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Reliability Analysis of Bearing System in High Speed Railway and Software Implementation

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Abstract: In order to improve the reliability of high speed railway axle box bearing system, extend service life and reduce maintenance cost, the reliability analysis of high speed railway axle box bearing system was carried out based on the theory of system reliability design. Firstly, the reliability model of axle box bearing system was built and it was conducted with failure mode, effect and criticality analysis(FMECA) and fault tree analysis(FTA). Then, the reliability of the system was predicted and allocated. Finally, the reliability analysis software of high speed railway bearing was developed on the Visual Basic(VB) software. It has an important significance to find out the weak link of product design, maximize the bearing working potential, reduce the bearing fault and guarantee the security of the train.

1. Introduction

Axle box bearing is the key component in locomotive running gear of high speed passenger train. It has the function of bearing and transmitting load and guarantee the safety operation of the train[1]. At present, aiming at the research of high speed railway axle box bearing reliability, M.N. Kotzalas[2] and S.M. Zaharia[3] improved the reliability of the bearing by doing fatigue analysis of tapered roller bearing. X.F. Li[4] and P. Wang[5] used the fault diagnosis technology to give the correct judgment to the various failure symptoms of the axle box bearing, and extended the service life of the bearing. E.K. Koltsakis[6] set the contact stress model of bearing, improved the reliability of the bearing by the observation of the influence of the contact stress and the secondary surface stress on the bearing. All of the above studies were analyzed just on the bearings without considering the reliability of the axle box bearing system. This paper used the system reliability design theory to carry on the reliability analysis of axle box bearing system, and make the reliability analysis software of high speed railway bearing based on VB language. It has an important guidance for providing corresponding measures to reduce the incidence rate of bearing in the operation process, extending the service life and assuring the safe operation of trains.

2. Reliability Analysis of High Speed Railway Bearing

2.1 The Establishment of the Basic Structure and Reliability Model of Axle Bearing System

The bearing of the high speed train in China is using the double row tapered roller bearings now, the main components ares shown in Fig. 1.

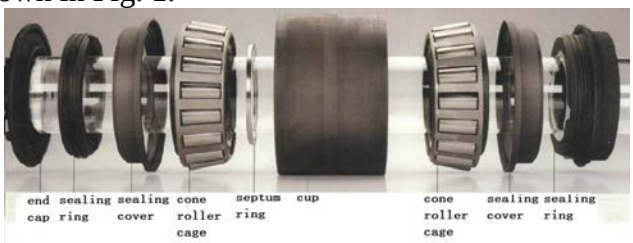

Fig. 1 Bearing structure of high speed railway

According to structure composition and working principle of the high speed railway bearing, the

axle box bearing system satisfies the characteristics of the series system, its mathematical model can be expressed as

$$R_s(t) = R_1(t) \times R_2(t) \times \cdots \times R_n(t) = \prod_{i=1}^{n} R_i(t) \tag{1}$$

Where Rs(t) is the system reliability, Ri(t) is the reliability of the ith series parts.

The reliability block diagram of the box bearing system was obtained by equation (1), are offered in Fig. 2 below.

Fig. 2 Reliability block diagram of axle bearing system

2.2 FMECA of Axle Bearing System

FMECA of axle box bearing system is analyzing each potential failure mode of bearing products and ensuring their effects on the products[7]. According to the statistical data of the fault mode of the axle box bearing system, the FMECA calculated results has been put forward in Table 1.

Table 1 The FMECA results of the fault multiple parts

Parts	Code	Failure Mode	Failure Causes	Failure Effects	$\lambda_b/10^{-3}$	α_j	β_j	$C_{mj}/10^{-6}$
cone	01	spalling	over load	surface spalling	3.39	0.02	0.1	6.78
	13	ware	impurity entry	cone ware	3.35	0.15	0.05	25.4
	17	fracture	over load	cone fracture	3.39	0.01	1	33.9
	20	corrosion	sealing failure	surface rust	3.39	0.15	0.05	25.4
	22	pitting	impurity entry	spalling	3.39	0.15	0.5	254
cage	07	cage damage	vibrationa	cage deformation	5.1	0.1	1	510
cup	01	spalling	over load	surface spalling	3.39	0.02	0.1	6.78
	13	ware	impurity entry	cone ware	3.35	0.15	0.05	25.4
	17	fracture	over load	cone fracture	3.39	0.01	1	33.9
	20	corrosion	sealing failure	surface rust	3.39	0.15	0.05	25.4
	22	pitting	impurity entry	spalling	3.39	0.15	0.5	254
roller	01	spalling	over load	surface spalling	3.21	0.02	0.1	6.42
	13	ware	impurity entry	cone ware	3.35	0.15	0.05	25.4
	17	fracture	over load	cone fracture	3.39	0.01	1	33.9
	22	corrosion	sealing failure	surface rust	3.21	0.03	0.5	48.1

2.3 FTA of Axle Bearing System

The paper regards bearing failure of bearing axle box system failure as the top event and regards cup fault, cone fault, roller fault and cage fault of multiple sites as an intermediate event preliminary. The fault trees of axle box bearing are shown in Fig. 3 and it is followed by the codes and names of basic events in Table 2.

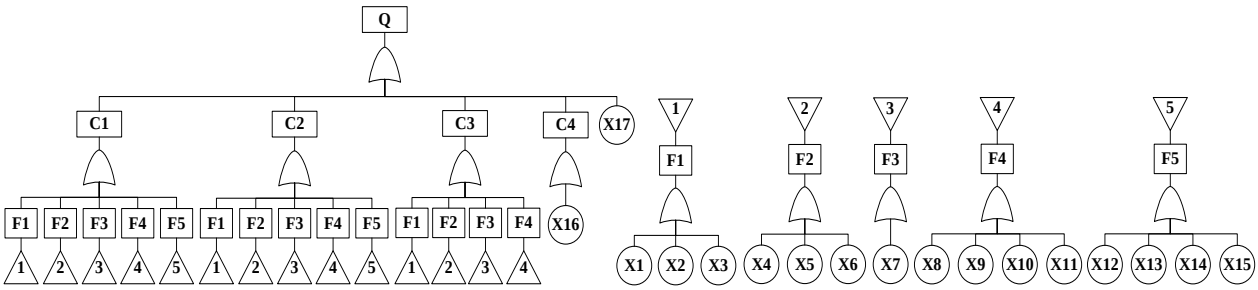

Fig. 3 The fault tree of axle box bearing

Table 2 The codes and names of basic events

Code	Event Name	Code	Event Name	Code	Event Name	Code	Event Name
Q	Bearing invalid	F3	Fracture	X5	Low hardness	X12	Impurity entry
C1	Cone invalid	F4	Corrosion	X6	Bad lubricant	X13	Over load
C2	Cup invalid	F5	Pitting	X7	Over load	X14	Bad lubricant
C3	Roller invalid	X1	Over load	X8	Bad lubrication	X15	Friction
C4	Cage invalid	X2	Bad installation	X9	Sealing failure	X16	Vibration
F1	Spalling	X3	Bad lubrication	X10	Bad prevention	X17	Others invalid
F2	Ware	X4	Impurity entry	X11	Improper storage		

2.4 Reliability Prediction of Axle Bearing System

Expert evaluation method was used for axle box bearing to predict the reliability. According to the document, the cage of axle box bearing was defined as the base part, the failure probability is 0.001. Each part was estimated through this index, and the results of detailed reliability prediction are shown as Table 3.

Table 3 The results of reliability prediction

Component	Complexity	Operating Hours	Environmental Condition	Technical Level	ω_i	C_i	λ_i
cup	5.2	5	6	6	936	0.29	2.93E-5
cone	4.2	5	5.4	5.8	657	0.74	1.67E-5
roller	4.4	5	5.2	5	572	0.64	6.45E-5
cage	5.6	4.4	6	6	887	1	0.001
sealing ring	1.4	1.4	8.8	8.6	148	0.17	1.67E-5
sealing cover	1.4	2.4	9.2	8.4	300	0.29	2.93E-5
septum ring	1.4	1.8	8.4	9	191	0.21	2.15E-5
end cap	1.6	2.2	1.6	8.6	48	0.05	5.46E-6

2.5 Reliability Allocation of Axle Bearing System

Expert rating allocation method was used for axle box bearing to do reliability allocation. The reliability that the axle box bearing system runs for 1.2×10^{-6} km without maintenance is 98.5%[1] and the reliability index is allocated among the components. It is shown as Table 4.

Table 4 The results of reliability allocation

Components	Complexity	Operating Hours	Environmental Conditions	Technical Level	ω_i	C_i	λ_i
cup	6	5	6.5	5.8	1131	0.28	0.27E-3
cone	4.3	5	5.5	6	709	0.17	0.18E-3
roller	4.5	5.2	5.3	5.2	645	0.16	0.16E-3
cage	5	4.6	6	6.5	897	0.22	0.22E-3
sealing ring	1.6	1.4	8.5	8.8	167	0.04	4.13E-5
sealing cover	1.5	2.2	9.5	8.5	266	0.07	6.57E-5
septum ring	1.6	1.5	8.7	9.2	192	0.05	4.74E-5
end cap	1.5	2.5	1.5	8.5	48	0.02	1.18E-5

3. Software Implementation

The design goal of reliability analysis software of high speed railway bearing is based on the theory of system reliability. The function of software was realized on VB platform. The mainly modules are described in Fig. 4.

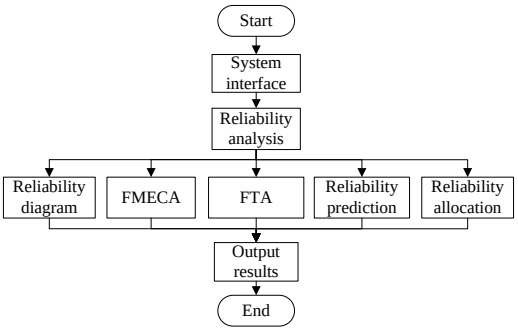

Fig. 4 Flow chart of software

Engineering database connected with VB is established based on Microsoft Access software. The software interface and the design of each module were finished by using VB language and the theory of system reliability design, are shown in Fig. 5.

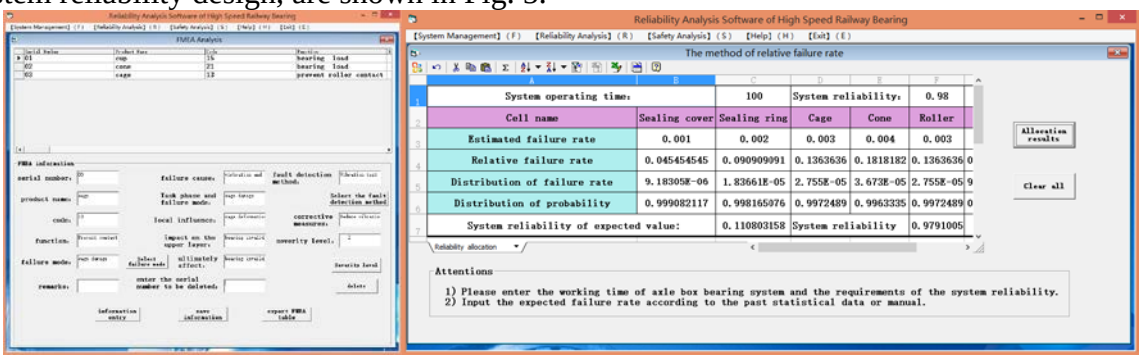

Fig. 5 Users operation interface

4. Conclusions

(1) In this paper, the reliability of high speed railway axle box bearing system was analyzed by using the system reliability design theory. It makes the system performance, manufacturing cost and life more coordinated compared with the reliability analysis of parts. The failure modes, effects, prediction and allocation were obtained by analysis. It plays an important role in designing the best axle box bearing system, ensuring the safety of high speed passenger train.

(2) The reliability analysis software of high speed railway bearing was developed combined the powerful programming function of VB with strong data processing, statistical analysis ability of the Access Microsoft database. The software provides a variety of functional modules of analysis for the reliability analysis of bearing system. The interface is concise and control organization is logical. The use of software operating which is close to the user habits of thinking can be convenient for users.

5. Acknowledgments

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