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Process and knowledge management in a collaborative maintenance planning system for high value machine tools

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ABSTRACT

Product manufacturers are extending their responsibilities in the whole life cycle by providing services to their customers. In recent years, product service system has become an important research topic to address the special requirements in the new service driven business model. High value machine tools in modern manufacturing factories are special products: they are regarded as 'products' from maintenance point of view, and they also manufacture other products. In the new business model, the quality and behavior of a machine tool not only affect the quality of the parts it manufactures, but also affect the profits of the machine tool's manufacturer. However, in the research area of product service systems and related computerized maintenance systems, there is a lack of investigation into the special nature, problems and requirements of high value machine tool maintenance, which are very important in modern digitized manufacturing systems. Therefore, this research investigated the various relationships between different stakeholders in the machine tools' lifecycle, focusing on knowledge management, communication and the decision-making processes. This research also explored the potential application of advanced content management systems, which are widely implemented in the financial, business and government organizations, in the manufacturing engineering domain which has been dominated by traditional engineering information systems. A prototype collaborative maintenance planning system is proposed, developed and evaluated using an example machine tool, which indicated that significant improvement could be achieved and the content management technology has a number of advantages over the traditional engineering information systems, such as computer aided engineering, product data and lifecycle management, and enterprise resource planning systems, in managing machine tool maintenance and service information including dynamic and unstructured knowledge.

1. Introduction

One of the main trends in the manufacturing industry is that product manufacturers are expanding their role in the value chain by offering advanced services or complete solutions which are closely coupled to their products, also called servitisation [1,2]. To address the challenges and requirements of the new service driven business model, as opposed to the traditional product and technology focused approach, product-service systems have been proposed as potential solutions, enabling tools and an important research topic [3]. This paper presents research and development of a collaborative maintenance planning system for high value machine tools in modern manufacturing factories. Machine tools are regarded as 'products' in product-service systems, which also manufacture other products from manufacturer's point of view. In sophisticated and high value manufacturing systems, maintenance plays important role in keeping or renovating the manufacturing equipment in or to its designed functionality. Machine tool maintenance and services include scheduled maintenance, unscheduled maintenance, repairs, calibration and testing, involving internal and external stakeholders [4].

In digitised and globally distributed manufacturing systems, the maintenance and service providers are facing the challenges in managing increasing amount of information and data related to products and maintenance operations including associated knowledge, lessons learnt and best practices. For example, voice from customers about equipment reliability are gathered, but not fed back to the Original Equipment Manufacturers (OEMs) for the improvement of new product design. Some information in current

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practice is sometimes not up-to-date, such as scheduled maintenance procedures when equipment is changed. Poor communication and sharing of information between various stakeholders because of distrust affects effective collaboration in the planning and scheduling of maintenance tasks and supporting resources. Current information and knowledge management systems are mainly designed and implemented for mainstream product design and manufacturing operations, even product lifecycle management (PLM) systems rarely support product maintenance and service tasks [5].

Industrial product-service systems are recently being developed by researchers mainly for large and complex products or facilities [6,7]. However, in the literature there is little reported research work that has been devoted to the maintenance and service of machine tools in the product-service systems research area [8]. Therefore, the research reported in this paper aimed at exploring the special requirements of complex machine tool maintenance and services, various relationships with stakeholders and the processes of operations. The focus will be on knowledge management, communication and decision support processes.

Another main aim of this research is to explore the capability, feasibility, advantages and disadvantages of Content Management Systems (CMS) in managing engineering information and knowledge. Traditional engineering information systems such as database, enterprise resource planning (ERP) and PLM systems have rigid structures. They are good at dealing with numerical data but difficulty to respond to changes. As pointed out by Metso et al. [4], not only the sophisticated Information and Communication Technology (ICT) systems, but also human and organisation that are key elements in successful maintenance. The required ICT system should provide a platform for stakeholders to exchange information and knowledge timely, and allows them to look for the right information more quickly and reuse lessons learnt.

CMS are being taken as one of the most important ICT tools in managing organization information and knowledge, especially unstructured information and knowledge, in business, media, financial and social applications [9], but very few applications in the areas that are dominated by traditional engineering information systems. Due to its high flexibility and extendibility, and the advantages in managing unstructured information, compared with traditional engineering systems, this research project used an Open Source CMS as the platform for the development of a collaborative maintenance and service planning system for high value machine tools focusing on process and knowledge management involving stakeholders within and beyond a manufacturing organisation.

2. Previous research in computerised maintenance management

Relevant previous research and development is broadly in the area of E-maintenance, which has been proposed since early 2000, as a key element of e-enterprise, and also an aspect of growing importance in e-manufacturing [10]. In a manufacturing system, e-maintenance is a concept by which the operations of manufacturing equipment are enabled to achieve predictive near-zero-downtime performance through a maintenance management system that monitors plant floor assets by integrating supervisory control, data acquisition and business systems, using Web-enabled and tether-free (wireless) technologies [11]. E-maintenance has the potential to improve the collaboration and cooperation between different maintenance actors (experts, maintainers), enterprise departments (maintenance, production, procurement) and external business partners (spare parts suppliers, machine manufacturers, machine users).One important industrial requirement is to achieve knowledge-based operation and maintenance, and e-maintenance systems should allow different people to learn from past experiences [10]. Using advanced ICT tools, e-maintenance solutions allow users to make decisions more effectively and efficiently with “just-in-time access” to maintenance related information [12].

Typically, e-maintenance solutions are implemented as a Computerized Maintenance Management System (CMMS), through which the users can access maintenance data and information [13]. A CMMS system includes a number of functions such as equipment management, work orders, preventive maintenance instructions, and spare parts control. Traditional CMMS is normally a standalone system that can be used for complex maintenance operations conducted in a plant [14,15]. As the manufacturing equipment is arranged with production tasks every day, maintenance planning has to be carried out jointly with production planning. The on-line monitoring of machine tool performance and in-process inspection of machined parts should be linked to machine tool maintenance as well, especially. Li et al. [16,17] reported an integrated on-line monitoring and inspection system based on an innovative dynamic feature concept as the basis for modelling dynamic production information to achieve accurate machining process control. In their dynamic feature model, the various relationships between the interim geometry of a part and associated machining characteristics have been investigated and dynamic information linked to different interim feature states have been represented. Furthermore, CMMS systems should be integrated with other manufacturing execution systems such as ERP and dynamic on-line machine tool monitoring and part inspection systems, if appropriately doing so, CMMS will be a critical and useful tool to manage maintenance activities and improve manufacturing process performance [18]. A CMMS stores a large amount of data, information, previous maintenance cases and best practices including equipment number, failure mode, diagnosis method and maintenance solutions.

However, there are some common limitations in current CMMS [19]. For example, technical documents, drawings and instructions in other systems are not easily accessible, even the information stored in the same system is difficult for users to search and get the right information quickly. The incompatibility with other information systems such as production management, spare parts inventory and purchasing systems makes it difficult for users to make decisions when relying on information stored in elsewhere, and need manual input of information leading to low accuracy and efficiency. The incompatibility in spare parts systems may lead to the confusion and delay of parts delivered since the maintenance engineer and the spare parts supplier are using different systems. There are inconsistent, incomplete and not up to date instructions for engineers to undertake maintenance tasks. Poorly designed user interface and lack of visualized presentation of maintenance information as tables or images may reduce the efficiency of understanding current situations. Furthermore, there is a lack of knowledge sharing mechanism in the system for maintenance engineers to learn from best practices and lessons learnt [8].

Therefore, this research investigates and uses the latest ICT technologies for applications in engineering and also in other sectors, to improve current computerised maintenance management systems for applications in modern digitised manufacturing systems concerning the maintenance of high value machine tool. The main objectives are to develop a collaborative maintenance planning system to be used by different stakeholders including machine tool users, manufacturers, part suppliers and service providers, consisting of the following functions (or modules):

- a product knowledge management module to manage all information and knowledge related to machine tools, their components failure modes and level of maintenance status;