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Bearing Fault Prediction System Design Based on LabVIEW

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Abstract: High-precision machine tools are important equipment of production line in general [1]. However, it is too difficult to do failure prediction and maintenance of the spindle bearings. Equipment utilization will be decreased if the damaged bearing is not replaced in time. This paper designed a set of bearing failure prediction system based on LabVIEW programming environment, according to the requirement for the maintenance of spindle bearing on production line. The system will predict the bearing failure through the analysis of the size precision of the parts. The system mainly consists of two parts, data acquisition system and data analysis system. It achieves the following functions: data analysis and calculation, data display and storage, system failure alarms, etc.

Keywords: Data analysis, fault prediction, LabVIEW, System components, Data acquisition system, Bearing fault.

1. INTRODUCTION

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a virtual instrument software development platform based on Graphics compile G (Graphics) language [2]. It has data acquisition, data analysis, signal generation, signal processing, input-output control and other functions. As the first graphic programming system uses the virtual panel user interface and the block diagram to establish virtual instrument, LabVIEW is widely accepted by the industry, academia and research laboratory. It is regarded as a standard data acquisition instrument and instrument control software.

With the development of science and technology, advanced mode of production improved labor productivity, reduced costs and ensured the quality of the product. But on the other hand, the economic losses caused by the failure of mechanical equipment are also growing and even lead to catastrophic casualties. Therefore, failure prediction technology emerges. This technique can predict the working status of the equipment development trend in the future and estimate the modification date and failure occurred. It can effectively reduce the economic losses. With the development of computer technology, signal analysis, processing technology and automation technology, failure prediction technology mainly leads to intelligent, systematic, non-linear, network-oriented direction [3].

Spindle bearings are generally an important part of machine tools and precision supporting basic parts. They are known as mechanical joints [4]. Bearing quality directly affects the performance of products. So it not only represents the development of bearing technology but also represents the entire development of machinery industry. But the applications environments of bearing are often complex and their species and lives are different. So the regular maintenance of the bearing is not scientific. This brings great difficulties to the troubleshooting and maintenance of bearings.

2. SYSTEM DESIGN

2.1. System Components

The system mainly consists of two parts, data acquisition system and data analysis system. Transmit the data collected by the size measurement tools through data acquisition card to the computer, then calculate and analyze the data through data analysis system on the computer, so that the data display, data storage and alarm function are achieved. System data flow diagram is shown in Fig. (**1**).

2.2. System Functions

Spindle bearing failure prediction system will achieve the following functions:

(1) Collect the size data of parts machined by bearing and store them.

(2) Manage the collected data that has collected [5]. Store the data when the device is operating normally and failure respectively. This will be used to set analysis parameters threshold and deeper analysis of equipment.

(3) Use a variety of methods to calculate the size of the collected data, which will provide the basis for the prediction of bearing failure.

(4) Display the value and trend of data through a waveform diagram in order to find the cause of bearing failure.

(5) Timely and accurately alarm and remind staff to replace bearing before it fails.

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1874-155X/15 2015 Bentham Open

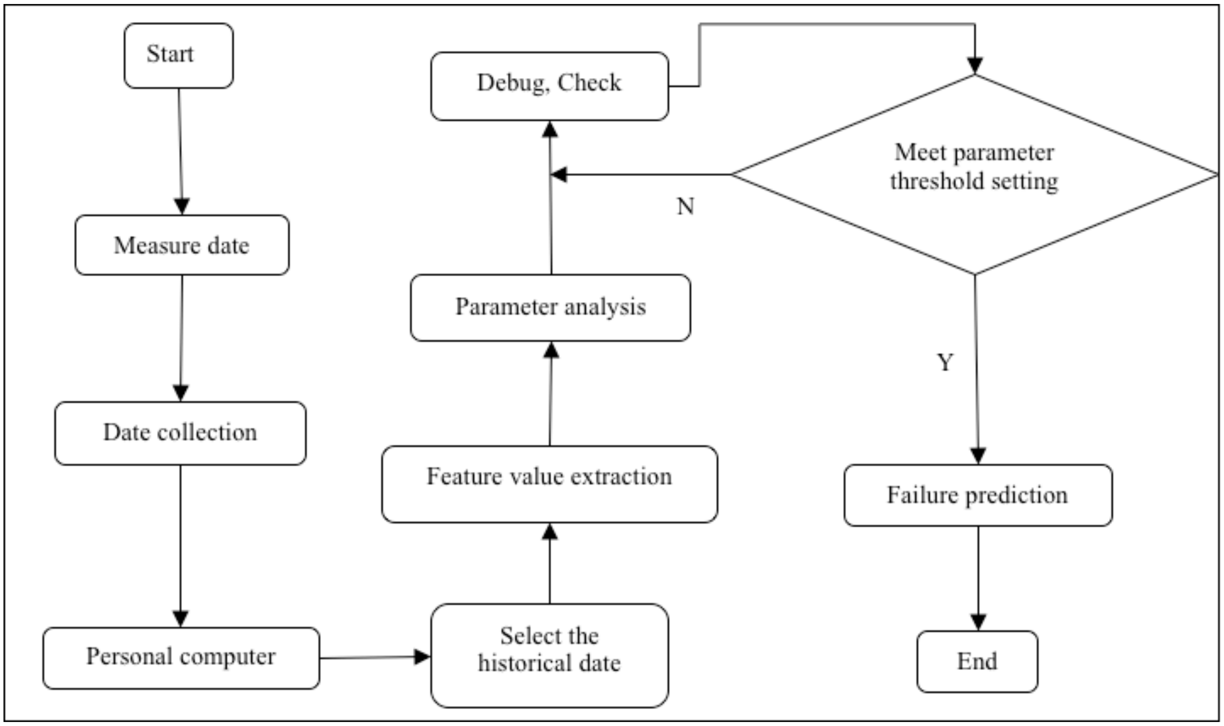

Fig. (1). System data flow diagram.

3. DATA ACQUISITION SYSTEM

The data acquisition system used a high-accuracy multifunction data acquisition card of M Series NI Company. The data acquisition card has: NI-STC 2 used for overall timing and trigger control; NI-PGIA 2 used for multi-channel accurate scanning; four times higher accuracy of self-alignment and up to 18 digit of resolution; six DMA channels can increase data throughput; digital line protection, counter, timer and filter; analog/digital (A/D) and digital/analog (D/A) converter with cutting-edge technology [6]. All of these help ensure the accuracy of the measurement.

Before data acquisition, data acquisition cards should be installed [7]. Insert the acquisition card into the PCI slot of the PC machine. Because the type of acquisition card and LabVIEW software belong to the same company, there is no need to rewrite the driver for the acquisition cards. Simply follow the prompts to install. Set the equipment number, analog input polarity, analog input mode, the analog output polarity and other parameters after installation. Select RC68-68 (68-pin economical cable) and CB68-LP (68-pin economical terminals) to connect to the data acquisition card and measuring instruments. So during the data measurement, data signal detected by measuring instruments is transmitted to the PC through data acquisition cards. Then use LabVIEW software for data processing. The data acquisition process is shown in Fig. (**2**).

4. DATA ANALYSIS SYSTEM

In order to achieve the bearing failure prediction, and achieve the purpose of user-friendly design, the entire data analysis system is divided into three modules, namely, data analysis and calculation module, data storage display and

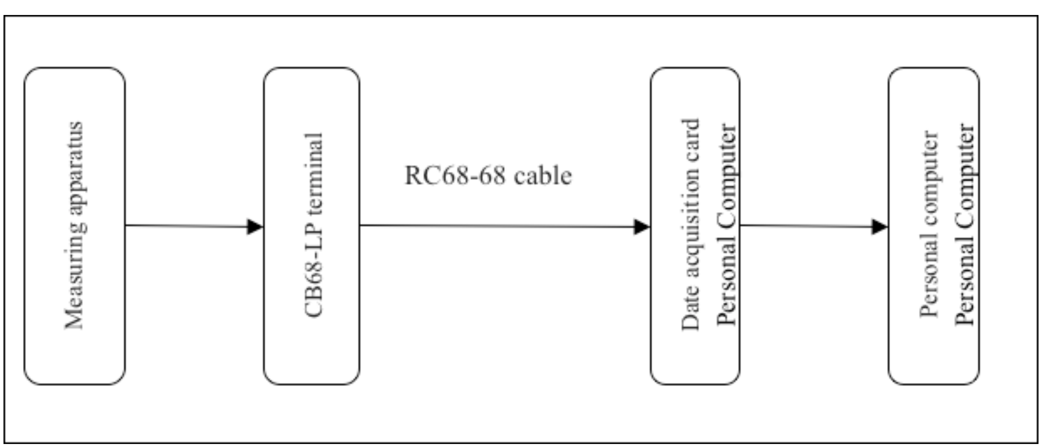

Fig. (2). Data collection process [8].

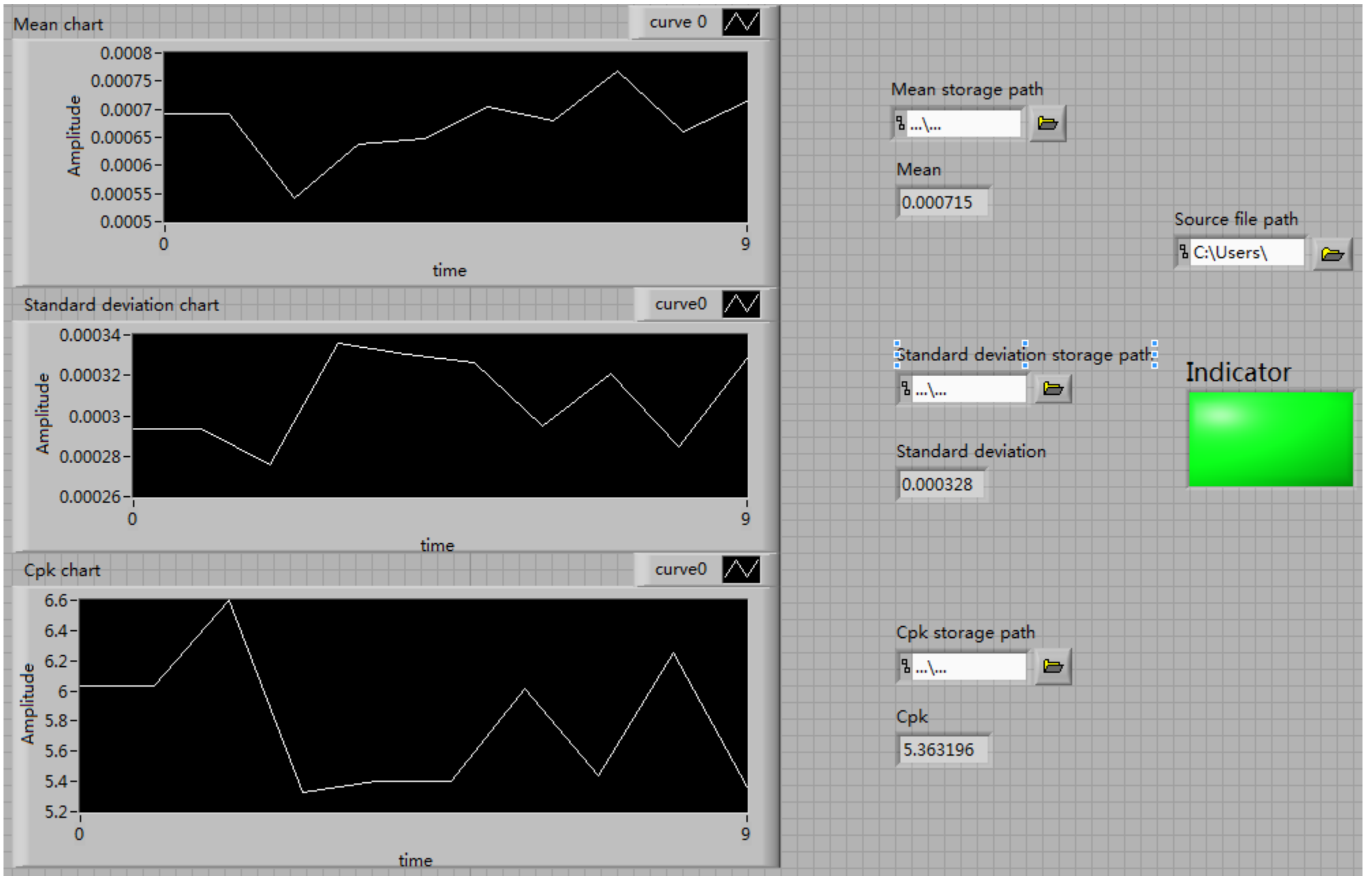

Fig. (3). Program interface.

storage module and alarm module. Program interface is shown in Fig. (**3**).

Program interface includes open source control, numerical display controls, storage controls, chart controls and indicator control. Operator can choose the spreadsheet files from the open source control, select the storage path of calculation results from the storage control, observe the result and variation trend of the data from numerical display controls and chart controls, and determine whether the parts size data reaches dangerous range from indicator control.

4.1. Data Analysis and Calculation Module

This module is used to calculate and analyze the data collected by acquisition system. Import data into this module by opening ".csv" format data source file on the PC. In this case, each parts size is measured twice. So we have got two columns data. Calculate the mean, standard deviation and process capability index of these data.

Mean: reflect an indicator of data central tendency [9].

$$\bar{x} = \frac{\text{sum of sample values}}{\text{sample size}}$$

Standard deviation: The performance of the density degree of deviation between the sample values and the mean

$$S = \sqrt{\frac{(x_1-\bar{x})^2 + (x_2-\bar{x})^2 + \ldots + (x_n-\bar{x})^2}{n-1}}$$

$x_1(x_2)\ldots\ldots x_n$ −the measured values

$\bar{x}$ −mean n−sample size

Process capability index: Evaluate the overall process, only the stable process can continue to provide qualified products.

$$C_p = \frac{\text{tolerance}}{\text{process spread}} = \frac{T}{6S}$$

S−standard deviation

As Fig. (**4**) shows, first read the spreadsheet file. Then transpose and index the two-dimensional array that is composed by two columns of data, because row order is main sequence for two-dimensional array in LabVIEW. The number of data collected varies each time, Use a 'For' circulation to make a statistics on the number of radom data. Then calculate the mean and standard deviation of the data through the mean command. In this case, process capability index is calculated according to the tolerance center 0.06. Set these three parameters preliminarily. We can set multiple parameters according to different needs in practical application.

4.2. Data Display and Storage Module

As shown in Fig. (**5**), in this module, three sets of calculated data are shown in the chart respectively. Staff can observe the fluctuation of the parts data and write the results into spreadsheet for later reference.

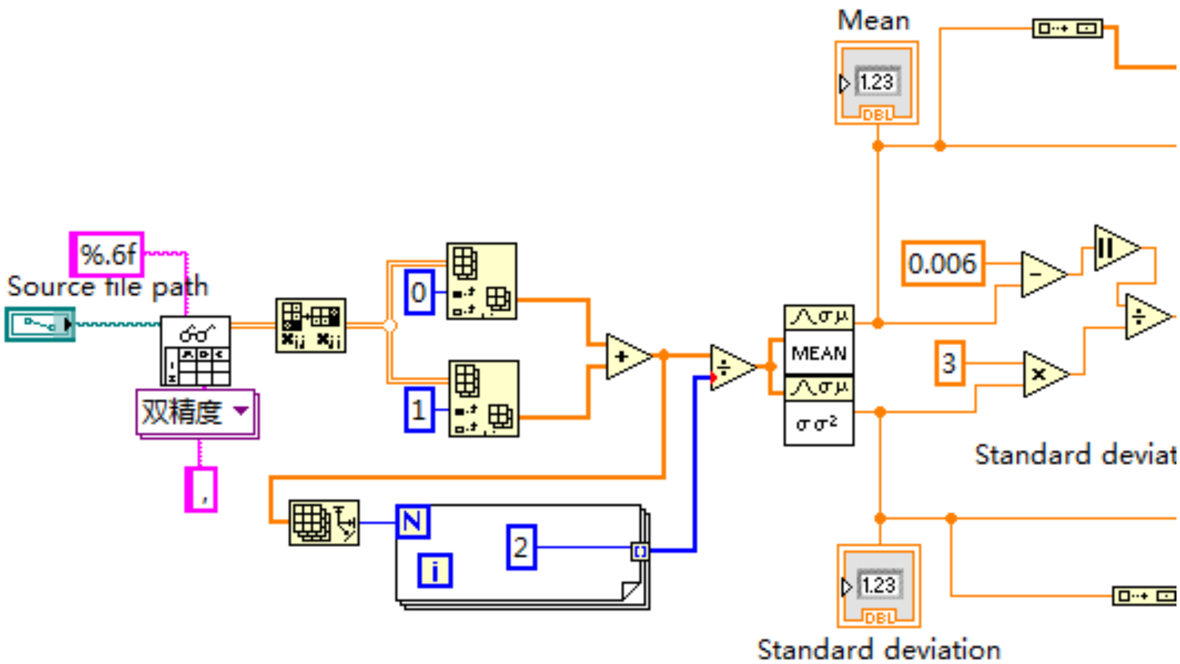

Fig. (4). Data analysis and calculation module.

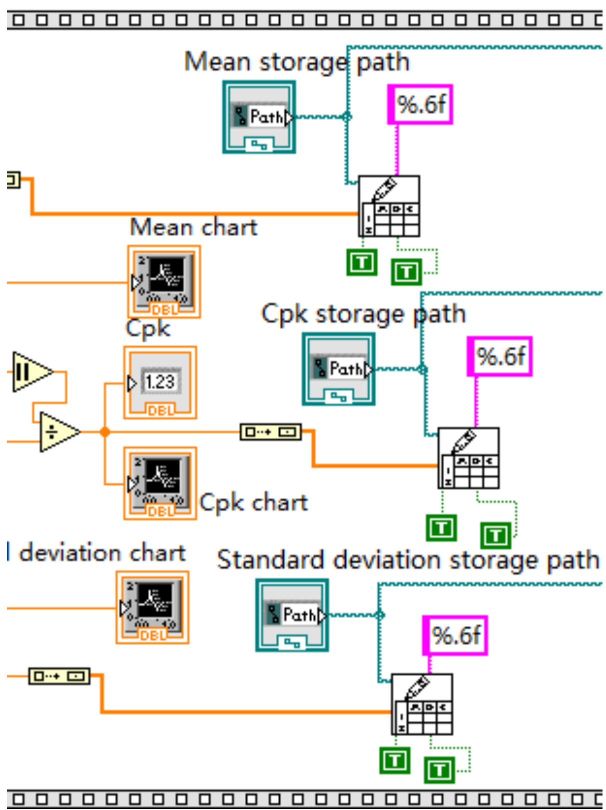

Fig. (5). Data display and storage module.

4.3. Alarm Module

As shown in Fig. (**6**), in this module, bring up and calculate the data that has been written into spreadsheet, and then index them into an array. Next step is to reverse one-dimensional array and index its subsets (array of length n). Calculate the average. This realized that every calculation results are the average of a subset of array (length n) that are recently entered into the system. The final calculation results were compared with pre-set critical thresholds. And the results are connected with indicator through three "or" logical relationship. One of the three parameters exceeding the critical threshold will trigger indicator and prompt the replacement of bearings.

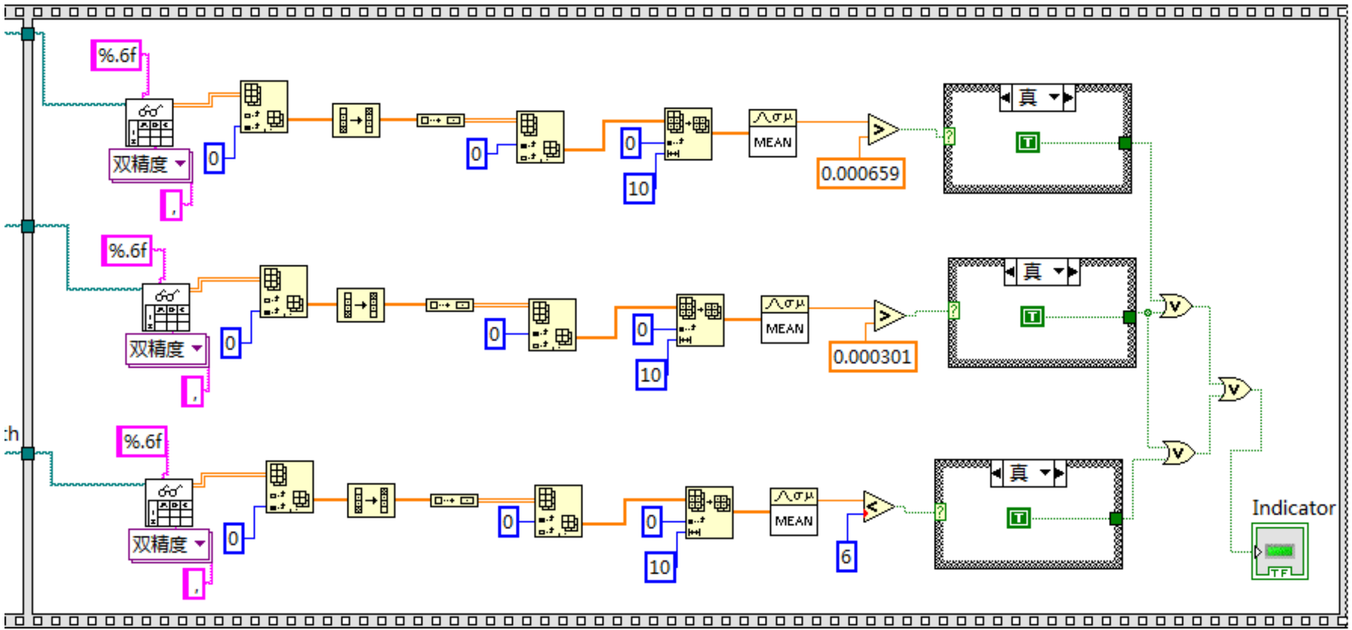

Fig. (6). Alarm module.

CONCLUSION

This article describes a new type of bearing fault prediction system. First, use the data acquisition card to collect the data of the parts that are machined by bearings and program based on LabVIEW. Then import the collected data into the program [10]. Realize data calculation and analysis, data storage and display, alarm and other functions. Determine the work status of spindle bearings through the dimensional accuracy of the parts. The system can alarm automatically before the bearing retainer failure is prompt to replace the bearing. This will improve equipment utilization and have a good human-computer interaction.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

Declared none.

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Received: January 8, 2015 Revised: January 15, 2015 Accepted: January 16, 2015