Research on equipment health management system based on PHM

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Abstract. Aiming at the safety and health requirements of equipment in chemical machinery field and combining with the current intelligent industrial manufacturing background, a PHM based equipment health management system is developed. Taking 316L stainless steel diffused welding joint of micro and small heat exchanger as the research object, the PHM system framework is designed. The system is divided into six parts: object layer, perceptual transport layer, data layer, analysis layer, recommendation layer and implementation layer. In addition, it mainly analyses test experiment construction, evaluation means, maintenance management, etc., and solves the problem of "Information Island" caused by the separation of processes in the current system.

1. Introduction
In recent years, due to the rapid development of the modern industry, the service environment of equipment has become more and more severe, which puts forward higher requirements on material performance, structural design and life evaluation. From the perspective of foreign research status, since the first use of the PHM technology in US F-22 fighter jets in 2000, the focus has shifted from repair to prevention, greatly reducing the failure rate and avoiding major accidents and losses [1]. Subsequently, various industries in various countries are using relevant technologies to form their own systems to grasp the overall fault prediction and health status. However, our country still pays attention to the maintenance system, the test, the maintenance and the management processes are separated into the “information islands” [2, 3]. In addition, the PHM research in China is mainly carried out on one of the problems, such as life expectancy prediction, health management, etc., and systematic research on the technical framework is relatively rare[4, 5]. Therefore, it is urgent to optimize the original system, develop and integrate the PHM system with the new intelligent acquisition and decision-making algorithm, so as to meet the needs of the rapid development of modern industry.

In this paper, the 316L stainless steel diffusion welded joint of the micro-miniature heat exchanger is taken as the research object, and the PHM framework based on test, evaluation, maintenance, design and management is systematically planned. In addition, the discussion and analysis of each key component subsystem are carried out, and then the PHM system is built from the aspects of reliability, real-time and maintainability. Though monitoring the high temperature creep durability test of material,
the life and reliability of the material are predicted and analyzed, and then the fault diagnosis and health evaluation of the material are carried out with the actual maintenance data.

2. The structure of Equipment health management system

Aiming at the problems of test, evaluation, maintenance, design and management process separation problems in the field of mechanical and chemical engineering, the 316L stainless steel diffusion welding head of micro-miniature heat exchanger is taken as the research object. Refer to the OSA-CBM framework [6], the equipment health management system based on PHM is designed and studied in this paper. As shown in Figure 1, the system composition scheme is mainly composed of six parts: the object layer, the perceptual transport layer, the data layer, the analysis layer, the suggestion layer, and the implementation layer. The related objects and parameters are set by the object layer. The perceptual transmission layer is responsible for the acquisition and transmission of the original data of the creep persistent test. The data layer is responsible for the collection and storage of the data, and the B/S, C/S server is built in order to ensure the timely alarm signal at the same time. The analysis layer is responsible for data preprocessing, and uses the model base model for life prediction and preliminary material fault diagnosis. The suggestion layer is responsible for displaying the analysis results to the maintenance department and the design department, providing suggestions and collecting the department data at the same time. The implementation layer makes accurate classification decisions on the fault according to the maintenance department and design department data, and gives the health assessment and maintenance guidance scheme at the same time. Considering the huge amount of data, the Hadoop platform is used for storage and processing.

3. Key technologies of all Layer

3.1. Object Layer

The object layer is a physical layer closely related to the specific application device of the PHM, including the design and analysis for specific application objects (equipment, equipment), etc. (This article is a 316L stainless steel diffusion welded joint of micro heat exchangers) At the same time, the acquired data information, prediction parameters and related fault operation mechanism parameters and so on are easily generated. In this paper, the acquired signals of creep-sustained experimental acquisition are designed for temperature, creep deformation, fracture time and load stress. The prediction parameters are hour (h), creep strain (%), and fracture reliability (%).

3.2. Perceptual transport layer

As shown in figure 2, the perceptual transmission layer mainly performs the data acquisition and transmission through condition monitoring, including the selection of sensors, the optimal layout of sensors, and the design of transmission modes and so on. The temperature signal of this paper is acquired by K-type thermocouple and controlled by MR13 temperature controller. The data layer sends reading and writing commands to MR13 though RS485 bus to realize the automatic collection, transmission and
control of temperature during the test [7]. The creep deformation signal is converted into DC signal by the CBW digital displacement meter, and then transmitted to the data layer after ADAM4017 analog-to-digital conversion, so as to realize the automatic acquisition of creep deformation. When the permanent specimens break, the switch turns on, electrical signal is converted to digital signal and transmitted to the data layer, which realizing the automatic recording of the long-term break time. The load stress signal is acquired by the pressure sensor, and the communication between the Siemens S7-200PLC and the pressure sensor is realized by Modbus [8]. The data layer reads the load data or sends the load control parameters through the RS485 bus, and then controls the servo motor to rotate the rod to accurate loading. Through bus system and address distinction, up to 256 electronic creep testers’ signal such as temperature, stress, strain and break time can be automatically acquired and monitored.

3.3. Data Layer
Considering the problem of poor anti-interference and low transmission baud rate of RS232 communication in industrial environment, the data layer and the perceptive transmission layer are closely connected by the RS485 bus. The PCI-1611U multi-serial port communication card is used as the communication medium to realize the transmission of the perceptual transmission layer data, as well as the standardized data classification and storage management operations. In this paper, VB6.0 is used to develop data monitoring software based on Win XP. The MSComm control is used to initialize baud rate, parity check, data bit and stop bit, etc., and configure communication address and buffer. After reading the buffer through the VB program, it is written to the Access database through the ADO control. At the same time, in order to ensure the timeliness of the alarm signal, the server of the B/S and C/S architectures is built in the data layer. In the B/S framework, Apache+ Tomcat is used as the web application server, and the standard 80 port is configured as the web terminal request port. The servlet written by Java is responsible for interactively browsing and modifying the data. In the C/S framework, server’s 9100 port is used as the client connection port. The Socket Server is written in Java for client connection, and message is encapsulated and transmitted in XML file to realize data transmission and timely push of alarm signals.

3.4. Analysis Layer
The analysis layer uses the data of the data layer to analyze the health status assessment, remaining life prediction and fault diagnosis reasoning of the object through mathematical models, intelligent

Figure 2. Equipment health management system structure.
algorithms, reasoning techniques and so on, which provides the theoretical basis for the subsequent recommendation layer and implementation layer. As shown in figure 2, the analysis layer contains a PHM management system developed by Java, which is responsible for dynamic data preprocessing and decision making. The model library provides analysis models for life prediction and health assessment in `.class` format, such as the theta function model, the Norton equation model, the Larson-Miller equation model, the Weibull failure model, the Bayesian failure model, etc. Figure 3 is the service time/strain curve and the service time/fracture probability curve of the analyzed diffusion welded joint.

![Figure 3. The results of Analysis layer.](image)

3.5. Recommendation Layer
The recommended layer mainly displays the results of the creep-lasting test analysis to the maintenance department and related structural design department. At the same time, the suggestion layer provides repair suggestions for material faults, design theory, fault early warning and so on. In addition, the recommendation layer is also responsible for receiving data such as maintenance, faults, resource costs and other data for the maintenance department.

3.6. Implementation Layer
Both the implementation layer and the analysis layer are developed by Java and built on the server. The implementation layer is mainly responsible for the management of maintenance decisions, spare parts allocation, and resource optimization based on the actual micro-miniature heat exchanger maintenance data, fault data, resource costs, etc., so as to ensure that the object can be healthy, safe, economical, continuous and effective operation. In this paper, the implementation layer is based on the material life prediction of the analysis layer, combined with the actual service failure data, maintenance data, assessment of health conditions or preliminary classification of material failures, mechanical failures and other failures, etc. Then the neural network, fault tree and other methods are used to further accurate the fault and the fault repair strategy is provided.

Considering that the test data, maintenance data, fault data, resource data, etc. are all processed by the server, the load capacity of the sever is limited, so the Hadoop platform is built on the server. Using VMware virtual machine to distribute multi-core computers evenly, other slave computers can also operate through gateway connection. Data layer and actual maintenance’s data can be stored in HDFS and distributed computing by Map Reduce to ensure the safe, efficient, stable and rapid execution of the system.
4. Conclusion

This work constructs a set of equipment health management system based on PHM technology, and redesigns the PHM framework through in-depth analysis of the actual situation. The system is divided into six parts: object layer, perception and transmission layer, data layer, analysis layer, suggestion layer and implementation layer. The high temperature creep endurance test, life evaluation, structural design and maintenance of the equipment are systematically managed. The results show that the system runs stably and the test data is reliable.

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