

A Review on Rapid Prototype Technology

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ABSTRACT

Rapid Prototyping (RP) techniques are methods that allow designers to produce physical prototypes quickly. It consists of various manufacturing processes by which a solid physical model of part is made directly from 3D CAD model data without any special tooling. The first commercial RP process was brought on the market in 1987. Nowadays, more than 30 different processes with high accuracy and a large choice of materials exist. A CAD technique to allow “Automatic” creation of a physical model or prototype from a 3-D model leads to concurrent engineering. In the RP process the 3D CAD data is sliced into thin cross sectional planes by a computer. The cross sections are sent from the computer to the RP machine which builds the part layer by layer. It is bonded to a starting base and additional layers are bonded on the top of the first shaped according to their respective cross sectional planes. The advantages of RP is Possibility of manufacturing parts which are impossible to be produced conventionally in a single process, it can be fully atomized also reduce lead time, and no supervision is required. Also it has High Resolution and No geometric limitations. This paper provides an overview of RP technology in brief and emphasizes on their ability to shorten the product design and development process. Classification of RP processes and details of few important processes is given. The description of various stages of data preparation and model building has been presented. An attempt has been made to include some important factors to be considered before starting part deposition for proper utilization of potentials of RP processes.

Keywords: CAD, RP Processes, Product Design, Automized, Automatic, 3D-Model

I. INTRODUCTION

Rapid Prototyping (RP) has become one of the fastest growing new technologies since its introduction in 1986. By means of this technology it is possible build prototypes and touches them in just a few hours, from a CAD file in which the geometry of the model is defined in 3D. These prototypes are used to visualize those complex shapes not easily seen or understood on conventional drawings [1]. It gives to the designer the possibility of verifying the shapes of the product, validate if it fits into the assembly or if it complies with the desired functions. It cuts down the required time to design a product. This technology was covered an industrial applications to speed up the design and manufacturing process. But having a 3D touchable model of what you want to or even wish to build is something that can be useful in lots of fields. It has been used in medical application, arts (jewelry etc.), architecture and it is a potential tool for the mechanical field. In this paper, the design process methodology is described. It tries to be a guide of the logical procedure to introduce RP into a mechanical engineering design process and take the maximum benefit from it. Finally, the case studies illustrate the benefits of this technology applied to the mechanical field.

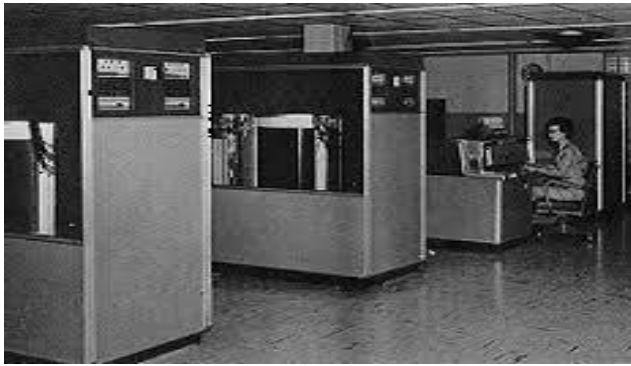


Fig. 1 First computer in 1946

A. History

TABLE I: THE HISTORICAL DEVELOPMENT OF RP AND RELATED TECHNOLOGIES

Sr. No.	Year	Technology
1	1770	Mechanization
2	1946	First computer
3	1952	First Numerical Control (NC) machine Tool
4	1960	First commercial laser
5	1961	First commercial Robot
6	1963	First interactive graphics system (early version of Computer Aided Design)
7	1988	First commercial Rapid Prototyping System

B. Prototype

We define a prototype as a *concrete representation* of part or all of an interactive system. A prototype is a tangible artifact, not an abstract description that requires interpretation. Designers, as well as managers, developers, customers and end users, can use these artifacts to envision and reflect upon the final system.

C. Prototype Model

The prototyping model is systems developed method (SDM) in which a prototype (an early approximation of final system or product) is built, tested, and then reworked as necessary until an acceptable prototype finally achieved from which the complete system or product can now be developed. This model is works

best in scenarios where not all of the project requirement is known in detail ahead of time. It is an iterative, trial-and-error process that takes place between the developers and users.

II. RAPID PROTOTYPE TECHNOLOGY

Advances in computer and communication technologies have led to globalization and increased competition. This in turn has fuelled interest in new methodologies and technologies to improve and accelerate product development. The most promising of these is Rapid Manufacturing, a combination of Rapid Prototyping and Rapid Tooling technologies. Rapid Prototyping (RP) involves automated fabrication of intricate shapes from CAD data using a layer-by-layer principle. These “three dimensional printers” allow designers to quickly create tangible prototypes of their designs, rather than just two dimensional pictures. Such models make excellent visual aids for communicating ideas with co-workers or customers and can also be used for testing purposes. For example, an aerospace engineer might mount a model airfoil in a wind tunnel to measure lift and drag forces. While designers have always Utilized prototypes, RP is now allowing them to be made faster and less expensively. At least six different rapid prototyping techniques are commercially available [2], each with unique capabilities. These are: Stereo lithography (SLA), Fused Deposition Modeling (FDM), laminated object Manufacturing (LOM), Selective Laser Sintering (SLS), Solid Ground Curing (SGC) and Ink-Jet Printing (IJP). A software „slices“ the CAD model into a number of thin layers (~0.1 mm), which are then built up one atop another. Rapid prototyping is an *additive* process, combining layers of paper, wax, or plastic to create a solid object. In contrast, most machining processes (milling, drilling, grinding, etc.) are subtractive processes that remove material from a solid block. RP’s additive nature allows it to create objects with complicated internal features that cannot be manufactured by other means [2].

Major limitations of RP include part volume (less than 0.125 m³), and part materials (mainly polymers). Most prototypes require from three to seventy-two hours to build, depending on the size and complexity of the object. Initial investment is very high. For simple shaped metals parts required in large quantity, conventional manufacturing techniques are usually more economical.

III. RAPID PROTOTYPE

Rapid Prototyping (RP) is defined as a group of technologies used to quickly produce a scale model of a component or group of components using 3-dimensional computer aided design (CAD) data. The goal of rapid prototyping is to develop prototypes very quickly, in a fraction of the time it would take to develop a working system. By shortening the prototype-evaluation cycle, the design team can evaluate more alternatives and iterate the design several times, improving the likelihood of finding a solution that successfully meets the user's needs. A family of fabrication processes developed to make engineering prototypes in minimum lead time based on a CAD model of the item RP allows a part to be made in hours or days, given that a computer model of the part has been generated on a CAD system. Prototype model should be used when the desired system needs to have a lot of interaction with the end users. Typically, online systems, web interfaces have a very high amount of interaction with end users, are best suited for Prototype model. It might take a while for a system to be built that allows ease of use and needs minimal Training for the end user. Prototyping ensures that the end users constantly work with the system and provide a feedback which is incorporated in the prototype to result in a usable system. They are excellent for designing good human computer interface systems.

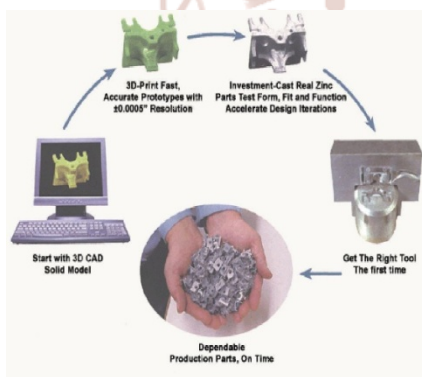


Fig. 2 Prototype

A. Principle

Rapid prototyping works on the basis of adding or removing layers of material to form the desired shape [2]. The majority of commercial rapid prototyping system. build object by adding one layer after another. For simplicity, it can be visualized as stacking slices of bread until complete three-dimensional bread loaf is achieved. Rapid prototyping is a highly automated layer manufacturing process. The object is designed in

any Solid Modeling Software (CAD) and the data is converted into a standard format widely known as Standard Triangularisation Language (STL) which is understandable by the rapid prototyping machine .Rapid prototyping software receives data in this format and creates a complete set of instructions for fabrication on rapid prototyping machine such as tool path, layer thickness, processing speed, etc. Rapid prototyping machine then manufactures the object using layer manufacturing method. Upon completion of a three-dimensional model, it is subjected to post processing treatment for removing support material that was used to support overhang features during fabrication.

B. Characteristic

Manufacturing of real models using directly solid 3D CAD files. The manufacturing of the model is taking place layer by layer from the bottom upwards, based on the solid CAD file. RM methods can result in time reduction compared with the conventional manufacturing methods. Production of highly customized products with no need of tooling.

C. Necessity

To increase effective communication. To decrease development time. To decrease costly mistakes. To minimize sustaining engineering changes. To extend product lifetime by adding necessary features and eliminating redundant features

Rapid Prototyping decreases development time by allowing corrections to a product to be made early in the process. By giving engineering, manufacturing, marketing, and purchasing a look at the product early in the design process, mistakes can be corrected and changes can be made while they are still inexpensive.

The trends in manufacturing industries continue to emphasis the following:

- Increasing number of variants of products.
- Increasing product complexity.
- Decreasing product lifetime before obsolescence.
- Decreasing delivery time.

Rapid Prototyping improves product development by enabling better communication in a concurrent engineering environment.

D. Design Process Methodology

The aim of this section is to show the design process, from the thinking of the idea of a model to its materialization in a touchable solid model [3]. Figure 3 shows the process where researchers can differentiate perfectly the necessary steps to obtain the model. The process is divided in four stages:-

First stage: - it is based on designer's idea. As we know that any project begins with an idea, a sketch made by the designer by hand or by means of a design software, or with a scale model made by hand of any material. The two important aspects of this stage are the idea (which is in the designer's mind) and the initial given information for the accomplishment of the project, as main dimensions, surrounding constraints or others.

Second stage: - It is based on modeling in the computer. It is the logical step, to work with the computer, by means of bi dimensional CAD software; researchers will make the necessary.

Section, sketches and all details for the correct understanding of the original idea. It is not really necessary to start always with a 2D model, but it is quite helpful in making 3D CAD models during the creation of the solid model.

Third stage: - It is based on conceptual design. Once the 3D solid model is completed, it should be saved in STL format (means stereo lithography format). This file will generate a fact model (the facets can be controlled therefore the final resolution of the model) and finally the model is sent to be built. Most of the software can export the model to this format. A touchable model on the designer's hand help the designer to see if the model is what he shaped in his mind. If he needed some necessary changes, he can go back to the 3D model, and make necessary changes as he wants, until the desired model is achieved.

Fourth stage: - It is based on detailed design. At this point it is possible to achieve directly the correct 3D model or by successive approaches building intermediate models with rapid prototyping, until designers obtain the desired final model, all details for the correct understanding of the original idea. It is not really necessary to start always with a 2D model, but it is quite helpful in making 3D CAD models during the creation of the solid model.

IV. ADVANTAGES AND LIMITATIONS

A. Advantages

Users are actively involved in the development. Since in this methodology a working model of the system is provided, the users get a better understanding of the system being developed. Errors can be detected much earlier. Quicker user feedback is available leading to better solutions. Missing functionality can be identified easily [2].

B. Limitations

Practically, this methodology may increase the complexity of the system as scope of the system may expand beyond original plans. Incomplete application may cause application not to be used as the full system was designed. Incomplete or inadequate problem analysis.

IV. CURRENT TRENDS AND FUTURE SCOPE

A. Current trend

Rapid prototyping processes and techniques are moving toward a rather unique goal; that of providing a manufacturing process flexible and accurate enough to produce any part geometry required, to the necessary tolerances, with the appropriate material properties, quickly, and in expensively. This "lot size of one" goal is the ultimate in manufacturing flexibility and represents the epitome of JIT manufacturing. While no rapid prototyping process currently available even approaches this goal, strides are being made in the material properties available, speed, and accuracy of the various processes. Rapid tooling techniques are also further reducing development cycles and planning of horizons. While there are plenty of reasons to believe that rapid manufacturing is a promise of the future, it can be a practical solution that is applicable today. There are circumstances where the benefits and opportunities outweigh the limitations and risks. While these conditions exist in only a small percentage of all manufacturing activity, there are situations where rapid manufacturing is an ideal solution. To recognize the opportunities, manufacturers must keep an open mind to the practicality of rapid manufacturing.

B. Future Trends

It is quite easy to see why RP is a technology that has aroused the interests of many researchers. Whilst it is technology in common use in industry, it is still relatively new and represents a significant milestone in manufacturing Technology. It is a technology that directly links to CAD without the need to focus specifically on the fabrication process, thus providing a mechanism to produce parts automatically. This section discusses the various ways in which RP is developing in order to overcome one or more of the limitations mentioned above.

VI. APPLICATIONS

Applications of rapid prototyping can be classified into three categories:

- [1] Design
- [2] Engineering analysis and planning
- [3] Tooling and manufacturing

A. Design Applications

Designers are able to confirm their design by building a real physical model in minimum time using RP [2].

B. Engineering Analysis and Planning

Existence of part allows certain engineering analysis and planning activities to be accomplished that would be more difficult without the physical entity

1. Comparison of different shapes and styles to determine aesthetic appeal
2. Wind tunnel testing of streamlines shapes
3. Stress analysis of physical model Fabrication of pre-production parts for process planning and tool design.

C. Tooling Applications

Called Rapid Tool Making (RTM) when RP is used to fabricate production tooling Two approaches for tool-making:

1. Indirect RTM method
2. Direct RTM method

CONCLUSION

The use of Rapid Prototyping technologies is essential in any design fields. Although it was conceived as an medical application, arts, architecture applications, the mechanical field can also take benefit from this technology. It gives the mechanical engineer, the possibility to visualize those complex shapes not easily seen or understood on connectional drawings, and touch them to verify the shape. It can be used to in early design stages to build a conceptual model or in later stages when details are needed. Complex shapes can be obtained using surface and solid modeling CAD software, and then build the physical model. In a few hours the model can be built easily, in a similar way as a 2D drawing is plotted. In a short time, rapid prototyping will become a technology that will be used routinely by many design engineers in conjunction with the traditional existing ways of creating scale models of mechanical parts.

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