Research on Visual Production Process Control System Oriented to Discrete Manufacturing

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Key words: production process control; data acquisition; production tracing; event tracking

Abstract: Firstly, the requirements of production control and the features of discrete manufacturing process were researched, the production process control system architecture was built. Then, the key technologies used in the system realization were studied. Automatic identification technology was used in data acquisition; product tracking and event tracking technologies were used to implement production monitor, abnormal monitor respectively in application server; Web technology was used in production statistics and analysis in presentation layer. Data acquisition and statement analysis implementation were separately based on the Windows and Web application of NET platform; products tracing and event tracking implementation were based on the configuration visual software platform: GE Cimplicity. Every layer is distinct and seamless integration in the entire system, the whole architecture has strongly robustness and expandability. Finally, a case proved the validity of this system.

Introductions

In the highly competitive business environment, enterprise decision-making needs to access the production information. Production process control performs coordinating functions between production planning and manufacturing execution; makes the production plan implemented through real-time monitoring production process, correcting deviations [1]. Production process control objects include manufacturing schedule, work-in-process, inventory, cost, quality and abnormal monitoring. Building such a control system is very important and difficult in the complex discrete environment or process, which is one of the functions of manufacturing execution system (MES). The MES bridges the gap between the business planning systems and real-time control systems [2]. As the key module of MES, production process control system is various in different industries. Many research institutions and companies have done a great deal on research and practice, and got a lot of achievements. Reference [3] compared the features of process and discrete industry MES.

Steel industry is a hybrid industry, steelmaking belongs to process manufacturing, and rolled steel is a discrete production. Reference [4] proposed iron and steel industry information system integrated architecture, and discussed the integrated technologies, such as database, middleware, and communication, application server. Reference [5] constructed three layers integrated network architecture, PLC, workstations for car industry production process control system. Reference [6] realized a vehicle production process circulation records and man-hour analysis system used barcode technique in the passenger car enterprises.

All the above-mentioned literatures founded various systems for different industries and
manufacturing environments. But they seldom discussed the characteristics and requirements of discrete production process. On this respect, this paper constructed production process control system architecture for monitoring and controlling the complex discrete manufacturing process, and the core technologies.

**Research on discrete industry production process**

To establish production process control system, we need to analyze the production process firstly, including process model, factory model, control object, abnormal classification. Production process information is very complex, and workers must complete the production operations firstly in the tense production environment, so convenient and accurate data acquisition method is necessary for information collection method.

Discrete production process is divided into two main stages: processing and assembling, processing phases are divided into blank makings, machining; assembling stage includes sub assembling and final assembling. Because of the complexity of manufacturing process, mechanical processing and assembling tend to become parallel process. In the whole production process, from the initial raw materials to finished products, the products form is constantly changing: raw materials - blank - parts - components - finished goods. At different stage the main technology also varies, discrete Production process was illustrated in fig.1.

The production process control, need from the factory to a single product auto-merging control, it is needed to establish factory model and products model. The factory model elements include factory, shop floor, production lines, operation station, buffer station, working buffer, etc. Based on the ISA SP95 standard factory model, one factory has multiple workshops, one workshop has many production lines and segments; one production line or segment has multiple workstations and buffer [7]. Each station can deposit one product. The item stand for one product, through the production order and sales order, is related to the customer. Fig.2 illustrates the factory model and products model.

The production process mainly deals with the abnormal control, mainly control objects including equipment, personnel, material, and events which attached to these entities object, such as the unscheduled halt of equipment, personnel absence, material shortage, quality substandard etc. All those abnormal factors could cause delay for production schedule. Through establishing the anomaly information management files, making corresponding processing plan, the production efficiency will be improved if the abnormal events were obtained in time in the production process and noticed support or management departments’ timely handling. Table 1 is an abnormal events classification example.

Based on the analysis of the characteristics of discrete industry production, characteristics of production process control system are: (1) Convenient data information collection methods; (2) Visual production process monitoring; (3) Abnormal events monitoring.
The focuses of production process control are data acquisition, product tracking, event tracing, and production monitoring and abnormal monitoring. But there exist following inadequateness in the great majority discrete manufacturing enterprise. Firstly, data acquisition method is laggard. The production data collection mainly uses process inspection card recording. The shortcomings are data formats disunity, information transfer delay, paper-based media, and result in difficulty for preservation, analysis and statistics. Secondly, production monitoring is laggard. Due to the various abnormal events of production process, production executions deviate from production scheduling. Information of production on-site collected and submitted to production management department manually, causing the lagged information, omit decision-making, so production progress and parts are often uncoordinated and production planning and scheduling are adjusted constantly. Finally, abnormal event classification and flow handling support system are in shortage. Lack of abnormal events classification, not unified classification codes, the similar problems exist many descriptions, hard to track the event process flow. Event handling process dispersed, mainly by telephone communication and on-site treatment, without information support platform.

In view of the above questions, combined with discrete enterprise production control requirements and industry characteristics, this paper constructs an integrated data acquisition, data transmission, database, application server, and user interface production process control system. Fig.3 describes the system architecture. This system is based on information technology architecture according to their function, summarized as relatively independent five layers, the function of every layer as following:

**Data acquisition layer.** This layer is responsible for collecting the production process data and events using automatic identification technology, such as barcode, electronic tags. The data format adopts uniform templates. The devices include personal digital assistance (PDA), programming logic computer (PLC) and scanner.

**Data transmission layer.** This layer is in charge of communication. Network protocol use TCP/IP and UDP. The linking from data acquisition devices to server use Microsoft message queue (MSMQ) and Web services technology, and then from server operation system to database use OLE for process control (OPC) server.

**Database layer.** The data storage and data integrated are implemented in this layer. Real-time
database and historical database are separated. The production monitoring and abnormal monitoring use Real-time database, ensure the response and transmission efficiency. Data statistic and analysis use historical database, ensure the integrity of the data and large number of data access.

**Application server layer.** This layer deals with the system application function, which including product tracking, production control, abnormal monitoring, factory model, production statistics and analysis.

**Presentation layer.** This display layer is a platform for interacting with user. The visual and dynamic monitor view can represent the real-time production process and event information.

**Development platforms and key technologies of system realization**

System realizing involving two development platforms: .NET and GE Cimplicity. .NET is used to implement the data acquisition, data transmission, abnormal handling, statement statistics, and barcode print. .Net is Microsoft’s new generation development platform, has Windows and Web application development function of integration, the basic services, terminals, user service in integral whole. GE Cimplicity is used for products tracking in discrete manufacturing environment, which can establish production process model to ensure the reliability of tracking process and expansibility, and provide rich component and object-oriented API interface. The track records may contain all the work details data, such as content, status, and location. The track records are used to drive the production process model. This platform is a configurable intelligent system in automation industrial, which has the formidable picture editor, equipment integration, data acquisition function and good system security, stability, and widely used in automobiles, transportation, steel industry etc.

**Data acquisition based on automatic identification.** Automatic identification technology is the key technology of data acquisition. The product information, location information, process information and the abnormal information are united coded. The real-time data collected using barcode scanners and PDA. Data records are transferred into the server queue through MSMQ and Web service, and then driving product tracking model and abnormal events processing flow.

Data record consists of products, position, the shift, operation, abnormal events, and time. Automatic identification technology improved the efficiency of data collection and unity, and ensured the data integrity and time-ordered.

Data acquisition is developed based on Windows application of the .NET platform. Data acquisition software has the client database files, support offline scanning, which can be deployed on Windows Mobile, Windows CE, Windows XP operating systems, and PDA, industrial PC and so on the different equipment.

**Production monitor based on product tracking.** Product tracking is the key technology to realize production monitoring. System monitors the whole production process based on the collected information, plant model, production progress recording position and state of products. In the monitoring picture of production control system, factory and shop floor view are created according to factory model, monitored the production status information real-time, and presented the on-site information to production management persons. Using Web function, even if production managers travel to other place, the production status of the factory also can be acquainted at any time.

The realization of the production monitoring based on the CimEdit and CimView module of GE Cimplicity platform. CimEdit is a visualization realizing tools, which has huge Smart functional notations library and picture editing functions. CimEdit support OLE and ActiveX object, facilitate
to edit monitoring view, and depict production process rapidly. Database connection use ODBC driver. CimView is a runtime visual environment, can dynamic display text and image information.

**Abnormal monitor based on event tracking.** Based on establishing standardized abnormal events classification rules, we further construct abnormal events process platform. Abnormal event handling system present abnormal event to shop floor administrator timely, who coordinate technical, maintenance, storage and other departments to handle by mail, short message directly notification event responsible department or individual. Event handling finished, production is back to normal. This time, the personnel of event handling should cancel event, and record the causes, solution of event. This contributes to deal with similar events as reference, help enterprise knowledge accumulation. Administrators analyze abnormal events regularly, and find out the high-frequency events, carry out special rectification to help promoting the production efficiency. Abnormal events monitoring, in concurrent, improve response of event handling; afterwards, facilitate process-event analysis and responsibility trace; by the long-term data mining, help enterprise establishing the alarm system. Figure 4 illustrates abnormal events process flow.

![Fig.4 Flow of abnormal event](image1)

![Fig.5 Production process control](image2)

Through the key technology researching, the technologies used by the whole system have strong configurability, expandability and stability. At the same time, the entire system layering and modularization make the whole system with high cohesion and low coupling, satisfy the production control system agility requirement, and can easily cope with the production control requirements caused by business process, production process, and organization structure changes.

**Application case**

The above system architecture was implemented in a famous domestic bus of MES project as an application system. System deployment includes welding, painting, assembly, inspection four production stages, more than 60 processing operations. Through the system implementation, the production system black-box is opened, the production process under the real-time monitoring. Abnormal event processing platform improved the production efficiency. The system includes data acquisition, vehicle tracking, vehicle scheduling, production monitoring, abnormal monitoring, production statistics, and analysis etc core production control modules. Fig.5 shows factory monitoring, workshop control, production line control and workstation views. At factory level, the input/output plan, input/output actual progress and abnormal production monitoring helped
controlling production equilibrium, delivery and WIP. At workshop level, the vehicle locations, vehicle status, production progress, operation time, buffering time, and equipment status are monitored.

**Conclusion**

We proposed a system structure based on requirement of discrete production process control system and key technologies and development platforms. The data collection of automatic identification technology is the foundation. The product tracking and event tracking are based on the factory model. The realization of production monitoring, and abnormal monitoring as the core content of the production process control system are based on the product tracking and event tracking. The system provides the basic data for production statistics and analysis. Through the application case implementation proved the system is valid. But in the system, some problems still need to be perfected, such as, data collection need scanning manually, existing omissions, fault, and timeliness problem; management must be strengthened. MSMQ technology of data transmission exist instability. In addition, equipment control, material control and production executive control are important parts of the system need further research.

**References**

[1] Li Huaizu: *Production Planning and Control*. Beijing: Science and Technology Publishing House, 2005, p.222-242.

[2] Young, S.L: Technology-the enabler for tomorrow's agile enterprise. In: ISA Transactions, 1995, vol. 34, p.335-341.

[3] Hu Chun, Li Ping. *Process Industrial Production and Discrete Industrial Production MES Comparison*, Control and Instruments in Chemical Industry, 2003, 30(5), p.1-4.

[4] Xin Hui: *Consolidation Technology of MES System in Iron & Steel*, Information Technology and Standardization, 2009.5, p.53-56.

[5] Peng Qingxiang, Li Peitang: *The Implementation of Vehicle Production Process Control Based on ControlLogix5550*, Industrial Control Computer, 2007, 5(20), p.83-84.

[6] Cao Zhenghong: *The Application of Information Technology in the Bus Production Management*, Bus Technology and Research, 2007, (02), p.60-62.

[7] ANSI/ISA-95.00.01-2000, Enterprise-Control System Integration Part 3: Models of Manufacturing Operations Management.

[8] Christian Nagel, Bill Even, Jay Glynn Write, Li Minbo Translate. *C# Advanced Program*, 4th ed. Beijing: Tsinghua University Press, 2006, p.337-511.

[9] GE Fanuc Proficy Tracker Production Tracking operation Manual GFK-1216F, 2005.

[10] Peng Jinsong: *Automotive Supply Chain Strategy, Management and Information System*, Beijing: Electronic Industry Press, 2006, p.342-352.