DESIGN AND RAPID PROTOTYPING EVOLUTION

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Abstract

Design informatics has been focused in designing freeform surfaces and renderings for communication purposes. Nowadays, technological advances in CAD/CAM and Rapid Prototyping (RP) systems demand the integration of CAD models in the industrial downstream processes.

Rapid Prototyping systems emerged in 1987 and are closer to the revolutionary concept " a factory in a box". These new technologies are becoming a powerful tool for concurrent engineering, creating in this way a new competitive edge. Economic concept modellers are now commercially available and supported by Internet infrastructures, can play an important role in the future evolution and market demand of these additives manufacturing processes.

The aim of this study is to present a survey of the historical and future evolution of RP technologies and the specific implications in the design methodology.

The Concurrent Engineering and the Iterative Process

Between the challenges that characterize the actual economy, one highlights the existence of more market niches, product variations and shorter life cycles.To survive in this economy, marked by the competition and the globalisation, one searches to include in the product developing process, the design, the engineering, the marketing and the production department, which composes a known industrial methodology called concurrent or simultaneous engineering [1]. This new methodology is based in the fact that changes in the product design and processing, when the production and commercial stages are implemented, imply expensive costs and great production delays. This means that the multidisciplinary design team needs to pay more attention on the early stages of the product development to collect the maximum information, performing more iterations and design revisions. In this way the costs and the time to market have more chances to be reduced.

In the past and nowadays, the innovation process demands iteration (Fig. 1). The product development process begins with concepts or ideas. In the design stage, one must select materials and define configurations that must carry specific loads and perform specific tasks. The materialization of these configurations becomes a prototype, assuming physical or virtual nature. This prototype must be assessed qualitatively or quantitatively. In the beginning, the process starts from a crude configuration, and modifications and analysis are repeated in an iterative fashion, until all the design requirements are satisfied and an optimised configuration is obtained.

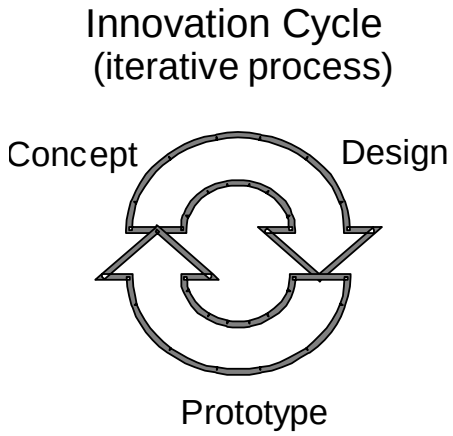

Fig. 1. Iteration in the innovation process.

An essential difference in the innovation cycle, between an old process and an actual industrial process, is related with the time committed to the design stage. In the past, a product with a successful design could take years or decades to get an optimal performance. Nowadays, greatest time compression is demanded as well as reduced costs. Frequently, the price of these iterations limits their number, so other means to speed up the process at a low cost are been investigated.

RP and Rapid Tooling (RT) systems are powerful tools for the implementation of concurrent engineering because they allow models and prototypes manufacturing directly from CAD files.

CAD and RP Systems Evolution

Since Pre-history man uses 2D sketches and drawings to express and communicate ideas, concepts and messages. This establishes a natural resource of effective and fast communication and an economical and accessible

tool that designers frequently use to materialize and support their proposals. The emerging of sophisticated and powerful computer resources has been changing the processes and the development methods of new products for the conceptual and production design areas. The CAD programs that are in the basis of this change are more and more user friendly, delivering accessible and intuitive interfaces, simulating the manual sketching that designers perform during their creative research.

The traditional processes based in 2D technical drawings are being obsolete and replaced by CAD systems that are able to generate tri-dimensional solid models. The presentation with photo realistic images and computer animations allows to change the customers' attitude and sometimes, to avoid the manufacture of expensive prototypes.

Due to the advances of computer programs, the concept of Virtual Prototyping (VP) is emerging as an option for physical prototyping. Virtual prototyping, allowing analysis and simulations in early steps of the product development process, turned out to be an excellent design tool.

CAD software can be associated with other specialised technologies, allowing the creation of a global approach to the product development and production. RP is an example of such technologies that allow the manufacturing of prototypes and pre-series with a reduced time to market [2-3]. RP systems manufacture prototypes directly from a CAD drawing and so they can produce a physical model that presents an unquestionable advantage compared to a virtual model. It may be said that if a picture is worth a thousand words, so a part is worth a thousand pictures.

The first additive RP technology appeared in 1987 and was termed Stereolithography (3D Systems), a process that solidifies layers of UV-sensitive liquid polymer using light from a laser. In the subsequent years, RP market grew at an average annual rate of 40% [4]. After that period, RP reached a slow growth. Nowadays, there is a wide group of RP and RT processes patented, but only a small group is commercially available. Annual sales represent about 200 million euros [4].

A Factory in a Portable Box

RP promotes concurrent engineering, and offers a high potential for a faster response to market needs, creating in this way a new competitive edge. Nowadays, there is another innovative and attractive concept that relates RP machines with a factory in a portable box (Fig. 2). This concept was first materialised in the late 1940s, when the first computer-numerically controlled (CNC) machines began to operate. In these processes, the raw material, a solid block, is removed by a cutting process such as milling, turning or electrodischarge machining (EDM), under digital control from a computer file. Nevertheless, complex shapes and materials with high hardness values are difficult or impossible to manufacture with these technologies and can have very high production costs. A high volume of material, removed during the cutting operation, is wasted. Time consuming and specialized skills in programming complicated tool paths and fixturing are demanded in complex shapes machining. Today, this industry, based in subtractive processes, represents about 10 billions euros in terms of annual sales of machines [4].

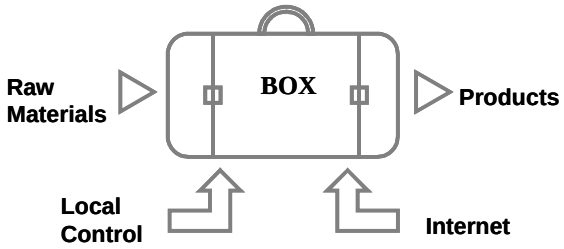

Fig. 2. A factory in a portable box.

Apart from the additive (RP) and subtractive (machining) technologies, other processes are under development. In recent years, Gene Kirila [5] materialised the concept of RP systems. He lives in an industrial area of USA, Pennsylvania's Shenango Valley, and grew up obsessed by manufacturing. Kirila's idea was to create some kind of box that could manufacture any product, anywhere, and be operated on site or via the Internet. He says: "If operating systems could run computers, they should be able to run a factory". He developed the VEC (Virtual Engineered Composites) process that is based in a portable cell for moulding composites. His industrial career was very successful and his VEC system was applied to manufacture large products like pipes and boat hulls. He creates in 1995 the world' first automated boat plant at Little Falls. In that company, the traditional process to manufacture fibreglass boats by hand was substituted by digitally controlled VEC cells, which can produce a boat hull every 35 minutes [6].

A VEC system presents two innovative concepts:

- A computer control that supervises and adjusts 280 different manufacturing operations. For example, resin's temperature and viscosity are under constant control during the curing time.

- A "floating mould" that is composed by two polymeric composite laminated skins that are attached to a universal metallic mould frame. The space between each skin and its metallic support

is filled with water, becoming a rigid hydraulic system that can support the pressure of the material that is injected into the cavity;

The mould for the cell, whose application is for low and medium production volumes, is only 25,000 euros, which is 1/40 to 1/80 the price of a traditional metallic reinforced mould.

Kirila's manufacturing concept explains why enthusiastic RP people designate these systems by Santa Claus Machines, Fabber (digital fabricator), Autofab or Personal factory [7-8].

Nowadays, the commercialisation of RP equipments, termed concept modellers or 3D-printers is in great expansion [9]. They represent the type of RP machines that are closer to the "factory in a box" concept, and although they use a very reduced class of cheap materials with poor mechanical characteristics, they allow corrections and the possibility to quickly test the ideas that designers are developing during the creative process (Table 1). The designer can have a full perspective of the iterative process of creation without the traditional economical and materials limitations. He only has to send the CAD file to the RP equipment, like an usual inkjet printer, placed in an office. So it is possible to test new ideas with better accuracy before its concretisation, avoiding misunderstandings and delays, and inciting the positive criticism through the involvement of the technical staff from all the related departments.

RP Systems	Concept Modellers
Expensive investment	Price an order of magnitude lower (30,000 – 75,000 euros)
Expensive materials	Low cost materials
High maintenance costs (complex mechanisms, e.g. lasers)	Economic maintenance
Functional, technical prototypes and pre series	Models for design visualisation and verification
Industrial equipment	Office equipment
Rapid Tooling Rapid Manufacturing	

Table 1. Comparative analysis between RP systems and concept modellers.

"Sagrada Familia" in Barcelona is an example of how these modellers can be useful to compress time and costs [10]. About the acquisition of a Thermojet printer to support the construction processes of the Sagrada Familia, Jordi Bonet coordinator architect says: "Thermojet printer is a key system in Sagrada Familia project (Fig. 3). Specifically, in aspects related to the design validation, allows the production, in a fast and simple way, of more prototypes per part. Earlier we needed longer periods to validate the news designs. Now we can get a validated part approximately in one day". Nearly two years was the time necessary to recover the investment.

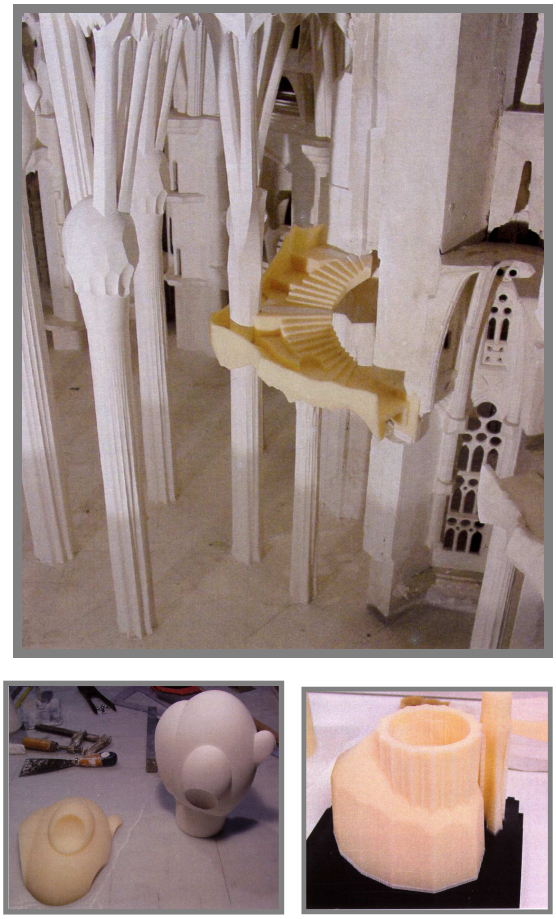

Fig. 3. Prototypes generated by Thermojet printer (3D Systems) in Sagrada Familia, Barcelona (courtesy of 3D Systems).

Internet is a noticeable partner of RP technologies. In industrial countries it is usual that companies that don't have RP equipment, send CAD files through Internet to Service Bureaus. After receiving the files, these bureaus can immediately work in processing and converting them in prototypes that are sent to their clients by mail or other means of transport (Fig. 4).

Other multinational companies use Internet to e-mail CAD files to sister companies placed in different continents. This is a new 3D fax that can quickly link a design company in Europe or USA to other company in Asia, for instance. Nowadays, Adidas project department e-mail files with new designs of shoe soles, to sister companies placed

in different parts of the world, that have RP equipment to produce the physical models.

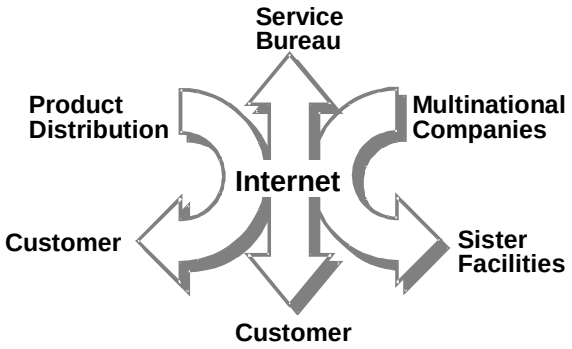

Fig. 4. Potential applications derived from the combination of RP systems with Internet.

In the future, probably, it is estimated that it will be possible to deliver physical products by "downloading" on the Internet and manufacturing directly in customer's homes and offices, like 3D faxes [11]. The possibility of designers, artisans and creative people to become independent from the traditional production and distribution circuits will be a noticeable consequence aimed by the introduction of these revolutionary technologies. This new relationship, joining producers and customers, shortens the distance of concept from the final product, avoiding intermediate stages.

Burns [12] believes that RP will become an emancipating technology for the 21st century, offering to mankind the freedom to create, in the same way as the book was in the 15th century or the automobile was in the 20th century to the freedom to learn and the freedom to travel, respectively. He foresees that computers with 2D display will be replaced by 3D displays' computers with digital and voice input, that allows the designer to sculpt the desired geometry in the air with its fingers. Hinzmann [7] suggests diverse potential scenarios relatively to the expansion and future use of these technologies.

Conclusions

Rapid Prototyping and concurrent engineering must be integrated into the workflows of product development processes to achieve high efficiency. This may provide the key to ensure better innovation, quality, flexibility, lower costs and reduced time to market.

RP supported by Internet, besides offering great potentialities as a tool for designers and companies, promises to become a freedom tool to human creativity, revolutionizing manufacturing and trading principles.

The future evolution depend on multiple factors, namely, cost, ease of use, materials and technological advances, availability of CAD and Internet supporting facilities and market demand that, in the most favourable scenario, could interest the average consumer to buy and use RP in home. Intellectual property and security control will be other related problem to be solved in Internet commercial transactions based in 3D data files.

Keywords

Rapid Prototyping, Rapid Tooling, Design, RP historical evolution.

Bibliography

[1] Vasconcelos, P., Lino, F. and Neto, R., O Fabrico Rápido de Ferramentas ao Serviço da Engenharia Concorrente, Tecnometal, 136:Set-Out, 17-21 (2001).
[2] Lino, F., Braga, F., Simão, M., Neto, R., Duarte, T., Protoclick – Prototipagem Rápida, Porto (2001).
[3] Neto, R., Paiva, B., Paiva, R., Obtenção de Protótipos Metálicos para Fundição Injectada, 11º Congresso Nacional de Fundição, Ipanema Park Hotel, Porto (2001).
[4] Wholers, T., Rapid Prototyping & Tooling State of Industry: 1999 Worldwide Progress Report, Wholers Associates Inc (1999).
[5] Bylinsky, G., Heroes of US Manufacturing, *Fortune*, March (2000).
[6] Gibney, F., The Revolution in a Box, Time Magazine, 31/07 (2000).
[7] Hinzmann, B., The Personal Factory, SRI International from MCB Internet Conference on Rapid Prototyping (1996).
[8] Burns, M., The origins and Direction of the Fabricator Revolution, Rapid News, September (1997).
[9] Smith, P., Using Conceptual Modellers For Business Advantage, Time-Compression Technologies, April, 18-24 (2001).
[10] 3D Systems, Sagrada Familia, Aportaciones Tecnológicas de 3D Systems al Patrimonio de la Humanidad, 3D@work, XII (2001).
[11] Burns and M., Howison, J., Napster Fabbing – Internet Delivery of Physical Products, Presentation at O´Reilly Peer-to-Peer Conference, San Francisco, Feb. 16 (2001)-
[12] Burns, M., "The Freedom to Create", Technology Management, 1:4 157-63 (1995).