Process Data Management for the Shortening of the Whole Product Creation Process

Veit Rueckel[1], Alexander Koch[2], Klaus Feldmann[1], and Harald Meerkamm[2]

[1] Institute for Manufacturing and Production Systems, University of Erlangen-Nuremberg, Egerlandstraße 7-9, 91058 Erlangen, Germany
{rueckel, feldmann}@faps.uni-erlangen.de
[2] Institute for Engineering Design, University of Erlangen-Nuremberg, Martensstraße 9, 91058 Erlangen, Germany
{koch, meerkamm}@mfk.uni-erlangen.de

Abstract. Companies have to shorten the innovation cycle for products to obtain a competitive advantage. Thus not only time to market but also time for developing new products has to be reduced. Due to that several software tools are used to facilitate a computer based product synthesis. One of them is a Product Data Management System (PDMS) for the integration and administration of all kind of CAx-data. With dedicated data transfer, information processing methods and self-generating assembly sequences it is possible to shorten the time between the arrangement drawing, part production and final assembly to a few moments. Because of a continuous data model it is even possible to transmit data backward in the product creation process. The information can be used as rules for an engineering workbench or for the visualization of the progress. Consequently a PDMS as an information feed-back control system can realize a more robust and sustainable product synthesis.

1 Introduction

Nowadays it is more important than ever to shorten the time from a new product idea to the first salable product, the so-called time to market, because of the demand for shorter innovation cycles and the fact of shorter product life cycles. The here from resulting product creation process has to be seen as interleaving work steps, according to simultaneous or concurrent engineering, more than single tasks stringed together. Therefore a reasonably planned strategy is necessary as well as an intensive data exchange between the different divisions of the company in such a way to achieve highly overlapping work steps.

One of the most important strategic targets of companies is to widely accomplish the development of a new product or the processing of a customer order with methods of up-to-date information techniques. For this purpose specific software tools are used in every division. With these tools a complete product description shall be built up, which represents the base for product planning, manufacturing, assembly and quality assurance [7]. In figure 1 an assortment of electronic data is shown that builds up a complete product description.

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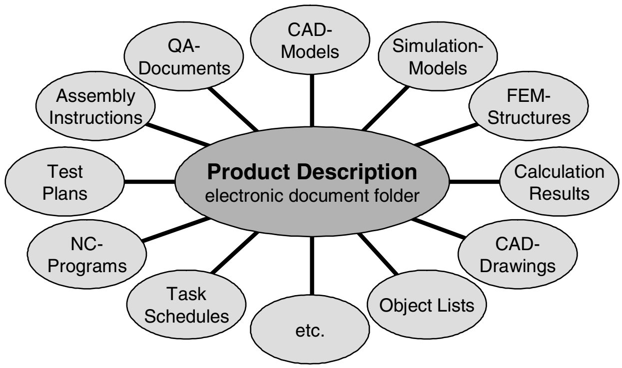

Fig. 1. Different documents from all divisions contribute to the product description (source [7])

One of the biggest challenges is the well known difficulty of designing interfaces between the available software tools. That means nearly every software tool is self-contained and as a result data exchange is handicapped. More and more software tools use a data model adapted to their own requirements but not specialized for data exchange between different programs. Standardized interfaces exist but they do not provide functionalities for a holistic data exchange, only geometry and some additional information. Furthermore a version monitoring is not provided as well as a structured repository of information like CAD-drawings and -models, test plans for quality assurance, FEM-structures, calculation results etc.

For this reason Product Data Management Systems (PDMS) are more and more used not only in big groups but also in small and medium sized enterprises. PDMS can merge the advantages of specialized software like CAD, FEM, CAQ, CAM and CAP etc. by gathering data files, storing the meta data and administrating them centrally [8]. Out of this results a complete electronic product description like shown in figure 2.

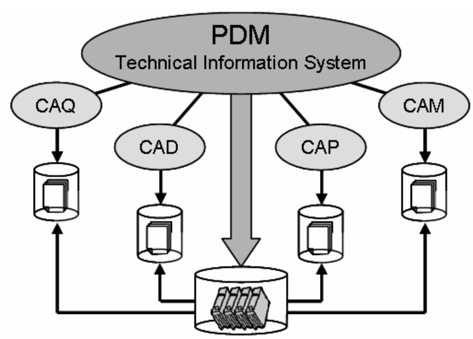

Fig. 2. Systems integration of CAx-applications by means of a PDM-System (source: [7])

2 Possibilities and Benefits with the Use of PDMS

Product Data Management (PDM) is a strategic approach, but enterprises do mostly not notice the outstanding importance of its possibilities. Thereby a PDMS is the middleware for all data generating applications: it copes the product- and process-data-management, offers a common user interface and controls the file and data sharing for all users [1]. In general PDMS are used for product-related data which is routed and prepared especially in the direction of the product creation process [5]. This means the generation of data starts at the product development respectively with the order processing and is transported to the production, quality management up to the final assembly.

A weak point of these systems is in particular the one way data stream. For example in the production planning a NC-program has to be created, it is possible to use quickly the existing digital product specification. But the important dimensions, like maximum measures of the parts, their compounding positions and the like, must be separated by hand from the stored data files and entered again manually [2]. In the field of the Collaborative Research Centre (CRC) 396 “Robust, shortened process sequences for lightweight sheet parts” – funded by the German Research Foundation (Deutsche Forschungsgemeinschaft) – a PDMS is used for the data exchange between several sub-projects. Due to that all institutes like product development, production, quality assurance and assembly can be situated in a virtual process chain “product creation CRC 396” and represented in the PDMS.

Typically the product development can be seen as producer and the assembly as consumer of product data. Not only geometry but also semantic information like tolerances, producing data or material is defined. Furthermore the chronological order of the assembly steps is specified. All these values can be stored in a PDMS for the easy use in following divisions.

Recapitulating it is possible to say that the benefit of PDMS is consistent data management, built in versions monitoring, access control for all kind of data and companywide available holistic product description. All of them are standard PDM functionalities that can be used with minimal effort for implementation and customization [6]. But PDMS provides much more possibilities of data administration, processing and providing. A custom approach of a multidirectional data exchange from product design to assembly and backwards is introduced in the following chapters.

3 PDMS Upgrade to Specific Requirements

Another potential of advancement during the product creation process is not only the flow of data but also the further processing in succeeding divisions. To obtain a robust and shortened process chain “product creation” the PDMS was upgraded to extract automatically the relevant data for a special assembly step from the already stored data record. To demonstrate the mechanism the two divisions “product development” and “assembly” are coupled together.

The first step was to integrate a new modular entity “article” in the PDMS to handle different geometric and semantic information of every part. Because of the modularity an adoption to changing requirements can be realized very quickly. In this case modularity means that besides the basic meta data of a part a sub-record for every single specification like tolerances, material or processing parameters is set up. Each sub-record is designed in a tabular form so that all parameters for this special interest can be stored and administrated in there. For additional fields of interest accruing in later stages of the product creation more sub-records can be assigned to the entity "article". This structure provides a basis for the holistic product description throughout the product creation process.

Besides a variant of different parts and their semantic information about function, processing and appearance, all sub-processes like screwing, gluing, pick&place, drilling, milling etc. with their characteristic parameters should be stored separately. For this purpose another but also modular designed entity "process" was implemented. This second new entity is also built up modular and has the same structure like the entity "article". In the tabular structure a sub-record exists for every type of process and these sub-records can also be filled up with each special interests specifications.

With these two new entities "article" and "process" it is possible to store own parameters for each part and process. During the design process the geometry with additional information about tolerances, material and also the production process like milling, turning, grinding etc. and furthermore the chronological order of the assembly steps are predefined and saved. By using self developed interfaces, it is possible to extract automatically the specific data for the following division from all

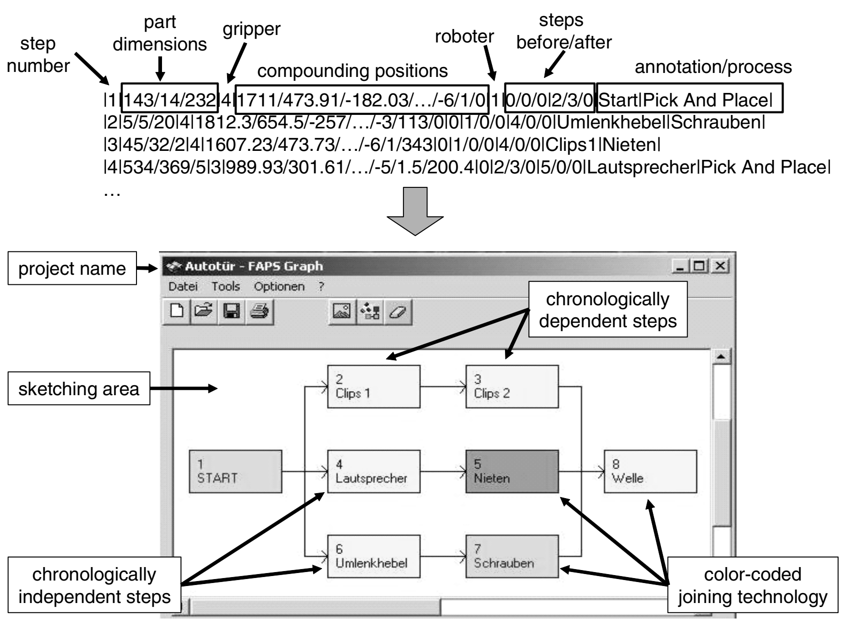

Fig. 3. Example of an ASCII data set exchanged between PDMS and applications

stored data records. To simplify matters these interfaces all are ASCII-interfaces. The interesting values are formatted in a standardized format readable and writable by all joined applications (cp. figure 3). So it is possible to obtain all relevant data without a fault-prone reentering of information and having at the same time an extremely short process sequence.

As shown in figure 3 it is difficult to understand the chronological order directly from the ASCII-code which is defined by the steps before/after. Thus a visualization tool was developed to visualize the assembly sequence for a better understanding. The different processes are characterized by different colors. Furthermore some steps can be done parallel, so-called chronologically independent, and others are chronologically dependent.

4 Continuous Data Structure from the Product Development Until the Assembly

With this approach it was possible to couple both divisions "design" and "assembly" that it is now feasible to create programs for the assembly robots automatically from the CAD-data, which is explained in the following abstract. Another advantage of this PDM architecture is the expandability to other sections of the product creation process. Each of the used applications in the CRC 396 can read and write ASCII and comes up with APIs for customizing.

All parts and assemblies occurring in the product creation process "CRC 396" are designed in a common 3D-CAD-System. All information which is necessary for the assembly is stored in an enhanced CAD-data-model and can be exported with convenient sub-routines and interfaces. Values of interest are for example the maximum part dimensions, compounding positions, the chronological assembly order and the compounding process. Furthermore the assembly positions in the real assembly cell can be calculated by regarding the geometric dimensions and the arrangement of the parts. All these information is collected and visualized in a special window of the PDMS shown in figure 4.

Until now the product designer has to build up the CAD-data model and defines parts, sub-assemblies and also the assembly order. But especially the chronological sequence needs a lot of experience and time. To help the planner and reduce the need of time, an algorithm is integrated in the 3D-CAD-system, which is able to calculate, starting at the 3D-arrangement drawing, every feasible assembly order automatically. A decision criterion for a possible step is a collision free path during the assembly execution. If several solutions exist, the identification of the best one is necessary. Therefore a kinematics simulation with a model of the assembly cell is needed to predefine the cycle time.

The developed extended assembly graph includes not only the chronological order but also process specific data and is the base of the automatic generation of robot programs [4]. With an export routine it is possible to rearrange all the values to a special data format (cp. chapter 3). Now it is possible to use the self-made pre-processor to create sequences for a kinematics simulation. The user is able to change the calculated trajectories in the simulation to optimize them. Input for the

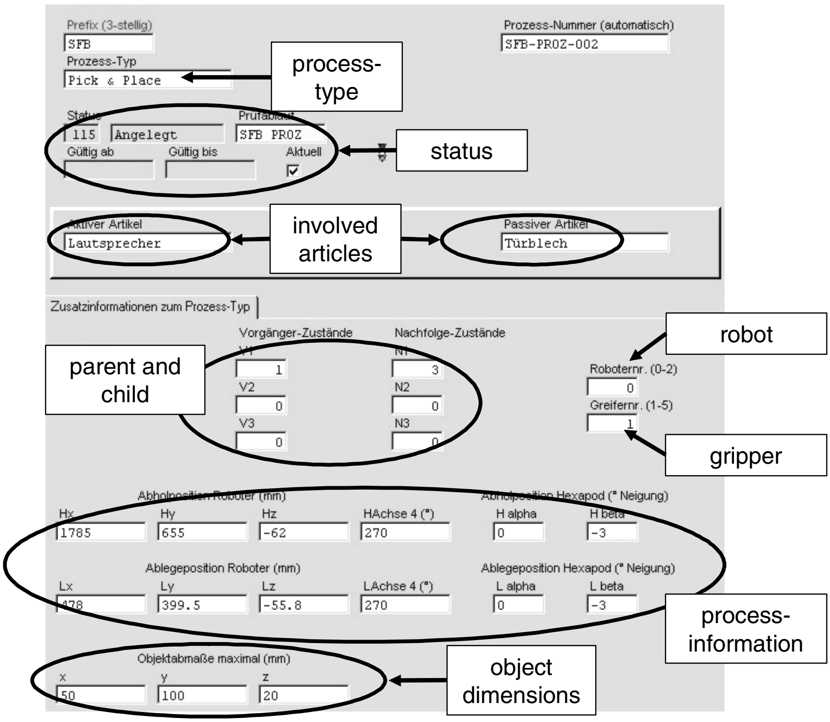

Fig. 4. Providing all relevant data with the use of input masks (here: compounding process “pick&place”)

post-processor, which creates the real robot programs, are the extended assembly graph and an init file, in which the geometry of the assembly cell and possible grippers are stored. The user has not to write one line of code, because every program for the robots is written automatically and even the movements are pre-calculated. Due to that no error in the programs and no collision between the robots occurs and the time for the program generation can be reduced to a few seconds instead of several hours of teaching the trajectories.

Using such a continuous flow of data, it is possible to integrate all sub-divisions in the product creation process by adapting only the two entities “article” and “process”. Due to that two important advantages are obtained during the product development. On the first hand side it is possible to reuse the information and avoid completely transmission errors because of manual input of process- and product-data. Therefore a robust process chain is realized. On the other hand side an enormous ratio potential is given by this method. Starting from a simple CAD-model the real robot programs for the final assembly can be created automatically, which is shown in figure 5. Using a continuous data structure each division of the enterprise is able to extract the needed information like tolerances for the measurement from already stored data. Moreover it is possible to attach some gained information like an adjustment vector for the division “assembly” to adjust the robot programs to the measured part.

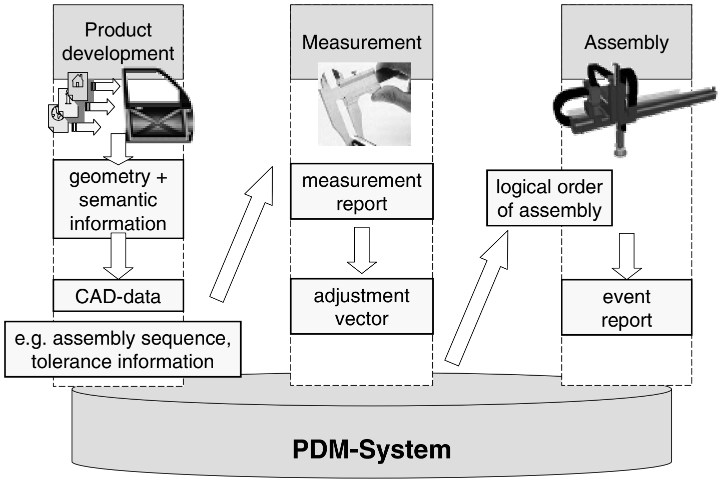

Fig. 5. Fully automated assembly program generation via continuous data structures starting in the product development

5 Realization of the Multidirectional Data Exchange

The way of processing information shown above correlates to the conventional way of data exchange during the product creation process and provides the opportunity to forward all kind of data in the direction of product creation. That allows a robust and shortened main process by transmitting all data fast and efficient. Also important is the other way round which means from the later stages of product creation to product development and design. By coupling different divisions via PDMS it is possible to report information like protocols about successful completion or malfunction, cycle time or piece numbers back to the early stages automatically.

Especially in this case a huge potential for avoiding errors can be seen, because information is available at any time of the product creation process. Due to that it is possible in case of an error to give a direct feedback to the responsible person. Then measures can be taken to minimize the reject due to defects. If the process works well, but an improvement can shorten the process time or make the sequence more stable, this data can also be collected within the PDMS. Then a small team, concerning e.g. a product designer, quality auditor and production manager are able to evaluate given proposals and to develop ideas for a more stable and fault-tolerant process sequence.

To realize a transparent flow of data and give everybody the possibility to visualize information of interest a so-called “process monitor” was developed and implemented inside the PDMS to list all partial stages of the product creation process and get a quick survey e.g. of the assembly. In a real productive environment many innumerable processes are taking place the same time and many articles are handled. To get a quick and easy view of only the processes and their parameters of interest a prefix for classification of articles and processes was established. This prefix classifies a set of all articles and processes belonging to one category. Starting the process monitor first this prefix has to be chosen and in the second step all corresponding processes are listed. Each process occupies exactly two articles – an

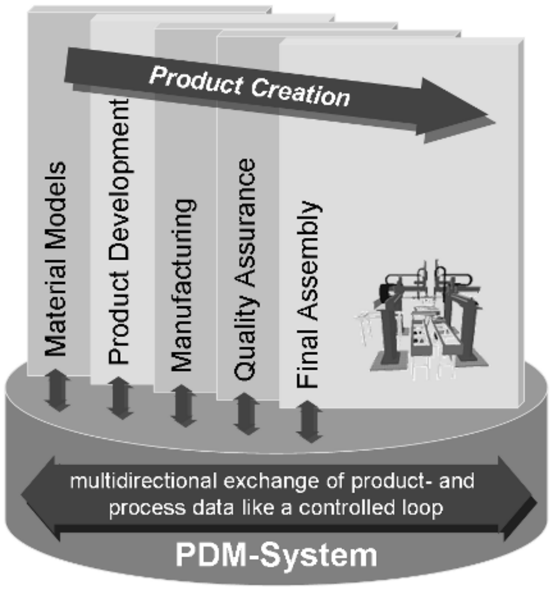

Fig. 6. Multidirectional exchange of data between all divisions involved in product creation via PDMS

active and a passive one. For example a pick&place process uses an active article – the one which is placed to another one, the passive article in this process. These two articles are shown in the processes overview too. Additionally all states of each sequence are listed and their successful termination or the possible malfunction is reported. Thus it is possible to realize a quick and computer aided flow of information back to the earlier stages of product creation via PDMS (cp. figure 6).

Within the CRC 396 an engineering workbench was developed and implemented to assist the developer holistically by accomplishing the design tasks. Both main modules (synthesis and analysis) of the engineering workbench uses a shared knowledge base filled with information about materials, manufacturing technologies and assembling directives etc. in the form of rules. On the one hand side it is possible to extend the nominal shape of a design object inside the CAD-system with semantic information (e.g. the tools closing direction in case of die casting). On the other hand side it is possible to check attributes directly inside the CAD-System whether they achieve criteria of Design for X or not (like Design for Casting, Design for Welding etc.). The engineering workbench never changes anything of the design object and its context. It only points to violated rules. This assures to also include boundary conditions that can not be represented in the knowledge base (so-called non-formalizable knowledge). Up to now it was necessary to gather and summarize this knowledge manually in the later stages of product creation [9]. This procedure is very extensive because no automatism is available neither for gathering nor for summarizing of data. Furthermore this circuitous procedure is very fault-prone because of the manual evaluation. With the realized multidirectional exchange of data introduced in this paper the fundamentals are built for the automatic generation of rules for knowledge based synthesis and analysis. This causes a significant more robust and shorter process sequence "product design" [3].

6 Summary and Perspective

Specialized software tools are more and more used by companies to meet the requirements of shorter innovation cycles of new products and the associated short ranges for product design. The use of a Product Data Management System is an auspicious approach to shorten the time to market sustainably. In the CRC 396 methods and tools are developed to get a robust, short and fault-tolerant process sequence "product creation". Within these projects a PDMS is used that enables a continuous data structure. A special feature of this method is the exchange of data not only along the direction of product creation which means from product development as their generator to the final assembly as their user but also back from the later stages of product creation to the earlier stages like product development and process planning. For example it is now possible to create assembly-sequences out of CAD-models immediately after their completion. Therefore an assembly analyzer was integrated which is able to extract every feasible chronological assembly sequence. If there are several possibilities, the best one is chosen by regarding different cost functions, like cycle time, using a kinematics simulation.

The self-generation of the assembly graph enables an immense decrease of time compared to conventional methods. Furthermore the required information is extracted out of the stored datasets which eliminates their re-entering. This procedure also saves precious time in the product creation sequence. But much more important is the fully avoidance of redundant data management and human errors caused by the re-entering of data.

More divisions besides development and assembly like manufacturing and quality management should be associated with the PDMS in future for a holistic representation of the whole product creation process with all its single steps as well as a complete electronic product description.

The approach introduced in this paper of a continuous data structure using a Product Data Management System offers as a result the possibility to shorten the whole product creation process effectively and to organize it more robust and fault-tolerant due to the continuous use of data. With this solution it is possible for companies to come up much faster to a product ready for the market and to acquire the gained knowledge systematically, link it to an engineering workbench and use it for future developments and products.

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