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VIRTUAL DESIGN METHODS FOR THE NEW PRODUCTS

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Abstract: *This paper presents some aspect concerning the design methods for new products using CAD-CAM-CAE systems to generate virtual products, technologies and manufacturing processes in order to obtain better real products at lower costs. Basically, the products, the manufacturing process and working environments can be generated, simulated and optimized considering all the aspects of the mechanical engineering design.*

Key words: *virtual reality, computer aided design, simulation, optimization, virtual product.*

1. INTRODUCTION

Nowadays, there is a hard competition in the industry for getting out new, better and lower cost products. The manufactures have to deal with the increasing demand of the customers.

They have to continuously improve the conception methods of the products, to modernize the organization structure in order to create a fluent link, between studies, conception, preparation, manufacturing, commercialization and working life of the products. To become more competitive into a world with a diversity of products, which continuously change, the companies must modernize, therefore, to increase the flexibility of their production systems [1].

In this complex and evolutionary environment, industrialists must know about their processes before trying them in order to get it right the first time. To achieve this goal, the use of a virtual environment will provide a computer-based environment to simulate individual processes from the marketing phase to the end of life and the total manufacturing enterprise.

The companies find out that the investment amortization using interactive computer integrated conception of a product (to create visual data base for CAD-CAM-CAE and industrial geometry design), is the most efficient tool for analysis and evaluation. Creation and simulation on the computer of products or processes allow to make substantial economy regarding the costs of the tests and conception errors and also reduce the costs for the manufacturing changes asked by the beneficiary [2].

2. LEVELS OF PRODUCT VIRTUAL DESIGN

In industrial environments, the access to a sharable and global view of the enterprise project, product, and/or service appears to be a key factor of success.[5]

It improves the triptych delay quality-cost but also the communication between the different partners and their implication in the project. For these reasons, the digital mock-up (DMU) and its functions are deeply investigated by industrials [4].

Based on computer technology and virtual reality, the DMU consists in a platform of visualization and simulation that can cover different processes and areas during the product lifecycle such as product design, industrialization, production, maintenance, recycling and/or customer support [2].

The tri-dimensional modeling, simulation and optimization by computer based on the mathematical algorithm, become a very useful research tool in many fields of human activities.

In the field of the mechanical engineering the Computer Aided Design – CAD has become an indispensable tool in the conception phase of the product.

With the evolution of the hardware computer systems, many engineering design software have been developed. The concept of the computer aided design has to be integrated in the life cycle of the products.

By using the computer software in research, innovation and conception, a new field has been developed: Computer Aided Engineering – CAE, that means not only the computer simulation of the continuous or discrete systems (based on the differentials or ordinary finite equations systems). It is also about the modeling of the bodies and stress field using techniques like Finite Element Methods or Finite Element Analysis – FEM/FEA or any other similar methods used to solve equation with partial derivate used field of since of the material strength etc. [3].

Computer Aided Manufacturing – CAM is the modeling of the manufacturing process of the product.

The advanced CAD-CAM-CAE software, like CATIA or ProEngineer, allows to design, and simulates a product, a process and an technical and/or working environment of the product.

There are 4 levels of virtual design for a product:

- Product design;
- Manufacturing design;
- Working model;
- Product presentation.

Each of this level has some sublevels specifying the phase of the design.

In Fig. 1 the level for the product virtual design into a CAD-CAE system as CATIA or ProEngineer is presented.

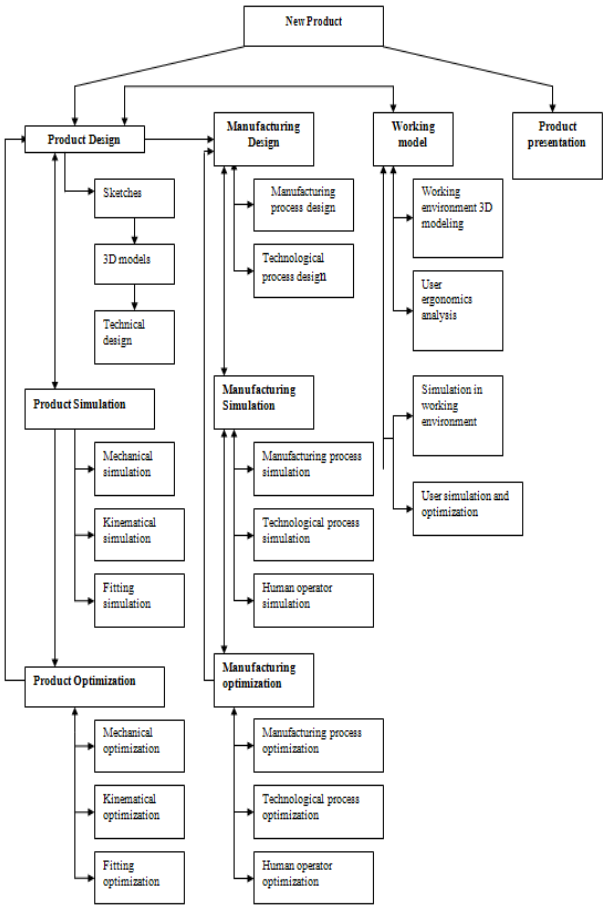

Fig. 1. Level of the design into CAD-CAM-CAE systems [1].

3. PRODUCT DESIGN

The most accessible visualization technology currently in use in large engineering firms is the virtual prototyping software, often used in conjunction with CAD (Computer Aided Design) systems and analysis software. Virtual prototyping allows engineers to test their designs on a computer, rather than by building a physical prototype. Virtual prototypes can simulate real operations, i.e., a computer simulation can predict how a part would act in real world conditions. If the part fails a test or an analysis, engineers can work out how to modify the design in the CAD system in order to produce a second prototype that shows a better performance. Eventually, a physical prototype will be built near to the end of the process to confirm the CAD model.

In CAD software like CATIA, ProEnginner, UniGraphics etc. the first step in the design process is to make a sketch of the product. The designers' team has some software tools to create free sketches which can be geometrical and dimensional constrained. This represents section or portions of section of the 3D model of the pieces (Fig. 2).

Based on these sketches 3D models of the pieces are generated using commands for extrusion, revolution or other. To generate a complex piece are used several sketches and 3D commands (Fig 3).

After all the pieces of a product were created, the next step is to generate a virtual assembly which must have all the pieces in the correct position, as in reality (Fig. 4).

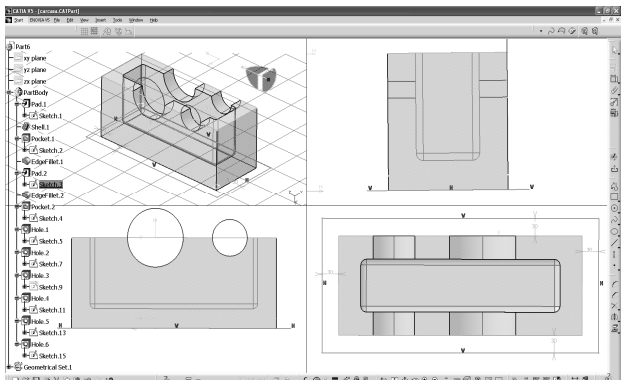

Fig. 2. Sketches of the pieces in CATIA V5.

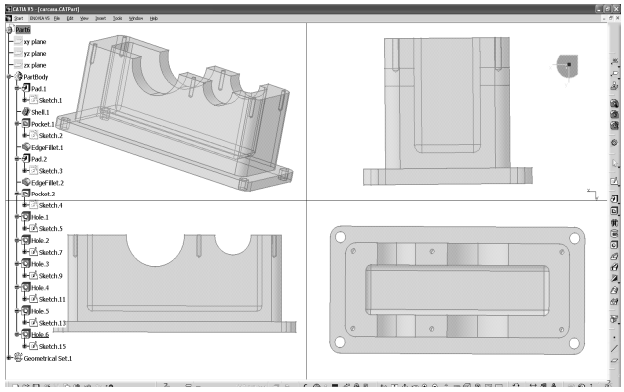

Fig. 3. Complex piece of the product in CATIA V5.

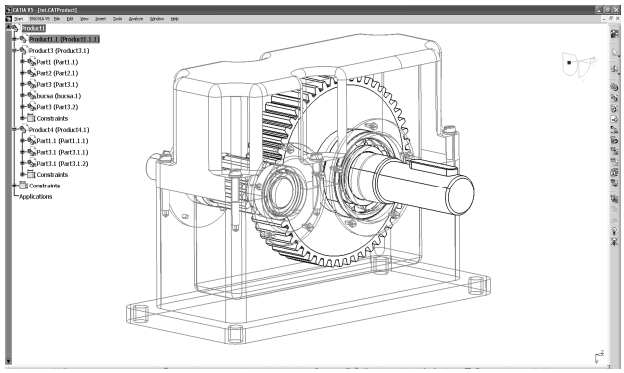

Fig. 4. Complex assembly of the product in CATIA V5.

Mechanical simulation is made to test the static and dynamic behavior of the 3D pieces or 3D product. Specialized software which can work with advanced 3D models is developed for this type of simulation. Good results can be obtained if the working conditions are correctly defined. These results are used for the optimization of the pieces and product.

The mechanical optimization can be made from the point of view of materials, dimensions and forms. In this way it is possible to predict the pieces or the assembly behaviour in static, dynamics, thermal condition. In the engineering field this kind of simulation is known as finite elements modeling and finite elements analysis.

In Fig. 5, some results obtained from a finite element analysis for a static condition are presented.

The optimization of the product can be made using the result of the simulation. In fact the simulation is a step in the optimization process (Fig. 6).

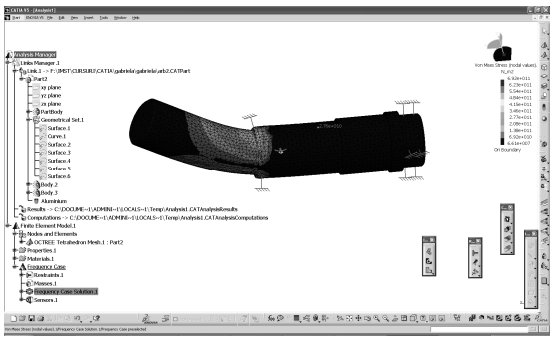

Fig. 5. Frequency analysis on a spindle with FEM.

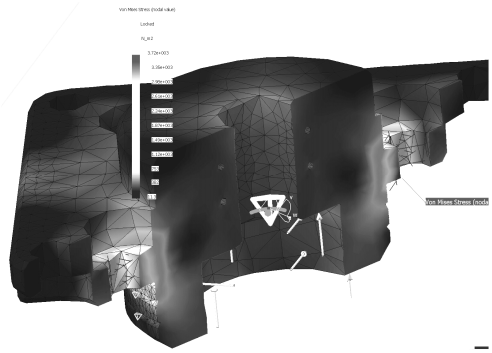

Fig. 6. Static analysis on a of the cylinder bonnet.

The kinematical simulations are used to test and verify the product behavior at different kinematical condition. It can be defined parameters of the direct kinematics or indirect kinematics and tested the functionality of the product. In Fig. 8 it is presented kinematical simulation of the hydraulic cylinder.

The fitting condition of a product can be simulated by many assembling methods (Fig. 7), so it can create and optimize the assembly line of the product [7]. The fitting simulation has two directions: one, the simulation of the product assembly (the order of the pieces fitting); the other, simulation of the product fitting in the working environment.

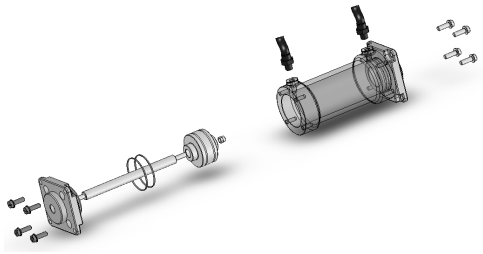

Fig. 7. Fitting simulation.

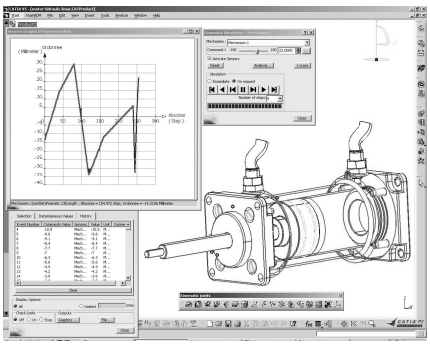

Fig. 8. Kinematical simulation.

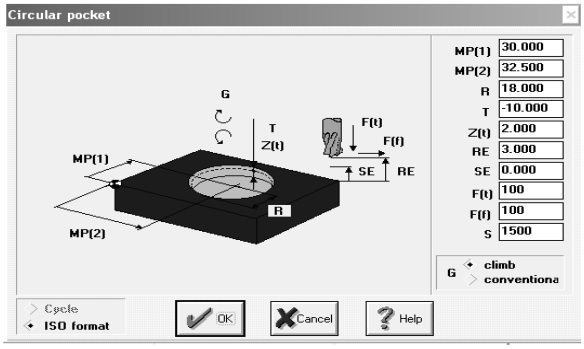

Fig. 9. Set-up Milling parameters in WinCAM.

4. MANUFACTURING DESIGN

Another direction in integrated conception is the design and modeling of the technological process of the product manufacturing.

The manufacturing process design is made with specialized software which automatically generates the CN software. The advanced CAM software uses 3D models of the pieces to generate complex CN programs for many types of operations: surface milling, turning at high and classical speed on machine tools with up to 5 CN axis (for milling process). Some operation simulation is presented in Fig. 9 [6].

The technological process design is made using software like Arena or Witness. The simulation of the production fluxes in the product manufacturing is very useful because it offers the possibility to verify and test many solutions, to consider the eventually problems which can appear (for example the possibility of machine tools mall-function). This kind of simulation and optimization, can define the human operator and make an ergonomically analysis. For example, in advanced software like CATIA V5, specialized modules for ergonomics analysis were integrated. A lot of dimensional types of human, working position and movements can, therefore, be defined.

Some calculus and analysis modules, can be defined, in function of the type of the human activities and based on international standards.

5. WORKING MODEL

Before a product is sold on the market, it has to be tested. Using a virtual prototype of a product in a virtual working environment, it can be tested before the manufacturing process starts and the changes can be made without any costs. For this, a virtual working environment has to be created. All the major conditions of the real working environment must be modeled. In one way this is similar with the technological process design, but the working environment can be less or more complex. For example a hydraulic cylinder can be a part of a machine tools or industrial robots (that represents a well known working environment). Simultaneously, it can be used in an application in complex environments (space application, military etc).

If the users are working with the product, it is more likely to consider the virtual working environments model. In Fig. 10 are presented some examples of the virtual environments modeled for educational application. In this case the human operator is considering in the

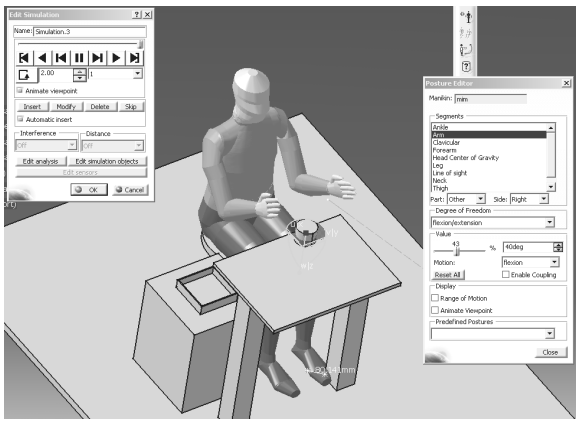

Fig. 10. Human activity analyses (in CATIA V5).

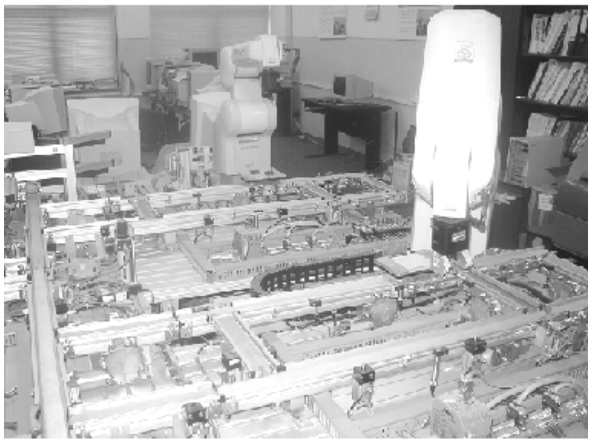

Fig. 11. System CIM Festo in Optimum laboratory.

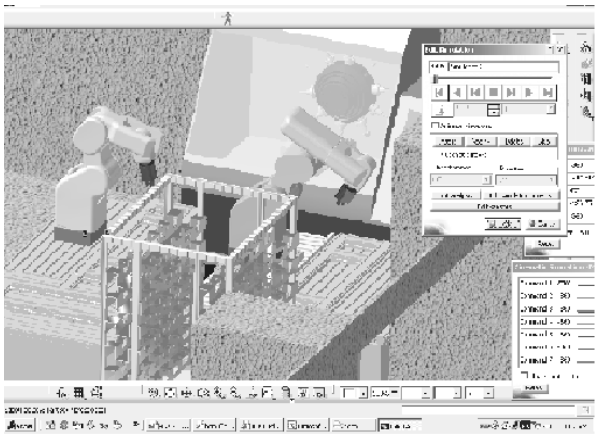

Fig. 12. 3D model and simulation of the CIM-Festo System.

working position. In the first picture is presented the laboratory of the National Center of Research of the Technological Systems Performances – Optimum at University "Politehnica" from Bucharest and in the second picture a virtual model of it. The entire model was created and simulated using CATIA V5.

The level of detail in such a type of model and simulation depends of the purpose. For example the model in the figure 11 was used for test if it is possible to implement a machine tools in the laboratory space and to test and optimize some possible space configurations. The entire, laboratory was created at scale 1:1.

6. CONCLUSIONS

Virtual design represents the future way in the industrial design of products and processes. Using advanced software of 3D modeling makes it possible to generate virtual technological environments considering all the aspects of real environment. The products can be designed, manufactured and tested in a virtual world considering all the real technological and functional aspects.

The optimization of the virtual product (the future real product) can easily be made without any kind of risks (financial, functional, technological, human etc).

Theoretically, all the aspects presented in figure 1 can be simulated and studied with high performance CAD-CAM-CAE software. Today computer aided design is a usually step in product conception. The other aspects just began to be applied in the civil industry (machine tools, automotive etc), but the performances of new products are obviously better than before.

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