Object-oriented Product/Production-Model

- Integration Concept and Application in Production Management

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Abstract

This paper discusses an object-oriented approach applying an integrated database for production systems. The basis for integration is an object-oriented Product/Production-Model (PPM) which has been developed at an interdisciplinary research center of the University of Karlsruhe. Based on this object-oriented PPM, new ways of organizing engineering processes become possible. By using pre-defined methods of the database objects, the development of modular software tools is enabled. The common database ensures redundancy-free data management, uniform data structures for all relevant views and avoids repeated input of basic data. As an application for the described methods, the paper discusses a new planning approach for the design of production systems based on the PPM and an integrated computer aided library of planning methods.

Keywords

Product/Production-Model, Object-oriented modeling, Integration in Manufacturing, Systems engineering

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1 INITIAL CONDITIONS AND PROBLEMS

The demand for support of engineering functions in the production industry started with computer aids of design functions based on CAD-Systems. This development was followed by additional steps in automation of other engineering functions like NC-programming, up to wider CAM-functions. On the side of production planning and control, MRP-systems were installed to manage orders, capacities and materials.

This development may be described as an automation of single aspects in the manufacturing process. Especially the links between product design and production management processes are missing (cf. Corradi et al. 1997). The loss of time and data must be yet stated as a disadvantage, especially if the process flow and organizational structures remain unchanged.

2 SOLUTION TO IMPROVE THE SITUATION

In the context of increasing market pressure to cut time and cost, an integrated view becomes important to overcome the disadvantages of organizational interfaces, to close gaps in the information flow and to avoid lacks in the coordination of the work flow.

Figure 1 Comparison of Different Concepts for Computer Aided Engineering Processes.

The approach used to solve these problems is the definition of an object-oriented *Product/Production-Model* and an *Integrated Desk for Engineering Applications* to provide engineers with a highly integrated software environment (cf. Fig. 1). This allows to concentrate abilities on rising the added value and not on the handling of interfaces.

3 INTEGRATED PRODUCT/PRODUCTION-MODEL

At the University of Karlsruhe, a special research center on "Computer Integrated Design and Manufacturing of Parts (Sonderforschungsbereich 346: Rechnerintegrierte Konstruktion und Fertigung von Bauteilen)" has been working since 1990 to overcome the problems of interfaces in the process of product development, design, production planning and manufacturing. Four institutes from the field of production technology (Institute of Human and Industrial Engineering, Institute of Logistics and Conveying Systems, Institute of Computing in Planning and Design, Institute of Machine Tools and Production Science) and two institutes from the field of computer science (Institute of Programming Structures and Data Organization, Institute of Telematics) combine their knowledge and experience in order to solve this interdisciplinary task. The research center aims to develop an integrated *Product/Production-Model* (PPM) by using an object-oriented modeling approach (for integrated models see e.g. Grabowski et al. 1997).

The PPM is a meta-model of an object-oriented database which contains the most necessary objects and relations of main engineering steps in the field of parts production. Several views can be applied to the PPM: a product model for the product-oriented view, a process model with an order-oriented view and the production model with a resource-oriented view (cf. Fig. 2). Hereby, it focuses on design and manufacturing data, like product functions or geometric information, as well as on the necessary data for planning the needed production resources, even up to the design of organizational structures.

The object-oriented database covers also well known mechanisms of object-oriented modeling techniques, such as aggregation or inheritance. Additionally, special methods for cooperation in decentralized systems have been added, for example distribution and migration methods and features to set-up a generic object model. A special object-oriented modeling technique OMK (Object-oriented Modeling Technique Karlsruhe) has been developed for the modeling of the production systems. The method is based on the OMT approach by Rumbaugh et al. (1991) and is divided into a static model, a dynamic model and a functional model (for the application of object-oriented design methods for manufacturing systems see also Bartolotta, Garetti 1998).

For the implementation, the object-oriented database software ObjectStore (cf. Object Design 1995) is used. In the actual phase of development, an intermediate layer between the database and the applications is in progress, based on the

CORBA standard (Common Object Request Broker Architecture; see e.g. Ben-Natan 1995) for the exchange of engineering data. In the future refinements, the objects and methods will be represented by using a JAVA description in order to enable a hardware independent platform.

Figure 2 Architecture of the Integrated Product/Production-Model (following Zülch 1995).

As already mentioned, several views can be applied to the PPM. The product-oriented view focuses on single products, using data of the offer phase, design information like product functions or geometric information, bill of materials and production plans. The process model represents the order-oriented view with all its steps of the order processing from offer preparation through delivery. The process model partially uses information from the product model, like design information and the bill of materials. The production model is a representative of the resource-oriented view which contains the necessary data for planning the production resources. It contains objects like organizational structures, production facilities, material flow, human resources, and information systems.

4 APPLICATION IN PRODUCTION MANAGEMENT

The PPM can be used for several applications in the field of production management. Here, the simulation aided planning of organizational structures will be used as an example.

Many influences and data must be taken into consideration while shaping organizational structures of production systems (cf. Zülch, Brinkmeier 1998). The

process of reorganization can be supported by a simulation aided procedure in order to consider the dynamic behaviour of the planned structure (cf. Zülch, Brinkmeier 1995). The collection and analysis of the data is one of the most demanding tasks in the initial steps of a simulation study. The analysis and modeling phase can be shortened by the recycling of data from other information processing systems. This will be demonstrated for the modeling of process plans, which are in this redesign concept the basis for the design of departmental structures (Figure 3).

Figure 3 Simulation aided design of organizational structures.

Especially in small series or one-of-a-kind production the flow of orders depends on the structure of the product. For the planning of the workflow the customer inquiry for a product or the winding-up of the orders must be modeled using process plans. The process plans represent the needed activities for the processing of a product and is therefore linked to the product structure. Fischer (1995) developed a special object-oriented modeling method for the assembly of process plans out of a process library. With this modeling procedure complex process plans of customer inquiries as well as order flows can be modeled in a fast and flexible way (Zülch, Fischer 1995; Zhang, Zülch 1996). After combining process plans out of a process library with a special modeling tools the plans can be stored in the data base. From there they can be used for several tasks like planning personnel, machine tool, material handling, transport or information systems as well as organizational structures.

The modeled orders, customers and process plans are a basic information for the design of organizational structures. With the help of an integrated desktop this

information can be taken out of the data base. For the design and dynamic analysis of organizational structures a simulation tool is used which can operate with this data without an repeated input of already existing data. After the design of a new organizational structure, information about production segments, departments or personnel structures can be stored in the database for the use in other planning tasks.

5 FURTHER STEPS AND FUTURE DEVELOPMENT

The object-oriented Product/Production-Model has been developed at an interdisciplinary research center of the University of Karlsruhe in several steps. Meanwhile, this model is well established in the research work at this university.

At present, a special Integrated Desktop for Engineering Applications (*IDEA*) is under development. In this framework new methods for the representation and navigation in object-oriented databases and a special integrated computer aided library of planning methods will be implemented (Figure 4).

Figure 4 Planning methods library and analysis tool for process plans.

By using an integrated environment the planning of production systems can be performed with more flexibility.

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7 BIOGRAPHY

Gert Zülch, born in 1946, studied Mechanical Engineering at the Technical University of Brunswick, Germany, and Industrial Engineering at the University of Technology at Aix-la-Chapelle, Germany. After his graduation as a doctor in 1979 and 10 years of experience in research and industry, in 1985 he became head of the newly founded ifab-Institute of Human and Industrial Engineering at the University of Karlsruhe, Germany.

Bernd Brinkmeier studied Mechanical Engineering from 1985 to 1989 at the University of Kaiserslautern and from 1989 to 1992 at the University of Karlsruhe. He graduated as Dipl.-Ing. in 1992 and is working as research assistant at the ifab-Institute of Human and Industrial Engineering at the University of Karlsruhe, with focus on simulation aided planning of organizational structures of production systems in the frame of an interdisciplinary research center at the University of Karlsruhe on computer integrated design and manufacturing of parts.