Research of Primary Technique to Manufacturing Execution System Based on Digital Production Model

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Abstract

This article presents SIA-MES platform based on digital factory models according to MESA SP95 standard. The development of MES in standardization is reviewed. The structure of SIA-MES, design concepts, system process, and MES application solutions based on digital model are introduced. By digital production process model, SIA-MES present a clear and full product production process. Function models of MES for automobile gear-box assembly production line are advanced based on several practical projects and MESA 11 function models. Practical MES application proved that the industry-oriented MES platform is extensible.

1. Introduction

In the face of increasing competitive pressures, manufacturing companies face a number of growing challenges from reducing manufacturing costs, improving product quality, training, introducing new technology through to speeding up production processes. MES is the key element to guarantee the integration of all components, ensuring optimal quality and production efficiency across all global facilities.

Manufacturing Execution System (MES) is a package of functions designed to ensure real-time control of the product process. It also includes the transformation of logistic information into process control data. Initially, MES has no specific definition. It includes almost all application programs or products, which can not be divided into other levels. Most of these products are evolved from some customized application programs, which are developed for special customers by system integrator and are aim at certain functions such as scheduling, quality, product tracing, and so on.

Thereafter, related international organizations develop more specific definitions for MES. MESA (Manufacturing Execution Systems Association) put forword MES object models [1], [2], [3], [4]. SP95 standard committee of Enterprise Control system Integration of ISA (International Federation of the National Standardizing Associations) released interface standard model between ERP and MES. Manufacturing Science and Technology Center of Japan released openMES, which involves object-oriented model, platform, function modules, computer network and CORBA. Among of them, SP95 (Enterprise Control system Integration Standard) and SP98 (Batch Control Standard) are especially important.

Many scholars engaged in research work on MES standardization. Gilman [5] summarized enterprise rules, intelligent agent, STEP and workflow for design, and application of visual enterprise. Michael McClellan [6] introduced core functions, System Configuration/Architecture, Scheduling, Simulation, and Constraints Management of MES. Kletti [7] describes the optimization requirements for Manufacturing Execution Systems. They give an overview of the efficiency potentials and different applications of Manufacturing Execution Systems.

For the actual instance, industry-oriented information integration model should be build and defined by reference of ISA SP95. Data flow between management level and manufacturing level, together with functions should also be regulated particularly. The work will promote industry application and impel perfection and development of standardization research. MES solution for Industry application has been drawn by great attention [8][9][10].

Many companies understand the challenges facing manufacturing industries and offer their Industry-oriented MES solutions, such as Siemens SIMATIC IT, GE Fanuc Proficy, and so on. We are also doing the research work and development of Industry-oriented MES. In this paper, a MES platform based on Factory Models and automobile Industry-oriented MES

0-7695-3038-9/07 $25.00 © 2007 IEEE
DOI 10.1109/ICCIT.2007.404

framework will be introduced, and primary technique will be presented.

2. SIA-MES platform

Shenyang Institute of Automation Statistic Manufacturing Execution system (SIA-MES) provides an extensible, comprehensive solution with powerful functions. Through digital production process model, SIA-MES presents a clear and full digital product process. Analysis and reporters function are operated not only based on time, but also on special events happen in overall running. SIA-MES provides a real-time platform for production data, thus actualize integration of MES, ERP and low-level automation system.

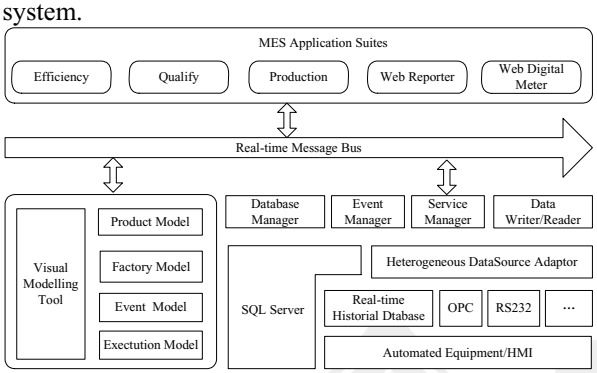


Figure 1. Structure of SIA-MES

The SIA-MES platform foundation is composed of infrastructure service, production model (factory model, product model, event model and execution model), visualized modeling tool, real-time message bus, heterogeneous data sources adaptor, and MES application suites, which is shown in Figure 1. OOA&D (Object Oriented Analysis and Design) method is used to construct factory model, product model, event model and execution model. Factory resources, enterprise production activities and shop floor business are abstracted and classified, which are described with series special basic semantic meta-object. Related models are expressed with complex objects formed by certain semantic meta-objects. Visualized modeling tool is developed to describe related domain realities by OWL. Ultimately, factory resources are described as factory model, production activities are described as event model and enterprise business is described as execution model.

The aim of MES platform is to present a digital workshop by modeling product ingredients, product line and material feeding, etc. Sequence exchange of production activities is implemented by describing and controlling production event and product statement, thus enables management functions as production planning, material feeding, product tracing and quality analysis. Management services offered are as follows:

- Constructing factory, product, event and execution model
- Monitoring product quality in overall manufacturing process
- Managing production execution process
- Feedback real-time information
- Tracing material movements and consumptions in production locale
- Accessing historical database
- SPC and OEE
- Integration exchange standard: ISA S88 XML S95
- Web report forms and digital meters

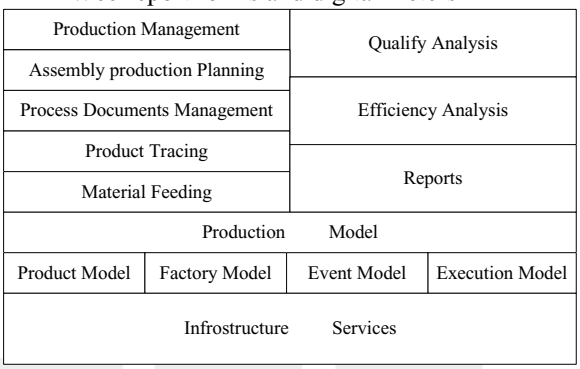


Figure 2. System structure of MES platform

Functions provided by SIA-MES platform include infrastructure services, construct production model, production management, quality analysis, efficiency analysis and statistic modules, etc as Figure 2.

Product model is to define product, material, criterion, formulation and process, and to build assembly BOM (Bill of Material). Assembly BOM includes information of parts, components and processes. For a special product, its assembly BOM provides information of process assembly directory, material racks and feedings.

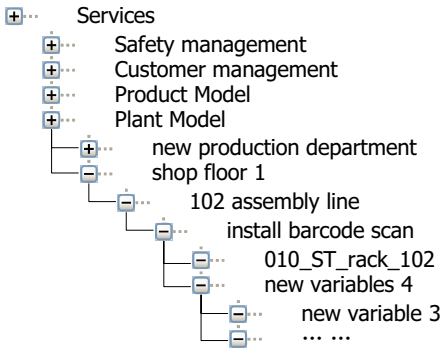
Factory model is to define factory, equipments, product line and relevant organization mode. On the basic of factory model, production event of product process is defined. Production event is basic element to manage production activities. Product process can be controlled by production event established.

Execution model is to define production and operation rules, flow of material and information to control and trace manufacturing process.

3. Overall design concepts and system process

3.1. Design concepts

Implement of the whole production management is based on Factory Model and Product Model. All the production objects including the assembly stations, racks, quality inspection stations, all the products type, correlated attributes, materials and process specifications are build to digital model by SIA-MES. Models are managed in real time by the inner product events and execution models. Quality tracing and reports are based on the definition of these products and production specifications. All the function modules are configured on the basic of production model. Factory model is established till variables elements. Example is shown as follows:



By reference to the S95 objects model, objects like production planning, equipments, production process, resources are created. All the function modules are realized on these objects model, and standard functions in S95 are implemented in SIA-MES by the standard production events. All the objects, information flow and function specifications are based on S95 standards.

3.2. System Process

An outline of the system process is given in Fig. 3. Product model, factory model, event model and execution model are expressed with complex objects formed by certain semantic meta-objects, and meta-objects are mapped with collected data. Then it is possible for an automated event processor based on production model to detect, control and handle event in real-time.

The kernel in the architecture of MES platform is product/factory/event/execution model and infrastructure services. On the basic of established production model, manufacturing process management is realized through event-driven business modules in background as Figure 3. The procedure is described as follows:

(1) Establish enterprise product model, factory model, event model and execution model using visualized modeling tool.

(2) Release production order by assembly planning received.

(3) Production "start" event is triggered, system control is handed in background.

(4) Corresponding business procedure is executed.

(5) Monitor production event on-line. Step 3 to 5 will be executed while production events happen.

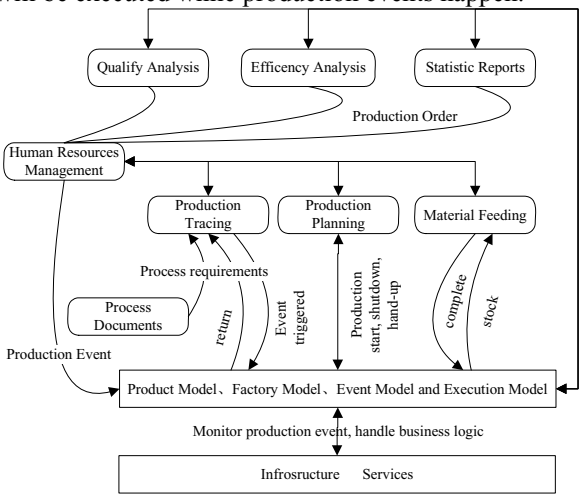


Figure 3. System process of SIA-MES

4. Industry-oriented MES platform

4.1. MES development based on digital model

Development solutions of MES application system is implemented as figure 4.

Product Model is to define product structure, material, BOM and process.

Execution Model is to define production rules, material flow and information flow to control and trace production process.

Event Model is to define production event of manufacturing process related to the Factory Model.

Factory Model is to define locale factory equipments and relevant organizations.

I*nterfaces* include connections in common use between SIA-MES and business system like ERP and connections with historian database or other factory data resources.

Enterprise function modules include functions like efficiency, quality, production, batch, web reports and web digital dashboard defined in S95 standard, and so on.

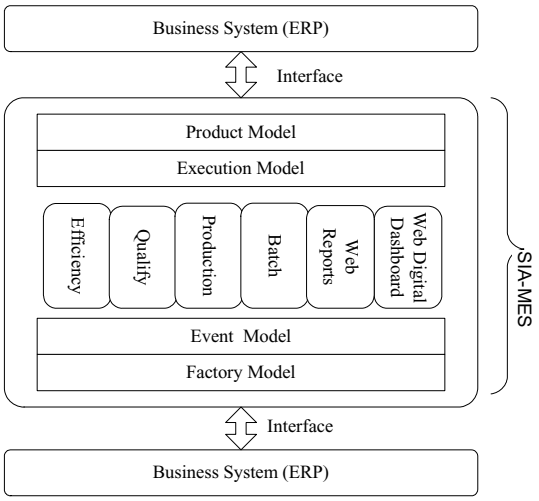


Figure 4. SIA-MES platform

4.2. Automobile gear-box MES

4.2.1. Management model level. According to practical requirements of several projects and MES function models of MESA, function models of automobile gear-box MES are introduced in this paper. The model is composed of several management functions in different levels as Figure 5.

The management model includes several functions in five levels: Data Collection Level, Operation Control Level, Operation Supervise Level, Planning and Scheduling Level, and Execution Intelligent Analysis Level as shown in Figure 5.

The lowest level is Data Collection. Data Collection Level is to realize real-time data collection of automated equipments and human-machine mutual during the manufacturing process. OPC interface standard is generally adopted for system expansibility.

The second level is Operation Control Level. The level is to control operator action, which insures consistent of assembly action and assembly process.

The third level is Operation Supervise Level. The level is to supervise the assembly process, alarm messages will be shown in locale computers while malfunction happen. Assembly process is displayed in locale computers to supervise assembly actions according to the assembly products and stations.

The fourth level is Planning and Scheduling. The level is to decompose ERP planning to sub-assembly production planning and general assembly production planning, and assign planning to production stations. Production planning is supervised or modified according to locale instance.

The fifth level is Execution Intelligent Analysis Level. The level is to complete business intelligent analysis of collected historian data. Performance and efficiency of the assembly line will be given.

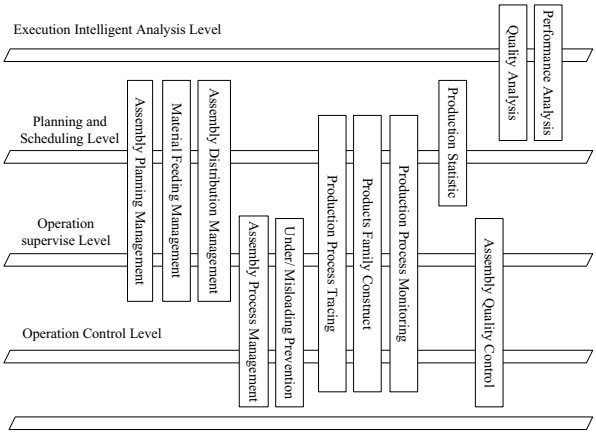


Figure 5. Management model of auto gear-box MES

4.2.2. Management model content. Function modules of automobile gear-box MES in different levels are shown in Figure 5. Function modules are described as follows:

Assembly Planning Management Accept daily assembly planning from ERP automatically or by manpower tape record. Make group assembly planning according to task priority, balance in group task, etc. Decompose group planning to batch production planning and conform time interval between each batch. Scheduling tasks during assembly process.

Material Feeding Management Make feeding orders according to assembly BOM and planning. Complete material sorting, cleanout and box up. Dispatch material distribution orders. Return completion of material distribution system.

Material Distribution Management Make material distribution planning according to the material priority and optimization rules. Dispatch transport orders and monitor execution of planning. Return completion information to material feeding system.

Assembly Process Management Build and maintenance of assembly process orders database. Dispatch and display of assembly orders data. Build and maintenance of assembly process parameter database. Assign assembly process parameters.

Under/Misloading Prevention Assembly action control. Decompose each assembly task in station to basic actions which enable to be inspected, and system will inspect each action automatically. Configure intelligent rack in easily misleading stations.

Production Process Tracing Using collected data of assembly process, system automatically track operators, equipment parameters, and material batch information of each station passed.

Product family construct Using collected material data, material family is build automatically. Product family offer support for after services, offer references

to stock department for suppliers appraise, and offer references to product recall for quality accident.

Production Process Monitoring Using collected process data, locale mangers can monitor the overall assembly line, and response to the abnormity in manufacturing process, improve efficiency of the whole production line.

Production Statistic Report forms about Shift, group, daily, month and yearly of product yield or employee wok load. Statistic forms of product check out ratio once. Statistic of quality causes.

Performance Analysis Using collected process data, mangers can analysis the overall efficiency of each assembly station and production line. Matters exist in each assembly station and bottle-neck station of the whole production line will be detected, which offer reference to adjustment of operators and production time.

Assembly Quality Control Monitoring products assembly quality in real-time according to assembly process parameters with collected process data.

Foundation data Maintenance **B**asic database maintenance of assembly BOM, operators, shift or group, stations.

5. Conclusions

In this paper, we review development of MES in standardization, and present SIA-MES platform based on digital factory models according to SP95 standardization. The structure of SIA-MES, design concepts, system process, and MES application solutions based on digital model are introduced. Practical MES application proved the industry-oriented MES platform to be extensible. By digital production process model, SIA-MES present a clear and full production process. SIA-MES provide collected data from real-time and historian database, and analysis these data with report forms on time and event with digital model.

Function models of MES for automobile gear-box assembly production line are advanced based on several practical projects and MESA 11 function models. The function models are the same with management of large size products assembly line in mechanic industry resemble to automobile gear-box. Based on these function models, MES for assembly line of East-wind Chaoyang Diesel Engine Company of Liaoning is implemented successfully.

Acknowledgments

The authors acknowledge the financial support of the National Natural Science Foundation of China funding (67646114) and Hi-tech Research and Development Program of China funding (2006AA04Z164). The authors would also like to acknowledge the helpful comments and suggestions of the SIA-MES software group. Their efforts are greatly appreciated.

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