5 > N_6 > N_4 > N_2 > N_1$$

By using three methods to calculate, different sorting is obtained. The different order of influencing factors of the two bearing vibrations are listed in Table. 5 and Table. 6.

Table 5　The order of vibration influencing factors of bearing A

Serial Number	Calculation Method	The order of vibration influencing factors of bearing
1	Average membership degree	$X_4 \succ X_3 \succ X_6 \succ X_1 \succ X_5 \succ X_2$
2	Euclidean distance	$X_4 \succ X_3 \succ X_6 \succ X_2 \succ X_1 \succ X_5$
3	Base-based Closeness degree	$X_4 \succ X_3 \succ X_6 \succ X_1 \succ X_5 \succ X_2$

Table 6　The order of vibration influencing factors of bearing B

Serial Number	Calculation Method	The order of vibration influencing factors of bearing
1	Average membership degree	$X_3 \succ X_5 \succ X_6 \succ X_4 \succ X_2 \succ X_1$
2	Euclidean distance	$X_3 \succ X_5 \succ X_6 \succ X_4 \succ X_1 \succ X_2$
3	Base-based Closeness degree	$X_3 \succ X_5 \succ X_6 \succ X_4 \succ X_2 \succ X_1$

According to qualitative fusion theory, the factors affecting the vibration of the bearing A are taken the top three - X4, X3 and X6 and the factors affecting the vibration of the bearing B are taken the top three - X3, X5 and X6. According to the intersection operation of set, the main factors affecting the bearing vibration- X3 and X6 are finally determined. Because the order of X1, X2, X4 and X5 is indefinite, it is difficult to distinguish the magnitude of their influence on the bearing vibration.

Conclusions

The influence degree of the outer ring channel shape error, the inner ring channel surface roughness and structural size on the bearing vibration is small, which indicates that the study of bearing outer ring shape error, the inner ring surface roughness and structural dimensions has reached a relatively high level. Because these influences on the bearing vibration are no longer major factors, so the quality of products for production can maintain the current level. The influence degree of the inner ring channel shape error and the outer ring channel surface roughness on the bearing vibration is large, which indicates that there are still some problems in the design or processing of the bearing. Therefore, the inner ring channel shape error and the outer ring surface roughness become the main factors affecting the bearing vibration[10].

In order to improve bearing performance, the problems of bearing vibration caused by the inner ring channel shape error and the outer ring channel surface roughness should be committed to solve.

Acknowledgements

References

[1] A. Nabhan, M. Nouby, A.M. Sami, and M.O. Mousa: Journal of Low Frequncy Noise Vibration and Active Control, Vol. 35 (2016) No.4, p312-325.

[2] M.A.A. Ismail, N. Sawalhi: Insight, Vol. 59 (2017) No.3, p149-154.

[3] T. Peter W and D. Wang: Sensors, Vol. 17 (2017) No.2.

[4] A. Prudhom, J. Antonino-Daviu, H. Razik and V. Climente-Alarcon: Mechanical Systems and Signal Processing, Vol. 84 (2017), p747-762.

[5] J.F. Guo, J.X. Shi, C.L. Lei and X.C. Wei: Journal of Vibration and Shock, Vol. 34 (2015) No.23, p8-13.

[6] C.M. Pezzani, J.M. Bossio and A.M. Castellino: Mechanical Systems and Signal Processing, Vol. 85 (2017), p354-366.

[7] Q. Wang: Practical Fuzzy Mathematics(Science and Technology Literature Publishing, China 1992), p.13-15. (In Chinese)

[8] Z.Y. Wang, X.T. Xia and J.M. Zhu: Non-Statistical Theory of Measurement Uncertainty(National Defense Industry Press, China 2000). (In Chinese)

[9] J.H. Park, H.E. Kwark and Y.C. Kwun: Journal of Computational Analysis and Applications, Vol. 22 (2017) No.4, p709-725.

[10] X.T. Xia, Z.Y. Wang and H. Chang: Journal of Aeronautical Dynamics, Vol. 20 (2005) No.2, p250-254.