Research on fault diagnosis for CNC machine of Flexible Manufacturing System

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Abstract: In order to find and treat fault or abnormal occurrences in numerically controlled machine tool of flexible manufacturing system in real-time, a study for computer numerically controlled (CNC) on-line fault diagnostics system has been carried out. The system can look up one or more sticking points of numerically controlled machine tool fault simply, locate CNC faults rapidly and accurately, but solve the problem between fault diagnosis and knowledge application. To provide CNC apparatus terminal with reliable trouble shooting suggestion, give a deep analysis between servo control subassembly and background service, make a description of fault database and test procedure design. The research has solved the problem of system maintenance, expansion and upgrade.

Key-Words: Fault Diagnosis of Machine; Diagnosis; Knowledge Application; CNC Servo Control Subassembly

1 Introduction

Numerically controlled machine tool plays a key role in the system during the manufacturing process. In complex systems how to find and treat fault or abnormal occurrences of the numerically controlled machine tool timely is a difficult issue for manufacturing at present.

The Machining Flexible Manufacturing System is made up of logistics, information flow and energy flow[1]. Logistics is composed of CNC machine tool group, tool and fixture station, automatic conveying car, storage rough and semi-manufactured goods or finished product and automatic warehouse. It is used to transfer material. Information flow consists of main computer, central management computer, and logistics control computer and information transmission network among them (the relation is showed with single arrow in the picture). Energy flow is mainly grouped in the inside of manufacturing unit.

Analyzing the functions and features of the Machining Flexible Manufacturing System[2,3] get results as follows:

(a) Main Computer Main Computer is mainly used in production plan, procurement of materials and outsourcing, CAD customers ordering plans and contract management. It can also control the sub-central management computer and sub-logistics control computer.

(b)Central Management and Control Computer Central Management and Control Computer receives orders from main computer of factory and monitor the whole system. The computer control every CNC system, machine processing data, command data of each industrial robot, intensively manage and control tools and fixtures, coordinate action of different control units.

(c)Logistics Control Computer Logistics Control Computer is used to coordinate and control automatic warehouse, automatic conveying car, machining rough and finished product, cutting tool and fixture.

(d)Information Transmission Network Information Transmission Network is a cable communication system contacting information among CNC system, industrial robot, tool and fixture station and central management computer.

(e)Automatic Warehouse Automatic Warehouse automatically store call machining rough, parts and semi-manufactured goods or finished product.

(f)Automatic Conveying Car Automatic Conveying Car is a conveying tool controlled by logistics control computer, establishing a link between machine tool and automatic warehouse. It also completes transporting parts and parts in/out carbarin.

(g)Manufacturing Unit Manufacturing Unit is the basic unit of FMS, it is made up by CNC
machine and industrial robot.

(i) **Tool and Fixture Station** Tool and Fixture Station is integrated management station of tool and fixture.

(ii) **Accompanying Work Station** Accompanying Work Station is the carrier of parts transfer between automatic car and manufacturing unit, for temporarily storing rough and finished product.

The energy transmission of CNC machine tool group in manufacturing unit and the liaison of information transmission network in whole system play a key role in the operation of flexible manufacturing system. CNC machine of manufacturing unit is the key to the process of digital manufacturing.

This paper does research into CNC on-line fault diagnostic system and presents a core of flexible manufacturing system. The CNC closed-loop servo control system structure is designed reasonably and efficiently. Furthermore, it deeply analyzes the function allocation of servo control subassembly and the background service of fault diagnosis.

### 2 System Fault Diagnosis

The structure of the machining flexible manufacturing system shows in Fig.1.

Some fault occurrences are caused by various facts and some are a chain reaction of failure as to the complex system [4,5]. So when there is a fault in numerically controlled machine, it is not satisfying to check only by artificial detecting. The method relying mainly on on-line check test while making off-circuit test subsidiary should be adopted. This method is convenient for finding out one or more fault cruxes.

#### 2.1 Fault Diagnosis of Flexible Manufacturing System

Fault diagnosis of The Machining Flexible Manufacturing System is displayed in Fig.2.

When any remote site CNC machine of Flexible Manufacturing System breakdown, the system begins to test and diagnosis faults at once. It contains:

(a) **CNC terminal equipment management** receives fault information and send diagnosis request to central management computer.

(b) **Central management computer** receive diagnosis request from CNC terminal equipment management.

(c) **Central management computer** initialize equipment of CNC diagnosis.

(d) **CNC diagnosis** sends diagnosis to CNC terminal equipment management. The diagnosis include name of fault equipment and information ready to deal with the diagnosis.
CNC terminal equipment management of remote CNC site, calling for the name of fault equipment, builds relation of remote fault equipment and correspondent CNC diagnosis, send the location of fault equipment and working conditions signal to CNC diagnosis timely.

CNC diagnosis starts doing further diagnosis after dealing with the information received. Then the diagnosis and suggestion will be fed back to CNC terminal equipment management.

CNC terminal equipment management will send information of finishing diagnosis to Central management computer after clearing off failures. Then Central management computer receive signal, turn diagnosis to wait-state, waiting to build new connection with other equipment. CNC diagnosis is core content of CNC on-line fault diagnostic system.

2.2 Diagnosis and Knowledge Application
CNC diagnosis could drive the state data of equipments timely and send the data to data-processing unit. The processed data will drive inference engine to work. Then inference engine make judgment and inference by using regulations of Knowledge Base.

(a) If the fault is not new, which can be found in Knowledge Base, the system will finish diagnosis quickly and take measures immediately to cope with faults. While if there is unknown fault which cannot be judged exactly for having no enough knowledge from Knowledge Base. At this time, CNC diagnosis will turn to central management computer for help. Then central management computer make a connection between fault extension interface of module and Knowledge Base[6,7]. So that inference engine could use the knowledge of fault extension interface and Knowledge Base to infer and judge again.

(b) If the new knowledge, coming from fault extension interface, could solve fault, they will be stored in Knowledge Base. As Knowledge Base is expanded, the ability of diagnosis and knowledge application is further improved. When diagnosis system cannot solve the fault, diagnosis will be rolled out. At this time we must turn to experts in this scope for new diagnosis knowledge to cope with the completely new fault.

(c) When the input information is abnormal, inference engine give out warning signals and some control signals for remote control equipment. There for dangers could be avoided.

2.3 Structural Design of CNC Closed-loop Servo Control System
The high speed X-Y axes working table is the critical part of numerically controlled machine in The Machining Flexible Manufacturing System. Its structure of servo control system is showed in Fig.3.
In the course of testing, according to different functional requirement, signal generator, firstly, provides actuated signal to tested card; secondly, timing and qualitatively test the response signal of tested card. If the response signal is not exist or not meet the technical specification, fault diagnosis and testing system confirm that there is fault in this function testing. After confirming fault, CNC terminal equipment management will pop up prompt dialogue showing information of fault’s location, name, possible reasons and measures coping with the reasons and giving out trouble shooting suggestion.

3 Function and Background Service

We can know, from analyzing the control structure of CNC servo system, that servo control subassembly has many abilities, including , monitoring functions of system power supply in real-time; Function of board testing, subassembly relation test, fault location and trouble shooting suggestion; ability of database management and test report prints. The function of system’s maintenance, extension and upgrade is also included.

3.1 The Relationship between Servo Control Subassembly and Background Service

According to the research on fault diagnosis testing and structure of CNC servo control system, we can build a relationship between servo control subassembly and background service. The relationship is shown in Fig.4.

![Fig.4  Relationship Between Servo Control Subassembly and Background Service](image)

(a) **Monitor module of system power supply in real-time** The monitor module of system power supply in real-time realize testing system, real-timely monitor and display voltage or current of tested CNC machine power supply. If voltage or current is abnormal during the test process, the test equipment should cut off power automatic in real-time to protect equipment and make sure that servo test platform will operate safely and reliable.

(b) **Board test module** The board test module is important part of numerical servo control system. It’s used to complete the stabilization, search and tracking function of CNC platform. In open-loop status, it simulates board’s normally operation progress and confirms input/output relation of every board, to insure that every board of servo control subassembly satisfies the design requests.

(c) **Subassembly relation test module** The subassembly relation test module connect servo control subassembly with main operate machine of servo control system when every interface sub-subassembly fulfill the design requests, and transmits corresponding control orders. It will test flexibility and stability of diagnosis test system, to confirm servo control subassembly fulfills the design requests.

(d) **Database management and test report prints module** The database management and test
report prints module preserve the abnormal monitoring data of power supply and every testing data results in database. It builds history data file for every test board and take many classification managements for data. It can also print out test report according to fixed format, convenient for scientific management.

(e) Module of system’s maintenance, extension and upgrade The system should be of stronger universal, scalability, portability and be convenient for secondary development and use. The system with good maintainability should have self-test function to test internal system and outside interface. It also has perfect self-checking function, measurement and test interface, manual intervention function and upgrade function.

3.2 Diagnosis Database Description and Test Procedures Design

Diagnosis Database As many kinds of CNC system, servo system and mechanical system which used in numerically controlled machine, fault occurrences are frequent. The total database adopts extended structure. The database stores existing fault phenomenon (or abnormal phenomenon). Firstly, the base analyses new theoretical and experiential fault phenomenon (or abnormal phenomenon). Secondly, the base summarizes and organizes database cases[9,10]. There are many means to build application program database. In this paper it adopts digital coding method.

According to digital coding method, diagnosis numerical code is made by 4 parts. The fault position code, fault type code, fault phenomena code and fault reason code. We can see it in Fig.5.

![Fig.5 Compiling and Description of Numerical Code](image)

In Fig.5, fault position, fault position code displayed by letters. It includes NC system, servo control formation, power supply, motor and feed system, which are separately displayed by (S), (F), (E), (M) and (X, Y, Z, A, B, C). The corresponding data can be called by database. Fault type code fault phenomena code and fault reason code are all displayed by 2 figures.

Test Procedure In view of digital coding method, the job of finding fault in whole test system can be realized by programming. CNC testing progress is showed in Fig. 6.

Fault position test addressing is used to finish finding out fault equipment of manufacturing unit in whole testing system. When fault equipment addressing indicates CNC group, the test will go on. Otherwise, it will turn out. Its main working progresses are:

(a) Diagnosis send excitation signal (testing vector) to tested object, moreover, the test firstly turn to specific position of fault equipment in manufacturing unit.

(b) Receive excitation responses of tested object.

(c) According to the relation between excitation and responses, it analyses and decide the next excitation vector.

(d) Confirming fault position and type, based on excitation sequence.

4 Conclusion

As to the research of manufacturing progress, some fault occurrences are caused by various facts and some are a chain reaction of failure. Relying mainly on on-line check test while making off-circuit test subsidiary, this paper has solved fault location and diagnosis problem, when remote site CNC machine breakdown. Depending on the design of close-loop servo control system, this paper dose research on relationship between servo control subassembly and background service platform. It also finds out fault database description and testing progress.

The outcome of this paper is convenient for finding out one or more fault cruxes, locating CNC fault fast and exactly. It provides trouble-shooting suggestion. It also provides operative space for database management, system maintenance, expansion and upgrade.
Fig. 6  CNC Testing Progress Design

References


