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Implementations of Model Based Definition and Product Lifecycle Management Technologies: a Case Study in Chinese Aeronautical Industry

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Abstract: The paper describes and analyzes the Model Based Definition (MBD) and Product Lifecycle Management (PLM) technologies and their related Computer-Aided X applications in order to enable the implementation of an integrated design and manufacturing system in Chinese aeronautical industry. Using the full three-dimensional technology allows the MBD specification of geometry, features and attributes for mechanical parts. It also supports an integrated design method for specifying MBD models of these parts. Considering the manufacturing specifications based on MBD, the feature machining and Coordinate Measuring Machine (CMM) control technologies are used for intelligent manufacturing of parts. Machining and quality inspection programs are automatically generated including the associated MBD process and quality models. Finally, the integrated design and manufacturing system based on MBD and PLM technologies is applied on the case study of an engine fan blade in order to assess the proposed method.

Keywords: Model Based Definition; Product Lifecycle Management; Intelligent Manufacturing; Feature based Machining; Quality Inspection.

1. INTRODUCTION

Model based definition (MBD) is a technology for digital definition of product and associated specifications of manufacturing processes based on computer-aided X (CAx) applications (Quintana et al., 2010). It allows the integration of design and manufacturing information (product geometry, bill of material, part features three-dimensional specifications, a variety of production engineering information, etc.) to be merged in a common definition based on three-dimensional (3D) model of the product. It also ensures the uniqueness of the 3D product data for integrated design and manufacturing (Song et al., 2005). MBD not only describes the geometric information of design, but also defines the 3D manufacturing information of the product and non-geometric management information. It aims at the integration of existing 3D geometric models, 2D drawings and other design and manufacturing information (Alemanni et al., 2011, Lee et al. 2004). MBD technology can be considered as the new generation product definition methods for manufacturing industries. Its core is based on a full 3D modelling of product features and characteristics (Bronsvoort & Noort, 2004; Chandrasegaran et al., 2013) associated with integrated and collaborative model-driven documents (Eynard et al., 2005), digital information (Wan et al., 2014), etc.. In traditional practices of industry, the 3D solid model describes the geometric information of product, and the 2D engineering drawings defines the dimensions, tolerances and process information. After the implementation of MBD technology, the 3D solid model will be the unique basis for product definition, manufacturing process engineering, production planning and quality inspection. Then, it will avoid time consuming with the traditional manufacturing methods which are based on engineering drawings.

Nowadays, manufacturing industry is in a transition period from 2D to 3D approach for manufacturing methods. As an advanced digital definition method, MBD technology plays a key role in changing the traditional manufacturing methods. Considering the rapid development of information technology companies are vigorously implementing the MBD technology in order to shorten the manufacturing cycle, to improve product quality, to reduce production costs and improve market competitiveness,. The paper focuses on the implementation of MBD technology in advanced design and manufacture of complex systems as a new collaborative support system enabling the integration of design, manufacture, quality management which will also largely

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based on product lifecycle management (PLM) as suggested by (Ming et al., 2005; Terzi et al. 2010).

First, the section 2 will detail the research background and main feature of MBD technology. Second, the section 3 will present the proposed approach based on MBD for integrated design and manufacturing. Third, a case study focusing on a fan blade development will show the application of the proposed approach. Last, the concluding section will summarize the main outcomes of the paper and will introduce future work.

2. RESEARCH BACKGROUND OF MBD TECHNOLOGY AND RELATED WORKS

Currently, the North American and European countries are relatively mature in the implementation of MBD technology. Taking benefit of Boeing expertise, the American Society of Mechanical Engineers (ASME) began to carry out some research work on MBD standards in 1997, and to develop United States national standards in 2003 "ASME Y14.41-2003 - Digital product definition data practices" (ASME-Y14.41 2003; Srinivasan 2008; Wan et al. 2014). The Boeing Company, as one of the initiators of the MBD technology, specified some applications based MBD technology - BDS-600 series. As the upstream business, Boeing has fully implemented the model definition based on digital technology with its industrial partners. The aeronautical industry has achieved the integration of design and manufacturing information according to the definition of 3D product models using the MBD technology as the unique digital (Proctor & Wash, 1994; Lu & Fan 2006). USAF JSF fighter and the Airbus A380 have been successfully developed based on MBD technology enabling to transform the traditional design and manufacturing methods (Dolezal, 2008).

While the North-American and European countries are relatively mature in the application of MBD technology, there exist limitations in many ways. So many research works have been conducted in this field. The U.S. National Institute of Standards and Technology (NIST) studied numerous aspects of product information integration (Rachuri et al. 2008; Fenves et al., 2008; Fiorentini et al. 2010). They developed a framework for product information modeling supporting the full lifecycle of information needs with the Core Product Model (CPM). This product master model and several other extensions are based on the functional models which can capture the product information from the conceptual design to the end of lifecycle. Quintana et al. analyzed the issues and solutions for the product lifecycle management and especially focused on the implementation of the MBD technology (Bouikni et al., 2008, Quintana et al., 2010, Louhichi & Rivest, 2014). They also summed up the advantages of MBD technology in the manufacturing process. Alemanni et al. proposed a product lifecycle management solution including MBD technology (Vezetti, 2009, Alemanni et al. 2011). They carried out a PLM implementation using the MBD technology for modeling of complex product structure on a spacecraft case study.

Some researchers succeeded in the field of the modelling and integration of product information in the whole lifecycle (Noël & Roucoules 2008; Srinivasan 2011; Le Duigou et al. 2011). For many of them, they generalized the use of 3D model as the unique basis for the design of product and process. But this research work missed the use of manufacturing information in collaborative engineering (Eynard & Yan, 2008). The manufacturing information cannot be intelligently used for planning of machining operations and quality inspection (Liu et al., 2013).

China is relatively backward on implementation of MBD technology. The full 3D modelling and MBD technology are also gradually developed by Chinese subcontractor working for Boeing's production. Nowadays, the design patterns of "3D model going down to the workshop" are in full swing in Chinese aerospace industry. The specification of full 3D design model is constantly being improved and the application level is also rising based on CATIA, NX, Creo and other competitors. Aircraft, satellites, rockets (and other typical aeronautical and space products) definitions are trying to get full benefit of digital data integration and management through the entire design and manufacturing processes. In China, manufacturers of large assembly such as CSR Group and CNR Group are also implementing full digital work using MBD technology for design and manufacture of high-speed train (Jia et al., 2011).

Chinese academics also developed many research works on the MBD technology applied in the design and manufacture of products. These works were more focused on the 3D design. But they also made remarkable achievements. Tian & Zhang (2012) studied the standards system for 3D models definition. This system has some clear guidance on product design in 3D and digital definitions according to the use of MBD technology. Tian et al. (2012) presented the application of MBD principles for process engineering based on the 3D modeling of process information and then achieving the implementation of MBD technology in digital manufacturing. Feng et al. (2012) studied the application of MBD technology as support of digital collaboration in manufacturing and provided some ideas to intensive the collaborative manufacturing based on MBD for Chinese aeronautic companies. Fan (2012) developed an integrated management system using MBD dataset which includes standard management system, design and analysis processes, and the interfaces with CAx and product data management systems. His work has a clear significance for implementing an integrated design and manufacturing method based on MBD technology.

Thus, the paper proposes a holistic method to achieve a complete implementation of integrated design and manufacturing system based on MBD and PLM technologies. Adopting the full digital technology to obtain the geometric specifications and attribute information for the parts to be modeled allows an effective design method based on MBD technology. It also enables an intelligent application for 3D modelling for management of manufacturing information in order to define and plan the process. Last, according to Song