RAPID PROTOTYPING TECHNOLOGY - STUDY OF FUSED DEPOSITION MODELING TECHNIQUE

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Abstract— Rapid Prototyping is a group of techniques used to quickly fabricate a scale model of physical part or assembly using 3D CADvia 3D printers or additive manufacturing technique. Additive Manufacturing has ability to create any shape and geometry. Rapid Prototyping can be classified into solid, liquid, paste and gases. Fused Deposition Modeling is an additive manufacturing technology. FDM is more quicker and cost effective method. Basic material used in Fused Deposition Modeling is ABS- Acrylonitrile Butadiene Styrene. For higher mechanical properties of FDM, advanced materials are also used. This paper focus on Fused Deposition Modeling Technique.

Keywords— Additive manufacturing, Rapid prototyping, Fused Deposition Modeling, Kaveri Engine, NASA mars rover.

I. INTRODUCTION

Prototyping is one of the important steps to finalize the product design. Manual prototyping has been an age-old practice. Nowadays Rapid Prototyping is used. Rapid Prototyping was introduced in1980's. Rapid Prototyping is group of techniques used to quickly fabricate a scale model of physical part of assembly using three dimensional Computer Aided Design(CAD). Rapid Prototyping (RP)is a method to make prototypes quicker and more cost-effective. It is a technology which saves time especially for complicated products. The part or assembly is made by using 3D Printer or Additive Manufacturing Technology. Additive Manufacturing process makes three dimensional parts directly from CAD models by adding materials layer by layer. Rapid Prototyping is widely used in many industries i.e. from shoe to car manufacturers.

Rapid Prototyping Technique has two types: additive manufacturing and subtractive manufacturing. Subtractive type RP is a material removed technique from solid piece until the desired design remains. Additive type RP is opposite to subtractive type. In this type material is added layer by layer up to desired design. Additive fabrication has ability to create any shape and geometry.

II. RAPID PROTOTYPING TECHNOLOGY

Rapid Prototyping Technology is grouped to their fundamental metal deposition and working principle. RP contains different ways of classifying RP processes. One representation based on German standard of production processes classifies RP processes according to state of aggregation of their original material.

RP technology requires lesstime for classical prototyping in sense of creating – testing – redesigning – rebuilding and repeating the process. There are number of specific methods used in area of RP: Stereolithography (SLA), Laminated Object Manufacturing (LOM), Fused Deposition Modelling (FDM), Laser Engineering Net Shaping (LENS), Solid Imaging (SI) or Multi-jet Modelling, 3D Printing (3DP) or Selective Binding, Selective Laser Sintering(SLS).

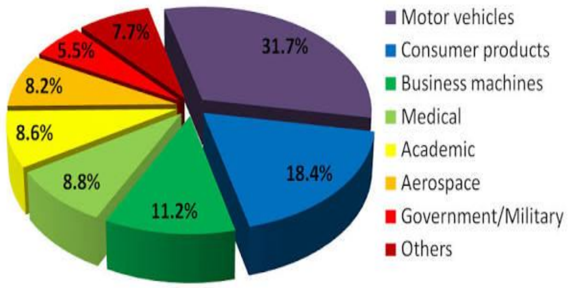

Fig. 1 Percentage use of RP technology worldwide

Global Scenario of Fused Deposition Modeling Stratasys has got more than 60% market share of FDM in India and having more than 200+ FDM Systems Installed in Indian Market in various segments like Education, Defense, Government, Automotive, Aerospace, Consumer Goods and Heavy Industries. Balance 30% market share is of other RP Technologies. Globally Stratasys (FDM) has more than 45% market share .

III. FUSED DEPOSITION MODELING TECHNOLOGY

Fused Deposition Modeling was developed by Scott Crump, the founder of Stratasys. FDM is an additive manufacturing technology commonly used for modeling, prototyping and production applications. FDM has 3 steps:pre-processing, production, post-processing. In pre-processing, a CAD model is constructed which converted into STL format for FDM process. FDM machine processes. The layers are created until completion of the model. In post-processing, the model and any supports are removed by washing or stripping away. The surface of the model is then finished and cleaned.

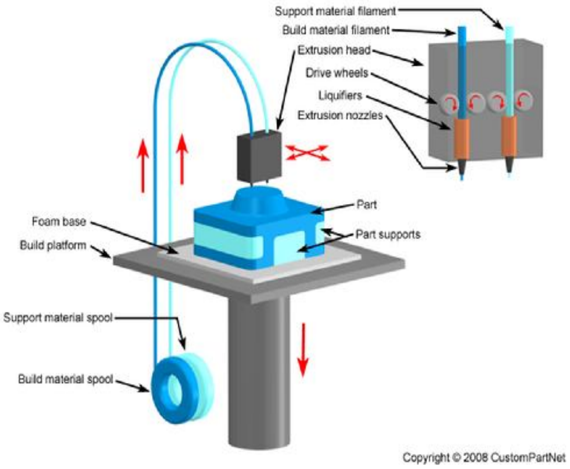

Fig. 2 FDM process

FDM Technology build parts layer-by-layer by heating thermoplastic material to a semi- liquid state and extruding it according to computer-controlled paths. FDM uses two materials: modeling material and support material. Modeling material which constitutes the finished piece, and support material, which acts as scaffolding. Material filaments are fed from the 3D printer's material bays to the print head, which moves in X and Y coordinates, depositing material to complete each layer before the base moves down the Z axis and the next layer begins. Once the 3D printer is done building, the user breaks the support material away or dissolves it in detergent and water.

FDM is a clean, simple-to-use, office-friendly 3D printing process. FDM technology builds the most accurate part of any additive fabrication system. FDM uses real production grade thermoplastics. Thermoplastics can endure exposure to heat, chemicals, humid or dry environments, mechanical stress. Soluble support materials produce complex geometries and cavities that would be difficult to build.

IV. MATERIALS

FDM provides functional prototype of ABS plastic. ABS parts are sufficiently resistant to heat, chemicals, and moisture that allows FDM parts to be used for limited to extensive functional testing, depending upon the application. FDM materials allow to manufacture real parts that are tough enough for prototyping, functional testing, and installation. Thermoplastics are more stable and have no appreciable warpage, shrinkage, or moisture absorption, like the resins (and powders) in competitive processes. Some of the basic materials used are [2]:

1. ABSplus thermoplastic (Acrylonitrile Butadiene Styrene):

- Environmentally stable - no appreciable warpage, shrinkage or moisture absorption,
- 40 percent stronger than standard ABS material.

2. ABS-M30 thermoplastic (acrylonitrile butadiene styrene):

- 25-70 percent stronger than standard ABS material,
- Greater tensile, impact, and flexural strength,
- Layer bonding is significantly stronger for a more durable part,
- Versatile Material: Good for form, fit and moderate functional applications.

3. ABS-M30i thermoplastic (acrylonitrile butadiene styrene):

- Biocompatible (ISO 10993 certified) material,
- Ideal material for medical, pharmaceutical and food packaging industries,
- Sterilizable using gamma radiation or ethylene oxide (EtO) sterilization methods.

4. ABSi thermoplastic:

- Translucent material,
- Ideal for automotive tail lens applications,
- Good blend of mechanical and aesthetic properties,
- Available in translucent natural, red and amber colors.

5. PC-ABS thermoplastic (polycarbonate acrylonitrile butadiene styrene):

- Most desirable properties of both PC and ABS materials,
- Superior mechanical properties and heat resistance of PC,
- Excellent feature definition and surface appeal of ABS,
- Highest impact strength.

6. PC thermoplastic (polycarbonate):

- Most widely used industrial thermoplastic,
- Accurate, durable, and stable for strong parts,
- Superior mechanical properties and heat resistant,
- High tensile strength and can handle high temperatures

7. PC-ISO thermoplastic:

- Biocompatible (ISO 10993 certified) material,
- Ideal material for medical, pharmaceutical and food packaging industries,
- Sterilizable using gamma radiation or ethylene oxide (EtO) sterilization methods,
- Best fit for applications requiring higher strength and sterilization.

8. PPSF/PPSU hermoplastic (polyphenylsulfone):

- Highest heat and chemical resistance of all FDM materials

- Mechanically superior material, greatest strength,
- Sterilizable via steam autoclave, EtO, plasma, chemical, and radiation sterilization,
- Ideal for applications in caustic and high heat environments.

9. FDM Thermoplastic Material - ULTEM 9085:

ULTEM 9085 is a thermoplastic developed primarily for the aerospace industry and also has applications in the marine and other niche industries. ULTEM 9085 is a strong, lightweight, flame-retardant thermoplastic widely used in aircraft interiors. The material has a V-Zero rating for flame, smoke and toxicity (FST). ULTEM 9085 is certified for use on commercial aircrafts, which will allow manufacturers to bypass a lengthy certification process. The material is an ideal candidate for functional prototyping and end use parts applications in the aerospace and marine industry. - V-Zero rating for flame, smoke & toxicity (FST), - High strength to weight ratio, - High heat deflection temperature (320° F / 160° C), - Flight & other certifications in aerospace industry.

For rapid fabrication by FDM with higher mechanical properties, new metallic and ceramic materials are used. Rutgers University in the United States create components on FDM using ceramic powders mixed with organic binder [2].

The interest of Lamborghini in components made with the rapid prototyping technology has found its origin in requirement of solving the problem for immediate delivery of 100 Gallardo's model to the first dealers and customers, the pre-production models. The parts in consideration were the headlight washer cover flap. The RP materials available on the market until that moment didn't reach the minimum mechanic and thermal properties that this application was requiring: once painted the part had to be fitted directly on the car. Considering that the Gallardo can easily reach 300 km per hour and has to resist at every climatic condition, both in winter (-20°C) and in summer (+50/60°C), rain, hail, snow or sun, the challenge was very exiting. They asked for a consulting and the suggestion was laser sintering and hi-performance materials. At the beginning of 2003 the most appropriate material was the Windform PRO, aluminium and glass filled, granular and flat. The part has then been produced in Windform XT, carbon fiber filled material: the tests made on the first and then on the second have underlined a good increase in performance with the carbon fiber filled, so we suppose that if at that time the carbon fiber filled material had been used, the performance would have been higher. Despite this, the Windform PRO pieces didn't have any problem. The components made from injection moulding used previously weren't suitable for this first phase. For this reason the particular was still at a non-definitive definition and presented some showy defects, from project and process [3].

V. APPLICATIONS

RP technologies are used by various industries like aerospace, automotive, jewelry, coin making, tableware, saddletrees, biomedical, etc. It is used to fabricate concept models, functional models, patterns for investment and vacuum casting, medical models and models for engineering analysis.

Aerospace icons like NASA & Piper Aircraft employ the most exciting FDM (3D printing) applications in the world.

1) NASA Mars Rover[5]

There are 70 parts having complex shapes. FDM offers the design flexibility and quick turnaround to build tailored housings for complex electronic assemblies [1].

2) Kaveri Engine Project

The Gas Turbine Research Establishment (GTRE) of Bangalore, India is a government laboratory whose primary function is research and development of marine and aeronautic versions of gas turbines.

The most challenging task while designing the Kaveri was positioning piping runs which minimize length to reduce weight and cost and line replaceable units(LRUs) on the outside of the aircraft. Many of the LRUs are connected to interior of the engine that carries hydraulic fluid, fuel and lubricant.

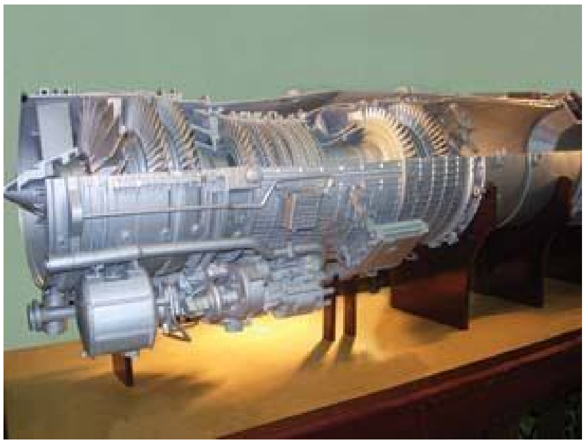

Fig. 3Kaveri Engine

There are approximately 2500 engine components in the design. Initially layout of piping was created by CAD software. If GTRE would have considered building the prototype using CNC machining it would have taken a minimum of one year. It considered Stereolithography, but the project was not suited for this method. GTRE realized that conventional rapid prototyping methods would have made it necessary to produce solid pipes which would have eliminated the possibility of flow testing. There is uncertainty between conventional and new design. New design also have problem. A prototype is used as part of the product design process to allow engineers and designers the ability to explore design alternatives, test theories and confirm performance prior to launch of new product. RP is capable of making parts with very small internal cavity and complex geometrics. It is possible to see the real product in an early stage of the development process.

CONCLUSION

FDM technology provided the ideal solution. GTRE also like the fact that FDM creates parts from real engineering thermoplastics, such as ABS, which allowed them to make high-strength durable components for the project. Nowadays more than 20 vendors are available for FDM. FDM's applications can be used in every sector such as design engineering, analysis, testing, optimization, and manufacturing. Rapid Prototyping is going to serve as Industrial Revolution due to its very low time consuming property and proper strength and surface finish.

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