COLLABORATIVE ENGINEERING IN PRODUCTS DEVELOPMENT AND MANUFACTURING

Edward Chlebus

Corresponding author:
Edward Chlebus
Wrocław University of Technology
Institute of Production Engineering and Management
Centre for Advanced Manufacturing Technologies
ul. Łukasiewicza 5, 50-371 Wrocław, Poland
phone: +48 71 3202046, +47 71 3202705
e-mail: chlebus@pwr.wroc.pl

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Abstract
The manufacture and consumption of market products shows ever growing trends, and this means not only the supply and demand volume but also, to a higher and higher extent, searching for new products distinguishable from the variety of products on the market. Not only new methods of market investigation have appeared to specify its requirements, but some attempts were also made at elaborating suitable methods and techniques of engineering to ensure flexible and synchronised reaction to market demands. Thus, it is necessary to find methods of functional, logical and structural combination of the so far existing engineering applications like CAx, RP/RT/RE, PDM/TDM, PPC/ERP, CE/SE and RDBMS techniques. Competitive actions in the “product market” make a manufacturer and his sub-suppliers respond to market signals quickly and adequately, and to permanently improve their internal organisation, as well as co-operation, logistic and service interconnections. A new challenge imposed to manufacturers by the competitive market is the so-called “product customisation”, i.e. attending to an individual customer’s requirements in the features of a series manufactured product. The general objective of customisation is to elaborate features of a product, manufacturing processes, documentation and production organisation in such a way that the product’s individual features meet the customer’s requirements and its manufacturing process, price and service do not stray from series manufactured products. This contradictory production strategy requires using the newest achievements of computer methods and tools, as well as the newest manufacturing technologies and systems.

Keywords
collaborative engineering, production modeling, process planning, product development, rapid manufacturing.

Production process modelling

One of the most important problems that companies face nowadays is growing competition – success of a product is determined by its delivery time, price and quality. To meet these requirements and reduce the product preparation time, simulation tools are more and more often used in production preparation [1, 2, 7, 8]. Modeling and various simulations permit verification of the solutions to be implemented before their implementation, which is impossible with traditional methods of designing [3, 4, 10, 11]. Reliable results of simulation research can be obtained only on the ground of an integrated model of the company that covers all components of the manufacturing process, i.e. cubic infrastructure, production means, material and human resources, processes and their topology.

The most important components of the integrated model of a company used in simulation are, among others:
- planning models of the company, describing its organizational structure (centralized, spread, multi-branch, specialized etc.),
• competence and decision flow structure in the areas of marketing, production preparation, logistics (with stores) and service,
• flow structure and kinds of documents in individual stages of product development and life cycle,
• principles of planning and production management,
• structure and features of diagnostic systems that supervise machines and production facilities,
• principles and tools of monitoring the course of design, logistic, production and service orders,
• geometrical, technological and other models generated by CAX systems that can make ground for data generation for simulation models,
• simulators and editors of models for repeatable modification analyses (modifications of current processes or their courses resulting from immediate needs or failures),
• data banks being sources of necessary data and making ground for simulation analyses.

In actual conditions of companies operation, they should be treated as the most important components of company management, describing actual conditions of the processes executed in the company [5]. Basic components of a manufacturing process are schematically shown in Fig. 1.

Time and market orientation in product development

Of the general triad of antagonistic conditions and requirements imposed on today’s manufacturing systems, beside the cost and the quality, it is the time that becomes the most important. This parameter is strictly connected with flexible reactions to market demands and is a very strong factor of competitiveness, especially in distributed manufacturing systems. Globalisation, using the economy of scale in the manufacture, has contributed to the increase of production lots and distributed manufacture, as well as forced a radical reduction of production cycles. An example is shown in Fig. 2.
It is estimated that the year 2000 was a turning-point for classical methods of product development and creation of new product prototypes. The market pressure on new products and more and more frequent customisation require new methods and technologies. One should expect a dynamic technological development that can be seen even in rapid prototyping technologies.

The most susceptible to those changes are basic market sectors that include innovative products with high level of application of mechatronics and IT systems as well as automotive and machine building industries. However, contribution of information exchange and communication has increased significantly as a result of introducing the latest organisational solutions in design work – namely concurrent engineering and collaborative engineering (simultaneous engineering). In such organisation of design work designers spend a significant portion of their time for data searching and interchange. A common concept has become the “e-manufacturing” – completely integrated and synchronised design, manufacture, project management, etc.

Objectives of technological development in manufacturing

The economy globalisation has brought a rapid development to many fields, by finding new markets and using the economy of scale that allows for the reduction of production costs – see Fig. 3.

This is the current model of global objective realisation by global manufacturers. The model is stable enough but not very innovative. The purpose of all manufacturers is to introduce their products to the zones 3 and 4, which means dynamic technological development resulting in introducing to the current and new markets new products representing new functions and usable features and generating the highest added value with not necessarily large production volume.
It tools in development of product and manufacturing process

It results from the diagram in Fig. 1 that practically all the currently available IT methods and tools belong to the environment of methods and tools that support development of product, manufacturing processes and productivity. Four basic areas can be distinguished:

- integrated product development covering the problems of design using CAx tools (including VPI, RP/RT and FEM) as well as logic of data recording and processing according to PDM (Product Data Management) systems,
- integrated development of products and PDM processes covering the problems of process planning based on the data from CAx and PDM systems,
- engineering knowledge management in the fields of design and planning,
- functional and structural integration in organisation and communication layers of PLM system modules (network communication standards including Internet and relational databases RDMBS).

Most of these features, however not in full range, are attributed to modules of ERP systems that, together with PDM and RDMBS systems, play the role of integrators of system data and documents. The basic role of the PDM/ERP systems is not only functional integration of models, data and documents, but first of all flow synchronisation and management adequately to product/process development condition. In the present-day economic conditions, the market plays the most important role as the place of products and services disposal. Not less important are also the savings obtained thanks to the introduction of innovative technologies, just in the phase of conceptual design and building/testing of prototypes, both virtual and physical.

Rapid manufacturing

An important stage of a new product development is the manufacture and evaluation of its prototype. In many applications a virtual model does not allow for a full verification of a new product and it is necessary to make a physical prototype, e.g. using a technology from a group called Rapid Prototyping (RP), also named more generally Time Compression Technologies (TCT).

RP methods and technologies, together with technologies of Rapid Tooling (RT), usually make a transitory form in a product development and its lifecycle between a virtual model and the series production. Mechanical properties of RP models are, from the point of view of their applications in subsequent stages of product development, important features that are the requisite of effectiveness of a given method for designing properties of the planned product [6, 9].

A characteristic feature of RP technologies is a shorter time to obtain fully valuable prototypes of new products or their components thanks to the elimination of tools required in traditional mechanical technologies (dies in casting, cutters in machining, electrodes in spark erosion, etc.). The third attribute of RP technologies is their additivity – a physical object is built by adding the material, usually layers-wise, instead of subtracting it, as in traditional manufacturing. Depending on the RP technology, prototypes are manufactured by additive method in computer-controlled machines and can be built from paper (LOM), laser-hardened resin (stereolithography), plaster powder (3D-Printing), sintered powders of plastics or metals (Selective Laser Sintering), etc. – see Fig. 4.

Fig. 4. Product manufactured by SLA (Stereolithography) and DLM (Direct Laser Melting).
As an exception to building with a laminar growth of material there are technologies of High Speed Cutting (HSC) or High Speed Machining (HSM), sometimes also classified in the RP group, where a laminar loss of constructional material is realised by machining. The use of modern tool materials and designs, the progress in the machining technology and advanced constructional solutions in high speed milling machines allow for obtaining high productivity and very high machining precision in processing metals and other materials. Therefore the manufactured objects can be pattern models, prototypes, tools for shaping (dies, stamps), moulds for injection forming of plastics or moulds for metal casting. Direct application of HSM for manufacture of finished products in one-off or series production is an example of so-called Rapid Manufacturing (RM).

In combination with the modern CAD systems and Rapid Prototyping technologies, digitising has given a new meaning to such terms like “rapid product development” or “prototyping”, and in the complete cycle it can be called Reverse Engineering (RE). Basic digitising methods and their application range with regard to the accuracy is shown in Fig. 5.

Digitising has created and is still creating new possibilities and its application range is still developing. Its dynamic development results from nothing else but the growing demand. As a result of digitising, spatial positions of a number of points located on the surface of an object are obtained, based on which a 3D surface model is created in a CAD system environment.

PDM/PLM systems for process planning and management

The evolution of process planning and management systems goes back to the 60s of XX century, when first computer applications were used within the MRP systems with highly centralised data structure. Current trends in systems development tend towards scattered user’s environment and their logical structure and usable functions are developed on the ground of product structure and data generated in PDM systems. The first PDM systems were created as a response to needs of CAD systems users who needed a system to manage the prepared drawings. As the years went by, functional range of the PDM systems increased and in middle 80s it covered all the systems supporting engineering and manufacturing works (CAD/CAM/CAE). The development of the PDM systems was undoubtedly influenced by dispersion of co-operating companies that needed a tool to exchange product data. This was important at least with regard to control of information flow between companies, to promptness of implementing changes in the entire scattered documentation and, finally, to obtaining actual information on the product at any moment. Currently, the PDM systems integrate and manage processes, applications and information defining the product in various systems and media (Fig. 6). Today’s PDM systems are very large databases that collect information from other interconnected systems by means of integrated interfaces. As a system, the PDM offers two types of functions: user’s functions and system functions.
Fig. 6. Structure of ProEDIMS system.

The user’s functions supply the system user with interfaces of the PDM system. As various groups of users need different functions, the users functions are subdivided into five categories:

• data and documents management,
• workflow and process management,
• product structure management,
• process classifications,
• project management.

The system functions make use of the system easier and support the user’s functions. The system functions influence the operational environment and isolate the user from it. The system functions include:

• communication and notifying,
• data transport,
• data translation,
• system administration.

An exemplary application of ProEDIMS for product and process management based of the ProEDIMS system, developed by the team of Wroclaw University of Technology, is shown in Fig. 7.

Production modeling and simulation

This stage was aimed at designing the production line layout model for a representative product and determining the productivities required for planned time. An additional task was the optimization of:

• lengths of transport routes,
• number of transport means,
• use of production resources,
• area of the production line.

The original production line layout for the analyzed product is shown in Fig. 8. In all the models, the following was considered:

• real dimensions of the production shop,
• real dimensions of work-stands,
• necessary distances between work-stands,
• position of construction supports.

Fig. 8. Original layout of production line for the analyzed product.
Locations of stores, co-operation and the measurement machine are marked only schematically, however keeping real distances between them. Analyses of the simulation results made it possible to determine, among others, a complete frame production time with the attainable productivities and the flow time for the first piece of the new product. Results of such performed analysis also permitted determination of loads of the work-stands that appeared to be bottlenecks precluding fulfillment of the 2005 sales plan. In order to carry out the sales plan, it was necessary to reach the assumed productivity of 1 piece of product per shift, and twice as much for the parts of the product structure, i.e. 2 pieces per shift. Productivity of eight work-stands merely of seventeen ones present in the line was high enough. Simulation of the production line revealed also the problem of too long and crossing transport routes in the production shop and too low capacity factor of overhead cranes belonging to the vertical transport. To eliminate the bottlenecks, organizational changes were suggested, consisting in different assignment of operations to work-stands, introduction of third shift, employment of a new worker or purchase of one more work-stand, depending of the expected investment costs. New distribution of operations between the work-stands was also introduced and quality inspection was removed from the stand in the main production line (see Fig. 9). Finally, two versions of the layout were proposed, considering the above-mentioned organizational changes optimized with respect to length of transport routes. Owing to transport costs, the version was chosen, in which the transport trucks, as the critical resource, travel shorter distances and the major part of transport is executed by overhead cranes.

**Summary**

The computer techniques used in all the phases of product life decidedly improve the effectiveness of project realisation, utilising parallelism of engineering works, eliminating data redundancy, using determined access to the documents elaborated in electronic form and full control of the works in the scattered design, plannistic and servicing environment. The ISB data indicate that application of the PLM-oriented CPSM (Collaborative Production Management Systems) gives the following advantages:

- reduction of design and manufacturing processes by 40%,
- reduction of access time to data and documents by 75%,
- reduction of documentation volume in design and production by 50%,
- reduction of errors by 15%.

So, these are considerable results that improve not only the quality of projects, processes and products but, first of all, competitiveness of the product and the company. Further evolution of these systems tends towards integration of CAx systems with PDM and ERP systems and their equipment with the methods and techniques of engineering knowledge management and the techniques of decision supporting.

**References**


