ZIBELINE INTERNATIONAL PUBLISHING

ISSN: 1024-1752
CODEN : JERDFO

Journal of Mechanical Engineering Research and Developments (JMERD)
DOI : http://doi.org/10.26480/jmerd.04.2018.05.08

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REVIEW ARTICLE

THE FAULT LOCATING SYSTEM OF THE HIGH-SPEED MAGLEV TRAIN

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ARTICLE DETAILS

Article History:

Received 23 August 2018
Accepted 24 September 2018
Available online 29 October 2018

ABSTRACT

Analyzing and researching the levitation and guidance sensor fault location system of high-speed maglev train, we developed an offline testing method of sensor fault location system, which can carry on the fast positioning of sensor boards, and greatly improve the efficiency of maintenance. The research results have certain reference value for maintenance work of Shanghai maglev engineering demonstration line.

KEYWORDS

High-speed maglev train, gap sensor, fault locating system.

1. INTRODUCTION

The levitation guide sensor of high-speed maglev train is an important part of the levitation system of maglev train. By using eddy current effect, the coil in the sensor generates excitation electromagnetic field, and the clearance value is measured through the variation of eddy current magnetic field [1]. The levitation guide gap is transformed into electrical signal and transmitted to the suspension guidance controller. The levitation steering controller adjusts the current in the electromagnet coil dynamically according to the gap signal, so that the maglev train can be stabilized and suspended.

Each suspension guidance sensor produces two independent gap signals (channel A and B), an acceleration signal, a speed signal, and a diagnostic signal [2]. Each signal is transmitted to the levitation steering controller through its own RS485 asynchronous serial communication interface. The signal transmission of the suspension guiding sensor is shown in Figure 1 below.

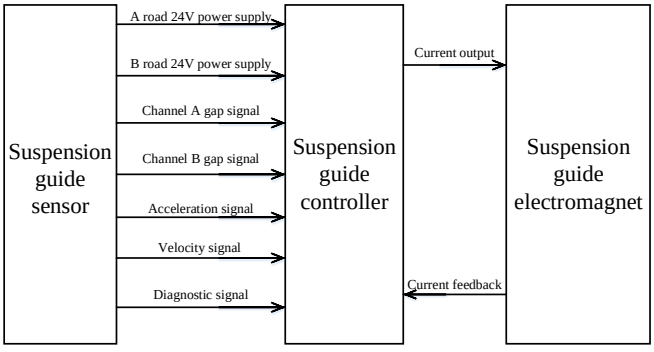

Figure 1 : signal transmission diagram of a suspension guide sensor

The suspension guiding sensor is installed at the bottom of the maglev train. Due to the different installation positions on vehicles, there are 4 different types of suspension gap measurement units TSM1, TSM2, TSM3 and TSM4 [3]. These 4 types of measuring units differ only in excitation frequency, and the other characteristics are exactly the same. The sensor's working environment is very bad, so we need to maintain and detect the sensor frequently. At present, the sensor fault detection and maintenance of Shanghai Maglev Demonstration Line is entrusted to the German side [4]. The maintenance cost is high, and the maintenance cycle is very long. In this paper, the signal processing board and detection coil flexible circuit board of high-speed maglev train are analyzed. The study of an off-line suspension guidance sensor fault location system has realized the rapid positioning of the sensor fault, greatly shortens the maintenance period and saves the maintenance cost.

1.1 The overall introduction of fault location system

The off-line test method is applied to the fault location system of the high-speed maglev train. Taking the upper computer as the center, using special signal excitation equipment, special signal acquisition and processing equipment, with power supply, display and interface circuit, the fault detection and diagnosis of circuit board are completed [5]. The principle of detection is shown in Fig.2. According to the working principle of the circuit board, the special signal generator is used to generate the transmission signal needed by the circuit board. The interface circuit is input to the tested circuit board to make it work close to the actual working condition. The output signal produced by the measured circuit board passes through the interface circuit and is transmitted to the upper computer system by the special signal acquisition device through RS485 serial communication [6]. The structure of the fault location device for floating guiding sensor is shown in Figure 2.

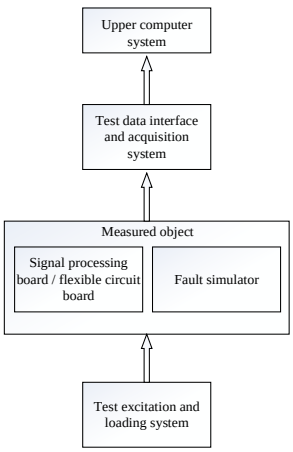

Figure 2 : Structure of fault location device for suspension guiding sensor

The upper computer compares the printed circuit board output signal with the given response signal through the circuit board fault location software to judge whether the circuit board is in accordance with its working principle [7]. If the comparison results are consistent, it indicates that the circuit board is normal: if it is not consistent, the fault dictionary can be used to determine which circuit is in fault according to the result of the comparison.

2.STUDY ON THE OVERALL DESIGN OF THE SYSTEM

2.1 Test excitation and loading system

The sensor fault location device test excitation and loading system can control the excitation signal generation and transmission of the suspension guide sensor and can control the excitation signal according to the preset test flow to drive the suspension guide sensor [8]. According to the technical characteristics of the suspension guiding sensor, the excitation signal can be divided into two types.

(1) General signal. The frequency, amplitude and loading time sequence of such signals can be clearly defined, such as 24V power supply, acceleration signal, crystal signal and so on.
(2) Use the signal. Such signals cannot be defined by a definite electrical signal. They must be applied by special agencies. It includes the gap signal and the speed signal.

As shown in Figure 3, the test excitation and loading system is designed as a control system based on FPGA chip. By configuring the relevant driving circuit, the FPGA software controls the programmable signal generator, generating the general excitation signal that meets the requirements such as frequency, amplitude and timing [9]. It can also drive the special mechanism to realize the excitation and loading of the sensor gap signal and speed signal.

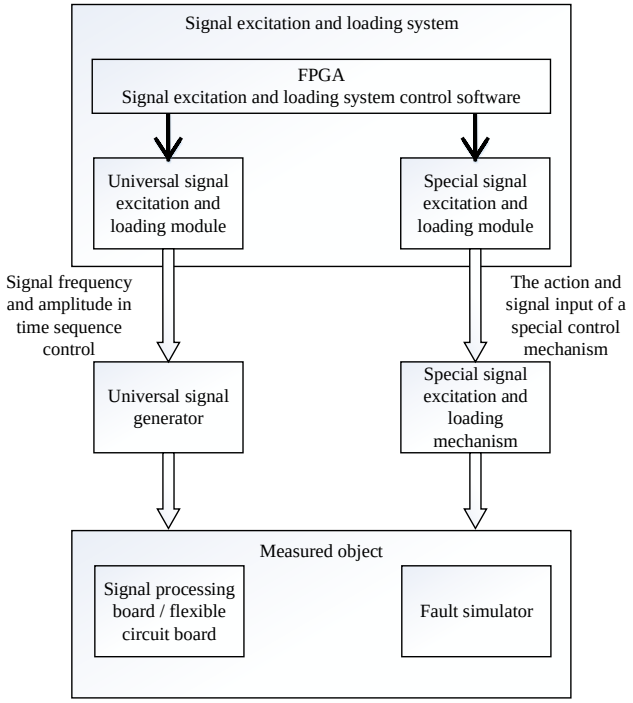

Figure 3: Test excitation and loading system

The universal signal excitation and loading module is used for those signals, such as the 24V power, the acceleration signal, the crystal oscillator, and so on, which can be defined clearly in the frequency, amplitude, and loading sequence [10]. The module is connected with the programmable signal generator and loads all kinds of general signals according to the test time sequence.

The dedicated signal excitation and loading module is used to load the gap signal and speed signal. The gap signal and speed signal are inductors, and the inductance changes of each sensor are also different for the same gap value and speed value [11]. Therefore, it is not possible to define clearances and speeds with definite voltage or current, and special bodies should be used to apply gap and speed excitation signals. The block diagram of the special motion mechanism researched and designed is shown in the Fig.4.

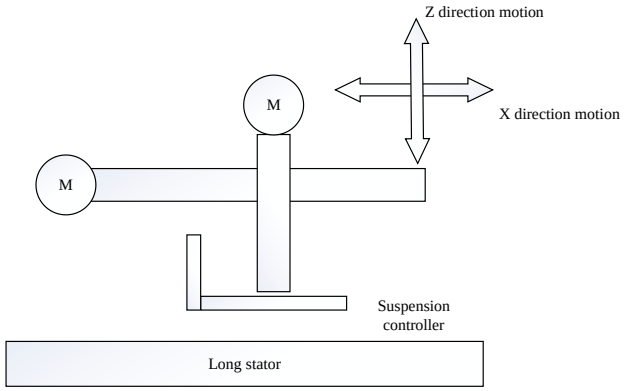

Figure 4: Special signal loading mechanism for suspension guide sensor

The mechanism consists of a long stator, a two-axis displacement mechanism and a motion control system [12]. The long stator provides clearance signal to detect the datum and the velocity signal slot surface. The dual axis displacement mechanism moves under the control of two axial servomotors of X and Z, changing the gap value and speed value, providing special excitation signal [13].

2.2 Test data interface and acquisition system

The test data interface and acquisition system of the suspension guide sensor are a set of data communication systems, which can collect analog signals or digital signals, and convert the data according to the preset protocol.

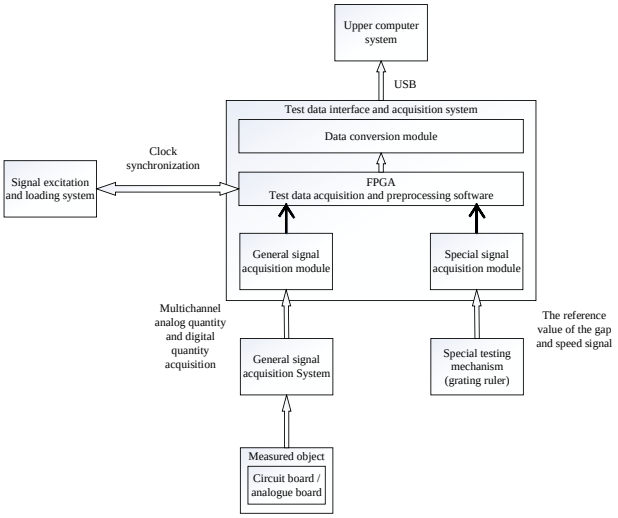

Figure 5: Debug data interface and acquisition system

According to the technical characteristics of the suspension guided sensor, the data to be collected can be divided into two types.

(1) General data. It refers to the signals collected on the measured circuit board or on the fault analog board. These signals have both analog and digital quantities, and the software can recognize both the analog and the digital.
(2) Special data. It refers to the reference gap and speed value of the dedicated signal loading mechanism of the suspension sensor. These data are generally obtained through a grating ruler.

The test data interface and acquisition system are designed into a set of communication system based on FPGA chip. By configuring the related driving circuit, the FPGA software gets the general data through the general data mining system, and the special data can be obtained by the special signal loading mechanism. The number of analog and digital channels will be designed according to the number of measuring points of the fault location device and the number of I/O ports of the sensor card, so as to ensure that data acquisition needs are met.

In order to keep the test data and the excitation signal synchronized, the clock synchronization relationship between the two systems can be realized, and the microsecond clock synchronization can be realized. In addition to general data and special data collection, the test data interface

and collection system also encapsulate these data and send the test data to the upper computer through the USB serial port.

2.3 The upper computer software system

The software system of the fault location device of the suspension guide sensor is a set of operation control software, which has the function of fault auxiliary positioning, automatic detection, data storage and fault analysis and positioning, and can assist in the fault location and testing function of the suspension guide sensor board. The software system of the fault location device of the suspension guide sensor is essentially a set of industrial measurement and control software system. Its structure, function and performance are all in accordance with the requirements of the industrial measurement and control software. According to the general requirements of the industrial measurement and control software system, the software system diagram of the fault location device designed by the research group is shown in Fig.6.

The software system takes the database and.Net Framework as the technical foundation, and the upper layer constructs the following four business modules.

(1) Detection process control module
(2) Fault data storage module
(3) Fault determination and control module
(4) Fault data analysis module

The command and test data are transmitted through the data interface between the software system and the positioning device.

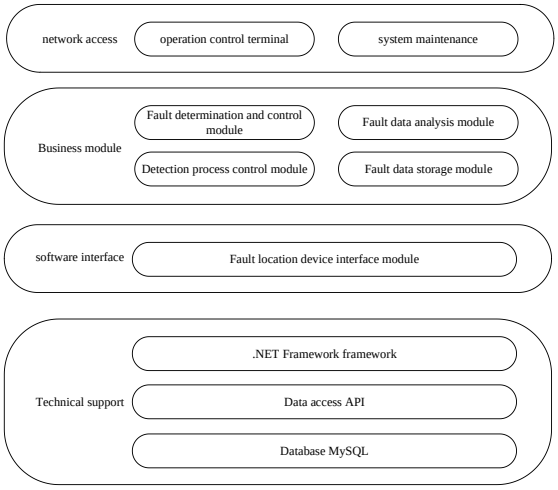

Figure 6: Software system diagram of fault location device for suspension guiding sensor

2.4 Test fault simulation

In order to test the fault diagnosis and location effect of fault location device, fault simulation board is developed. Through the fault simulation board, the fault type can be artificially set up to check the effect of the fault location device. The fault simulation board can realize the basic functions of the original board, that is, the resonant circuit, the detection circuit, the conditioning circuit and the communication circuit. The fault analog board can simulate the fault according to the test arrangement, exert influence on the electrical parameters of the test point, make it deviate from the normal value and make artificial fault phenomenon, in order to verify whether the device can detect the fault correctly. In the test, the fault simulator is set to a certain non-output RS485 signal through the fault setting program, and the damage of a certain resistance, capacitance and 485 communication chip of the communication circuit on the signal processing board is simulated. The order of the other signals is maintained at the normal value. Through the test, the fault location device gives the diagnostic results of each circuit as shown in Table 1.

Table 1: Output list of each branch circuit under the condition of fault simulation

Serial number	Circuit name	Diagnostic results
1	power supply circuit	OK
2	Clock signal circuit	OK
3	Oscillating signal circuit	OK
4	Demodulating signal circuit	OK
5	signal conditioning circuit	OK
6	Temperature conditioning circuit	OK
7	communication circuit	Failure

The standard values and measured values of the measuring points of the communication circuits are shown in Table 2.

Table 2: Report on fault diagnosis of communication circuit, the measured sensor model: TSM-1

parameter	model	Baud rate of serial data transmission (KHz)	Test point number	Measured baud rate (KHz)
gap	TSM-1	700	T811	697
gap	TSM-1	650	T812	No signal
velocity	TSM-1	875	T813	655
acceleration	TSM-1	875	T814	871

Because the output of power supply, clock, oscillating circuit, detection circuit and signal conditioning circuit are all normal, it can be judged that the input signal of FPGA is correct, and the fault occurs on the circuit branch of FPGA output to RS485 communication circuit.

3.CONCLUSION

Based on the actual operation of the Shanghai maglev engineering demonstration line, this paper proposes an off-line fault location system for the suspension guided sensor. This method is effective, which realizes the rapid location of sensor faults, greatly shortens the maintenance cycle and saves maintenance costs.

4.ACKNOWLEDGEMENT

This paper is supported by Shanghai maglev and rail transit collaborative innovation center and Hunan Province Special Fund for the Strategic Emerging Industries and New Industrialization.

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