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Analysis on the Influence Degree of Processing Quality Parameters on Bearing Vibration (Part Ⅰ: Theory)

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Abstract. Analysis on the influence degree of processing quality parameters on bearing vibration belongs to the problem that the probability distribution is unknown and the correlation is complex. Only classical statistical analysis is not comprehensive. In this paper, by selecting the channel radius of curvature, channel shape error and channel surface roughness as the processing quality parameters, the influence of different processing quality parameters on bearing vibration is studied by using the correlation analysis in fuzzy set theory and the main factors that affect the bearing vibration are finally drawn.

Introduction

The bearing is a precision mechanical element whose function is to transfer the rotational motion of the shaft to other resting members[1]. The performance of bearing plays an important role in modern mechanical industry. Therefore, the evaluation of influencing factors of bearing quality is very important.

The Processing quality of bearing has many parameters to represent. Such as vibration. The vibration of a bearing reflects the performance of a bearing. However, many factors affect the bearing vibration. The impact analysis of each factor on bearing vibration is a typical small sample problem. The feature information of research object is not complete and Changing tendency is unknown. In addition, the test samples and test data are seriously lacking.

Poor information refers to the feature information of research object is lacking or severely lacking[2-4]. The typical characteristics include less sample data, many samples, but less sample content, unknown probability distribution, unknown changing trend and unknown regular distribution. The evaluation method of Poor information can effectively solve the small sample problem. Based on the theory of fuzzy sets, the idea of classical statistical theory and the latest mathematical theory, Poor information can be used to study the actual evaluation problem which can not be solved by classical statistics.

Fuzzy Set Theory

In fuzzy set theory, the basic concepts used to describe the correlation in the research object include Euclidean distance, Closeness degree and Average membership[5-9].

Average Membership. Firstly, by using the following formula, the data X_{ij} will be mapped to [0,1]. This ensures that all data is fuzzy number.

$$f\left(x_{ij}\right)=\frac{x_{ij}-x_{\min}}{x_{\max}-x_{\min}} \quad (1)$$

Set S_j to be a fuzzy subset on finite universe M. The elements between one column and another column have different properties and the same column elements have the same property attributes. S_j is described as follows.

$$S_j = \left(s_{j1}, s_{j2}, \cdots, s_{ji}, \cdots, s_{jn}\right) \tag{2}$$

A matrix can be formed as follows.

$$S = \left\{s_{ji}; j = 0,1,2,...m; i = 1,2,..., n\right\} \tag{3}$$

By studying the compliance degree of S_j(j=1,2,...m) to S_0, the absolute difference is defined as follows.

$$\Delta_{ji} = \left|s_{ji} - s_{0i}\right| \tag{4}$$

$$\Delta_{i\max} = \max_j \Delta_{ji} \tag{5}$$

The membership function of the same attribute element is created as follows.

$$\mu_{ji} = \mu_{ji}(s_{ji}, s_{0i}) = 1 - \frac{\Delta_{ji}}{\Delta_{i\max}} \tag{6}$$

$$j = 0,1,2,...m; i = 1,2,..., n \tag{7}$$

Average membership is obtained as followed.

$$\mu_j = \frac{1}{n}\sum_{i=1}^{n}\mu_{ji}, j = 1,2,\cdots m \tag{8}$$

Sort μ_j from large to small as follows.

$$\mu_1^* \geq \mu_2^* \geq \cdots \geq \mu_k^* \geq \cdots \geq \mu_m^* \tag{9}$$

The greater the Average membership μ^*_k, the more obvious the relationship between S_k and S_0. On the contrary, the relationship between S_k and S_0 is less obvious.

Distance. Set P and Q to be two fuzzy subsets on complete set M. $x_i \in M$, $\mu_P(x_i) \in [0,1]$ and $\mu_Q(x_i) \in [0,1]$ are respectively the membership of P and Q. Minkowski distance is defined as follows[7-8].

$$d_p = d_p(P,Q) = \left(\frac{1}{n}\sum_{i=1}^{n}\left|\mu_P(x_i) - \mu_Q(x_i)\right|^p\right)^{\frac{1}{p}} \tag{10}$$

In the formula, n is the number of elements of set P and set Q. p is a constant, it is usually a positive integer.

When p=2, the Minkowski distance becomes Euclidean distance.

Distance d_p describes the degree of difference between P and Q. In the sense of Correlation, the smaller the distance, the more obvious the relationship between P and Q. On the contrary, the relationship between P and Q is less obvious.

Closeness Degree. The base-based Closeness degree of the two fuzzy subsets P and Q on the complete set M is defined as follows[7-8].

$$N = N(P,Q) = \frac{2\sum_{i=1}^{n}\left(\mu_P(x_i) \wedge \mu_Q(x_i)\right)}{\sum_{i=1}^{n}\mu_P(x_i) + \sum_{i=1}^{n}\mu_Q(x_i)} \quad (11)$$

In the formula, $x_i \in U, \mu_P(x_i) \in [0,1]$ and $\mu_Q(x_i) \in [0,1]$ are respectively the membership functions of *P* and *Q*.

The Closeness degree describes the degree of closeness between *P* and *Q*. In the sense of Correlation, the greater the Closeness degree, the more obvious the relationship between *P* and *Q*. On the contrary, the relationship between *P* and *Q* is less obvious.

Qualitative Fusion. In the given complete set *U*, Solution set is

$$T = (t_1, t_2, \cdots, t_i, \cdots, t_m) \quad (12)$$

And

$$t_i = (t_{i1}, t_{i2}, \cdots, t_{ij}, \cdots, t_{in}) \quad (13)$$

Set belonging to consistency as a symbol $\subseteq$. In the solution set *T*, there is at least one set of elements from *T*, which is the final solution f_0 satisfying criterion Θ. f_0 can be expressed as follows.

$$t_0 \left| \Theta \right| FromT \subseteq T_0 \quad (14)$$

T_0——the true set of system properties, the white box problem

$|\Theta$——under the criterion *A*

$|From\ T$——elements from the solution set *T*

Due to the lack of system information and data, different results may be obtained by different analytical methods. The results may be contradictory. If these different results are regarded as the different elements of solution set *T*, qualitative fusion means that, under the mapping of a criterion, a subset of a certain consistency element is extracted in the set T as a set of final solutions t_0[10].

In order to verify the feasibility of the Average membership degree, Distance and Closeness degree of the fuzzy set theory to evaluate the influence degree of the processing quality on the bearing vibration, the experimental part adopts two kinds of bearings (numbered *A* and *B*). The channel radius of curvature, the channel shape error and the channel surface roughness are selected as parameters for the processing quality of the different properties.

Conclusions

In this paper, the average membership degree, Euclidean distance and Closeness degree in fuzzy set theory are combined with qualitative fusion. The inner ring channel shape error and the outer ring channel surface roughness as the main factors affecting the bearing vibration can be effectively filtered out, which makes up for the shortcoming of lack of information on the characteristics of research object. And it provides a new theoretical basis for controlling and improving the quality performance of the bearing, which has a very important practical value.

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