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A Collaborative Information Sharing Platform for Virtual Manufacturing Analysis Preparation

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Abstract— **Virtual manufacturing (VM) has been studied in various activities of manufacturing. The objectives of the studies depend on the nature of investigation: ranging from optimization of product and process design, workplace design, simulation of plant operation and layouts, to improvement of manual operations in ergonomic studies. VM helps to shorten the product development process by its ability of various analyses in product and process design. It is important to convey effectively the product design information with the most current data to all people interested in the design. This paper presents a research work in two folds, firstly on the development of a Collaborative Information Sharing Platform (CISP), and secondly on the development of VM simulation models. The information of the VM simulation models can be shared and accessed by all interested parties through connections of the developed platform CISP. Simulation models for the manufacture of an AC motor are illustrated. The simulation models emphasize the integrative approach in product and process design, where same product data source is shared and used for analyses in virtual environment for the various manufacturing activities involved in the production of the electrical motor. Activities include product development, production planning, assembly analysis, work study, workplace design, operation simulation and plant layout.**

***Index Terms*—Virtual manufacturing. Collaborative design platform. Information Sharing. Computer simulation modelling.**

1. Introduction

Nowadays, manufacturers are facing global competition. In order to survive, they need to produce more innovative and higher quality products (Offodile, 2002). At the same time, concern must be taken in the production process to ensure minimum production costs are maintained at all times. Thus, the current challenge for the manufacturing sector is to produce new products with minimum or no requirement for design alternation, so that unnecessary manufacturing costs can be avoided. Consequently, there is a high demand for developing a new manufacturing approach in order to (i) eliminate or minimize design errors before releasing the product for manufacturing; and (ii) share product information efficiently and collaboratively with business partners in a real time manner.

It is understandable that to achieve at a hundred percent error-free design is quite impossible, but every effort should be made to minimize the design errors before manufacture commences. Virtual manufacturing (VM) provides the capability for analyzing the product and process design without the real testing of the physical products. In a VM environment, design modifications and design plans on different aspects of manufacturing can be easily made with the aim to reach an error-free design prior to the commencement of the real production. It is important that the latest design changes and their related information are dispersed instantly across the whole manufacturing concern so that the most up-to-date information is used.

In order to develop an effective collaborative information sharing environment, active inter-company communication is essential. There has been worldwide research that involves work to model, build and test agile and distributed manufacturing networks to share manufacturing information and resources among “loosely connected” firms (Lee and Lau, 1999). The type of organizational and enterprise change needed to support this new networked paradigm has been addressed extensively by a lot of researchers. However, the discussion on the importance of appropriate IT tools to bring effective changes into an organization has not led to any constructions of the tools. Despite the much publicized importance of information technology to increase the competitiveness of an enterprise, the exploitation of the Internet by most small and medium sized firms is still far from satisfactory and is still limited to information searching, e-mailing and posting of company Web sites. In addition, though much small and stand-alone application software is available, most of those market-available software packages for information sharing are not based on the browser/server architecture, i.e. users at different locations cannot have access to them and use them unless the receiving ends are pre-installed with the designated software. This limits their application in a network environment in which the product development, engineering, and assembly are all dispersed both within and across a company, no matter whether small or large.

Braganza (2002) discussed the use of enterprise application integration (EAI) technology to create competitive capabilities. Following this argument, in this paper, it is adopted to construct a collaborative information sharing platform (CISP) for integrating various manufacturing activities. Virtual manufacturing (VM) are presented in details on various digital mockups of manufacturing activities. The developed CISP is used to disperse design information of the VM models. Through CISP, product and process design can be considered concurrently with other business partners in an integrated manner. Users are capable to utilize the same design database that is shared and used for the various analyses of manufacture. Such shared database will be developed with the advent of computer graphics that will give rise to visual engineering, which refers to the visualization of geometrical models of design concepts on computers. Coupled with simulation, animation, and 3D modeling techniques, realistic objects can be displayed on computers for examination dynamically and interactively (Crabb, 1998). The application of visual engineering in manufacturing facilitates the analysis of product and process design in a virtual manufacturing approach.

The followings of the paper are divided into three sections. Section 1 introduces the development and the architecture of the Collaborative Information Sharing Platform, CISP, while Section 2 describes the development and application examples of Virtual Manufacturing (VM) simulation models. The information of the VM models is linked to the CISP as an application tier in the developed platform so that the design information of the models can be passed around and shared by all users connected to the platform. Finally, a conclusion is drawn in Section 3.

1. ARCHITECTURE OF THE CISP AND KEY TECHNOLOGIES INVOLVED

The proposed collaborative information sharing platform (CISP) possesses distinct features including its capability to customize the product data and information, simultaneous amendments, and manipulation of documents in a distributed and cooperative environment. The platform is designed based on an open architecture and browser/server technology which makes it an ideal platform to be operated under a network environment. As shown in Figure 1, the platform is developed based on a seven-tier framework which includes the data acquisition tier, a customizable user interface tier, a web server tier, a collaborative operations tier, an applications tier, a product data interchange tier and a product database tier. Additional function and application modules can be incorporated in the application tier.

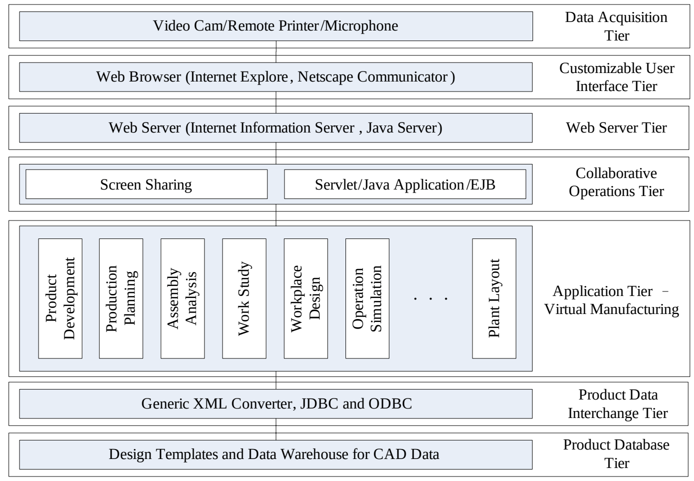

Figure 1: Architecture of CISP

1.1. DATA ACQUISITION TIER

Data acquisition tier is designed as the hardware interface that permits data acquisition devices such as video cam, microphone, remote printer, barcode scanner, keyboard and mouse to communicate with other layers of the platform. This first tier connects the platform to the sending and receiving signals, whether electrical or optical.

1.2. CUSTOMIZABLE USER INTERFACE TIER

The customizable user interface tier gives the users the tools they need to access, organize and share mission-critical information, collaborate securely from distributed locations and make faster, better informed decisions. A library of built in templates is provided for rapid customization of the optimal work environment within the platform using a standard web browser. Built in templates offer reusable structure, content and tools.

1.3. WEB SERVER TIER

A web service to the browser is provided by the web server tier. It contains two servers: the Java and media servers. The Java server is used to provide the web service while the media server is used to provide multi-media application services. Java server pages (JSP) and Java servlets are used to produce dynamical web pages and communicate with the backend database and applications.

1.4. COLLABORATIVE OPERATIONS TIER

The collaborative operation tier provides a robust platform for customizing and developing applications that employ instant collaboration. Users can embed instant collaborative capabilities into software applications installed in the application server. This is accomplished by a screen sharing and refreshing algorithm. As shown in Figure 2, the sharing screen allows multi-users to remotely share control of the server screen, mouse, keyboard and server applications such as

AutoCAD, Solid Work and Unigraphics (UG). A number of participants can conduct collaboratively such as editing an engineering drawing and specifications by sharing the server's computer resources—while the user looks on and participates.

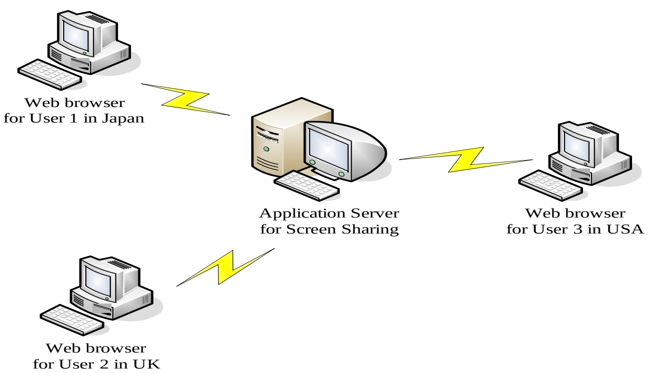

Figure 2: Graphical illustration of screen sharing operation

1.5. APPLICATIONS TIER

The applications tier provides services to support specific native applications and third-party software applications. In the context of study for this paper, virtual manufacturing applications are closely examined. Digital simulation models are developed for detail analyses of manufacturing activities, covering product assembly, process simulation, workplace design, work study, production planning and plant simulation. More details are given in section 2.

1.6. PRODUCT DATA INTERCHANGE TIER

The implementation of the CISP needs a common standard for interchange of product data over a heterogeneous computer-aided design (CAD) platform. The data interchange tier is designed to incorporate data of different format from various sources into a unified format in a consistent way. To achieve this, extensible markup language (XML), a new standard that formalizes the semantics of the contents of web files and facilitates electronic data interchange (EDI), was used. An XML schema with a neutral format, which can be customized to suit various CAD software packages such as Solid Work, Pro/E, etc., was used. A generic XML format converter was used so that the format conversion can be accomplished from a neutral standard to a company-specific CAD standard or vice versa. The format converter is generic in the sense that enterprises can customize it through a group of built-in functions to suit the specific format used by an individual company.

1.7. PRODUCT DATABASE TIER

The product database tier is composed of a series of product design templates and the product data warehouse. A series of adapters is built for the conversion of the data from different CAD formats to a common plain text format which is accessible to the product data interchange tier.

2. DEVELOPMENT AND APPLICATIONS OF VIRTUAL MANUFACTURING SIMULATION MODELS

2.1. VM AS AN APPLICATION TIER IN CISP

A prototype CISP platform has been built based on the framework described in last section. The socket communication and multi-thread technology of Java programming language have been used in the development of the platform. The capabilities of the prototype have been evaluated through trial applications of the developed simulation models in virtual manufacturing.

The VM simulation models are developed in collaboration with our industrial partner, Honeywell consumer product manufacturing company. They have a subsidiary production plant in Shenzhen of China, manufacturing consumer products such as electrical fans, dehumidifiers, moisturizers, warm air blowers, etc. for which AC motor is the main component for power transmission. The objective of this collaboration project is to build simulation models for the whole manufacturing cycle of the AC motor, which includes the motor design analysis, assembly sequence planning, production process planning, workplace designs, and suggestion of plant layouts. The developed simulation models will be closely examined with an aim to improve the productivity of making the motor. Through the CISP, designated users at different locations can access the VM models collaboratively.

2.2. VIRTUAL MANUFACTURING - SIMULATION MODELS

Virtual manufacturing analysis was highlighted with the application of visual engineering. Virtual Manufacturing software tools were used for developing digital models for analysis. The computer software tool used for the development work was Tecnomatix eMPower (2000). It supports a virtual manufacturing environment with analyses in areas covering the entire manufacturing cycle ranging from process planning and detail engineering to mass production. The tool was used to develop digital models for display of product assemblies, manufacturing processes, animation of manual operations and production plant layouts. The CAD data of the product was stored in the product database tier of CISP. Since the same database is used, it enables easy access, information exchange and interaction between the model developer and users. As shown in Figure 3, two users at geographically different locations undertook the collaborative design for a motor. In this case, the user was in the design office in Hong Kong, while the other was at the production plant in Mainland China. The developed CISP with video conferencing features enables both users to edit the product design and interact with each other within a collaborative and dialogue environment. This link facilitates sharing of design information between users and helps to trouble shoot the design of the motor anytime and anywhere via a standard browser.

What follows illustrates some VM simulation models of the motor developed in the studies for different manufacturing analyses.

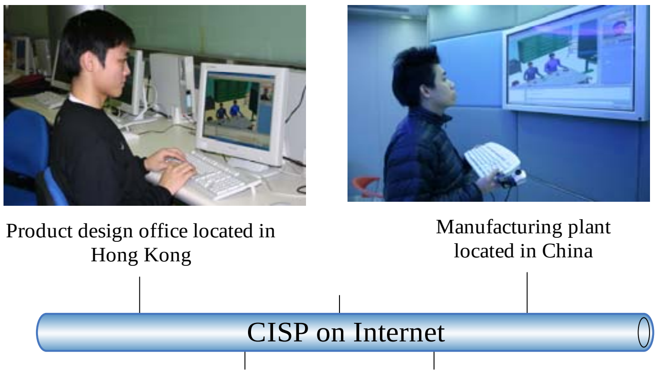

Figure 3: Demonstration of the operation of CISP

2.2.1 PRODUCT ANALYSIS

The product for the study was an AC motor which was set in graphical animation. Components of the motor were dynamically displayed revealing the assembly and disassembly of each of the motor parts in the correct sequence order. Sectional views of the motor design could be shown instantly at any desired planes to reveal the inside components for examination. The motor parts of the sectional views could be set in animation at any instance, should the need arise. A bill of material (BOM) could be generated when the design was defined. Figure 4 shows the design analysis and the BOM of the motor.

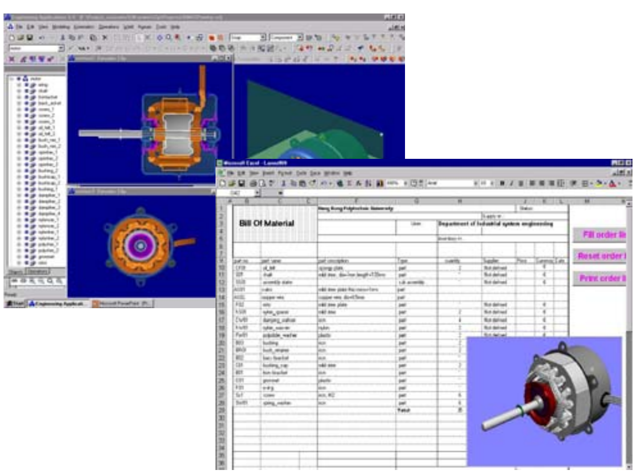

Figure 4: Motor Design Analysis and its Bill of Materials

2.2.2 ASSEMBLY EVALUATION

Once a product design is defined, its assemblability can be studied. The assembly evaluation was performed by using a module called Assembler of the eManufacturing software. Two aspects of the assembly study were evaluated: assembly planning and collision detection. For evaluation of the assembly planning, different assembly paths were created and tried for showing the assembly directions and assembly orders for each of the motor components in order to come up with the optimum assembly paths. The sequence of assembly operations could then be generated and the assembly plan was presented on a Gantt chart as shown in Figure 5.

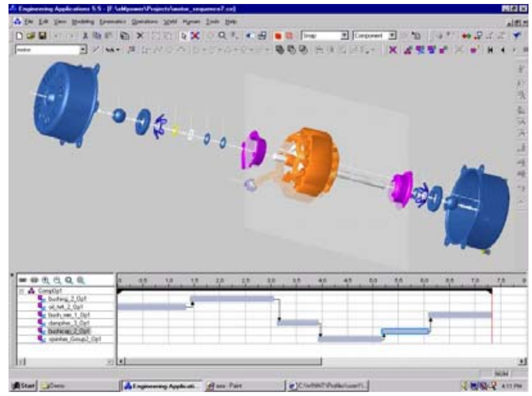

Figure 5: Sequence of Assembly Operations of the Motor Parts

A collision detection check was simultaneously performed during the assembly path creation process. When a collision occurs in assembling the parts, the system gives a warning by highlighting the colliding parts in red throughout the assembly process. This is illustrated in the motor assembly where the rotor shaft is press fit into the rotor hole as shown in Figure 6. The check detects collisions and gives warnings to note and fix the problems throughout the assembly process.

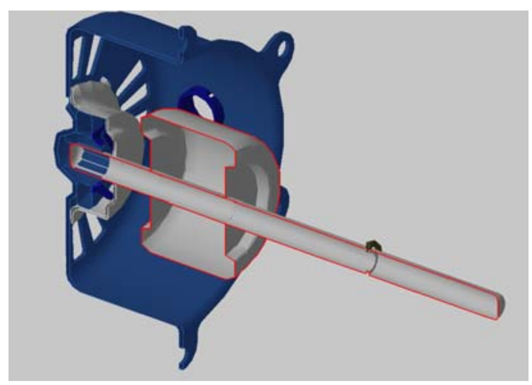

Figure 6: Shaft and Rotor turn red as the Shaft is press fit into the Rotor hole

2.2.3 PRODUCTION PROCESS PLANNING

This module in the virtual manufacturing environment enables the generation of manufacturing process plans of a product assembly in relation to its design analyses. The result is an electronic bill of processes containing a full description of the processes by which the product is assembled, manufactured, tested for quality and packed for shipping. The bill of processes is the basic token of information exchangeable between central planning departments, plants and contractors. In the motor case, manufacturing process routes were generated by using the module. The routes could later be used to generate the time and production costs. The manufacturing process routes of the stator and the rotor of the motor is shown in Figure 7.

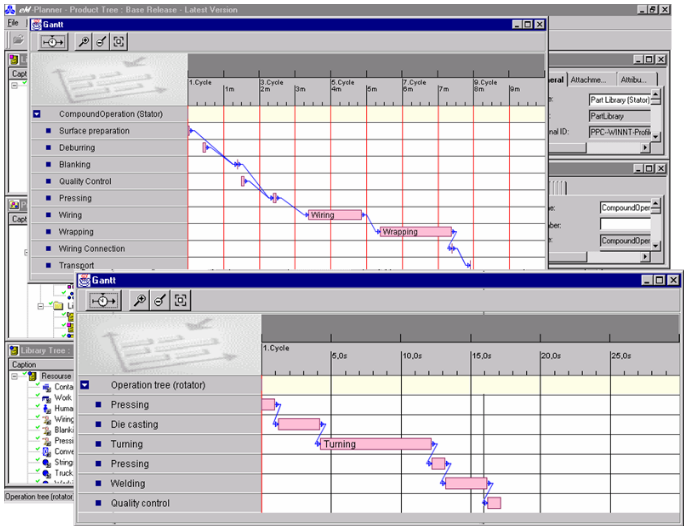

Figure 7: Production Routes of the Stator and Rotor of the Motor

2.2.4 WORKPLACE DESIGN

The design of workplace layout and the study of material flow within the workplace can map out the efficient use of available resources and facilities. 3D simulation models of workplace design were created with the help of the e-manufacturing software. This, coupled with a module that provides a library of human models, can include simulated human operators in animation of manual operations. This facilitates ergonomics studies such as arm reach analysis, posture and energy expenditure estimation, as well as the workplace design. Once the simulation model of a manual operation is established, work study such as MTM analysis can be implemented on the model to provide detail motion and time measurements of the operation. Figure 8 shows the MTM analysis for the final assembly operation of the motor.

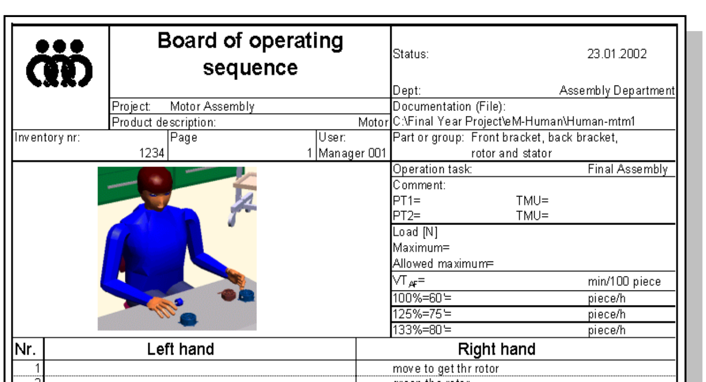

Figure 8: MTM Analysis for the Final Assembly Operation of the Motor

2.2.5 PROCESS AND PLANT SIMULATION

Similar to the workplace simulation, manufacturing processes and plant layout were modelled for simulation. 3D models of machines and equipment used in the simulation were either retrieved from the software system library or created with the aid of the modelling features provided by the system. Modelling for process and plant simulations enables closer examination of the process designs for improvements on operation details, equipment and plant facility design, production line layout, etc.

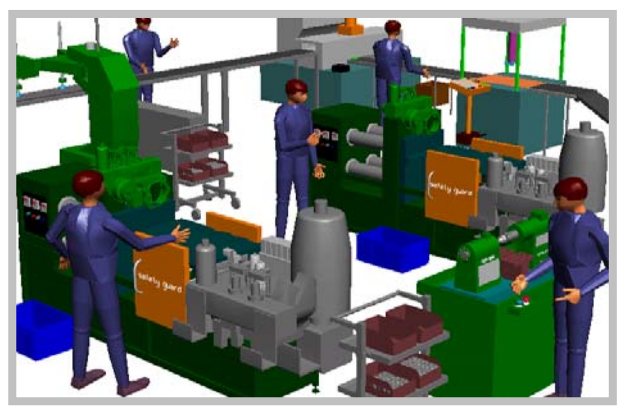

Figure 9: Plant Simulation of the Rotor Manufacturing Machines

3. DISCUSSION AND CONCLUSION

Applying internet technology to upgrade and enhance business is still far from mature for most of the small and medium enterprises. For a manufacturing firm, design information is needed to be clearly conveyed and understood by the various parties and units of the same organization at different geographical locations. A collaborative information sharing platform (CISP) has been developed which enables authorized users at dispersed locations to have access to the product design data stored at designated servers. The users can work simultaneously and collaboratively on any operating systems. Virtual manufacturing, an important development in manufacturing, has been illustrated with various manufacturing simulation models, which are developed as the application tier of the developed platform, CISP. The VM studies focused on the integrative approach in product and process design, in which simulation models have been developed for analyzing various manufacturing activities ranging from product design, assembly analysis, process planning, workplace layout, work study to plant simulation. Through implementation of CISP in Honeywell, it is found that requirements for design alterations have been minimized. Consequently, manufacturing cost reduction has become possible.

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