USING RAPID PROTOTYPING TECHNOLOGIES IN CONCURRENT ENGINEERING APPROACH

Gabriela Georgeta NICHITA
University of Oradea, Faculty of Management and Technological Engineering
e-mail: gnichita@uoradea.ro

Key words: concurrent engineering, rapid prototyping, rapid manufacturing, direct digital manufacturing, parts, model, functional prototypes.

Abstract

With increased competition from the global economy, manufacturers face the challenge of delivering new customized products more quickly than before to meet customer demands. Several technologies collectively known as Rapid Manufacturing (RM) have been developed to shorten the design and production cycle, and promise to revolutionize many traditional manufacturing procedures.
The success of new industrial product not only depends on its technical features, but also on commercial factors such as cost and the time until the product is laundched on the market. The different changes in the market requirements entail the necessity of a flexible and efficient manufacturing process.

1. INTRODUCTION

Concurrent Engineering, which is sometimes called Simultaneous Engineering or Integrated product development, was defined by the Institute for Defense Analylis, as a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule and user requirements. Concurrent Engineering is not a quick fix for a company's problems and it's not just a way to improve engineering performance. It is a business strategy that addresses important company resources. The major objective this business strategy aims to achieve is improved product development performance. Concurrent Engineering is a long term strategy, and it should be considered only by organizations willing to make up front investments and then wait several years for long term benefits. It involves major organizational and cultural change. In traditional serial development, the product is first completely defined by the design engineering department, after which the manufacturing process is defined by the manufacturing enginnering department. Usually this is slow, costly and low quality approach leading to a lot of enginnering changes, production problems, product introduction delays and a product that is less competitive than desired.

Concurrent Engineering brings together multidisciplinary teams, in which product developers from different functions work together and in parallel from the start of a project with the intention of getting things right as quiclky as possible and as early as possible. A cross-functional team might contain representatives of different functions such as systems engineering, mechanical engineering, electrical engineering, system producibility, fabrications producibility, qualiy, reliability and maintainability, testability, manufacturing drafting and layout and program management. Multidisciplinary groups acting together early in the workflow can take informed and agreed decision relating to product, process, cost and quality inssues. They can make trade-offs between design features, part manufacturability, assembly requirements, material needs, reliability issues, serviceability requirements and cost and time constrains. Differences are more easily reconciled early in design.

Getting the design correct at the start of the development process will reduce downstream difficulties in the workflow. The need for expensive engineering changes later in the cycle will be reduced. Concurrent Engineering aims to reduce the number of redesigns, especially those resulting from post-design input from support groups. By involving these groups in the initial design, fewer iteration will be needed. The major iterations that do occur will occur before the design becoms final. The overral time taken to design and manufacture a new product can be substantially reduced if the two activities are carried out together rather than in series. The reductions in design cycle time that result from Concurrent Enginnering invariably reduce total cost.

Concurrent Engineering provides benefits such as:

- reduced product development time;
- reduced design rework;
- reduced product development cost

and

- improved communications.

For examples the companies that using Concurrent Engineering techniques show significant increases in overall quality, 30-40% reduction in project time and costs, and 60-80% reduction in design changes after release.

The implementation of Concurrent Engineering addresses three main areas: people, process and technology.

It involves major organizational changes because it requires the integration of people, business methods, and technology and is depend on cross-functional working and teamwork rather than the traditional hierarchical organization. Collaboration rather than individual effort is standard and shared information is the key to success. Team members must commit to working cross-functionally, be collaborative and constantly think and learn. The role of the leader is to supply the basic foundation and support for change, rather than to tell the other team members what to do. Training addressed at getting people to work together in teams plays an important role in the successful implementation of Concurrent Engineering.

Concurrent Engineering is a business strategy, not a quick fix. It will, take many years to implement. If management doesn't have the time or budget to go through the above step, then it is unlikely that Concurrent Engineering will be implemented [2], [8].

2. TECHNOLOGIES IN CONCURRENT ENGINEERING

In concurrent engineering, design technologies are utilized that foster efficient cross-disciplinary analysis, experimentation, and representation of new product designs. Some examples of these technologies include: *computer aided design systems, rapid prototyping technologies, rapid manufacturing, rapid tooling and rapid testing techniques*, as well as techniques that enable the representation of product designs in a virtual context. The 3D model becomes a central component of the whole product or project information base, so thet in all design, analysis and manufacturing activities the same data are utilised. Product information captured in this way can be copied and re-used. All of these technologies contribute to the reduction of interpretation asymmetries between the experts involved, as well as to fast-cycle design and development, because they allow for high-speed iterations of analysis and experimentation on both concepts and models of the product. In fact, the time and cost, incurred by the development and construction of model and prototypes, generally are reduced by factors of 2 to 5, when using *3D computer aided design* and *rapid prototyping technologies*. These tools have become an important enabling factor in the concurrent engineering environment. Without their implementation and further upgrading, concurrent engineering might never be able to realize its full potential in terms of design cost and lead-time optimization. With increased competition from the global economy, manufacturers face the challenge of delivering new customized products more quickly than before to meet customer demands. A delayed development or delivery can mean business failure. Several technologies collectively known as Rapid Manufacturing, have been developed to shorten the design and production cycle, and promise to revolutionize many traditional manufacturing processes [3], [4], [6], [8].

2.1. Computer Aided Design systems

Computer Aided Design is an ideal tool for companies that want to improve quality and reduce development cycles and costs. A design built with CAD should be of higher quality than one made by traditional means. The geometric model in the computer is accurate and unambiguous. Many things can be done with it that are not possible or would take far too long carry out manually. A 3D CAD model of a part can be displayed on PC or workstation so the designer can see what it really looks like. The model can be viewed from different angles and magnified so the designer sees the details on the sreen. Any errors can be corrected immediately. Analysis can be carried out while the model is still in the computer, there is not need to wait for a physical prototype before testing starts. If a physical prototype is really necessary it can be produced directly from the CAD model by Rapid Prototyping technologies, again avoiding all the traditional costs of model making.

Those companies that do use CAD should have a faster product development cycle than chose that don't. Their development process should be cheaper and of hight quality. They will find it easier to get closer to customers. By getting their products to market faster companies using CAD should increase market share and profit.

2. 2. Rapid manufacturing

Rapid Manufacturing is a new area of manufacturing developed from a family of Rapid Prototyping technology. Before production of a product begins, a model or prototype is often required as part of the design cycle, to allow demonstration, evaluation, or testing of the proposed product. The fast creation of a prototype is known as Rapid Prototyping, and is generally carried out before specialized molds or tools are designed. Traditionally, prototyping required considerable skilled hand labor, time, and expense, typically applied to cutting, shaping, and assembling a part from standard stock material. The procedure was often iterative, with a series of prototypes being built to test various options. For many applications, this process has been revolutionized by a relatively recent technology known as layer manufacturing, Solid Freeform Fabrication or Direct Digital Manufacturing, in which a part of an arbitrary shape can be produced in a single process by adding successive layers of material. Rapid Manufacturing, also includes the fast fabrication of the tools required for mass production, such as specially shaped molds. Many different layer manufacturing processes have now been developed, using an increasing range of materials. The parts produced have been of steadily increasing size and durability, and as the quality has improved layer manufacturing is being used more and more frequently to fabricate the parts both for production tools and *functional prototypes*. The application of layer manufacturing to make the components used in production is termed Rapid Tooling. It has been applied to injection molding, investment casting, and mold casting processes. For some products, it can be economical to use layer manufacturing to produce the final products themselves, sometimes in a matter of days instead of weeks or months. Although the layer fabrication process itself is typically not as fast as traditional mass production techniques, it eliminates tooling, setup, and assembly processes, can produce parts of superior quality and complexity, and can be ideal for making custom parts based on a customer's special requirements [3], [4], [6], [8].

2.2.1. Advantages of these techniques

⇨ Layer manufacturing allows parts of completely arbitrary 3-dimensional geometry to be fabricated, offering designers a new freedom to shape parts optimally without the constraints imposed by forming, machining, or joining.

⇨ Another important advantage is that the process utilizes the computer description of the part shape directly, and allows integration of the Computer Aided Design (CAD) with the Computer Aided Manufacture (CAM) of the part. It therefore allows a manufacturing cycle with a seamless transition through the computer design, simulation, modeling, and fabrication procedures. In addition, the profiles used by the fabrication process are straightforward for the designers and customers to understand, thus facilitating technical communications. Basically, all layer manufacturing systems consist of a combination of a computer CAD system with an operation machine to perform the fabrication of a layer under computer control. First stage, a 3D CAD representation of the part is created by a computer software package such as ProEngineer, SolidWorks, SolidEdge, Inventor, AutoCAD or others 3D solid modeling package and convert the CAD model to STL format. The computer representation of the part is then sliced into layers of a certain thickness, typically 0.1 to 0.25 mm, and their two-dimensional profiles stored in a *.STL file*. In the second stage, the software, converts the .STL data to machine data, which are sent to the operation machine to generate each layer of the part by the specific fabrication process. The process is repeated many times, building the part layer by layer. The final step is finishing, removing the part from the machine, detaching support materials, and performing any necessary cleaning or surface finishing.

2.3. Direct Digital Manufacturing

”Rapid Manufacturing” has become a generic term that is applied to any process that produces manufactured good quickly. To avoid confusion, the Society of Manufacturing Engineers has adopted a new term, direct digital manufacturing. The association's definition of direct digital manufacturing is "The process of going directly from an electronic, digital representation of a part to the final product via additive manufacturing."

Direct digital manufacturing (DDM) is the technique of creating production grade parts directly for end-use with rapid prototyping equipment. Direct digital manufacturing parts are ready to use in internal assemblies, or can be finished to hight-quality surfaces with polishing, sealing or painting. Also called rapid manufacturing, additive manufacturing or additive fabrication, DDM offers benefits in increased speed and low-volume requirements over alternative manufacturing techniques such as injection molding and die casting.

Direct digital manufacturing allows a company to ramp up manufacturing of a new product without the delays of creating a traditional mold, rapid tooling or plastic tooling.

2.3.1. Direct digital manufacturing – impact and opportunity

The impact of direct digital manufacturing is far-reaching, and the opportunities and advantages are extensive. This is why direct digital manufacturing is heralded as the next industrial revolution.

Since the earliest days of rapid prototyping, experts have envisioned the application of the technology in the manufacturing process, and the focus of this vision has been on the initial cost and time savings that are realized when tooling is eliminated. However, the relative impact pales in comparison to the wide ranging advantages that exist when rapid manufacturing is implemented. Direct digital manufacturing will benefit nearly every discipline within a manufacturing organization, and it will change fundamental business processes. When adopted en masse, it truly will be an industrial revolution [10].

3. TECHNOLOGIES FOR RAPID MANUFACTURING

Virtually all rapid prototyping technologies are presently being used or considered in some form or another for Rapid Manufacruting. Those that have the advantage of already utilizing target materials in powdered or extruded form predominate at present. The list includes Selective Laser Sintering, Three Dimensional Printing and related technologies. In table 1 are gives a representative selection of today's major technologies used to make parts in specific classes of materials.

Table 1. Technologies being used for Rapid Manufacturing

Plastic parts	Metal parts	Ceramic parts
▪ Selective Laser Sintering (SLS) ▪ Fused Deposition Modeling (FDM) ▪ Stereolithography (SLA)	▪ Selective Laser Sintering (SLS) ▪ Selective Laser Melting (SLM) ▪ Laser Powder Forming ▪ Sprayed Metal	▪ Three-dimensional Printing (3DP) ▪ Selective Laser Sintering (SLS) ▪ Fused Deposition Modeling (FDM) ▪ Robocasting (TM) ▪ Stereolithography (SLA)

In the table 1, the technologies are arranged roughly top to bottom from most to be used and well-developed to least.

There are numerous additional technologies which are being pursued for particular applications or market segments.

4. CONCLUSIONS

- Rapid manufacturing is ideal for producing custom parts tailored to the user's exact specifications.
- Produce short-run quantities of parts where the cost of a traditional mold would be high on a per-part basis. Typically, quantities from single digits to the low thousands make economic sense for direct manufacturing.
- For short production runs, however, the process is much cheaper since it does not require tooling.
- Rapid manufacturing parts allow engineers and manufacturers to design, build and test their parts as many times as necessary.
- Require new product pilot builds to gain early or testing approval.
- Conduct continuous design iterations during feasibility and market validation studies.
- Materials. Additive fabrication offers the potential to use multiple materials as well as to control the local geometric meso- and micro-structure of a part.
- Need parts that utilize complex geometries with negative angles, undercuts, thin walls or complex injection mold parts.
- They can also validate market acceptance before committing to large manufacturing runs.

5. REFERENCES

[1] Boothroyd, Geoffrey, Peter Dewhurst, and Winston Knight. Product Design for Manufacture and Assembly. 2nd ed. New York: Marcel Dekker, 2002.

[2] Koufteros, X.A., M. Vonderembse, and W. Doll. "Concurrent Engineering and Its Consequences." Journal of Operations Management 19 (2001), pp. 97–115

[3] Nichita Gabriela Georgeta, Theoretical and experimental research regarding by using Rapid Prototyping technologies in manufacturing complex parts, Ph. D. Thesis, Technical University of Cluj-Napoca, 2004

[4] R. Hague et al, Design for Rapid Manufacture, http://www.lboro.ac.pt.fi/rp-ml/uk/departments/mm/research/rapidmanufacturing/projects/design_for_rapid_manufacture.html

[5] www.time-compression.com/x/conferenceprogramme.html, Rapid Manufacturing Today, Rachel Park, Editor, The TCT Magazine TCT Conference Programme:

[6] http://claymore.engineer.gvsu.edu/eod/manufact/manufact-309.html, Selective Laser Sintering

[7] www.lboro.ac.uk/departments/mm/research/rapid-manufacturing/

[8] www.time-compression.com/x/conferenceprogramme.html

[9] http://www.redeyerpm.com/WhatIsRM.aspx

[10] http://en.wikipedia.org/wiki/Direct digital_manufacturing