Computers in Industry 65 (2014) 200–209

Contents lists available at ScienceDirect

Computers in Industry

journal homepage: www.elsevier.com/locate/compind

# A design method for three-dimensional maintenance, repair and overhaul job card of complex products

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ARTICLE INFO

*Article history:*
Received 17 March 2012
Received in revised form 30 May 2013
Accepted 29 August 2013
Available online 12 October 2013

*Keywords:*
Model based definition (MBD)
Maintenance, repair and overhaul (MRO)
Job card
Disassembly simulation
3D annotation

ABSTRACT

Aiming to improve the feasibility of maintenance, repair and overhaul (MRO) planning, the accuracy of MRO description and the clarity of on-site guidance for complex products MRO job card, a design method for complex products three-dimensional (3D) MRO job card based on product 3D model and using the model based definition (MBD) technology was proposed. This method applies position–posture calculation of initial disassembly based on assembly constraints to realize the visual disassembly planning for complex products in 3D environment, uses dynamic viewpoint navigation method to implement the display of disassembly and assembly simulation process of parts conforming to the observation habit of human, adopts multi-view 3D annotation method to implement the separation showing for technical requirements from different MRO disciplines and operation tasks, and finally, transforms the MRO order information into 3D portable job card file based on lightweight model and releases it to MRO worksite. The aircraft right wing maintenance instance shows that this method can implement the intuitive, accurate and non-ambiguous MRO process description, improve the rationality of MRO planning, and increase the efficiency and quality of complex products MRO.



## 1. Introduction

Most of complex products, such as aircraft, heavy-duty vehicles and large vessels, are durable product with a life span of over 10 years or even more, and work in high-speed, high temperature, high pressure and other harsh environments or conditions. The maintenance, repair and overhaul (MRO) services are provided during products usage to ensure that product system continually performs its intended functions at its designed in level of reliability and safety [1]. The MRO of complex products is peculiar from MRO of other products due to the degree and intensity of the requirement of equipment, manpower, infrastructure, fault diagnosis, cost and time [2]. Complex products mostly have complicated product structure, large number parts with very different shapes, compact spatial structure and layout. These characteristics result in that MRO process lengthy and intricate and many MRO operations must be operated manually. So, MRO job card, as the carrier of MRO operation information and the main basis for MRO operation execution, is provided to instruct MRO workers how to execute MRO operations efficiently and exactly [3].

Because the describing and instructing capability of traditional MRO job card consisting of mass text description and two-dimensional (2D) technical drawings is still unsatisfactory. Text description and 2D drawings can only address MRO process and partial structure of parts, but not describe the operation sequence, path, direction and space collision clearly, accurately, intuitively and non-ambiguously. This will induce executing deviation from original intent of the MRO instruction, and affect MRO quality, efficiency and time [4]. American Society of Mechanical Engineers (ASME) studied and developed the model based definition (MBD) technology. This technology replaces the 2D drawing with the 3D digital model, and creates a new mode of digital design and manufacturing for complex products [5]. The MBD technology provides an implementation way to improve the accuracy, intuitiveness and non-ambiguity of MRO job card because the ease of accessing engineering definition, additional information and clarity associated with the 3D model.

This research will focus on improving both of description content and express way of MRO job card using MBD technology. The enough dimensions, tolerance, technical requirements and other design and manufacturing information from upper-stream manufacturing enterprises must be obtained and transferred to the MRO job card. And the job card must show the MRO order intuitively and accurately in order to make the MRO technician understand the MRO order easily and non-ambiguously. A

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http://dx.doi.org/10.1016/j.compind.2013.08.008

position–posture calculation of initial disassembly based on assembly constraints is used to realize the visual disassembly planning in 3D environment. A dynamic viewpoint navigation method is used to implement the display of disassembly and assembly simulation process of parts conforming to the observation habit of human. And a multi-view 3D annotation method is adopted to implement the separation showing for technical requirements from different MRO disciplines and operation tasks.

The remainder of this article is organized as follows. Section 2 introduces the previous research. Section 3 describes the general outline of the core process of MRO for complex products. Section 4 describes the 3D MRO job card design process with MBD. Section 5 describes the MRO job card design method with MBD including three key technologies. Section 6 describes how to generate the 3D job card with lightweight model. Section 7 provides a case study for aircraft industry and a results discussion. Finally, the conclusions are summarized in Section 8.

## 2. Literature review

Based on the preceding discussion it seems logical to classify the literature review into three categories, viz. the maintenance, repair and overhaul, MRO job card and model based definition.

### 2.1. Maintenance, repair and overhaul

Maintenance, repair and overhaul (MRO) can be described as the process of ensuring that a system continually performs its intended functions at its designed in level of reliability and safety [6]. The digitized MRO methods of complex products involve several aspects including maintenance planning and decision-making, MRO process execution supporting and maintenance data management.

The latest maintenance planning and decision-making methods, such as selective maintenance, optimal maintenance schedule decision, age-dependent maintenance policy, degrading system maintenance parameters selecting, maintenance operation resource allocation [7–11], are used in various industries, such as aircraft and aeroengine, machining line, electricity distribution network [12–16]. They improved the reasonableness of decision-making maintenance. The massive MRO data has been managed effectively through Product Service System, Integrated Repair System, eMaintenance, or PLM system [17–21]. The final quality of MRO depends on the on-site execution process [3]. MRO job card is the main basis for MRO operation execution to directly instruct MRO workers how to execute MRO operations efficiently and exactly. So, it has a major impact on the executing process of MRO and the quality of MRO.

### 2.2. MRO job card

However, a significant proportion of the technical causes of complex products accidents and serious incidents are attributed to human factors in various levels within MROs [22]. It is generally accepted that MRO, as a potential environment for critical interaction between humans and machines, attracts a large proportion of human factors induced problems [23]. A 2012 analysis of the NASA ASRS maintenance reports from 2001 to 2011 (14,267 reports) showed that nearly 64% (about 9000) of safety incidents coded in the reporting system were related to improper technical documentation including job card [3].

In order to improve the on-site MRO quality, the content of job card must be comprehensive, the format of job card must be intuitive, the order of job card must be validated [4]. Access to the right data, in real-time, on-demand, and in the work environment is more important today than ever. The next-generation technologies (e.g., 3D modeling, embedded simulation, and real-time interaction) will be utilized to generation high quality job card [3]. Today, in manufacturing phase of complex products, advanced manufacturing work instructions using MBD technology have become a highly productive tool in helping the mechanics improve manufacturing efficiency [24].

### 2.3. Model based definition

Model-based definition (MBD) is a new way of managing engineering and business processes using 3D models as complete sources of information for design, production, distribution, technical documentation, services, MRO and the overall product lifecycle. With MBD, any number of views of the 3D model can be composed, detailed, and annotated for specific downstream groups such as tooling, purchasing, manufacturing, planning, inspection, product services, procurement, maintenance and marketing/sales as well as clients and suppliers [5]. MBD is, at its core, a way of gathering and managing product/process data inside of a 3D model, in the form of annotations, parameters, and relations. Therefore, detailed simulations (logical, functional, and mechanical) can be developed from a single data source. For the manufacturing disciplines, the use of 3D models as comprehensive product/process data repository speeds up simulation tasks and makes them more controlled [24]. MBD technology provides a possibility to implement interactive, real-time simulation and 3D MRO job card.

### 2.4. Observations from the literature

The literature shows that researchers have recognized that MRO job card has a direct impact on MRO quality [3], but there is still a lack of the research from the perspective of MRO job card design method to support the MRO execution process. At present only a few papers studied the evaluating method for written quality of maintenance job card [4]. How to design and generate a comprehensive, intuitive and validated MRO job card has been a problem to be solved. MBD is, at its core, a way of gathering and managing product/process data inside of a 3D model, in the form of annotations, parameters, and relations. So, MBD can provide complete product definition information, interaction ability with visual 3D model, and the real-time simulating capability for MRO job card design and publishing. So, in this research, a design method of 3D MRO job card using MBD technology will be proposed which is suitable for the MRO process of complex products. This research will focus on how to improve both of description content and express way of MRO job card in order to instruct MRO workers to execute MRO operations efficiently and exactly.

## 3. General outline of MRO core process for complex products

The production process of MRO enterprise is different with manufacturing enterprise. The production process of manufacturing enterprise includes several major phases including product design, process planning, material preparation, part machining and inspecting, product assembly and inspecting and product testing. The production process of MRO enterprise consists of different phases including fault detecting, instruction design, product disassembly, parts handover, part repairing and inspecting, product assembly and inspecting, and product testing. Fig. 1 shows this general outline of MRO process for complex products.

The process shows that the production organization of MRO enterprises manages not only the assembly process, but also the disassembly process. The work quality of disassembly process determines the initial maintenance states of repaired parts and the accuracy of complement parts. At the same time, all of production