Rapid Prototyping – Additive/Solid Free Form Manufacturing in Automobile Engineering

Srisairam. V, Mathan Kumar C.D
UG Student
Department of Mechanical Engineering, Kathir College of Engineering, Coimbatore, India

***Abstract* - This paper deals with the application of Rapid Prototyping to save time as well as the cost of manufacturing critical components of automobiles. Rapid Prototyping is an ideal method for components that are complex in shape because it minimizes the time for developing the patterns, prototypes, and tooling. Additive manufacturing (AM) reduce the construction of complex objects to a manageable, straightforward, and relativity fast process. Automobile parts can be formed with any geometric complexity or intricacy without the need for elaborate machine setup or final assembly. The term Rapid Prototyping (RP) refers to a class of technologies that can automatically construct physical models from Computer-Aided-Design (CAD) data. RP techniques are often referred to solid free-form fabrication; Computer automated manufacturing or layered manufacturing. 3D printing is now the most common name given to a host of related technologies used to fabricate physical objects directly from CAD data sources. 3D printing has displaced RP for top honors, that term is still quite popular. Such systems are also known by the names: additive manufacturing, additive fabrication, solid free-form fabrication (SFF) and layered manufacturing.**

***Keywords* - Rapid Prototyping, Additive Manufacturing, Computer Aided Design, 3D Printing, SFF**

I. INTRODUCTION

The term rapid prototyping (RP) refers to a class of technologies that can automatically construct physical models from Computer-Aided Design (CAD) data. Using the Rapid Prototyping system almost any shape can be produced. Time and money savings vary from 50 –90 %compared to conventional systems. Rapid prototyping techniques are often referred to solid free-form fabrication, computer automated manufacturing or layered manufacturing. The computer model is sliced into thin layers and the part is fabricated by adding layers on top of each other. Since 1988 more than twenty different rapid prototyping techniques have emerged.

The basic process of Rapid Prototyping constitutes the following steps:

1. Creating the 3D CAD model of the design.
2. Converting the CAD model to STL format.
3. Slicing the STL file into thin layers.
4. Constructing the model one layer a top another.
5. Cleaning and finishing the model.

Significant advances in additive manufacturing (AM) technologies, commonly known as 3D printing, over the past decade have transformed the potential ways in which products are designed, developed, manufactured, and distributed. For the automotive industry, these advances have opened doors for newer designs; cleaner, lighter, and safer products; shorter lead times; and lower costs. While automotive original equipment manufacturers (OEMs) and suppliers primarily use AM for rapid prototyping, the technical trajectory of AM makes a strong case for its use in product innovation and high-volume direct manufacturing in the future. New developments in AM processes, along with related innovations in fields such as advanced materials, will benefit production within the automotive industry as well as alter traditional manufacturing and supply chain pathways.

A dominant technology for producing physical models for testing and evaluation purposes has been proved today as Rapid Prototyping. Rapid Prototyping (RP) techniques are fast becoming standard tools in the product design and manufacturing industry. The zero tool costs reduced lead times and considerable gains in terms of freedom in product design and production schedules are the appreciable facts regarding RP. The parts those were previously impossible or extremely costly and time consuming to fabricate can be built with ease with RP. The RP techniques are limited neither by geometry nor by the complexity of parts to be fabricated.

II. SIGNIFICANT REASONS FOR THE NEED OF RAPID PROTOTYPING

Rapid Prototyping is an automated fabrication process. Hence, it requires minimal human intervention.

1. It can build arbitrarily complex 3D geometries directly from CAD data.
2. It drastically reduces product development cycle time, because the product is directly fabricated from CAD data and process planning is almost eliminated.
3. It uses a generic fabrication machine, i.e., it does not require part-specific fixture or tooling.
4. The process planning is automatic, based on the CAD model.
5. It is most suitable for production of customized or single product.

6. There is no need of assemblage of the components. All the components in assembly are fabricated simultaneously, a layer-by-layer. A support material is used to fill-up the cavities.

III. ANALYSIS OF DEMANDS IN THE AUTOMOTIVE INDUSTRY

In automotive industry, all the parts that are required are with respect to the following aspects such as size, geometry, material, surface quality and accuracy. Regarding the size one can see that the part dimensions is mainly from small to medium (500x500x500 mm'), i.e. there is no need for development of larger machines. Further aspects were the part's complexity, material, surface quality and accuracy. Regarding the part properties this depends mostly on the development phase in which the part is used. While in the styling phase of a new car for most of the parts any material is permissible. Also accuracy demands and complexity increase. On the other hand the importance of surface quality is most important in the design phase.
Deeper investigations were carried out into the properties of available Rapid Prototyping materials. The investigations covered thermal properties like heat deflection temperature, thermal conductivity, coefficient of linear expansion, specific heat and also mechanical properties such as Young's modulus, elongation at break, tensile strength and impact strength. The final result was that the accuracy of today's Rapid Prototyping systems is mostly sufficient for a wide range of applications. Problems are poor material properties, high part costs and bad long term stability which still limit the use of Rapid Prototyping.

IV. 3D PRINTING IN AUTOMOBILE INDUSTRY

3D printing is a form of additive manufacturing technology where a three dimensional object is created by laying down successive layers of material. It is also known as rapid prototyping, is a mechanized method whereby 3D objects are quickly made on a reasonably sized machine connected to a computer containing blueprints for the object. This revolutionary method for creating 3D models with the use of inkjet technology saves time and cost by eliminating the need to design; print and glue together separate model parts. The basic principles include materials cartridges, flexibility of output, and translation of code into a visible pattern. 3D Printers are machines that produce physical 3D models from digital data by printing layer by layer. It can make physical models of objects either designed with a CAD program or scanned with a 3D Scanner. It is used in a variety of industries including jewelry, footwear, industrial design, architecture, engineering and construction, automotive, aerospace, dental and medical industries, education and consumer products.

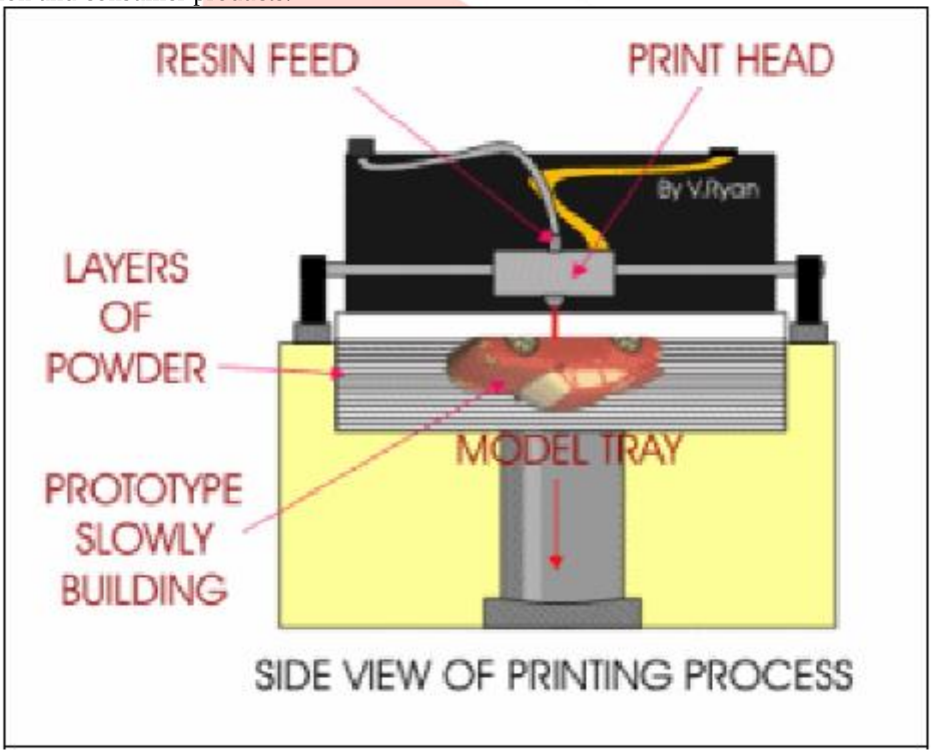

Figure 1: Manufacturing a model with 3D Printer

The model to be manufactured is built up a layer at a time as shown in figure 1. A layer of powder is automatically deposited in the model tray. The print head then applies resin in the shape of the model. The layer dries solid almost immediately. The model tray then moves down the distance of a layer and another layer of power is deposited in position, in the model tray. The print head again applies resin in the shape of the model, binding it to the first layer. This sequence occurs one layer at a time until the model is complete.
The technology for printing physical 3D objects from digital data was first developed by Charles Hull in 1984. He named the technique as Stereo lithography and obtained a patent for the technique in 1986. While Stereo lithography systems had become popular by the end of 1980s, other similar technologies such as Fused Deposition Modeling (FDM) and Selective Laser Sintering (SLS) were introduced. In 1993, Massachusetts Institute of Technology (MIT) patented another technology, named "3 Dimensional Printing techniques", which is similar to the inkjet technology used in 2D Printers. In 1996, three major products, "Genisys" from Stratasys, "Actua 2100" from 3D Systems and "Z402" from Z Corporation, were introduced. In 2005, Z Corp. launched a breakthrough product, named Spectrum Z510, which was the first high definition color 3D Printer in the market.

Another breakthrough in 3D Printing occurred in 2006 with the initiation of an open source project, named Reprap, which was aimed at developing a self replicating 3D printer.
The following figure (figure 2) shows the dataflow diagram for the automotive manufacturing process using Rapid Prototyping 3D technology. The figure 3 shows the complete prototype car.

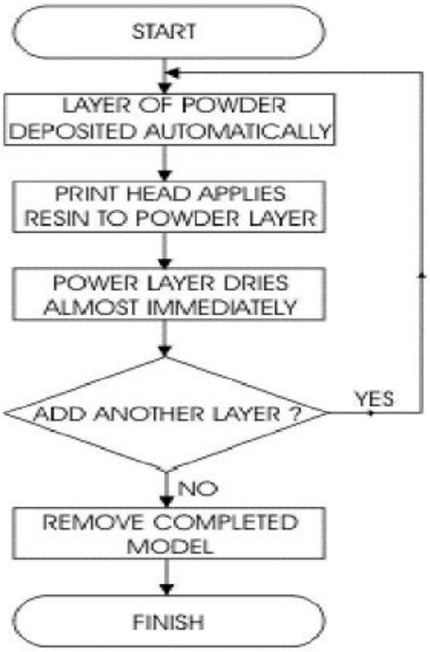

Figure 2: Work flow Diagram of 3D printing

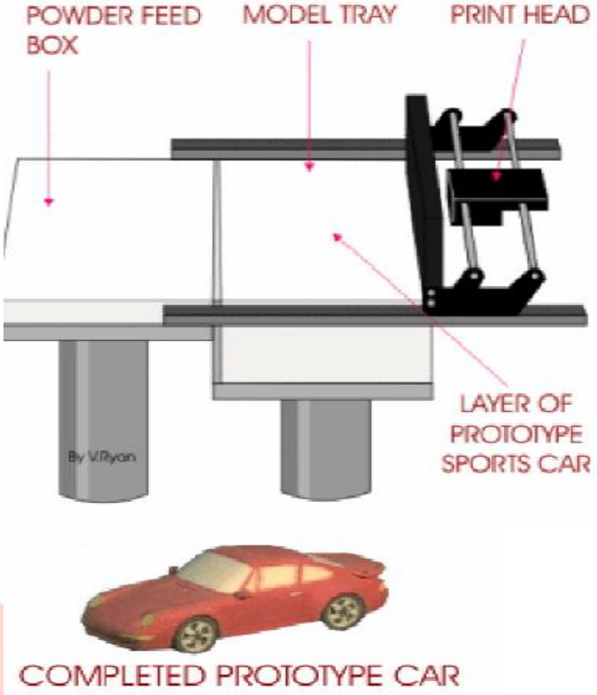

Figure 3: Complete prototype of a car

The following the currently available 3D printing technologies:

Stereo lithography - Stereo lithographic 3D printers (known as SLAs or **s**tereo lithography **a**pparatus) position a perforated platform just below the surface of a vat of liquid photo curable polymer. A UV laser beam then traces the first slice of an object on the surface of this liquid, causing a very thin layer of photopolymer to harden. The perforated platform is then lowered very slightly and another slice is traced out and hardened by the laser. Another slice is then created, and then another, until a complete object has been printed and can be removed from the vat of photopolymer, drained of excess liquid, and cured.

Fused deposition modeling - Here a hot thermoplastic is extruded from a temperature-controlled print head to produce fairly robust objects to a high degree of accuracy.

Selective laser sintering (SLS) - This builds objects by using a laser to selectively fuse together successive layers of a cocktail of powdered wax, ceramic, metal, nylon or one of a range of other materials.

Multi-jet modeling (MJM) - This again builds up objects from successive layers of powder, with an inkjet-like print head used to spray on a binder solution that glues only the required granules together.

V. CAPABILITIES OF 3D PRINTING

As anticipated, this modern technology has smoothed the path for numerous new possibilities in various fields. The list below details the advantages of 3D printing in certain fields.

- Product formation is currently the main use of 3D printing technology. These machines allow designers and engineers to test out ideas for dimensional products cheaply before committing to expensive tooling and manufacturing processes.
- In Medical Field, Surgeons are using 3d printing machines to print body part for reference before complex surgeries. Other machines are used to construct bone grafts for patients who have suffered traumatic injuries. Looking further in the future, research is underway as scientists are working on creating replacement organs.
- Architects need to create mockups of their designs. 3D printing allows them to come up with these mockups in a short period of time and with a higher degree of accuracy.
- 3D printing allows artists to create objects that would be incredibly difficult, costly, or time intensive using traditional processes.
- 3D Saves Time and Cost.

VI. APPLICATIONS OF RP IN AUTOMOBILES

Today production dashboards and cooling vents in some vehicles are already made using AM. With new improvements in process and materials technology and a wider adoption of AM, it is possible that we could see AM-based production of a greater number of components in the future. A no exhaustive summary of which components are presently manufactured using AM and which parts will be potentially manufactured in the future.

The following are the major advantages of RP in various fields

- Almost any shape or geometric feature can be produced.
- Reduction in time and cost (could range 50 –90%. Wohler)
- Errors and flaws can be detected at an early stage.
- RP/RM can be used in different industries and fields of life (medicine, art and architecture, marketing..)
- Discussions with the customer can start at an early stage.
- Assemblies can be made directly in one go.
- Material waste is reduced.
- No tooling is necessary.
- The designers and the machinery can be in separate places.

VII. CONCLUSION

Due to the novelty of Rapid Prototyping Techniques the definition of requirements of in the automotive industry gives the suppliers of RP systems and services a better understanding of the necessities. The knowledge about the demands is necessary to offer these new technologies to a wider range of people but also for opening up new application areas and for future developments. Detailed material tables and knowledge about influences of the manufacturing process give the RP user the possibility to choose material and processes according to the required prototype. The investigations carried out on various fields helped to integrate RPT deeper in the car development cycle. But as mentioned before due to the big potential of these techniques there are still further improvements possible and necessary. Thus the work in this field is still far from finished.

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