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ENGINEERING DESIGN IN INTEGRATED PRODUCT DEVELOPMENT
Design Methods that Work

RAPID TECHNOLOGIES IN INTEGRATED PRODUCT DEVELOPMENT

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Abstract: *The paper presents integrated product development supported by Rapid Prototyping and Rapid Tooling technologies as well as Reverse Engineering. Example applications of RP and RT in manufacturing industry and for medicine are shown.*

1. INTRODUCTION

Modern work organization patterns require high effectiveness of designers' work and full utilization of their creative potential, aiming at the same time at competitive advantages: short cycle and low cost of order realization and high quality of products.

These requirements may only be reached with complete **integration** of methods, models and information during development of a product, from the conceptual phase, through its manufacturing processes, to service and recycling. More and more, short product life cycle, its lower price and easier fulfillment of consumer needs cause fierce competition on local and global markets.

The need for reducing planning and design time encouraged the development of a set of new methods called *Time Compression Technologies* (TCT). They are capable of reducing the development stage from the expression of needs to the introduction into the market. TCTs also answer the necessity of reaching a good quality of a product – they extend the concept of quality from productive area to the whole product life cycle.

An object's mathematical model is considered to be a basic element of every TCT. This model must correctly describe the geometrical shape of the three-dimensional object. A model may be obtained either from a CAD system, where the object may be designed from scratch, or from an existing artifact – by using a *Reverse Engineering* technology to find a mathematical model for a measured physical object.

TCTs include technologies for *Rapid Prototyping* and *Rapid Tooling*. The term Rapid Prototyping means a set of processes that realize parts and components with layer-by-layer material addition and usually start from an STL computer file generated from a three-dimensional mathematical model. Rapid Tooling processes are used in manufacturing. Although they do not replace traditional manufacturing techniques, they meet a need for quick production of prototype parts and tooling. An example of their application is when – based on a computer model – an injection mould may be produced directly using a metal sintering machine or a mould cavity manufactured as a sprayed metal shell. *Rapid Manufacturing* is an extension of Rapid Prototyping and Rapid Tooling – the idea behind RM is to manufacture final products in processes similar to RP but in materials required in production parts.

Time Compressing Technologies save time: Rapid Prototyping may deliver a first prototype in a matter of **hours**; a time frame for the first series of products may be **days** with Rapid Tooling, while **months** if they are manufactured traditionally.

Integration of "rapid" technologies in the product development cycle is shown in fig. 1. Presented are also CAx tools used both in conventional construction-technology design and in "rapid" technologies.

2. INTEGRATED PRODUCT DEVELOPMENT

An example process of integrated product development is presented below. Subject of the design was a drive unit. The development was performed in the environment of CAD, CAE and RP systems.

Requirements for the designed unit were:

- rotary movements around the Z axis: from $+90^{\circ}$ to -90°, rotary movements around the Y axis: from $+20^{\circ}$ to -40°
- difference between successive positions around the two axes: about 3° (a step)

- available were stepper motors with minimal rotary step of 90° but for better control the step was increased to 360°; therefore the design should include a transmission with a ratio of 100 to 1
- manufacturing accuracy of Rapid Prototyping technologies is 0.1 mm, so the design should avoid elements with details smaller than that (e.g. teeth of toothed wheels)
- the casing for the drive unit was of spherical shape with a diameter of 60 mm and, certainly, the elements of the drive unit may not collide with one another or with the casing

As a design solution stepper motors were selected with their rotations reduced with worm gear (fig. 2). Complete collision analysis of all elements of the drive unit in a virtual 3D space is difficult and time consuming. It is always advantageous to verify a design with a **functional prototype**.

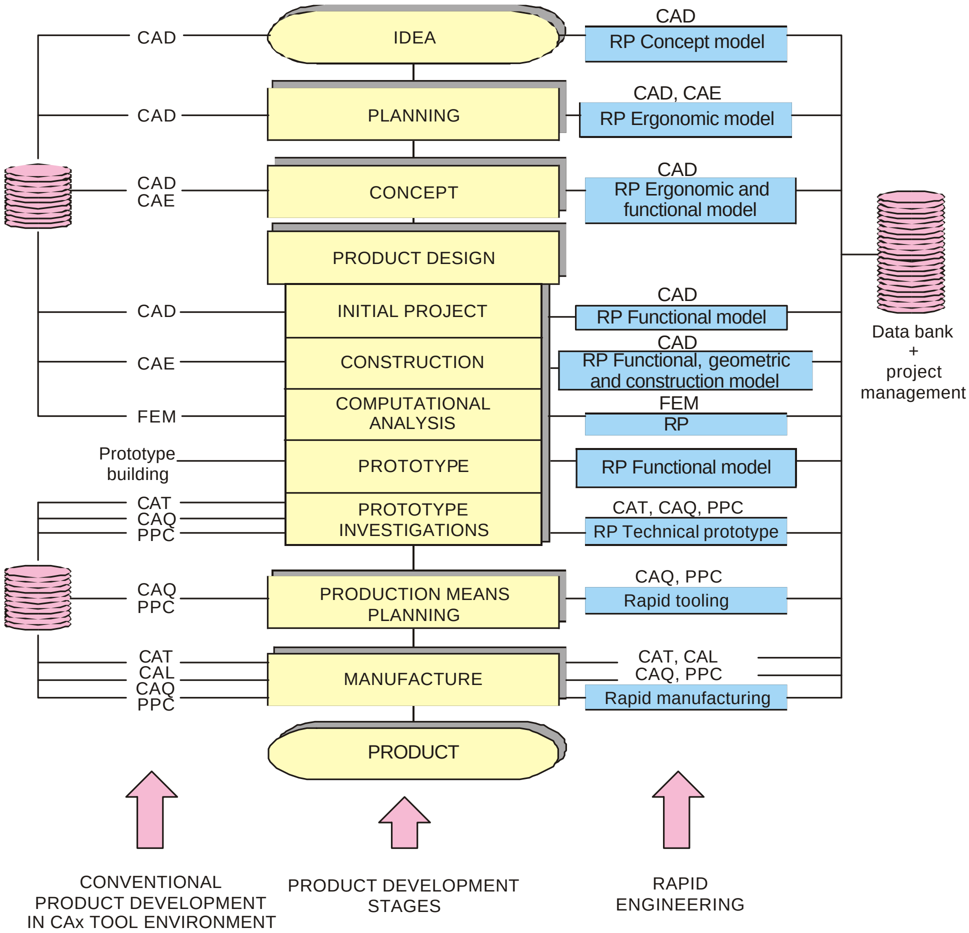

Fig. 1. *Data flow in integrated development of products and manufacturing processes [1]*

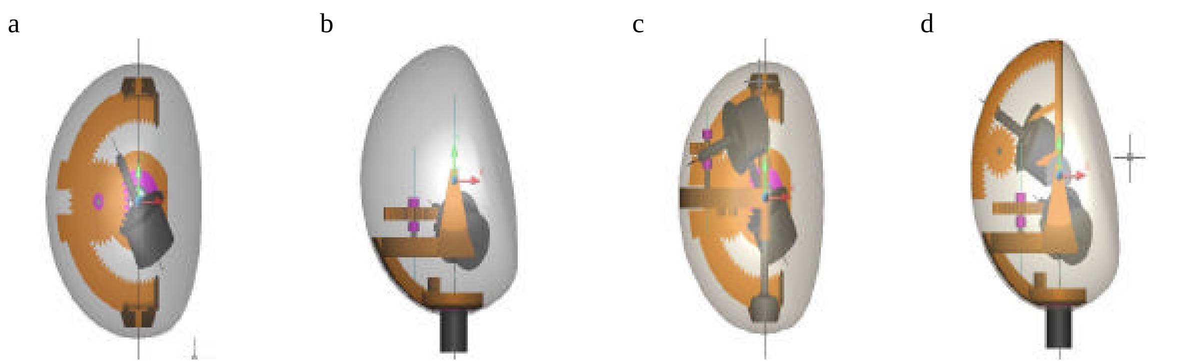

Fig. 2. *Design solutions for movements around the Z axis – "lower" gear (a, b) and around the Y axis – "upper" gear (c, d)*

a b c

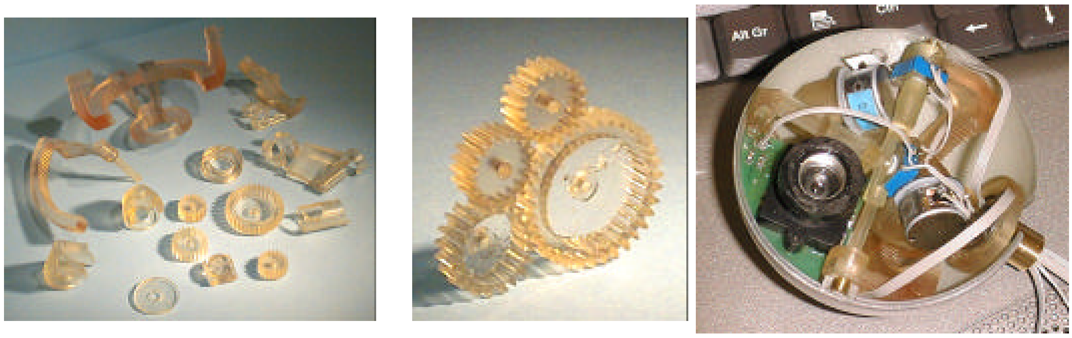

Fig. 3. *Parts of the drive unit manufactured in a stereolithography machine (a, b) and a component of the functional prototype assembled with them (c)*

a b c

Fig. 4. *Example parts manufactured in Rapid Tooling technologies: a – flexible keyboard cast in polyurethane with properties equivalent to elastomer, b – resin and aluminum prototypes of a medical implant, c – resin prototype, wax copy and a framework cast in brass*

3. RAPID PROTOTYPING IN PRODUCT DEVELOPMENT

Figure 3 shows physical models of all parts of the drive mechanism described above. The parts were manufactured in Rapid Prototyping technology. They were then assembled into a functional prototype and were subject to kinematics investigations.

4. RAPID TOOLING IN PRODUCT DEVELOPMENT

Testing and optimizing other properties of a product may require a prototype developed in materials with characteristics identical to those of the final production. Rapid Tooling technologies allow for manufacturing longer series of prototypes in different materials, including plastics with properties similar to conventional thermoplastics (elastomer, polypropylene, etc.) – see fig. 4a, or in metals – see fig. 4b and 4c. These technologies often base on a physical object manufactured in Rapid Prototyping. They enable examinations of those product properties which depend on the materials.

5. REVERSE ENGINEERING

In industrial practice new product designs are usually created in a CAD system from the beginning. Geometric models are digital and may be used in further computer aided stages of product development (CAE, CAQ, RP, CAP, etc.).

There are cases, however, when product geometry must be created from an existing physical object, e.g. to re-engineer a design of a product without any technical documentation or to transform an artist's view into industrial design. This is the job for Reverse Engineering, where physical artifact is digitized into a computer model.

The input to RE technologies is a material object, the output – its CAD model. Among contact technologies most widely used are measurements with a CMM machine, among non-contact methods – laser scanning (fig. 5) and computed tomography.

Contact and non-contact methods using visible light allow for reconstruction of geometry of outer surfaces of objects. Models representing objects with uniform internal structure may be recreated – this is a sufficient approximation for some applications (fig. 6).

a b

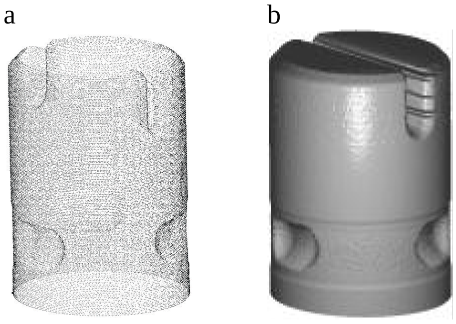

Fig. 5. *Geometry reconstruction of a physical object: a – result of a scanning process (point cloud), b – recreated geometry of the object's outer surface*

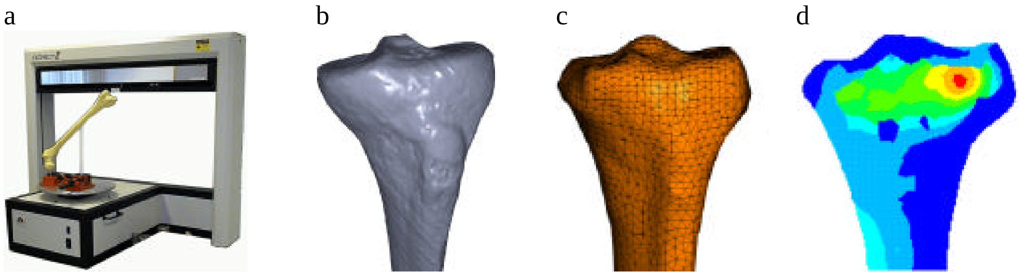

Fig. 6. *Object geometry reconstruction for CAE calculations: a – object in measurement setup, b – CAD model, c – FEA model, d – results of FEA calculations*

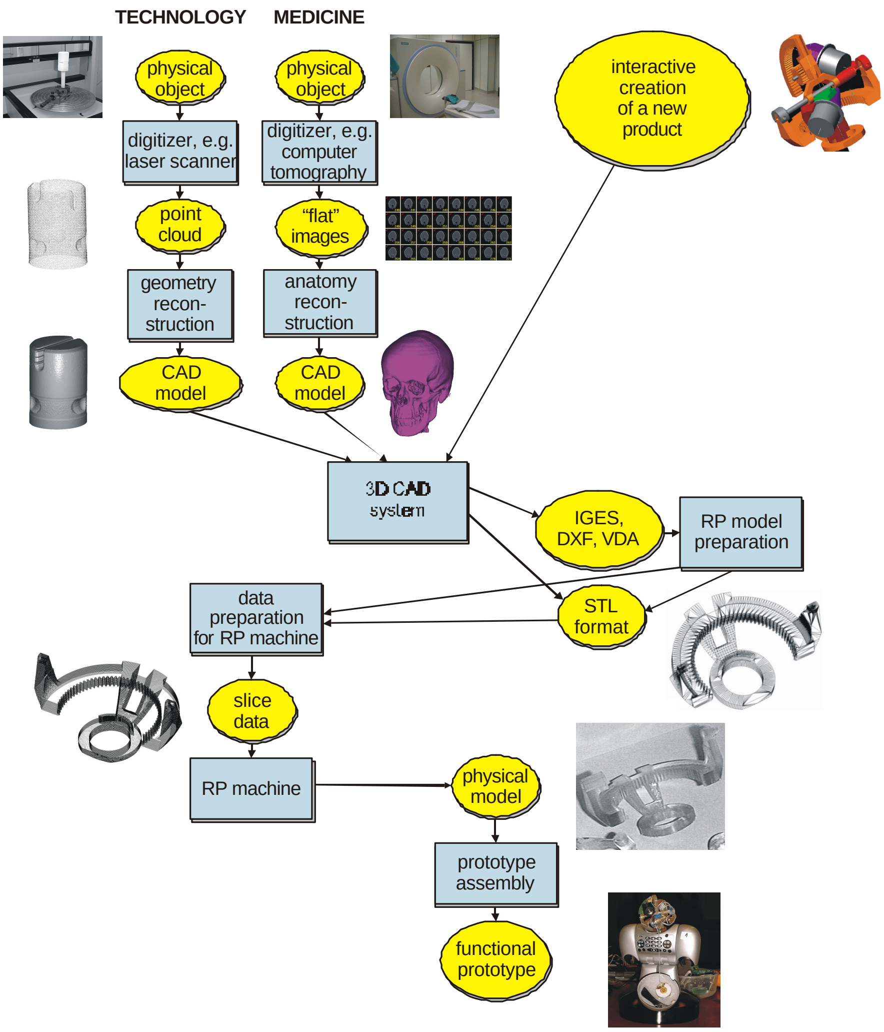

Fig. 7. *Work flow in product development – from design to functional prototype [2]*

5. CONCLUSIONS

Integrated product development is a cycle of engineering tasks supported with computer technologies, operating on a common product model. Basic component of a product model is its three-dimensional geometry, developed either interactively by a designer in a CAD system or reconstructed from a physical object. Figure 7 shows steps of product development up to a prototype assembly. The prototype may be utilized to test the design's functionality or may be a pattern for manufacturing production tools with Rapid Tooling technologies.

References

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