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A systematic approach to integrated fault diagnosis of flexible manufacturing systems

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Abstract

A flexible manufacturing system (FMS) is an application of modern manufacturing techniques. Like for other manufacturing equipment, the success of an FMS is very much dependent upon its trouble-free operation. It is crucial to monitor all the possible faults or abnormalities in real time and, when a fault is detected, react quickly in order to maintain the productivity of the FMS. Because of the complexity of FMSs, the functionally complete diagnosis of an FMS should be based on all the available information and various advanced diagnostic techniques so as to get a satisfactory result. This paper proposes a systematic approach to fault diagnosis of FMSs that integrates condition monitoring, fault diagnosis and maintenance planning. An intelligent integrated fault-diagnosis system is designed with a modular and reconfigurable structure. The implementation of the integrated diagnosis system is presented in detail. The system can monitor the major conditions and diagnose the major faults of an FMS, and give corresponding maintenance planning as well. The developed system has been applied to an existing FFS-1500-2 FMS in Zhengzhou Textile Machinery Plant and has achieved good results. © 2000 Elsevier Science Ltd. All rights reserved.

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1. Introduction

With the development of modern manufacturing technology, flexible manufacturing systems (FMSs) have become key equipment in factory automation. This kind of manufacturing equipment

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is being used more and more widely because of its potential to improve the strategic and competitive position of firms. However, such manufacturing equipment is very dependent upon the trouble-free operation of all its component parts. When a fault occurs, it is critical to isolate the causes as rapidly as possible and to take appropriate maintenance action. Typically, when an FMS goes down, only a small fraction of the downtime is spent repairing the machine that causes the fault. Up to 80% of the downtime is spent locating the source of the fault [1]. For this reason, corresponding diagnostic techniques and systems have been studied extensively with the application and dissemination of FMSs.

Many diagnostic techniques and systems appear to have been reported in the literature on diagnosis of FMSs. Toguyeni et al. proposed some reasoning mechanisms for the implementation of an on-line diagnostic system [2]. These mechanisms are based on a distributed processing of symptoms that enables the problem of the real-time constraint to be solved. Cheng and Lipheng proposed a model-based approach for automating the fault-diagnosis process of an FMS [3]. The approach utilizes a fuzzy digraph coupled with worst-first search reasoning for tracing the root causes of system faults. Weck and Hummels have described several aspects of on-line integration of a knowledge-based diagnostic system in a hierarchical automation structure of an FMS [4]. DeBonneval et al. presented a hierarchical and modular structure for real-time control of FMSs that integrates the monitoring of process failures [5]. Modularity is obtained by using a basic component — the module — to build the control system. Chang and Shah have proposed an integrated quality-diagnosis approach which models a manufacturing process using object-oriented programming (OOP) techniques and embeds the dynamic shop-floor information in the OOP model [6]. The approach alleviates the burden of storing massive diagnostic information for all the parts in an FMS environment. Milacic et al. developed a model of an expert system for the conceptual diagnosis and maintenance of FMSs' mechanical systems [7]. Wu and Joshi presented an approach for dealing with several critical issues that arise in performing the three activities of an error recovery module: error classification, error knowledge representation, and generation of recovery procedures [8]. In particular, the execution errors occurring in a manufacturing system are emphasized. Kuo and Huang proposed the coloured timed Petri net (CTPN) based statistical process control (SPC) and fault-diagnosis models to model the SPC and fault-diagnosis behaviours of FMSs [9]. Ye and Zhao developed a highly integrated system, integrating neural networks with a procedural decision-making algorithm, to implement hypothesis–test cycles of a system diagnosis on tested fault events [10].

All available diagnostic techniques as well as systematic approaches have their drawbacks, all are not absolute and there is a plea for the effective integration of condition monitoring and fault diagnosis, making full use of all the available diagnostic information and knowledge. In addition, in order that it can be generally used and easily transplanted so as to be convenient to disseminate and develop, the designed diagnosis system should have the following characteristics and functions:

- modular, expandable and reconfigurable structure;
- able to measure and process a large amount of analogue and digital signals;
- able to make complex, multi-parameter decisions;
- with on-line and real-time interfaces to the FMS controllers.