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Intelligent Embedded Monitoring System of Hydraulic CNC Machine Tool

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This paper designs the hydraulic CNC machine tool monitoring system based on the intelligent embedded theory. The mass data generated during the operation of the equipment is collected via the network. The diagnosis expert system is used to interpret these state data to achieve pre-judgment of fault, improve the equipment reliability and reduce the operating cost. The high-frequency network-based servo data sampling technology is developed using FANUC open Focas dynamic link database. The storage and management methods based on big data are studied. The upper layer data management framework is built. Open-source Historian real-time database is used for data mining. Finally, the diagnosis model is established to interpret the abstract data, and establish a relationship with the machine failure mode. The model of servo lean energy consumption is obtained by studying the energy consumption under different modes of CNC machine tool to optimize the energy consumption.

1. Introduction

The rapid increase in demand for vehicles brings challenges to machine maintenance and management, including personnel skills (Anders et al. , 2017), line operation strategy and equipment management methods. At present, most car companies adopt market-driven marketing mode, so the line operation strategy is subject to market changes and fluctuations (Bae et al., 2006). For example, the line runs with full load in the powertrain company (Dong et al., 2016), that is, 7-day 3-shift operation (Espinoza-González et al., 2016). This operation and maintenance mode occupies the traditional PM and TPM time. The maintenance activities are emergency maintenance caused by the machine fault in general (Esrin and Gartner, 1984). This passive operation and maintenance brought waste in each link of equipment management: high spare inventory (Ezrin and Gartner, 1984), long emergency maintenance response time and others. The quantity of equipment in the automobile industry increases (Gulyakova and Gorokhovatsky et al., 2017). The traditional maintenance mode cannot meet the demand for increasing capacity (Fernandes, 2016). The sensor, Internet and intelligent technologies continuously develop, which brought new and innovative equipment management and management modes and provided technical support (Ghahrizjani et al., 2016).

2. Scheme of intelligent monitoring system of hydraulic CNC machine tool

2.1 Mathematical modeling methods

(1) Object
For example, a CNC machining center contains the following parts by the control mode: CNC system, consisting of servo control unit, motor drive unit, servo motor, PLC and so on; drive system, consisting of screw, rail, coupling and so on; actuator, consisting of air cylinders, oil cylinder and other mechanical components; measuring unit: grating ruler, sensor and so on. Select the servo motor as the object.
(2) Failure mode
Select the servo motor as an example. The failure mode of the servo motor is analyzed. There are two failure modes: 1) Motor overheat due to decreased three-phase insulation and/or increased load etc. 2) Damage to encoder due to worn cable or dirty encoder etc (Rao et al., 2016).

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2.2 Architecture of the project

The data in data layer at device level is transmitted to the Historian real-time database via Ethernet. In this paper (Heffernan et al., 2014), the data mining techniques is used for association and collation, and the results are sent to the historical database for storage and analysis (Iyenghar et al., 2013). The obtained results is released in Internet through the WEB SERVER, and broadcast in various forms to display for users, including large-screen display, mobile AP (Jung et al., 2014) P, E browser of workstation etc. The data transmission layer will extract data which is changed at high speed (Kaleem et al., 2016). The storage analysis layer will solve problems on expert system analysis and big data storage (Laurita et al., 2017).

2.3 Architecture of host system

The system consists of two modules: data acquisition module and WEB management module (Lee and Chen, 2017). The intelligent monitoring system of CNC machine tool is based on the device state pre-diagnosis mode via signal transmission (Lenoir and Aubin, 2017). The source data and parameters are processed in the hidden data mining and analysis layer (Li and Wan, 2017), outputting the maintenance instructions, source data mining and analysis methods, and the analysis results to transmit (Pereira et al., 2016).

3. Mathematical model

3.1 Expert analysis system

(1) Data association and filtering
Data mining techniques include: correlation analysis, time sequence analysis, cluster analysis, fuzzy set based analysis, neural network based analysis etc. Time sequence analysis and correlation analysis are used for data filtering in this paper.
(2) Trend analysis
The trend analysis is called the trend curve analysis. A curve is fit based on known historical data which can reflect the trend of data. Based on this trend, the value at any time can be predicted. The common trend models include linear trend model, polynomial trend model, logarithmic trend model, power function trend model, exponential trend model and logistic model. It is easy to select a proper trend model. In this paper, the linear trend method is used to predict the performance of the actuator, and we will describe it based on the tool change gate.

3.2 Workflow of expert diagnosis system

Workflow of CNC machine status intelligent monitoring system: The data is sampled by the sampling tools (e.g., front-end data collector and servo sampling software) monthly. The sampled data are filtered and correlated to generate variables. These variables are stored in the historical database. The expert analysis system will perform comparison analysis, trend analysis and find the difference, outputting maintenance instructions. The machine is maintained and repaired based on the field instructions. After maintenance, retest the machine and check the effect.
In addition, establish a link between the project and field maintenance (Seo and Lysecky, 2016) e. The problems are summarized. The report consists of five parts: equipment attribute, history signal data, waveform, analysis result & recommended measures, as well as field maintenance & rectification feedback. The fifth part includes the recommended measures for field maintenance, and the feedback after rectification (Xue et al., 2015). This report reflects the closed loop control process from the release of information to the feedback of rectification.

4. Model training and application

4.1 Application of model

High-speed, high-precision CNC machining center is studied. It is difficult to capture and analyze the data. In this project, an innovative data sampling method is used for quick and convenient data capture, so that the data can reflect the state of the components. The model is learned and trained using a large amount of data for improvement. So far, this project covers more than 80% of parts of CNC machining center.

4.2 Application of model to enhance line processing efficiency

The CNC machining efficiency is inclined to be improved actively. In view of equipment management, the slow failure process of parts is often accompanied by the decreased speed, resulting in potential tact loss, which is not noticed. The movement time of motion part is compared with the standard value to find any abnormity for improvement, so as to avoid any loss. Figure 1 shows the analysis process.

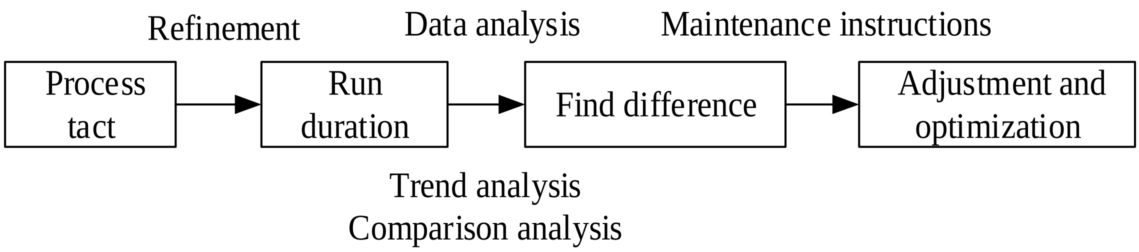

Figure 1: Analysis process

(1) Object
Select the representative Japan ENSHU JE60S of the powertrain company as an example. The servo control system is FANUC 31i-A system which can control 30 axes, five-axis linkage CNC machine tools with positioning accuracy Sum.
(2) Scheme
The tact of machine tool consists of many motion processes, including the cutting process of tools and the auxiliary motion process, such as tool change time, close time (Figure 2).

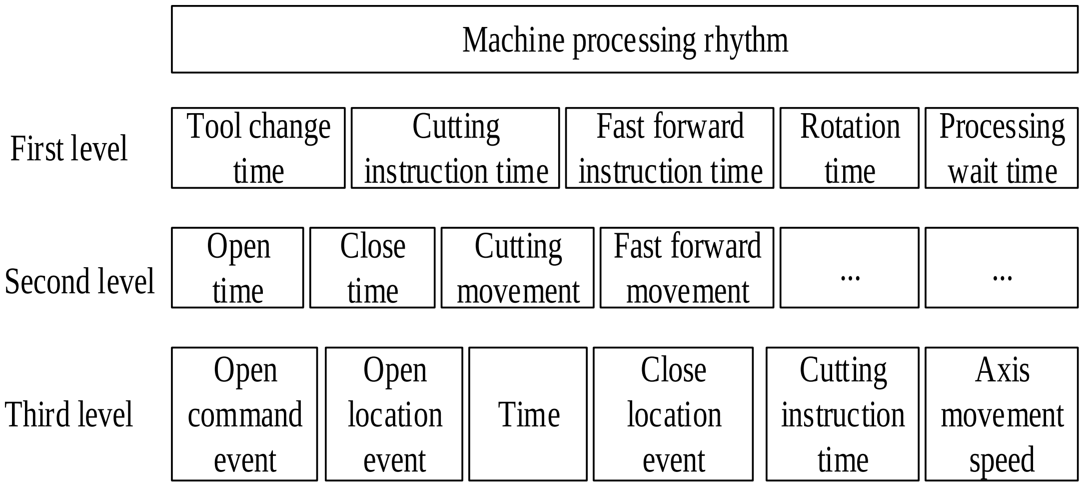

Figure 2: Processing tact H-level decomposition

4.3 Servo calibration for energy-saving

As can be seen from Figure 3, by optimizing the acceleration/deceleration and G00 speed, the energy consumption of the servo motor obviously decreases for the same distance. The same conclusion is got after analysis of G00 acceleration process: The motor consumes the least energy when it moves at constant velocity. Simultaneously optimizing acceleration/deceleration and increasing motion time at constant velocity can reduce energy consumption while meeting the processing requirements. Figure 4 shows the optimization process. A gearbox line in powertrain plant is studied. Figure 5 shows the equipment processing tact.
As can be seen in Figure 5, the tact of different equipment in the same LOOP is different, and there is an opportunity to improve the constant motion time. After optimization of acceleration/deceleration, the processing tact is prolonged. After modifying the start parameters, the energy consumption significantly reduced. Figure 6 shows the statistics.
During normal CNC machining, the energy consumption in fast-forward mode is the maximum (E.g., the energy consumption on X-axis in fast-forward mode accounts for 85.42%). The process of start-up tact is studied in fast-forward mode (maximum energy consumption), and found that the energy consumption during acceleration/deceleration accounts for 98.8%. The current at constant velocity is the minimum, accounting for only 1% of the energy consumption in the start-up tact in fast-forward mode.

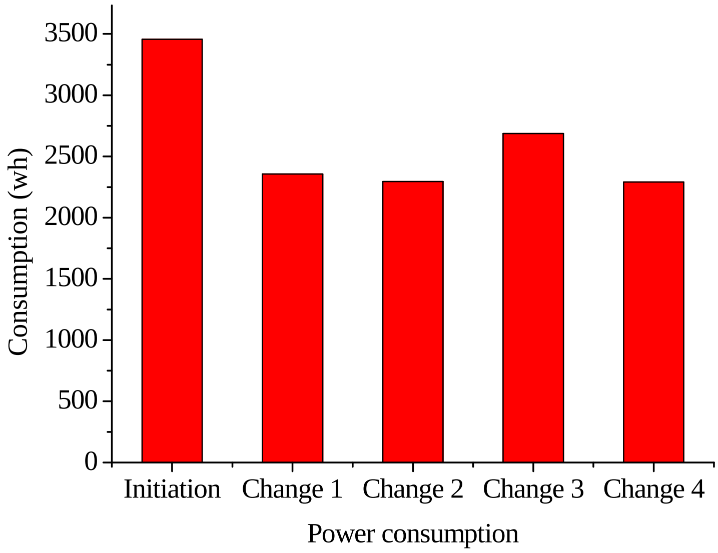

Figure 3: Previous calibrated energy consumption

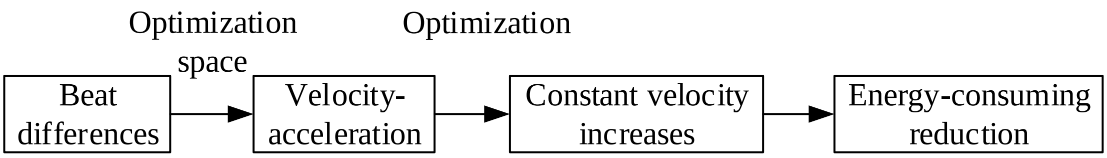

Figure 4: Optimization process

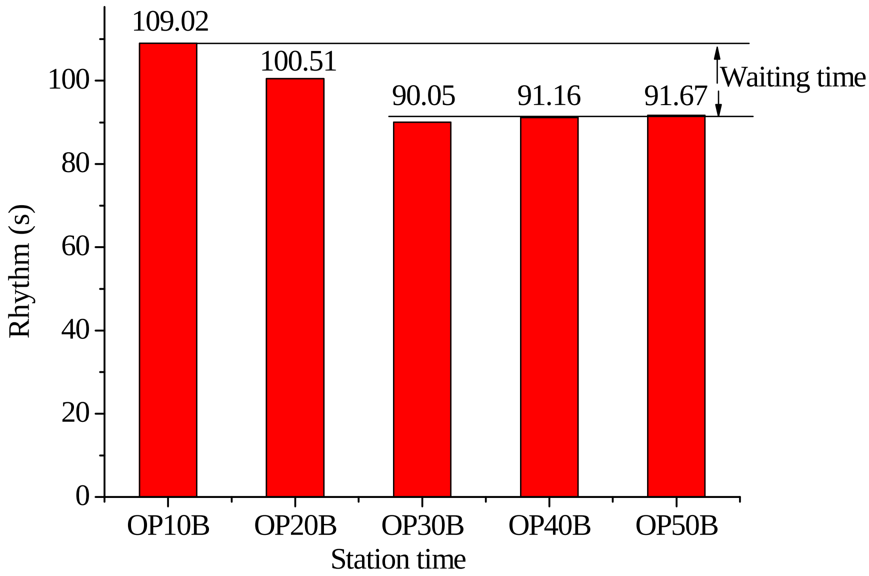

Figure 5: Tact in the same LOOP

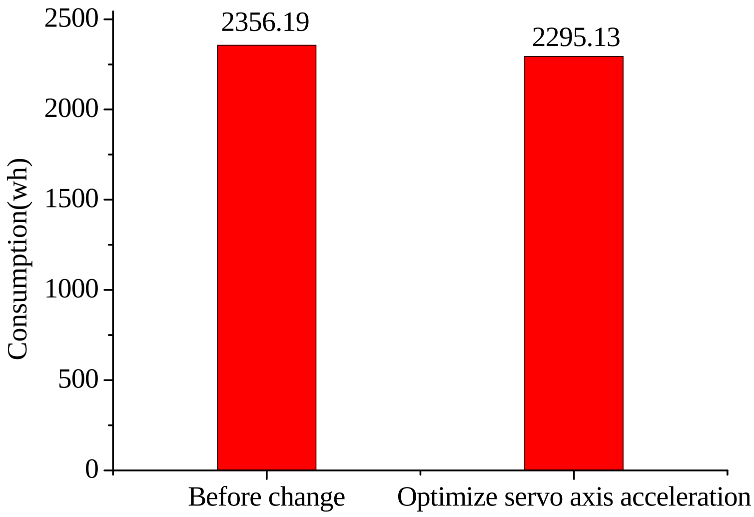

Figure 6: Energy consumption before/after optimization of servo parameters

5. Conclusion

This paper introduces the advanced equipment management concept in the automotive industry, and points out the disadvantages of various management modes. With the development of information technology, use of network and interconnection technology for proactive management of equipment is explored to improve the reliability of equipment and reduce the operating cost. This pre-maintenance mode based on the Internet was developed. This paper discussed the network architecture, hardware planning & design and modeling. The failure prediction model of key components of CNC machine tools (e.g., screws and motion parts) is established. The main methods of the fault trend analysis are summarized. The prediction model suitable for the CNC machine tool is selected using the big data mining technology, trained and forming the common curve of motion parts. The pre-diagnosis model of motion parts is put forward. Finally, the equipment life tact management strategy is discussed and established, including the intervention time for preventive management strategy, which is significant for equipment management.

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