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COMPUTER SUPPORTED TECHNIQUES IN PRODUCT DEVELOPMENT REDUCING TIME OF ITS INTRODUCING TO MARKET

Abstract

The necessity for quick responding to changing market conditions forces manufacturers to seek new ways of designing and implementing production facilities. One method manufacturers are quickly adopting is process modeling and simulation, often referred to as virtual manufacturing (VR). Virtual manufacturing allows engineers to view a computer-simulated version of how the final machines or processes should operate. They can eliminate process design flaws in the early stages of development, giving significant savings. The paper describes two examples of complex approach to solve typical engineering problems using advanced CAx system.

1. INTRODUCTION

Competitiveness and long-term success of a company is often dependent on its ability to produce a range of products that are continually improved. On the other hand market conditions demand time and cost reduction. The most often used solution in companies is, widely used, methodology of DFM and DFA (Design for Manufacturing and Assembly). These methods are adopted in process modeling and simulation, often referred to as virtual manufacturing (VR). Virtual manufacturing allows engineers to view a computer-simulated version of how the finished machines or processes should operate. Process modeling and simulation enables engineers to develop, evaluate, refine, and simulate the use of a complex system entirely on a computer, before any time and money are spent on its real creation 14,15,17].

Virtual Reality (VR) technology is usually defined as the use of real time digital computer and other hardware and software to generate a simulation of an alternative world or environment which is believed to be real or true by the user [10,16]. VR technology creates environment that can be useful for product creation. In general, a product life cycle consists of the complete cycle of design, planning, manufacturing, delivery, servicing and recycling. All these processes can be supported and carried out in virtual environment, particularly in cases of

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money deficiency. Virtual Reality is a very efficient way of engineering designing because it is the most natural kind of interface between designer and model.

This new technology helps to reduce investment risk by allowing engineers to view the system in operation via the computer and make adjustments during the design process rather than in the implementation stage, when changes are much more money consuming. Companies can benefit from virtual manufacturing in three primary ways: faster market response, lower production and equipment costs and improved quality. Since virtual manufacturing allows engineers to view a computer simulated version of how the finished machines or processes should operate on the plant production hall, they can eliminate process design flaws in the early stages of development giving significant savings. Engineers can monitor and implement product changes while simultaneous development of the production machinery moves ahead. It also allows engineers to implement technology enhancements prior to production, reducing development costs. In addition, operator training can occur in a virtual environment, minimizing risk to the operation. Among the key technology needs for virtual manufacturing have been the creation of common data models. These data models allow operators to specify and use of the structure in multiple applications, without repetition of the work. Once the virtual system has been "built," it can become electronically available to all members of the development team, including the plant production hall, the designers, and the machine assemblers. To take effective advantages of the benefits of virtual manufacturing, organizations are selecting software tools capable of capturing all the essential aspects of risky business operations, such as product packaging. Virtual manufacturing models are built using graphical objects, called modules, to define system logic and physical components such as machines and operators. To promote reusage of knowledge and techniques obtained and validated in successful simulations, virtual manufacturing software tools create templates for modeling of various types of systems. With these templates, you can complete research much faster by incorporating earlier modeling efforts. Current manufacturing systems and processes are being combined with simulation technology, computer hardware and operating system, reducing costs and increasing company profitability. Virtual manufacturing in many cases reduces the cost of tooling, eliminates the need for multiply physical prototypes and finally reduces material waste. Properly used advanced computer techniques allow everyone to get it right for the first time. It provides manufacturers with the confidence of knowing that they can deliver quality products to market on time and within budget. Even small improvement in manufacturing may have huge and profound effects in terms of cost and quality. Return on investment calculation has shown that small savings in material usage deliver enormous returns in a manufacturing environment. For example, an automotive customer found that each ounce of material saved in a car engine component saved many hundreds of thousands of dollars of material cost each year [12].

From manufacturing point of view, there are a lot of applications including training, collaborative product and process design, facility monitoring and management. This paper covers certain area, which has a potentially significant impact on virtual manufacturing and virtual product development Examples described below were made in CATIA system, which allows the users to create engineering idea from the sketch to process planning. For example, mechanical engineers can design, simulate and evaluate a new part in a 3D module without constructing a real prototype. Built-in in FEA system technology provides powerful tool to linear and nonlinear analysis. It provides detailed information about a product, which is used for optimization of such factors as manufacturability, final shape, residual stress and life cycle estimations. The design stage determines decision as to form, structure and material of the product. Many examples of efficient usage of virtual technology are given by MSC.visualNastran firm [12].

Advanced computer systems, such as Catia, allow to support the engineers' efforts on all stages of product creation, as it is shown on fig. 1. [10]. The thicker arrows of cycle represent the stages of product creation operations, whereas the thinner arrows of cycle represent the reverse flow of information/knowledge which is needed from the downstream to the up-stream of the product development cycle. Knowledge of manufacturing and planning must be taken into an account earlier, in the design stage, so that manufacturing and planning could be efficient and economic. Each of these stages presents unique technical challenges for different engineering professionals and/or final users, who are involved in various life-cycle concerns of product creation. The key to any successful product creation operation is the early incorporation of knowledge, flowing from downstream to upstream, fig.1.

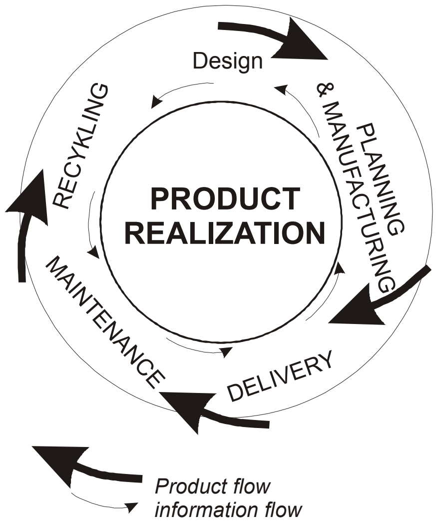


Fig. 1. Product creation cycle [10]

Computer supported techniques in product development, as well as the combination of information technology and production technology, have changed traditional manufacturing industry. Many tasks can be carried out only as information processing within computers. Mechanical engineers can design and evaluate a new part in a 3D system without constructing a real prototype. Such model can be used later to design manufacturing system and simulate its physical and informational characteristics in operation.

The architecture of computer supported techniques can be different; it depends on the main target of the project. Sometimes, there is only an idea (sketch) and we need to go through all stages from designing to planning and manufacturing, sometimes there exists a real model and there is the necessity to build a computer model. Advanced, up-to-date systems have possibilities to fulfill both tasks.

Current tendency in developing virtual environment is aimed to work-up a new methodologies and tools for the process simulation and for the offline programming in order to perform high quality and low cost works and provide a powerful and fast training tool for the final user [11]. On fig. 2 and 3 examples of advanced modeling of machine components and virtual production line are shown. This system integrates new woodworking machinery and advanced technologies for quality control in an innovative configuration of furniture factory. It includes a real-time production management system, which integrates design, scheduling and supervision tools, based on a "Distributed Information System", and a high-speed communication network inside the factory, up to the final customer. There is a built-in system of tools for the "Process Simulation" and for the "Offline Programming" in order to perform high quality and low cost works and provide a powerful and fast training tool for the final user. Such compatible technological solution can be reached only after a deep evaluation of customer needs and goods' market. The connections between virtual production and others subjects are shown on fig. 4.

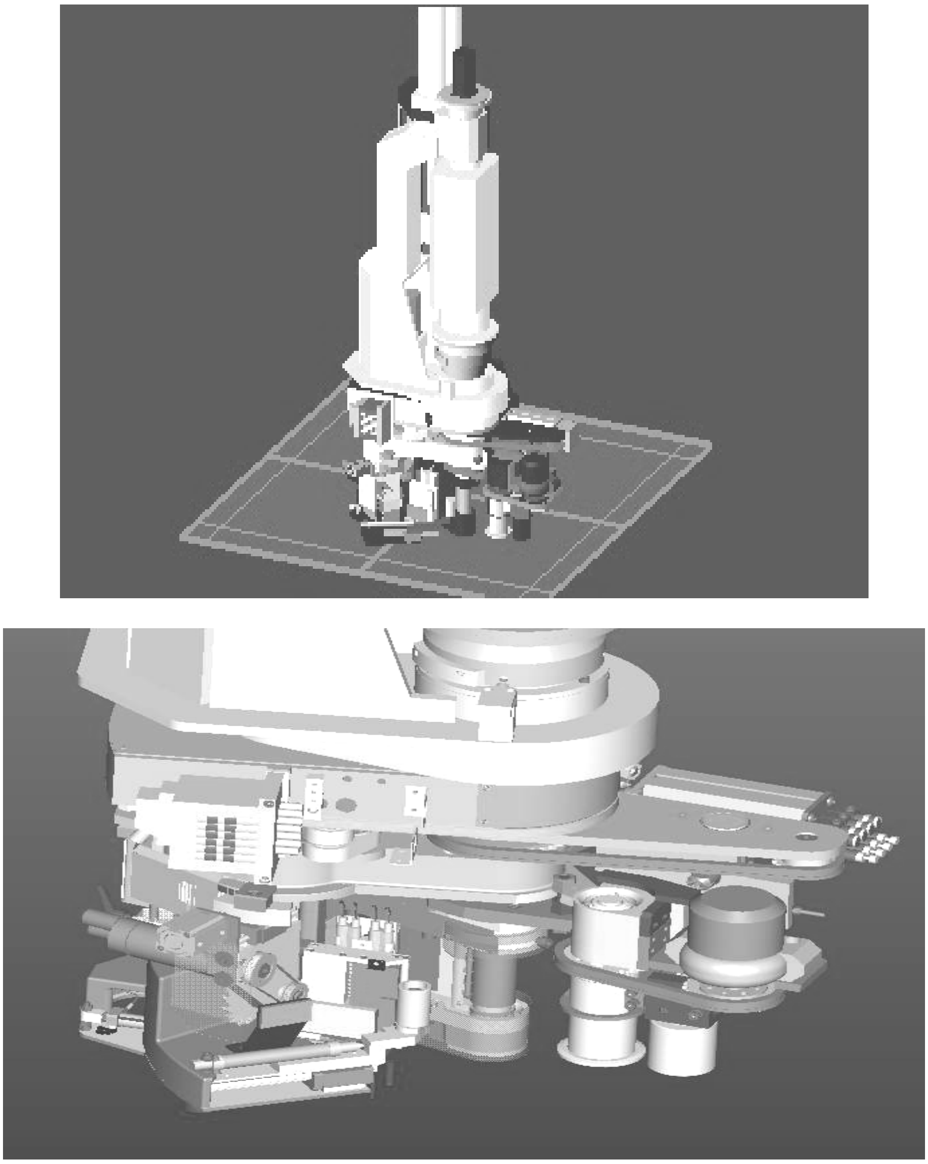


Fig. 2. Advanced modeling of machine components and of its logic [19]

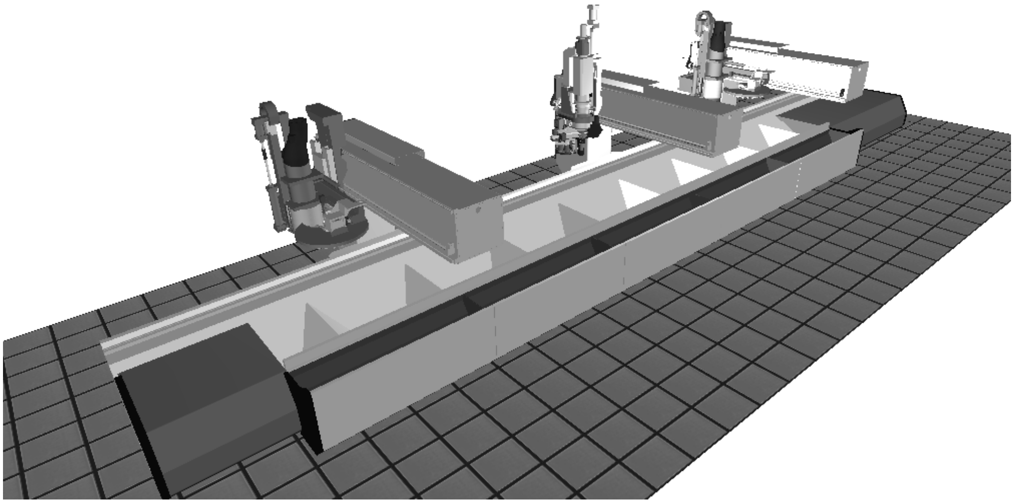


Fig. 3. Example of advanced virtual production [19]

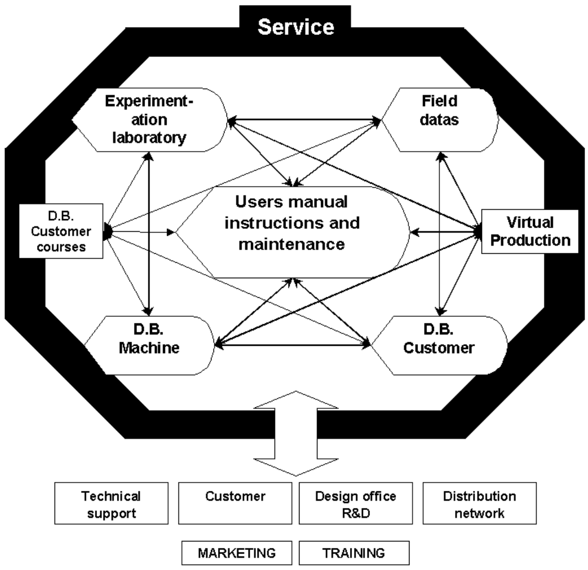


Fig. 4. Connections between virtual production and real subjects [19]

The next, important condition in virtual product creation is image and sound digitalisation, common with net-tools for transmission of information, data, for storing and processing them. All that is realized by multimedia technologies, Fig. 5.

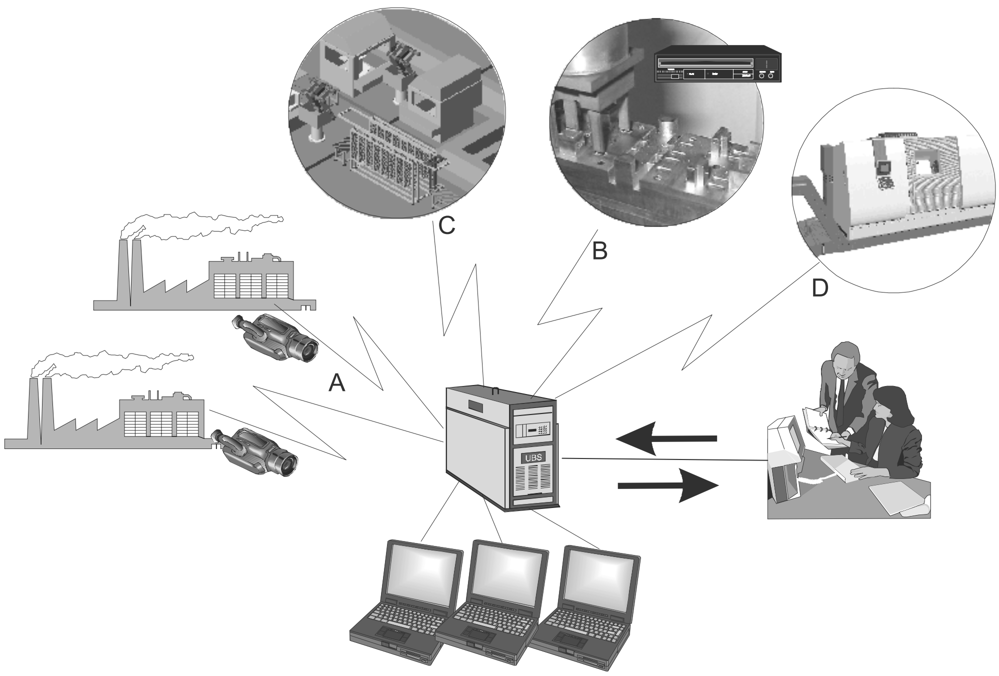


Fig. 5. Model of typical virtual system. A – connections to real plants, B – connections to earlier prepared files (e.g. avi), C – connections to simulation systems

Virtual production system, with established integrated production system, should provide functions for specifying, designing, simulating, analysing and evaluating production system. Below are given some of the functions that an integrated production system should provide [20]:

- identification of product specifications and production system requirements,
- product ability analysis for individual products,
- modelling and specification of manufacturing processes,
- measurement and analysis of process capabilities,
- modification of product design to address manufacturability issues,
- plant layout and facilities planning,
- simulation and analysis of system performance,
- consideration of various economic/cost trade-offs of different manufacturing processes, systems, tools and material,
- analysis supporting selection of systems/vendors,
- procurement of manufacturing equipment and support systems, task and workplace design,
- management, scheduling and tracking of project.

Most of described tasks could be realized in CATIA environment. But, as it is noticed by most authors working on virtual production system, still the main role in such an environment plays 3D design, especially DMU.

1.1 DMU in virtual design

DMU – Digital Mock-up Model usually means a 3D model processed during design stages. Such model contains not only geometrical information, but also information needed in other processes in production (materials, customer's requirements, tolerance etc.). In advanced CAx systems DMU appears as a separated module and gives possibilities for management, navigation, simulation, kinematics analysis and others [1,2,3]. At early stages of product development DMU is created as solid, surface or a hybrid model. To realize virtual production, a complete 3-D model of all objects in the scope of view are necessary. Such a model, after check-up is then used in consecutive stages of product development, fig. 6.

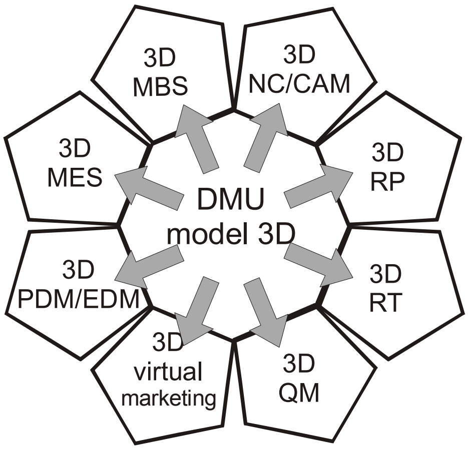


Fig. 6. Chain relations in virtual product development following the 3D model

Analyzing the process of a new product development it is worth noticing that near 50% of parts in designed new products come directly from existing products, near 30% need only some modification or adaptation, and only 20% constitute quite new DMU model created in CAx systems. Thus, important conclusion can be drawn: if the design process must be effective, the methodology of a design based on knowledge and history should be implemented. This idea is being widely developed in comprehensive IT systems, but it is really difficult to state effectiveness of its implementation [17]. On the other hand, all the processes connected with virtual product development should be managed by PDM system, which is a basic tool for functional integration of data, tasks and systems oriented on development and manufacturing determining class of products [13].

2. CASE STUDY 1 – PRODUCT DEVELOPMENT MANAGEMENT

Below, there is an example process of integrated product development supported by Catia system. The problem is as follows: a company needs a new soldering furnace. Design of the furnace is a complex process that requires, since the early phases, a lot of knowledge and experience. Moreover, it should be a compact product and the analysis of assembly, kinematics and strength must be done. In general the furnace consists of two systems technological and mechanical. To fulfill this task CATIA system was chosen due to its wide range of possibilities. CATIA provides the users with the wide range of tools that can be used for automating of some phases of designing process and for building up and sharing company knowledge. The view of final model of furnace is presented on fig. 7.

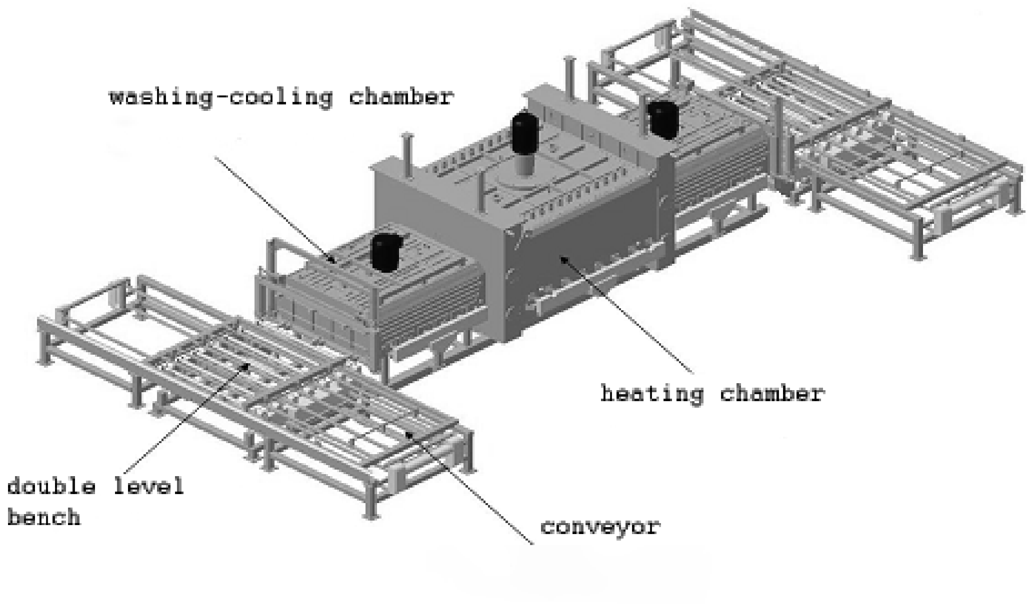


Fig. 7. The view of the final model of furnace built in Catia

The process of building 3D model was divided into several phases. The first stages concerned parts and subassembly design. On fig 8 one example of subassembly-heating heating chamber - is shown. Using "*clash*" tools all connections were checked out. CATIA system allows the user to take out a lot kinds of analyses in one fully integrated system. All the time during designing process it is possible to operate on "history tree". The models in question, were parameterized to allow easy modification of its structure. CATIA environment offers many tools and functions useful for process automation, such as: parameters, a feature-defining object, formulas that define parameters or constrains, etc.

After general acceptance of the project some important elements were chosen for strength analysis. A discrete model of the body is shown on fig. 9.

Such product development is a creative multidisciplinary process which include:

- product development – design phase,
- production development – product establishment and production phase.

CATIA environment integrates all this stages through sharing common CAD product data bill of material (BOM), fig 10. Data are directly imported into other modules, where bill of process is created. It is also possibilities to export data to ERP system in html or user defined format.

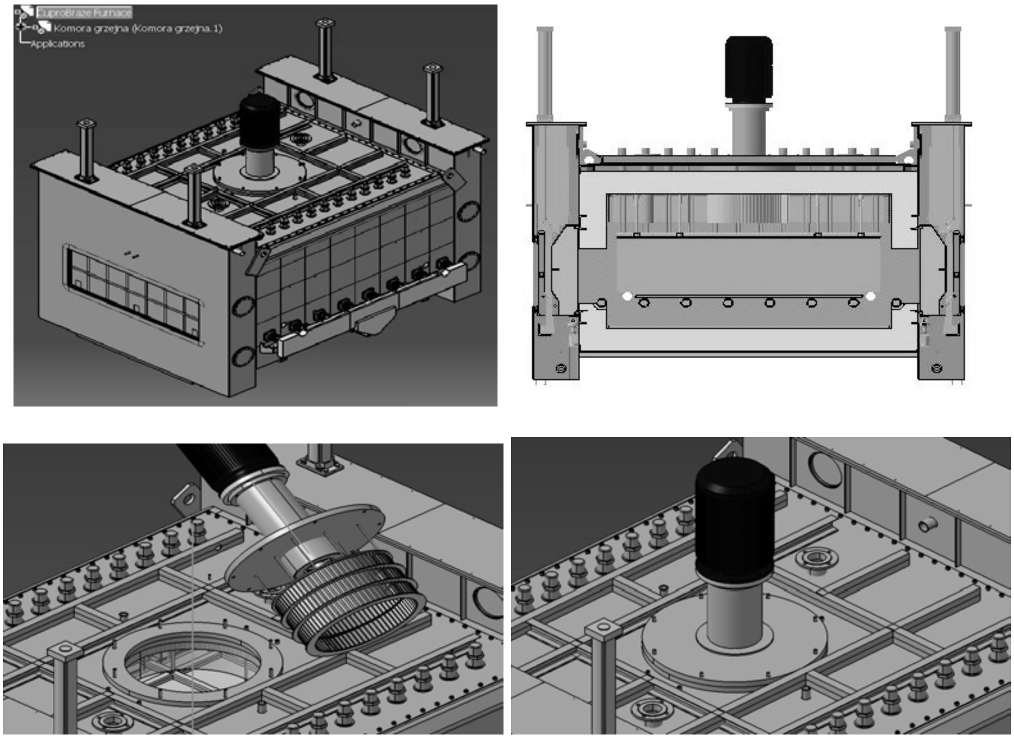


Fig. 8. Subassembly “heating chamber”

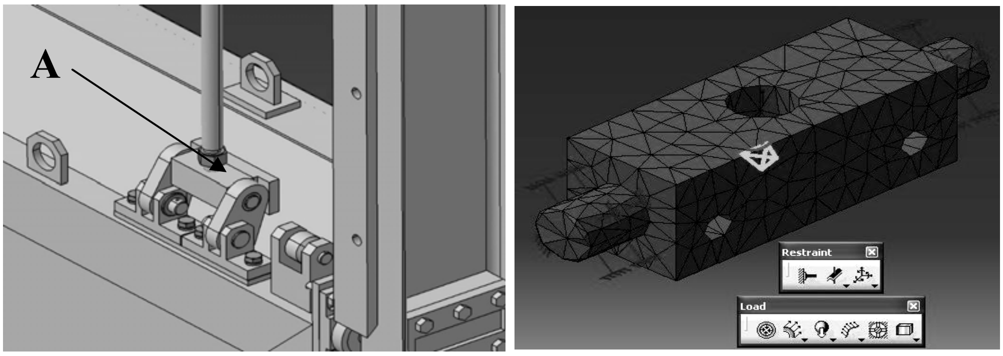


Fig. 9. Strength analysis (FEA)

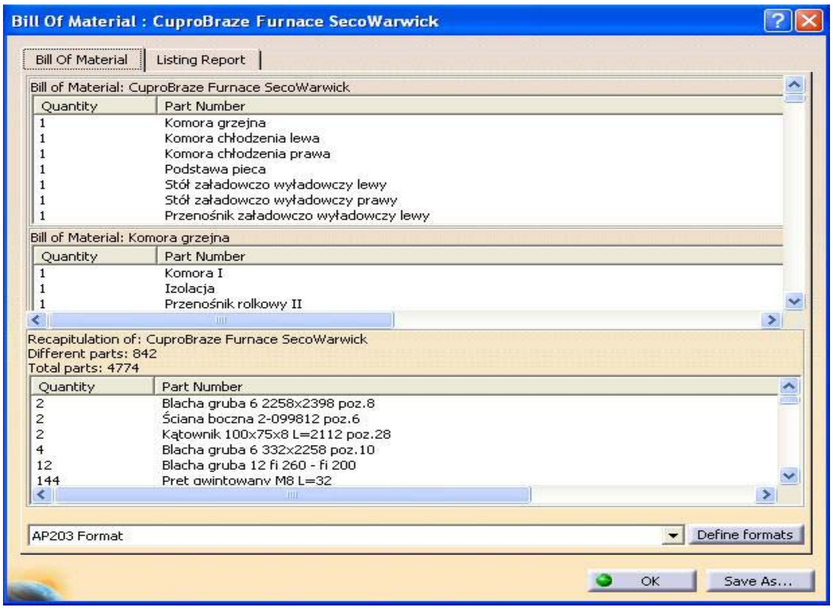


Fig. 10. Bill of material of designed furnace

Described process of product development in fully integrated environment reduced time up to 40% in comparison to SolidWorks system. Results of design process operations are stored in project history and documents such as: technical drawing, calculation, simulation results and can be modified during design process.

3. CASE STUDY 2 – REVERSE ENGINEERING AS A TOOL TO INCREASE QUALITY AND COMPETITION OF THE PRODUCTS

Reverse Engineering (RE) is defined as a process in which a copy of real model is built in virtual environment through functional and dimensional mapping. The main purpose is to obtain technical data (physical and material) useful for manufacturer. It can be simply said that it is a process in which 3D model is created throughout measurement of the existing part in order to describe dimensions and tolerance in a case there does not exist a formal specification. These operations in mostly cases are supported by advanced computer CAx systems; so reverse engineering is called today as Computer Aided Reverse Engineering (CARE).

Reverse engineering in this example establishes an integrated process used in engineering production. In connection with Rapid Tooling and Rapid Prototyping it gives powerful tool helping in decision-making, in quality assurance and in time reduction during collecting documentations for a new product. Moreover, the process using CATIA system will be shown on an example described above.

In production engineering, particularly in mechanical field of activity, this technology is more and more often used to tools' reconstruction, in cases where there exists complex geometry of the tools for plastic forming and foundry. There are many systems meant for this field, which are used in practical reverse engineering.

3.1 Base of Reverse Engineering

Reverse engineering technology is used to build digital model on the base of existing physical model, which could be made from gypsum, plastics, or on the base of parts from industry. Data processing relied upon the best digital mapping and was written in format, which is acceptable by CAx systems. This means that the main task of RE is identification of the any unknown surface of the model [3]. In the manufacturing industry it focuses on recognizing shapes of object and sometimes materials from which they were build.

The first stage of engineering activity is digitization. There are a lot of methods, but the widely used one is a contact method where the surface is touched by mechanical probes located at the and of an arm or on CNC mill machine.

Development of the product, due to reverse engineering technology, includes:

- digitalization of 3D model (object), rough and termed exact scanning, in this process a cloud of points is obtained;
- building surface model;
- building solid 3D model in advanced CAD systems;
- transformation into layers STL model or into CAM systems;
- making the physical model using rapid prototyping or milling.

This technology is often connected with rapid prototyping and short batch of products. General scheme of his method is given on fig.11. RE is widely used wherever a computer model is required for designing the products or manufacturing process. It usually focuses on recognizing shapes of objects. The below described example belongs to the class where there no existing documentation of the product and a computer model is needed for process planning.

The first, and most labor-consuming stage in RE is numerical digitization of the geometry of a physical object making its numerical model. It means that in this stage a set of points, which represent geometrical and tree-dimensional structure of model, is obtained. In manufacturing, there is a tendency to complete this task by using special heads assembled directly on CNC machines.

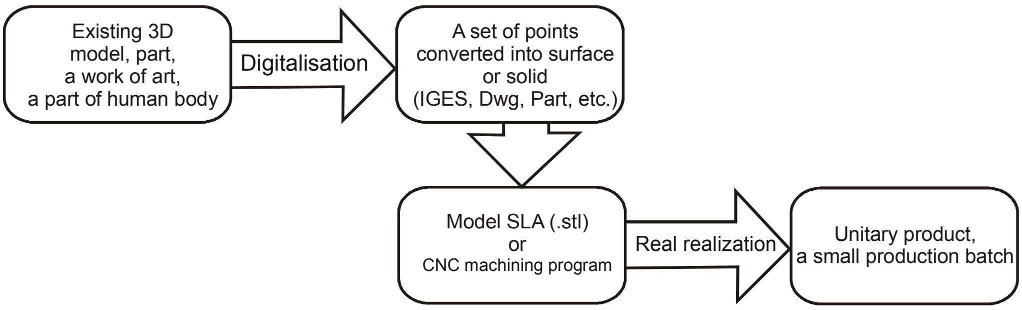


Fig. 11. Scheme of complex approach to the RE techniques

3.2 Base of triangulation

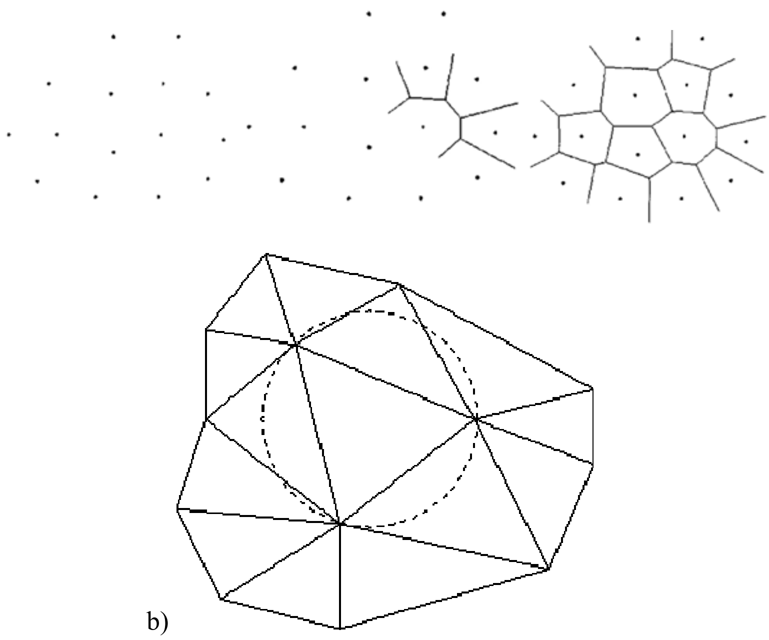
As it was noticed earlier, in the first stage of RE realization we obtain a set of point x,y,z,. This set is transformed into surfaces. Advanced CAx system, like CATIA have built-in tools helping in completing this work.

Surface representation is based on finite number of points and called triangulation because most of existing algorithms represent the surface as finite number of triangles. A triangular mesh generator rests on the efficiency of its triangulation algorithms and data structure. The most popular and well-known triangulation algorithms are:

- Delaunay triangulation,
- Bowyer-Watson triangulation,
- Green-Sibson triangulation,
- Tenemura-Marriana triangulation,
- Delunay triangulation with constraints.

There are many Delaunay triangulation algorithms, some of which are surveyed and evaluated. Delaunay triangulation relies on dividing the surface into triangles through out circles described on three proximity vertexes, fig. 12 b. It uses Voronin's tessellation in which equidistance points from the set of points are determined, fig. 12 a.

The Bowyer-Watson triangulation rely on adding new points, in such a way that Delaunay triangulation must be satisfied. After adding a new point, it should be checked to which described circles it belongs and then to be connected to all triangle vertexes on which they were described, fig. 13. According to similar rule Green-Sibson triangulation is based on. The difference is that the new point is first connected to triangle vertexes and then checked if there are no other points on circles that formed new triangles.



a)

b)

Fig. 12. Base of triangulation, a) Voronoi's tessellation, b) Delaunay's triangulation [7]

To conclude, most of triangulation methods are based on Delaunay algorithms. Estimation of practical efficiency is given in [4,5,6,7,8,9].

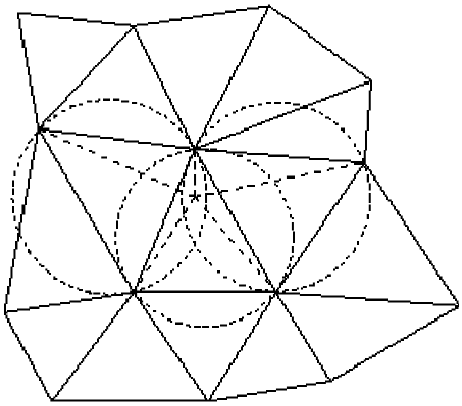


Fig. 13. Bowyer-Watson algorithm illustration [7]

Mesh, built up in this way in 3D, is converted into surface or solid model in CAx systems. Next, this model is used to CNC cod generation, simulation etc. Unfortunately, in most cases computer-generated mesh required interference to improve their quality.

3.2 Example

To show practical application of RE, there is given below the whole process in which 3D model is created. In this case there was no documentation of the die block, only physical model of the finished, existing part. This product is given on fig. 14 a, it is a piece of car body. From technological point of view it belongs to forming press. The task is based on building 3D model, from which it will be possible to produce die block on CNC mill without 2D documentation.

The scan process was realized on mill TME FS2 (fig. 14b) with scan probe Reinishaw SP2 installed directly on mill head, fig. 14 c.

a) b) c)

Fig. 14. Digitalisation of the product, a) a part, b) machining station – milling FS2, c) Reinshaw head

The obtained set of points (cloud points) in next phase was imported into module Digitiser Shape Editor in CATIA. After preliminary scan errors filtering, a set of points was obtained, fig. 15.

During filtering process in CATIA it is possible to use one of two methods: homogenous or adaptive filtration, whereas filtering parameters were estimated on the basis of initial experiment.

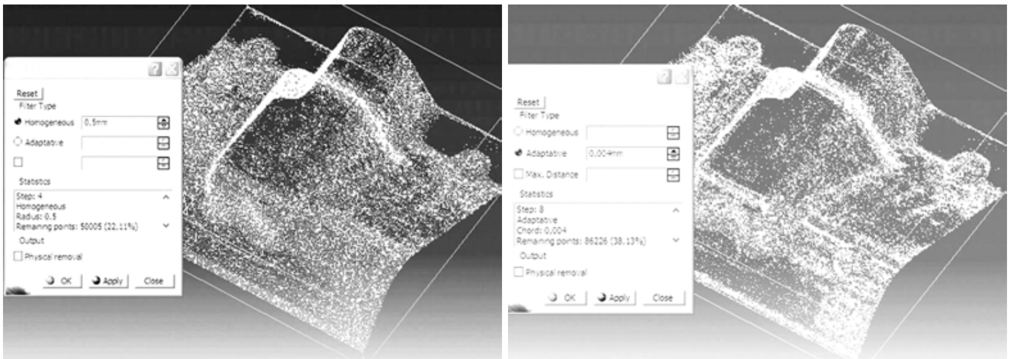
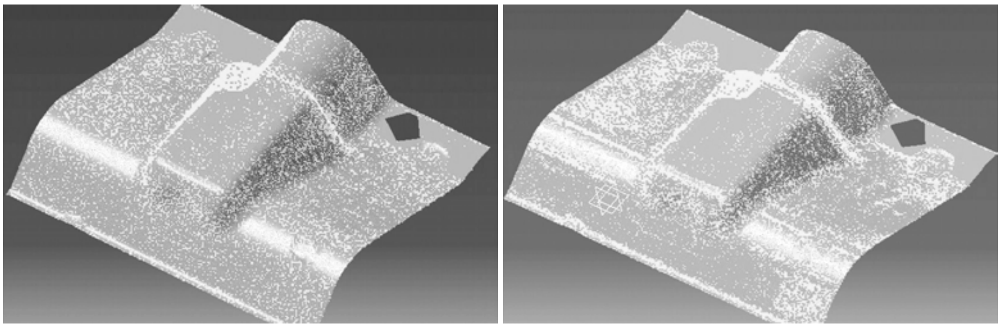


Fig. 15. A set of point after filtration process

This set of points was the base for generating the surfaces. Simplifying the filtering process Catia offers two methods: homogenous or adaptive. The biggest problem, which arises during mesh generation concerns adequacy of the neighbourhood parameter selection. This parameter determines accuracy of points and surfaces fitting. Based on some tests, in a range of parameter changes from 1 to 20, it was established that best fitting was obtained when the neighbourhood parameter had value ~15. The time of the mesh generation does not mean. For a million of points on graphical station it does not exceed 1 s. Examples of the obtained mesh are given on fig. 16.



a) *b)*

Fig.16. The views of the created mesh, a) in homogenous method, b) using adaptive method. (weight factor n=15 equal for both cases)

It was found that there are no significant differences between homogenous and adaptive method. Unfortunately in both cases, the engineer interference was needed. Many errors were formed on edges and on holes as a result of improper connection on triangles vertexes.

The final model (fig. 17) was compared with real part using for this measurements on measuring machine. In the end an analysis was carried out, which allows for stating that the virtual model is in accordance with real part, in established accuracy class.

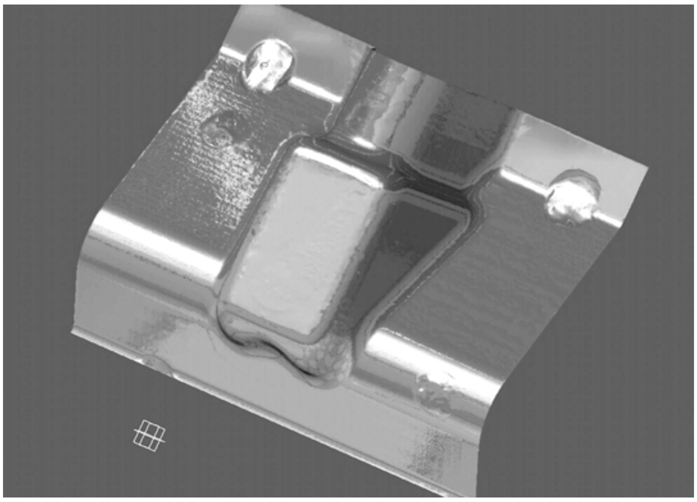


Fig.17. The final view of the product model

The virtual model prepared in this way was used in the following stages to produce die block on the same mill machine on which the digitalisation process was realized.

4. CONCLUSIONS

The two examples presented in this paper of advanced using IT technology in industry, specially CAx technique show their potential to reduce time and cost. Taking as an example such a considerable implementation in companies, it proves that the profit of the company from such a quick introduction into production of the fully examined and functional products is few times higher. Three-dimensional geometrical models presented earlier were made in the same CATIA environment, but the methodology of their creating was quite various. In both cases, cost reduction, improvement of quality of product and shortening the time of an introduction into production cycle, thanks to the new methods, were obtained. In practice, CATIA environment creates virtual manufacturing and production. Virtual manufacturing is expected to greatly support assessing the manufacturability of a candidate design and to provide accurate estimates for processing time, as well as product quality, because it is able to model both the processes for the product's manufacturing and the production process. Virtualisation is an approach that pools and shares IT in production. Research shows that in CATIA system it is possible to automate digitisation carried out with CNC machine equipped with the head without any specialized reverse engineering software.

Virtual design is a growing field in the future production. It has a lot of advantages to improve the production, production planning, production execution and analysis. Lately, virtual models became more realistic and very close to reality. Advanced DMU systems reduce the need for real prototypes. The whole product can be built virtually on the computer, and the user can see three-dimensional model and can simulate how the real product would look like. It is possible to identify risky parts very early, e.g. before conflicts in the constructed space.

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