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Reliability Analysis of Foundation Brake System of CRH1 Emu Based on GO Method

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Abstract: In order to reduce the fault of foundation brake system of CRH1 EMU effectively, the principle of GO methodology is present to analyze the reliability characteristics of foundation brake system. Based on GO methodology, the model of reliability is established. According to the reliability characteristic quantities such as availability and failure rate of the electrical components and mechanical parts and combine with the logic relationship of air source system operator, obtain the precision formula of failure rate and maintenance rate of repairable system, the reliability characteristic of foundation brake system of EMU is quantificationally calculated with development of the corresponding GO process. The result shows that this method can get all the possible factors and weak links of the foundation brake system failure to provide a theoretical basis on the maintenance and fault diagnosis of air source system.

Key words: CRH1 EMU, foundation brake system, reliability analysis, GO methodology

INTRODUCTION

Railway as the artery of transportation, it take an important role in the national economic development. With the continuous development of railway industry in our county, the EMU running speed is continuous improvement, braking performance of EMU braking system directly affects EMU operational quality and driving safety. And foundation brake system is the one of the most critical equipment of high-speed emu braking system and foundation brake system is the last line of security of high-speed EMU in case of other brake measures failure, therefore the reliability research of the EMU foundation braking system is crucial.

The foundation brake system of EMU is the repairable system, in this study GO method was applied to reliability evaluation of CRH1 train brake system, establishes the GO model and combines with the GO program, It can be quickly and easily to precise quantitative and qualitative analysis for availability and failure rate etc. Reliability characteristic of EMU foundation braking system. The results of reliability analysis is a great significance to improve the reliability of existing systems and provide theoretical basis for the fault diagnosis of the realization of the system

FOUNDATION BRAKE SYSTEM OF CRH1 EMU

Foundation brake is the brake actuator, sections vehicles are equipped with foundation brake device. Foundation braking subsystem is mainly composed of electric contact cut-off cock, brake hose, non-slip battery valves, speed sensor and brake cylinder.

As per the earlier studies[1-2] high-speed EMU, due to the high velocity, high braking heat load, foundation braking device is put forward higher requirements. For foundation braking equipment of high-speed EMU must meet the following conditions (Li and Lin, 2003; Han *et al*., 2011):

- Foundation braking device must be able to withstand huge load when emergency brake happen. In case of failure of the other brake types, foundation brake system is the main or even the only security, it must be able to bear the huge brake load of high-speed EMU and transform huge kinetic energy into heat energy dissipated in the atmosphere
- Foundation braking device must be flexible and reliable. Flexible movement and high reliability of foundation braking device of high-speed EMU is directly related to the safe operation of the train, when the dynamic brake failure, disc brake must be able to ensure high-speed EMU parking within the prescribed braking distance in order to ensure driving safety
- Structure of foundation braking device must be compact, high brake efficiency. Compact structure can meet the requirements of the high speed emu per shaft configure sets of foundation braking unit; disc brake braking efficiency is generally greater than 90%, in order to ensure that there is sufficient braking power output

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- The brake friction pair of foundation brake under different speed must have good friction and wear performance and wear resistance and stable friction coefficient
- Foundation braking should ensure the safety of trains on the regulation of ramp parking
- Foundation brake ought to have good environmental adaptability, in such as low temperature, rain and snow, sand, humid environment, etc. It can be also worked for a long-term

BASED ON THE GO METHOD OF THE FOUNDATION BRAKE SYSTEM RELIABILITY MODELING

Basic principle of GO method: As per the earlier studies[3-4] the GO method is a reliability analysis method which regards success as the guidance. The basic idea is that the system elementary diagrams, flow charts or engineering drawings are translated into GO diagram according to the rules. And then the GO operation is conducted according to operation rule of operators. After the calculation of GO model, the system final probability can be determined. Elements of GO method directly represent physical relationship and logical relation among components, so the obtained system GO diagram can reflect the original features of system (Huang *et al*., 2008; Shen and Huang, 2004) .

GO method model of foundation braking system: After the GO figure is established by the GO method, all operators data should be input and then conduct GO operations. The operator represent the logical relationship of between units function and units input and output signals in GO method. The attributes of operator include type, data and operation rules, the type is the main attribute of operator and operator type reflects the unit functions and features represented by the operator. GO method has defined 17 kinds of standard operators, type 1 operator is two State unit, has success signal entered on has output, fault signal is no output; type 5 operator is signal generator, is most common input operator, it no input signal, is independent of the system of external events or another system issued of signal, as the system input; type 6 operator is component which has signal and conduction, the operator simulation must have two input signals then output, except has main entered signal, Also the second input signal (Actuating Signal) switches on components, then allow primary input signal to pass; the type 10 operator is and door, there are multiple input signal, represent the logic relationship of input and output signal and output signal status value depends on the maximum values among multiple input signals has been researched by Shen and Huang (2004) .

Table 1: Characteristics data of foundation braking system

Operate No.	Operator type	Basic element	Fault rate	Mean time to repair (h)
1	5	Virtual Component	0.5	10.0
2, 3	1	Electric Contact Cut Simon	3.0	2.0
4, 5, 6, 7	5	Velocity Transducer	5.0	3.0
8, 9, 10, 11	6	Non-slip solenoid valve	3.5	8.0
12, 13, 14, 15	1	Brake Hose	3.0	0.5
16, 17, 18, 19	1	Brake Cylinder	6.0	1.0
20	10	AND Gate		

Foundation braking system of the speed sensor, the input signal is input unit in the system, using type 5 operator simulation; Electric contact cut cock, brake hose, brake cylinder simulated by type 1 operator; type 6 operator was used to simulate non-slip solenoid valve. This study main study the CRH1 emu foundation braking system braking process has been researched by Wang (2010) , transform the logic diagram of the working principle (Fig. 1) , obtain GO method illustrated model, shown in Fig. 2.

As shown in Fig. 2, the left side number of the dash represents the type of operator, the right side of the dash is the corresponding number of the system unit.

Unit reliability parameters of foundation brake system model shown in Table 1 which the data is from an operating history statistics of CRH1 EMU and experience.

SYSTEM RELIABILITY ANALYSIS

Reliability characteristic quantity of repairable system: In the industrial engineering system, components and equipment can often be repairable which is called repairable system. Repairable system is in normal working state and the state of the shutdown maintenance system of alternately, system failures and complete maintenance has randomness. This article assumes that components and subsystems of CRH1 EMU foundation brake system are to obey exponential distribution of repairable system.

After a sufficiently long time, when the system reaches steady the reliability characteristic quantity as Eq. 1-6 has been researched by Shen and Huang (2004).

Mean time between failures:

$$\mathrm{MTBF} = \frac{1}{\lambda} \tag{1}$$

Mean time to repair:

$$\mathrm{MTTR} = \frac{1}{\mu} \tag{2}$$

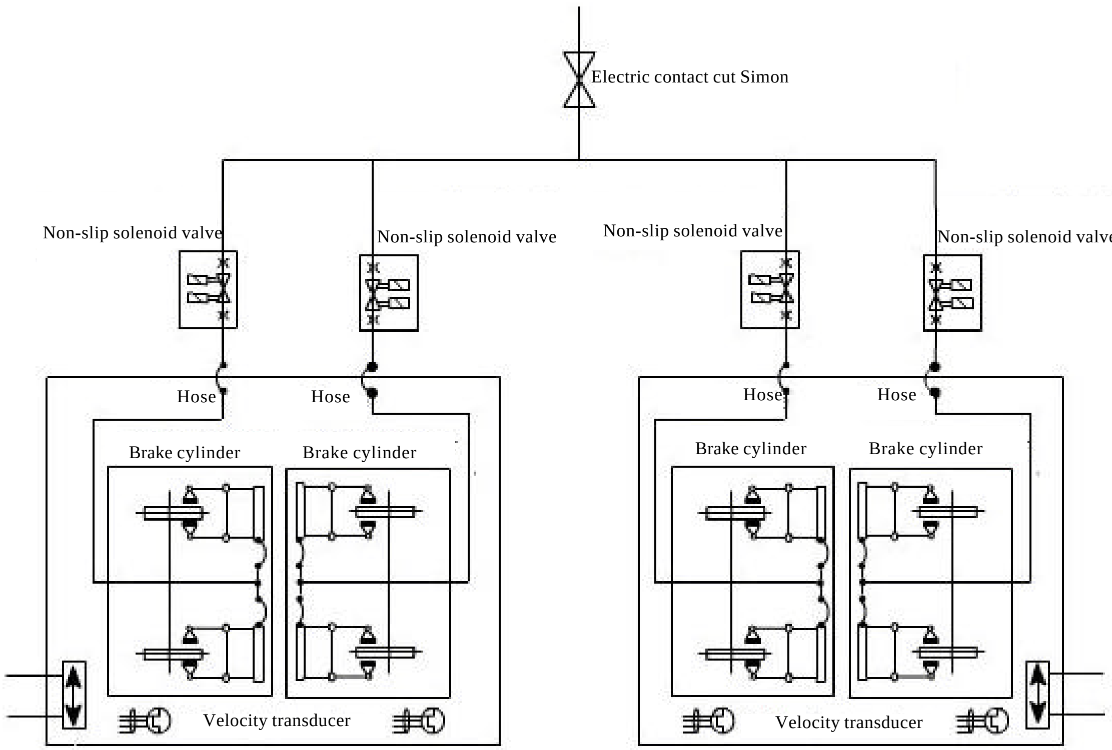

Fig. 1: Foundation braking system diagram

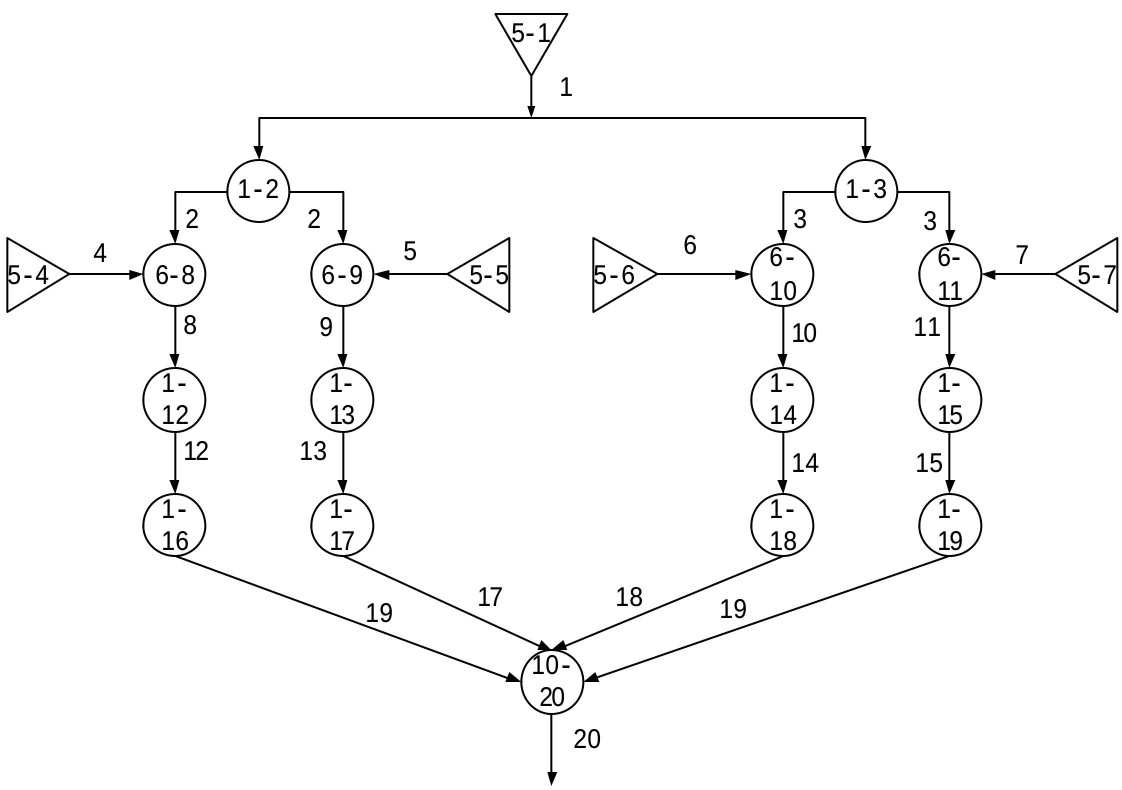

Fig. 2: GO model of foundation braking system

The average life cycle:

$$MCT = MTBF+MTTR \tag{3}$$

Average working probability:

$$A = \frac{MTBF}{MCT} = \frac{\mu}{\mu+\lambda} \tag{4}$$

Average shutdown probability:

$$\overline{A} = 1 - A = \frac{\lambda}{\lambda+\mu} \tag{5}$$

Unit time average fault time:

$$f = \frac{1}{MCT} \tag{6}$$

where, λ is failure rate, μ is maintenance rate, f is the average repair times per unit time and average number of cycles per unit time.

Logic simplifying operation steps of system GO model: Steady-state analysis of repairable systems is two state system.Normal state probability, downtime state probability, equivalent failure rate, equivalent maintenance rate of input signal of operator are respectively recorded as: $P_S(1)$, $P_S(2)$, λ_S, μ_S. Probability of success status, failure state Probability, failure rate, maintenance rate of operator are respectively recorded as: $P_C(1)$, $P_C(2)$, λ_C, μ_C. Normal state probability, downtime state probability, equivalent failure rate, equivalent maintenance rate of output signal of operator are respectively recorded as: $P_R(1)$, $P_R(2)$, λ_R, μ_R. Quantitative analysis application of GO method of foundation brake repairable system reference study (Shen *et al*., 2000) . In the GO method model of Fig. 2, the operator from 1 to 20 are concatenation logic, so, the operator 2, 4, 8, 12, 16; 2, 5, 9, 13, 17; 3, 6, 10, 14, 18 and 3, 7, 11, 15, 19 can be treated as a whole module, respectively and is a complete series modules. In complete series modules, the failure rate calculations is simple addition operation, maintenance rate of operations can also be calculated partial sum, the sub-module calculation formula is shown as Eq. 7 to 26:

$$\lambda_{R2} = \lambda_{C1}+\lambda_{C2} \tag{7}$$

$$\mu_{R2} = \frac{\lambda_{R2}}{\frac{\lambda_{C2}}{\mu_{C2}}+\frac{\lambda_{C1}}{\mu_{C1}}} \tag{8}$$

$$P_{R2}(1) = \frac{\mu_{R2}}{\mu_{R2}+\lambda_{R2}} \tag{9}$$

$$\lambda_{R3} = \lambda_{C1}+\lambda_{C3} \tag{10}$$

$$\mu_{R3} = \frac{\lambda_{R3}}{\frac{\lambda_{C3}}{\mu_{C3}}+\frac{\lambda_{C1}}{\mu_{C3}}} \tag{11}$$

$$P_{R3}(1) = \frac{\mu_{R3}}{\mu_{R3}+\lambda_{R3}} \tag{12}$$

$$\lambda_{R16} = \lambda_{R2}+\lambda_{C4}+\lambda_{C8}+\lambda C_{12}+\lambda C_{16} \tag{13}$$

$$\mu_{R16} = \frac{\lambda_{R16}}{\frac{\lambda_{R2}}{\mu_{R2}}+\frac{\lambda_{C4}}{\mu_{C4}}+\frac{\lambda_{C8}}{\mu_{C8}}+\frac{\lambda_{C12}}{\mu_{C12}}+\frac{\lambda_{C16}}{\mu_{C16}}} \tag{14}$$

$$P_{R16}(1) = \frac{\mu_{R16}}{\mu_{R16}+\lambda_{R16}} \tag{15}$$

$$\lambda_{R17} = \lambda_{R2}+\lambda_{C5}+\lambda_{C9}+\lambda C_{13}+\lambda C_{17} \tag{16}$$

$$\mu_{R17} = \frac{\lambda_{R17}}{\frac{\lambda_{R2}}{\mu_{R2}}+\frac{\lambda_{C5}}{\mu_{C5}}+\frac{\lambda_{C9}}{\mu_{C9}}+\frac{\lambda_{C13}}{\mu_{C13}}+\frac{\lambda_{C17}}{\mu_{C17}}} \tag{17}$$

$$P_{R17}(1) = \frac{\mu_{R17}}{\mu_{R17}+\lambda_{R17}} \tag{18}$$

$$\lambda_{R18} = \lambda_{R3}+\lambda_{C6}+\lambda_{C10}+\lambda C_{14}+\lambda C_{18} \tag{19}$$

$$\mu_{R18} = \frac{\lambda_{R18}}{\frac{\lambda_{R3}}{\mu_{R3}}+\frac{\lambda_{C6}}{\mu_{C6}}+\frac{\lambda_{C10}}{\mu_{C10}}+\frac{\lambda_{C14}}{\mu_{C14}}+\frac{\lambda_{C18}}{\mu_{C18}}} \tag{20}$$

$$P_{R18}(1) = \frac{\mu_{R18}}{\mu_{R18}+\lambda_{R18}} \tag{21}$$

$$\lambda_{R19} = \lambda_{R3}+\lambda_{C7}+\lambda_{C11}+\lambda C_{15}+\lambda C_{19} \tag{22}$$

$$\mu_{R19} = \frac{\lambda_{R19}}{\frac{\lambda_{R3}}{\mu_{R3}}+\frac{\lambda_{C7}}{\mu_{C7}}+\frac{\lambda_{C11}}{\mu_{C11}}+\frac{\lambda_{C15}}{\mu_{C15}}+\frac{\lambda_{C19}}{\mu_{C19}}} \tag{23}$$

$$P_{R19}(1) = \frac{\mu_{R19}}{\mu_{R19}+\lambda_{R19}} \tag{24}$$

$$\lambda_{R20} = \lambda_{R16}+\lambda_{C17}+\lambda_{C18}+\lambda_{R19}-\lambda_{R2}-\lambda_{R3} \tag{25}$$

$$\begin{aligned}\mu_{R20} &= \frac{\lambda_{R20}P_{R20}(1)}{1-P_{R20}(1)} \\ &= \lambda_{R20}\cdot\frac{P_{R16}(1)P_{R17}(1)P_{R18}(1)P_{R19}(1)/P_{R2}(1)P_{R3}}{1-P_{R16}(1)P_{R17}(1)P_{R18}(1)P_{R19}(1)/P_{R2}(1)P_{R3}}\end{aligned} \tag{26}$$

Table 2: Foundation brake system reliability analysis results

Foundation brake system reliability characteristic quantity	Numerical value
Failure rate $\lambda/(10^6\text{h})^{-1}$	77
Maintenance rate μ/h	1.2940
MTBF/h	12987.01
MTTR/h	0.77277
MCT/h	12987.7828
Average working probability A	0.9994
Average shutdown probability $\bar{A}$	0.000595
Unit time average fault time f/(次 $(10^6\text{h})^{-1}$)	0.76995

Reliability calculation of foundation brake system: Through the calculation of the Eq. 7-26, reliability data of foundation braking system are shown in Table 2.

Through inquiring lated data, MTBF of fundamental braking system is 12000 h, the study calculated MTBF is 12987.01 h, two data within the error range, by using the GO conduct reliability analysis for fundamental braking system of CRH1 EMU, can get the weak link in the system and then prove that the GO method is effective, simple and practical in reliability study of foundation braking system of CRH1 EMU, will certainly is a trend in system reliability analysis.

CONCLUSION

- By conducting analysis of foundation brake systems of CRH1 EMU and elaboration and elaborating the GO method, the applying GO method to conduct reliability analysis of foundation brake system of CRH1 EMU is proposed
- This method has been applied to reliability analysis of foundation brake system of CRH1 EMU, the results show that the GO method is a convenient and effective method of reliability analysis in the reliability analysis of repairable system

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REFERENCES

Han, X.H., J.S. Li, Y.M. Li and C.G. Zhao, 2011. Foundation braking equipment of HeXie EMU. Railway Locomotive Car, 31: 52-54, 60.

Huang, Y.Z., Q. Shi and J.F. Hao, 2008. Based on the go method of brake system reliability analysis. Autom. Meas. Control, 27: 77-77.

Li, H.P. and G.T. Lin, 2003. A Study on the Design of Fundamental Brake System for High-speed Train. China Railway Sci., 24: 8-13.

Shen, Z.P. and X.G. Huang, 2004. Principle and Application of go Method a System Reliability Analysis Method. Tsinghua University Press, Beijing, China, pp: 117-125.

Shen, Z.P., X.G. Huang and J. Gao, 2000. Application of go method in repairable system reliability analysis. Nucl. Power Eng., 21: 456-460.

Wang, Y.M., 2010. EMU Braking Technology. China Railway Press, Beijing, China, pp: 111-159.