AM Technologies: Presentation

FUSED DEPOSITION MODELLING

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INTRODUCTION

- Rapid Prototyping is a set of techniques and processes that are used to create a solid model of a part with assistance from CAD software.
- Some of the most popular 3D printing technologies are Fused deposition modeling (FDM), Selective laser sintering (SLS), Stereolithography (SL), Laminated object manufacturing (LOM).
- Among these most widely used 3D printing technique is Fused Deposition Modeling (FDM) which was introduced by S. Scott Crump in the 1980s.
- FDM has made a revolutionary change in the field of manufacturing by saving energy and material.
- FDM is mainly used in prototyping, manufacturing tooling, batch production, and modeling.
- The main benefits of using FDM are its simplicity, low-cost, and eco-friendliness.

- Explain how an FDM printer is working·

THE WORKING OF FDM PRINTER

The 3D printer that operates under the principle of FDM technology consists of,

1) **Printer platform (bed).**
2) **Nozzle.**
3) **Filament (Raw materials)**

- The Printer platform is made of some metals, ceramic and hard plastics and each successive layer is deposited on this platform.
- The nozzle/printer head is mounted on a mechanical chassis that is moved by a belt and lead screw mechanism. A motorized mechanism allows the entire extrusion assembly to move in the X, Y, and Z dimensions. The thermoplastic material is advanced into a nozzle by a fourth motor, a stepper motor. A computer controls the complete movement of the head and raw materials.
- The raw material is normally high grade thermoplastics and metals also can be used. The thermoplastic filament or metal wire is winded as a coil on a mounted spool. It is later fed through the printer nozzle. In a semi-liquid state, the material is to be extruded through the nozzle. Sooner, it will become solid and end up with better dimensional accuracy.

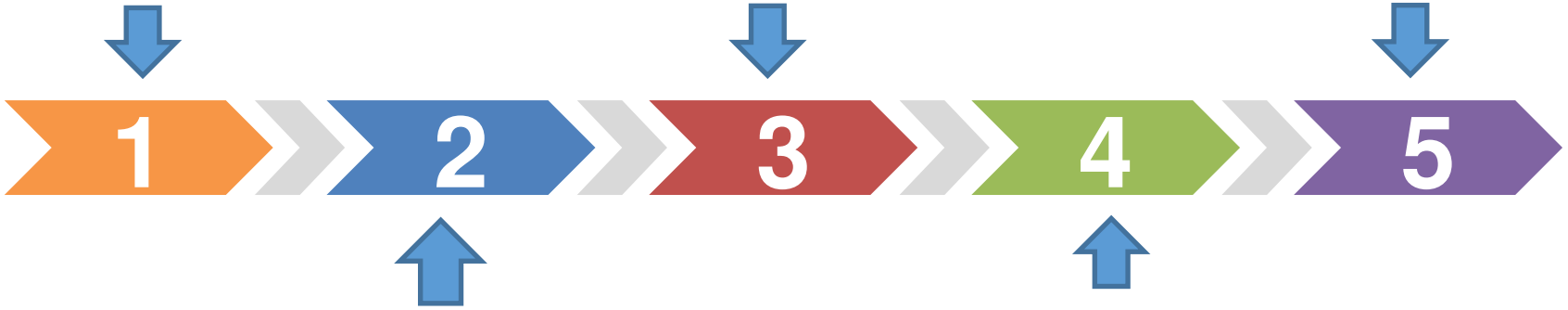
THE WORKING OF FDM PRINTER

STEPS IN FDM

3D Computer-aided design(CAD).

Slicing STL file

Cleaup and Finishng



Creation of STL file

Layer by Layer creation of model

THE WORKING OF FDM PRINTER

- The process is initiated with a 3D Computer-aided design(CAD).
- The Digital model was separated into many layers by slicing software and outputs a G-code file for the printer
- The Solid plastic filaments are heated up by FDM Printer.
- The Filament Melts and the printer extrude it from a nozzle.
- The FDM printer builds Layer upon layer onto a build tray to form the 3D object.
- The FDM printer starts with printing layers of support material which provides a foundation to the final product.
- The support material supports features such as overhangs.
- The layers of molten plastic are deposited on top of previous layers and instantly these layers fuse.
- Based on the resolution each layer can be 0.1mm to 0.08mm thick.
- The support material can be removed either manually (breakaway supports) or by immersing the part in water-based cleansers (soluble supports)

THE WORKING OF FDM PRINTER

Process Variables of FDM

1) **Head Temperature**
2) **Density of Part**
3) **Scaling and Orientation**
4) **Model Material**

- Head Temperature varies according to the material of base and model.
- Density varies according to the type of the model. For example, low density when the part is made for investment casting, medium density for design verification and high density for solid models.
- FDM can scale parts upward or downwards and the orientation can be in any plane.

- What type of material is used in general and how is it applied to the instrument?·

MATERIALS USED IN FDM

A Wide Variety of Materials are used in FDM and they can be basically classified into three.

1) Polymers
2) Metals
3) Ceramics

1) **Polymers**

- polymers are materials that are most commonly malleable and are made of synthetic or semi-synthetic materials.
- Polymers are widely used in Additive manufacturing because of their low cost, ease of manufacture, resistance to fluids, and their versatility.

Some popular Polymers used in FDM are

a) ABS:

- Most widely used material in FDM.

MATERIALS USED IN FDM

- The advantages of using ABS include high strength, good flexibility, shock resistance and, re- usability.
- The major problems of using ABS include non-biodegradable and ABS is known to shrink when in contact with air.

b) Polylactic Acid (PLA)

- Biodegradable unlike ABS
- Corn starch is used to make this product, which is made from sustainable resources.
- The easiest material to print and prints at a lower temperature in comparison with ABS.

c) Thermoplastic Elastomer (TPE)

- TPE's are a blend of rubber and plastic.
- The most popular TPE's are Thermoplastic polyurethane (TPU) and thermoplastic co-polyester (TPC). TPU's are used when high resistance and durability are a priority and TPC's are used when temperature resistance is important over other factors.

MATERIALS USED IN FDM

2) Metals

- Like Polymers Metals are a popular category of 3D printing materials.
- Metals are mostly used in Selective Laser Melting (SLM) and Direct Metal Laser Sintering (DMLS) and are not widely used in FDM.
- 3D printed metal parts have good mechanical and thermal properties.

3) Ceramics

- The major characteristics of ceramic material include high mechanical strength, hardness, and acceptable properties in thermal, electrical, magnetical, and optical fields.
- Additive manufacturing enables complex geometries of ceramic structures possible which was previously impossible in traditional methods.

MATERIALS USED IN FDM

Some commonly used Ceramics in FDM are

a) Alumina

- Alumina is usually found in powder form and is an oxide ceramic.
- The optimum conditions in which alumina is made are with 5 mm/s to 6 mm/s with plaster of Paris (POP) as the best option as a substrate because of better adherence

b) Silica

- Silica is an abundant material on the earth's surface especially in combination with other oxides such as alumina.
- The 3d-printed parts of silica are found to be of high quality.

- Elaborate the mechanical behavior of a printed part with this kind of technology·

MECHANICAL PROPERTIES OF FDM PRINTED PARTS

- The tensile strength of FDM created parts is comparable to the injection-molding method.
- The brittleness of FDM printed parts are relatively higher when compared to parts made from the injection-molding method.
- The Youngs modulus can be 13-15% less than the molded specimen.
- For obtaining the best mechanical properties, an orientation of 90 degree is recommended.
- Although the bending stress of the FDM printed part was comparable with the molded part, the bending stiffness was reduced by 40%.
- The surface finish of FDM printed models is considered poor when compared to other RP processes.
- Complex shapes are difficult to print with FDM.
- The parts made from FDM are found to be anisotropic.
- The anisotropic nature of the build part means raster direction determines strength of a local area of the part.

MECHANICAL PROPERTIES OF FDM PRINTED PARTS

Optimizing process variables to improve mechanical properties.

- Appropriate thermal treatment parameters have a positive impact on tensile and interlaminar properties.
- Using curved layers in FDM provide good fiber continuity.
- Temperature gradient which leads to better diffusion increases with the number of layers, but distortion within layers will also increase.
- Algorithms such as MOD can minimize the need for support structures which is known to degrade the surface finish.
- Post-process treatment is applied to objects manufactured with FDM to increase the surface finish and dimensional accuracy.
- With the addition of Acrylonitrile butadiene styrene (ABS) nanocomposites with organic modified montmorillonite (OMMT) content, both tensile strength and elastic modulus improved significantly.

MECHANICAL PROPERTIES OF FDM PRINTED PARTS

Optimizing process variables to improve mechanical properties.

- Reducing air gap delivers better diffusion of layers but also reduces heat transfer.
- The width of the raster and slice height has a positive impact on surface roughness.
- The surface roughness is the major problem with FDM and this is caused by staircase effect.
- A semi-empirical surface roughness assessment model has been provided and tested. This is performed through the use of hot cutter machining, a simple material removal process (HCM).

- Where is this technology used so far, where can you see this technique in the future?·

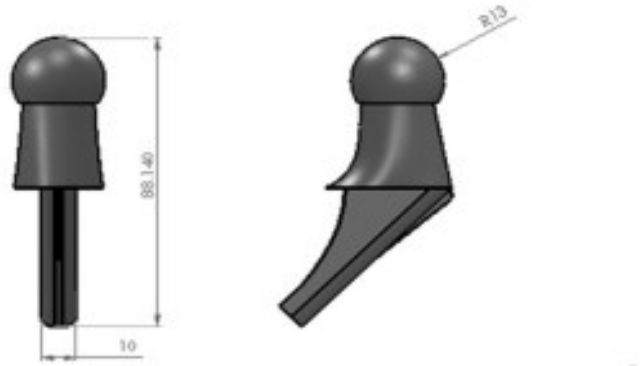
AREAS OF APPLICATION

- In recent years, FDM has seen broad use in industrial applications ranging from medicine to the automobile industry.
- The fields in which FDM thrives include aerospace, medicine, automotive, motorsports, etc.

1) Medicine

- FDM is widely deployed in the production of medical models.
- FDM has been used in designing tissues, customized prostheses, etc for medical applications.
- The fit of the prostheses can be tailored accurately to individual patients with the help of FDM.
- Various body parts such as hip joints, knee caps, spinal implants have been made using FDM.
- The required implants are first identified through a CT or MRI scan which is followed by creating a 3D model and then finally printing it through the FDM process.

AREAS OF APPLICATION



Hip Joint Model

2) Rapid Casting

- Rapid casting is the integration of 3D printing and conventional manufacturing.
- The main benefits for FDM in rapid casting include a reduction in time and cost for complex patterns.
- Rapid Prototype (RP) models offer high accuracy.

AREAS OF APPLICATION

- FDM can provide a near identical prototype model to the finished part.
- FDM requires little to no modifications to the existing foundry practices.
- The parts are mostly produced from ABS with CAD data as the pattern.
- The addition of metals and ceramics in the FDM process means more flexibility.

3) Rapid Tooling

- Rapid tooling can provide reduced costs and time in the field of prototype tooling.
- A fabrication method known as FDMet is used in rapid tooling where fabrication is done from CAD file while eliminating the use of molds or tooling.
- Fast and easily reproducible

AREAS OF APPLICATION

4) Automotive

- A rapid growth in the automotive industry was made possible by the development of AM.
- Some manufacturers use 3D printing to print dashboards and cooling vents of their cars.
- Used in prototyping, customized tooling, investment casting and parts production.

First 3D Printed Car

AREAS OF APPLICATION

Future Of FDM

- 3D printing came a long way where it used to be made from simple materials and had low accuracy.
- FDM can open doors to new possibilities in the aerospace and manufacturing industries.
- The future scope includes automatic bed clearing, colored printing, multi-material printing and closed loop feedback systems.
- The Intoduction of new materials such as graphene and cheap sensors to 3D printing can revolutionize this field.

Discussion:

- Fused Deposition Modelling (FDM) is referred to as the "new industrial revolution" since it has such a broad influence and offers so many chances and benefits.

- The printer platform, nozzle, and filament are all part of the FDM technology-based 3D printer.

- A 3D computer-aided design is used to start the procedure.

- FDM uses a wide range of materials, which are divided into three categories: polymers, metals, and ceramics.

Discussion:

- Because the amount of materials utilized in FDM is limited, it can only be employed for a few specific applications.

- The quality of FDM-produced goods is determined by process variables such as layer thickness, slice height, raster angle, raster width, tip diameter, contour breadth, contour depth, and air gap.

- The importance of FDM in obtaining parts with the proper degree of porosity has been highlighted. The use of FDM in the creation of complicated shapes has also been highlighted.

- FDM's utility in medicine has been forecast, and it has been discovered to be a beneficial tool in a variety of medicinal applications.

- Derive 10 Questions & Answers (Q&A) especially tailored for this presentation·

Questions and Answers (Q & A)

1) What are the factors affecting the quality of the printed parts? How do they affect the quality?

A:

- **Nozzle diameter of the 3D printer** : smaller nozzle diameter increases the quality of the part.
- **Nozzle Temperature** : Has to be set according to the printing consumables.
- **Material Quality**: the material quality affects the quality of the end product.
- **Layer Thickness**: Smaller the layer thickness, the higher is the quality of the printed model.
- **Extrusion and Printing Speed**: Appropriate extrusion speed and printing speed has to be set for high accuracy.

2) Name the most common infill patterns used in FDM?

A:

Gold infill, Lines/Rectilinear Infill, Triangle Infill, Tri-Hexagonal Infill, Cubic Infill, Cubic Subdivision Infill, Octet Infill, Quarter Cubic Infill, Concentric Infill, Gyroid Infill and Gyroid Infill.

Questions and Answers (Q & A)

3) Name the failures and their causes in FDM.

A:

- **Dimensional Inaccuracy:** Machine accuracy, Materials, Object size, Warping and shrinkage, Support structures, and Post processing are some of the factors that affect the final accuracy.

- **Under-Extrusion and Over-Extrusion:** Incorrect filament diameter, uneven nozzle diameter and variation in printing speed cause this.

- **Stringing or Oozing:** When the plastic seeps out of the nozzle as the extruder travels to a new spot, this failure happens.

- **Layer Shifting:** When the layers do not bond together tolerably, layer shifting occurs.

- **Bed Adhesion Failure:** Incorrect printing speed and temperature settings cause the print to adhere poorly to the base.

4) Difference between Fused deposition modeling (FDM) and Stereolithography (SLA).

A:

- The model size of the FDM 3D printer is greater than that of the SLA printer.

Questions and Answers (Q & A)

- SLA offers higher precision in printed parts when compared to FDM.
- SLA also offers a higher printing resolution than FDM.
- SLA printed parts are often costlier than parts made from the FDM process.

5) What are the advantages and disadvantages of FDM?

A:

Advantages:

- Scalability, cheap and accessible, user friendly printers, material flexibility, reusable filaments.

Disadvantages:

- Poor print quality, slow, parts might be prone to warping and shrinking, poor surface finish, requires support structure.

Questions and Answers (Q & A)

6) What are the design considerations in manufacturing for the FDM process?

A:

- Anisotropic property
- Fabrication time
- Aesthetics
- Static and Dynamic loading considerations.

7) How to cost effectively print in FDM?

A:

- One of the biggest advantages of the FDM printer is its scalability.
- Low cost to size ratio means FDM is more economical to larger sized products.
- Material flexibility offered by FDM ensures FDM printers can utilize cheap materials to print.

Questions and Answers (Q & A)

8) Why FDM is used in aerospace Industy?

A:.

- FDM can work with a wide range of materials which is important for aerospace industry.
- Reliability and durability.
- Great for prototyping and end user parts.

9) Does the color of the filament has any effect on the end product?

A:

- Pigments can affect mechanical properties of the finished product and different pigments have different effects because of their difference in chemical structure.
- Organic pigments can act as nucleating agents.

Questions and Answers (Q & A)

10)What software's are required for 3D printing?

A:

- For 3D printing, a slicer program is required (For example Cura)
- A CAD program is required to make the CAD model.

- State all references for the presentation and for the Q&A section

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