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A holistic product lifecycle management approach to support design by machine data

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Abstract

This paper is based on an experimental environment with various systems (CAD, CAM, ERP, PDM, MES, TMS) and a coupled milling machine. Based on a holistic view of the process chain and a methodical approach it is possible to ensure a smart bidirectional flow of information between the systems from order and design to manufacturing. As a result technical and economic advantages can be achieved in the early stages of the product life cycle. Especially in design phase plan costs, routing, machinability and processing time can be already considered.

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Keywords: Information Retrieval; Continuous Improvement Process; Internet of Things; Product Lifecycle Management

1. Introduction

In order to withstand international competition it is necessary to reduce production costs and to keep a high product quality. Especially high-wage countries has to produce more efficiently in order to stay competitiveness [1]. Another challenge is that there is a rapid change of knowledge and technology in many fields, such as software engineering, nowadays. This requires already networking and communication of knowledge in the early phases of a product [2]. In particular the product development process is important to reduce the overall costs. That means that between 60 and 80 percent of the entire costs are defined between the concept and preliminary design phase. The later the problems takes place the higher are the costs. The rule-of-ten states the costs to fix a problem in the next process step is ten times higher than before [2]. For that reason the improvement of the design process has a high saving potential.

Product lifecycle management (PLM) is a method to improve the information management in companies. The focus of product lifecycle management systems has long been in the area of planning, design and engineering functions. Nowadays the PLM-systems try to cover more and more of the whole product lifecycle from ‘cradle to grave’ [3]. To enhance the information flow three domains (people, process, information) needs to be carried out [4]. To implement a PLM-system across the entire product lifecycle there is a huge need for smoothly functioning, carefully designed product lifecycle management processes (Support processes, integrate systems, information conversion and preserving information over years) [5]. One problem is that often information are missed or have a bad quality. Especially in the design process, which is in an early phase of the product lifecycle, the information are incomplete and imprecise [7]. Usually the information feedback from low-level manufacturing activities to high-level design is handled by human interactions [8]. As a basic for improvement the machine data is transmitted and visualized in a Manufacturing Execution system (MES) [9]. Through diagrams/graphs and key performance indicators like Overall Equipment Effectiveness (OEE) production manager detect problems and initiate a change process [10]. A media disruption is so taking place in the information flow. This fact shows that there is improvement potential for automatization.

The more information are available in the design phase the less complications and expenses are in the later phases of the product lifecycle especially in the phase of production. A big

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benefit is to know already during construction which machine and which tools with which technology parameters are available. As a result the work piece of this framework is designed properly. Based on a good data quality the machinability can be ensured without major revisions. Another factor that already can be considered during design is to avoid if possible cost intensive features of the workpiece. For this assistance a software-tool with high quality data is necessary.

A complexity is to keep the individual system databases on a current state. Often an enormous effort is necessary to maintain all databases. For the supply of information with good quality data, the IT system environment and production must be smart linked. The interfaces of the individual systems often have to be adapted to the individual environment of the enterprises.

The aim is to establish a smart information cycle in the whole lifecycle. Internet of things is the approach which it is based on. “Internet of Things (IoT) is an integrated part of Future Internet including existing and evolving Internet and network developments and could be conceptually defined as a dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable, communication protocols where physical and virtual ‘things’ have identities, physical attributes, and virtual personalities, use intelligent interfaces, and are seamlessly integrated into the information network” [11]. Through the return of data from the production relevant databases can be filled which can support the designer. The importance of information at the right time with the right quality at the right place is worth a lot in the sophisticated corporate world. With appropriate software tools, lined with information, the designer can prepare already during the design process the workpiece optimally for the next steps.

2. Data management systems for design and manufacturing

IT-Systems become more and more importance for the industry. A very competitive factor is the information flow time. An effective information flow shortens the processes [12]. Another advantage of the computerization in manufacturing industries are new possibilities for the enterprises to try new methods like data mining and process virtualization for improving the overall performance [13].

The main IT-Systems in enterprises are the following:

- ERP: Enterprise Resource Planning
- PDM: Product Data Management
- MES: Manufacturing Execution System
- SCM: Supply Chain Management
- CRM: Customer Relationship Management

The constellation of the IT-systems depends on the different characteristics and size of the companies.

For simulation and demonstration aspects the Institute for Information Management at the Karlsruhe Institute of Technology in cooperation with cooperation partners from the industry established an IT-Systems environment oriented by a cutting enterprise. The landscape includes the following systems: Enterprise Resource Planning, Product Data Management, Manufacturing Execution System, Tool Management System (TMS), Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), CAD-Analysis-Tool. To implement the interfaces between the systems the institute works hand in hand with the cooperation partners. The IT-Systems are coupled with a milling machine. The IT-Systems are based on a server farm coupled with databases (Figure 1). Most of the IT-systems are based on a client-server model.

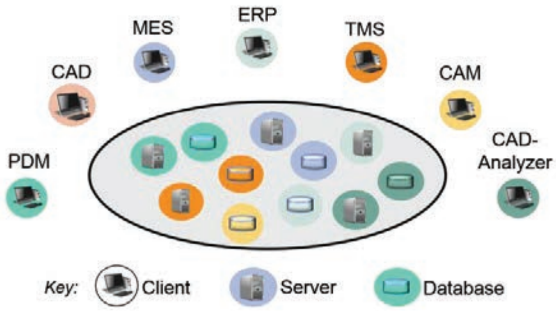

Fig. 1. IT-park

The system landscape is linked according to the principles of product lifecycle management and seeks to ensure a continuous bidirectional information flow without media disruption (Figure 2). Particularly critical is the repatriation of information from the manufacturing to the design process.

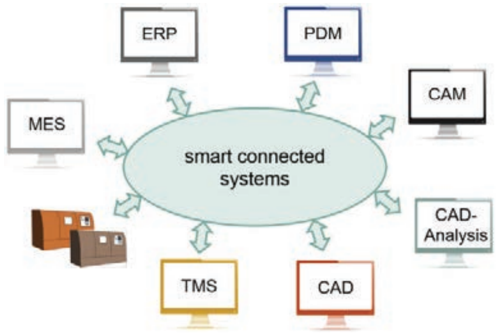

Fig. 2. Smart connected IT-system environment at IMI

To set up a demonstration environment it was necessary to define a simplified process from product development to production. This defined information flow affects the interfaces between the systems. The connection between the systems depending on the individual processes of the enterprises. By adding or exchanging a new system in a company there is this first big decision if the system adapts the existing processes or the processes adapt to the IT-system. The different implementation scenarios have to be evaluated. A successful implemented information system adoption involves the adaption process and a full absorption in the organization [14].

To optimize a process it was first necessary to define a demonstration scenario orientated on machining small and medium-sized businesses (SME). In the following paragraph a part of the scenario is described. The example attempts to show the information flow from product creation to production with the involved IT-systems.

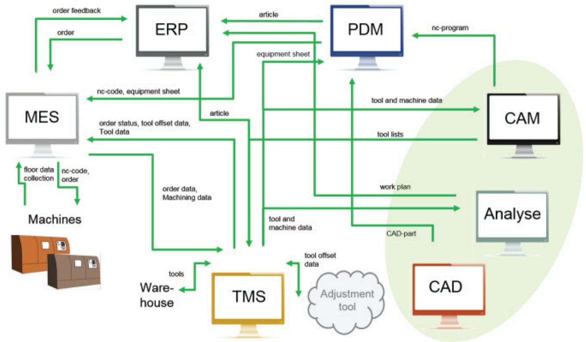

Fig. 3 Scenario of smart connected IT-systems

Bevor the process starts the tools and machines be created in the Tool Management System. Each tool has individual technological parameter for different operations. The stock of the tools is coupled with the Enterprise Resource Management System. The first step in the scenario is that after a successful costumer acquisition a sell order is created by the ERP-System. If it is a new item, the item can be created in the PDM-System and transfer the metadata automatically in the ERP-System. In the ERP-System the new item appears as new and relevant data has to be added. The designer can then create in the CAD-System the appropriate workpiece according to customer specifications. Through the CAD-analysis tool it is possible that the designer gets extra information like costs, processing time, work plan, machinability and processing time. In Figure 3 is an example how the designer can analyze problems at machinability or features which are cost intensive. The left picture shows the machinability. In this case the pocket is not machinable with the available tools in the enterprise because the corner radius is too small. The picture on the left shows which operation are more expensive than others. In this simplified case the drilling is most expensive operation. The analysis is listed in figures and some are graphically represented. With this information the designer can improve the design. The CAD Analyze Tool database is filled by the TMS Database.

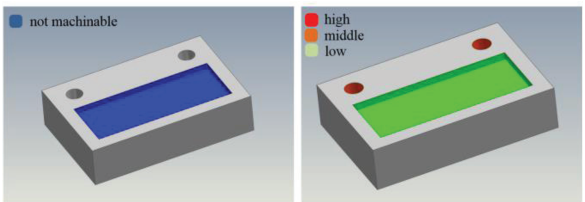

Fig. 4. CAD Analysis-Tool – Machinability (left) and cost drivers (right)

The CAX data is managed by the PDM-System. After the CAD-Model is designed the NC-programmer generates toolpaths in the CAM-System. The operations are based on the features of the workpiece. The database for the used machines and tools with technology parameters are given from the TMS-Database. In our demonstration environment, the CAM and CAD analysis tool is integrated in the CAD as an add-on. The nc-programm and the information which tools on which machine are necessary for this order are given to the TMS- and MES-System. The production order with all details is given by the ERP-System. The MES-System is then mapping the data from CAM with the production order. The production control system (part of MES) assigns the order to a machine and a production period. The preparation of the machine (for example tool magazine, tool length, etc.) are managed by the TMS-System. Finally the machine operator gets the necessary manufacturing information from the MES-System and can manufacture.

This was just a short inside view on the demonstration scenario. In detail the steps, tasks and links between the systems are defined in more detail.

3. Design supported by smart data management

The approach presented in this paper is based on a continuous improvement process. This section is about the method to gain technical and economic advantages through an improvement process originating by CAD. The design affects the subsequent steps significantly through the product lifecycle.

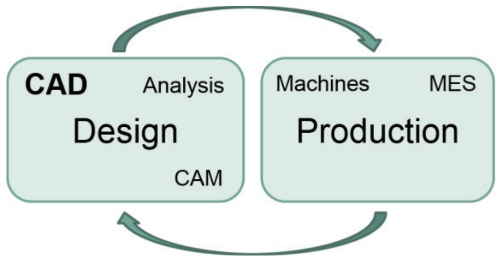

Fig. 5. Design improvement process

To provide additional Information the design process tools for CAD-analysis can be integrated in CAD. The add-on is based on a database. The Tool in our scenario can provide besides others the following information:

- processing costs
- processing times
- work plan
- machinability

Based on a geometry analysis the tool identifies features and analysis the work piece based on the data stored in the database. Therefore the quality and timeliness of the data in the database have to be ensured.

To obtain current and improved data from the production it is important to categorize the machining operations. Each machining operation in context of material, machine and used tool. In Figure 6 examples for machining operations are shown. For example operation A (Material: aluminum, machine: Model M, tool: 6mm end mill, process: face-mill) or operation E (Material: aluminum, machine: Model M, tool: 6mm end mill, process: pocket).

Each categorized operation has technology parameters:

- cutting speed
- feed rate
- cutting depth
- tool life

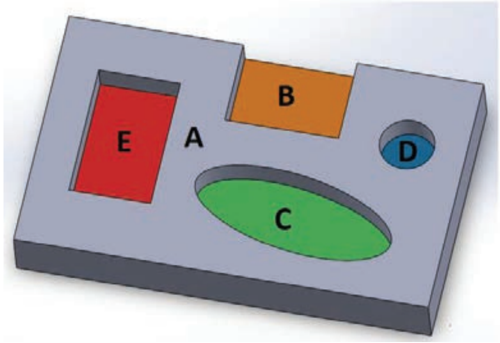

Fig. 6. Categories of machining operations

These parameters are saved in context of the operation in the TMS-Database which supplies the CAD-Analysis and CAM Database. For production the machine operator receives the technology parameters from the MES-System. If the given manufacturing process doesn't match the machinability or quality requirements changes are necessary. One way for necessary or presumed changes is to send a change request to the designer or nc-programmer. Another way, addressed in this paper, is that the machine operator, based on his knowledge and experience, makes the changes directly by changing parameters. Preconditioned the rights are given to the operator. The machine is linked with the MES-System. Sensors provide the real process data in context of the operation. With an analysis the real data and the existing data can be compared. An index based on criteria like quality, time is evaluating if the changes are an improvement or not. If the modifications have a positive affect the old parameters in the database are overwritten with the new parameters. By this procedure a continuous improvement process can be installed.

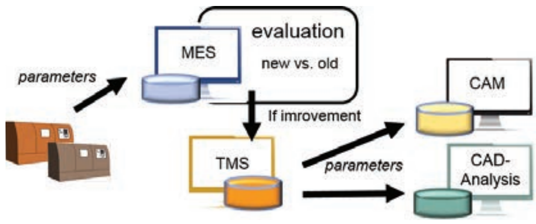

Fig. 7. Information backflow

The current data are saved in the TMS, CAD-Analysis and CAM Database. By using these data an improvement in the early stages of the lifecycle is possible.

The advantages are that the product costs can be reduced through a more efficient manufacturing. The work plan is more precise so the production can be planned better. Furthermore a positive impact on the quality is possible.

4. Conclusion

The work presented in this article proposes a new approach on continuous improvement in the design process. This approach is integrated in the product lifecycle and shows the impact between the main IT-Systems in a manufacturing environment. Based on a smart connected IT environment profitable benefits are possible. Through automatism in context of the interpretation of technology parameters from manufacturing benefits in the design process are gained. The method is addressed to enterprises of cutting manufacturing.

The quality of data which supports the designer is in a continuous improvement process. In the next steps the evaluation process needs to be researched further. Key indicators have to be defined and integrated in the improvement process. Furthermore additional dependencies between the IT-Systems can be evaluated and smart connected.

A smart connected IT-environment provides the basis for a smart factory.

5. Acknowledgements

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