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Review on Fused Deposition Moulding (FDM) in 3D Printing

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ABSTRACT: Fused Deposition Modeling (FDM) is a widely used 3D printing technology that builds objects layer by layer using thermoplastic materials. This paper explores the FDM process, including the types of materials used, key factors affecting print quality, and the advantages and challenges of this technique. In 3D printing, some methods to improve part quality and highlights the potential applications of FDM in various fields, especially in biomedical engineering. 3D printing, also known as additive manufacturing, is a process in which three-dimensional objects are created by sequentially adding material layer.

I. INTRODUCTION

Additive manufacturing (AM), or 3D printing, has changed how products are designed and made, particularly in medicine. Among different AM techniques, Fused Deposition Modeling (FDM) is popular due to its simplicity and cost-effectiveness. Developed by S. Scott Crump in the late 1980s and commercialized by Stratasys in 1990, FDM is now widely used for creating prototypes and small production runs. An intelligent pharmacy refers to the integration of advanced technologies, such as artificial intelligence (AI), automation, data analytics, and machine learning, into the pharmacy sector to enhance the efficiency, accuracy, and personalization of healthcare delivery. These systems enable pharmacies to optimize various processes, from medication dispensing and inventory management to rapid prototyping. Rapid prototyping is a group of techniques used to quickly create a physical model or prototype of a product or part using computer-aided design (CAD) data. This process allows for the fast fabrication of a physical object, typically through additive manufacturing (3D printing), but can also involve other methods like CNC machining or laser cutting. The goal of rapid prototyping is to accelerate the design and development cycle by enabling designers, engineers, and manufacturers to test and iterate on product concepts quickly. Deposition molding is generally linked to additive manufacturing or thin-film deposition, where materials are selectively deposited to form a structure or a part. In the context of molding, it could refer to techniques where a material is deposited into a mold or onto a surface to build up specific layers or parts. If you're thinking about processes like CVD (Chemical Vapor Deposition), PVD (Physical Vapor Deposition), or similar, these processes are used to deposit thin layers of material on a substrate to form coatings, microstructures, or components. In some cases, molding could be involved in shaping the deposition process. 3D printing has revolutionized industries by offering cost-effective, efficient, and flexible ways to create complex designs, reduce waste, and speed up production timelines. It is widely seen as a transformative technology in fields ranging from manufacturing to healthcare.

II. OBJECTIVES

2.1 This paper aims to:

1. Explain how FDM works?

FDM is popular because it's relatively easy to use, affordable, and suitable for prototyping, functional parts, and various other applications. However, its print resolution and material options can be somewhat limited compared to other 3D printing technologies like SLA.

2. Identify common materials used in FDM and their properties? PLA (Polylactic Acid), ABS (Acrylonitrile Butadiene Styrene), PETG (Polyethylene Terephthalate Glycol), Nylon (Polyamide), TPU (Thermoplastic Polyurethane), PC (Polycarbonate), HIPS (High Impact Polystyrene), PVA (Polyvinyl Alcohol), ASA (Acrylic Styrene Acrylonitrile).

3. Analyze how different factors affect print quality? Several factors can significantly influence the print quality in FDM (Fused Deposition Modeling) 3D printing. These factors interact with each other and must be carefully managed to achieve the desired results. Here's an analysis of the key factors that affect print quality:

4. Discuss ways to optimize the FDM process for better results. Optimizing the FDM (Fused Deposition Modeling) 3D printing process involves fine-tuning several settings and techniques to improve print quality, speed, and efficiency. Here are some ways to optimize the FDM process for better results: Print Temperature (Extruder & Bed), Retraction Settings, Filament Quality, Bed Leveling and Adhesion, Environmental Factors

III. MATERIALS AND METHODOLOGY

3.1 Materials Used in FDM

FDM primarily uses thermoplastic filaments that are heated and extruded through a nozzle to create parts. Common materials include:

Acrylonitrile Butadiene Styrene (ABS): Known for its strength and durability, ABS is often used for functional prototypes.

Polylactic Acid (PLA): A biodegradable plastic made from renewable resources like corn starch, PLA is easy to work with and provides good surface finishes.

PETG (Polyethylene Terephthalate Glycol): Durable, chemical-resistant, and food-safe, often used in manufacturing functional parts.

Nylon: Flexible, strong, and impact-resistant, ideal for functional prototypes, tools, and end-use parts.



3.2 Parts can consist of two types of materials:

Build Material: The main material that forms the printed object.

Support Material: Temporary structures that support overhanging parts during printing and can be removed afterward.

3.3 FDM Process Workflow:

The FDM process involves several steps:

1. **CAD Model Creation:** Design the part using computer-aided design (CAD) software.
2. **File Conversion:** Convert the CAD model into STL format for slicing software.
3. **Slicing:** Use slicing software to generate instructions (G-code) for the printer.
4. **Machine Setup:** Upload the G-code to the printer, set parameters like temperature and speed, and start printing.
5. **Part Removal:** Once printing is complete, detach the object from the build platform.

IV. PROCESS PARAMETERS AFFECTING FDM QUALITY

Several factors influence the quality of FDM prints:

4.1 Part Orientation: The way a part is oriented during printing affects material use, surface finish, and build time. Optimizing orientation can reduce defects like warping and improve accuracy. In 3D printing, part orientation refers to

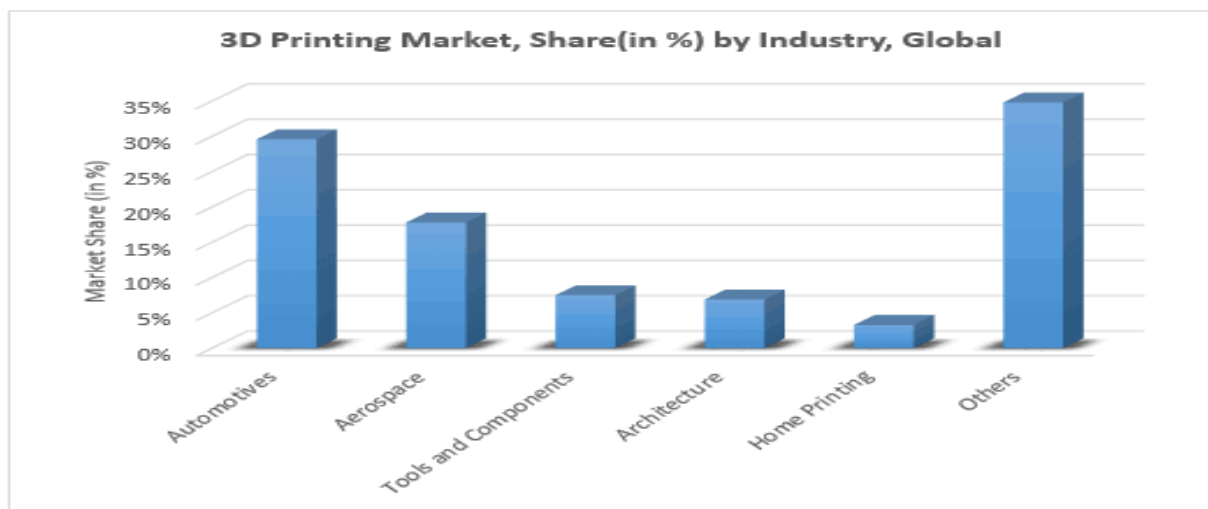
how the object is positioned on the print bed during the printing process. It plays a crucial role in the quality, strength, and print time of the final part. Here are the main factors to consider when deciding on part orientation:

4.2 Layer Thickness: Layer thickness impacts both surface finish and print time; thinner layers can produce finer details but take longer to print.

Thinner Layers: A smaller layer thickness (e.g., 0.05 mm to 0.1 mm) leads to higher resolution and a smoother surface finish, as the layers are finer and more details are captured. This is ideal for prints with intricate features or when appearance is a priority.

Thicker Layers: Larger layer thicknesses (e.g., 0.2 mm to 0.4 mm) result in a more visible layer structure and a rougher surface finish. However, thicker layers can be suitable for larger parts where surface finish is less critical. **Print Speed:** Print speed in 3D printing refers to the rate at which the printer's nozzle moves while extruding material. It is usually measured in millimeters per second (mm/s) and is an important factor that influences both the quality and the time required to complete a print. Here's a deeper look at how print speed affects 3D printing and some tips for optimizing it: **Thinner Layers:** While providing a smoother finish, thinner layers require more time to print because the printer has to make more passes (i.e., more layers) to complete the object. As a result, prints with smaller layer heights take longer. **Thicker Layers:** Using thicker layers reduces the number of passes, which leads to a faster print. However, this comes at the cost of resolution and the potential for visible layer lines.

4.3 Raster Angle and Width: The angle at which material is deposited affects layer bonding strength and porosity. **Common Raster Angles:** 0° and 90°: These are common in alternating layers, providing a grid-like structure. They offer good strength in both directions. 45° and 135°: These angles often result in stronger parts with more balanced stress distribution across both axes. This is commonly used for infill patterns. **Random Angles:** Sometimes, a random raster angle is used to help with better bonding between layers and reduce directional weaknesses.

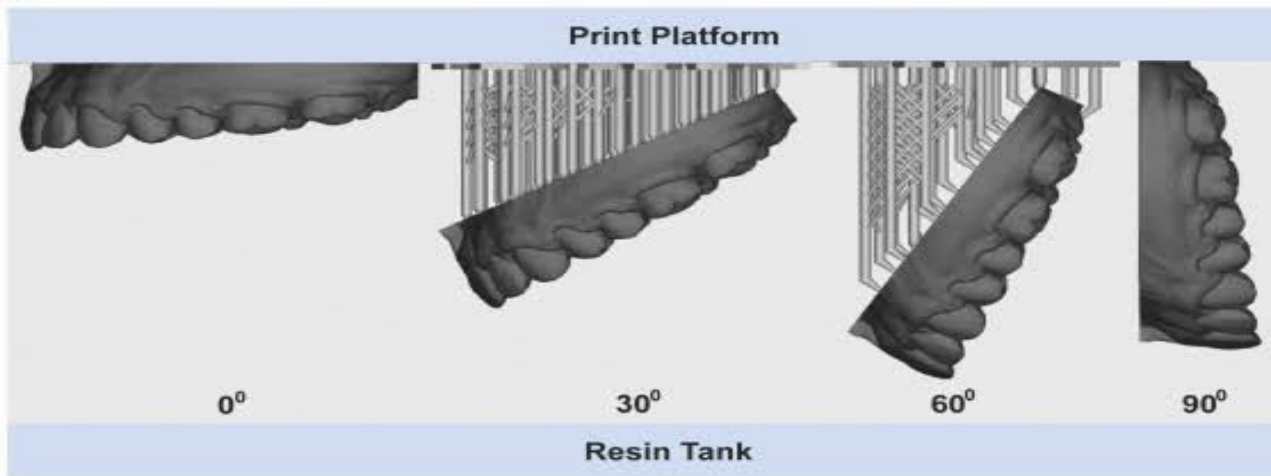


4.4 Raster-to-Raster Gap (Air Gap): The gap between adjacent layers influences how well they stick together; reducing this gap can improve strength. The raster-to-raster gap in 3D printing refers to the small space between the individual lines of material laid down by the printer. Gaps can result from improper extrusion settings, under-extrusion, incorrect slicing parameters (like line width and infill overlap), or low infill density. Minimizing raster-to-raster gaps improves the strength, surface quality, and overall integrity of a printed part. Adjusting slicer settings (e.g., extrusion width, infill overlap, infill density) and calibrating the printer can help reduce or eliminate unwanted gaps.

A

Build angle \ Layer height	20µm	50µm	100µm
0°	Group 1	Group 2	Group 3
30°	Group 4	Group 5	Group 6
60°	Group 7	Group 8	Group 9
90°	Group 10	Group 11	Group 12

B



4.5 Deposition Speed: The speed at which material is deposited affects layer adhesion; finding the right speed is crucial for good structural integrity. In 3D printing, part orientation refers to how the object is positioned on the print bed during the printing process. It plays a crucial role in the quality, strength, and print time of the final part. Here are the main factors to consider when deciding on part orientation:

- 1. Strength and Durability:** Layer Lines: 3D printed parts are often weaker along the layers due to the bonding of each layer. For greater strength, it's generally better to orient the part so that the most stressed areas align with the print's strongest axis (usually the Z-axis, or the vertical direction). Overhangs and Supports: Parts with overhangs (areas that extend outward without support beneath them) may require support structures. Orienting the part to minimize overhangs can reduce the need for supports, save material, and reduce post-processing time.
- 2. Surface Finish:** Top Surface: The top surface of a part (the side facing up) typically has a smoother finish because it is printed last, with fewer layers above it. Therefore, it's beneficial to orient the part so that the most visible or aesthetic surfaces are oriented upwards to minimize layer lines.
- 3. Bottom Surface:** The bottom surface (the one in contact with the build plate) may have visible striations or roughness due to bed adhesion, so it's often best to hide this side if appearance is important.
- 4. Support Structures:** Some prints will need support structures, especially for overhangs or bridges. Orienting the part in a way that minimizes the need for supports can save time, material, and effort in post-processing. However, in some cases, supports may be unavoidable if the geometry of the part requires it.
- 5. Warping and Bed Adhesion:** Parts that have large flat surfaces can experience warping or detachment from the print bed if not oriented correctly. For example, larger flat areas are more prone to warping in materials like ABS. Orienting the part in a way that minimizes large flat areas and maximizes surface area contact with the bed can help improve adhesion and reduce warping.
- 6. Feature Accessibility:** If a part has intricate features, such as small holes or complex geometries, the orientation can influence whether those features are printable without excessive support structures. For instance, orienting a part so that holes or internal channels are aligned with the print layers can help ensure they're printed properly.
- 7. Material Considerations:** Different materials have different printing characteristics. Some materials, like PLA, are more forgiving with overhangs and warping, while others like ABS may require more careful orientation to avoid issues. Always consider the material's properties when deciding on the orientation.



V. CHARACTERISTICS OF FDM PARTS

5.1 Dimensional Accuracy: Dimensional accuracy refers to how closely the final dimensions match the design specifications; this is influenced by factors like layer thickness and printer calibration. Dimensional accuracy in 3D printing refers to how closely the printed object matches the intended design in terms of size and shape. Achieving high dimensional accuracy is crucial for functional parts, prototypes, and models where precise tolerances are required. Several factors influence the dimensional accuracy of 3D prints:

1. Printer Calibration: Extruder Calibration: If the extruder isn't calibrated correctly, it can lead to over- or under-extrusion, affecting the final dimensions of the print. Axis Alignment: The X, Y, and Z axes should be aligned and free of play to ensure the print stays within dimensional tolerance. Bed Leveling: A misleveled bed can cause uneven layers, affecting the print's overall size and surface finish.

2. Material Choice: Different materials expand or contract at different rates, which can affect dimensional accuracy: Thermal Shrinkage: Materials like PLA, ABS, and nylon can shrink as they cool, especially during cooling after layer deposition, which can lead to warping or dimensional changes. Material Type: Some materials are more prone to dimensional inaccuracies due to their thermal properties. ABS, for example, is more prone to warping compared to PLA.

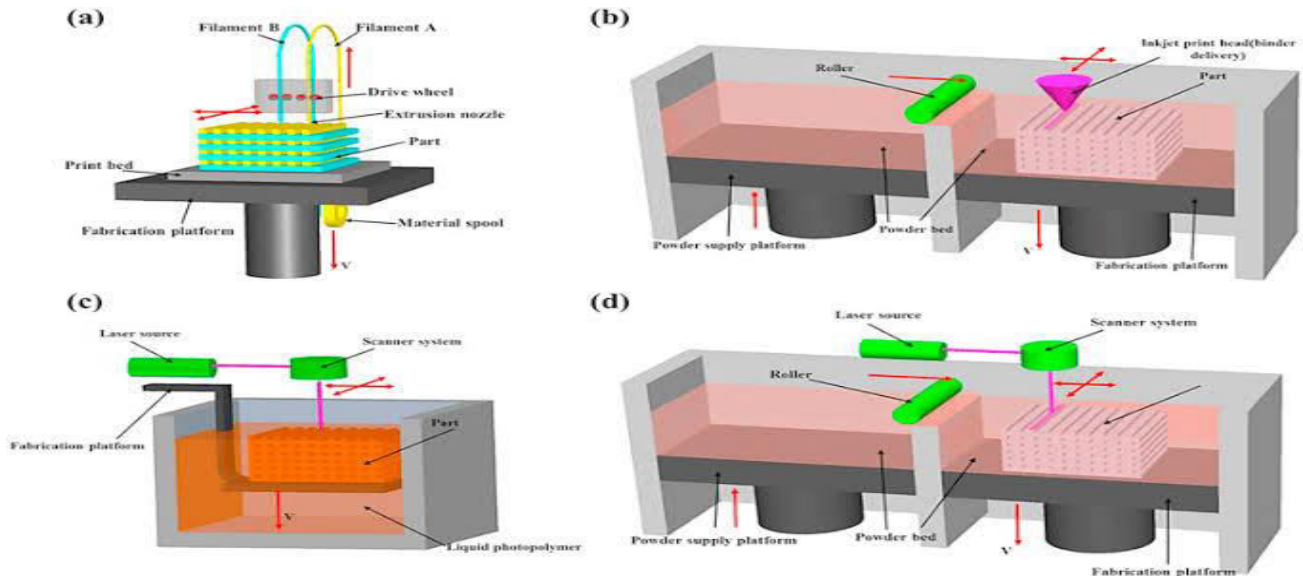
3. Printing Temperature: Temperature fluctuations can impact the material's flow rate and adhesion between layers, leading to dimensional discrepancies. Maintaining a consistent hotend and heated bed temperature can help improve accuracy.

5.2 Surface Roughness: Surface roughness can be a challenge due to the layer-by-layer nature of FDM; techniques like adaptive slicing or chemical smoothing can help improve this issue.

1. Vapor Smoothing (SLA or Resin Prints): How it works: SLA prints can benefit from a process called vapor smoothing, which involves exposing the print to vapors from a solvent (often alcohol-based) that smooths the resin's surface.

2. Polishing (Mechanical or Chemical):How it works: Polishing, either mechanically or chemically, smooths out the surface to create a glossy finish.

3. Heat Treatment or Annealing:How it works: Heat treatment involves carefully heating a printed part to a temperature just below its melting point to reduce internal stresses and improve the material's strength and surface finish.



5.3 Mechanical Strength: Mechanical strength depends on factors such as infill density (the amount of material inside a part) and fill patterns; optimizing these settings is essential for parts that need to bear loads. Chemical Smoothing (for FDM)

Material Choice: Different 3D printing materials have different mechanical properties, such as tensile strength, impact resistance, and elasticity. Common materials include:

PLA (Polylactic Acid): Strong and rigid, but brittle with lower impact resistance. Suitable for prototypes but not for load-bearing parts.

ABS (Acrylonitrile Butadiene Styrene): Stronger and more impact-resistant than PLA, but more prone to warping. Suitable for functional parts.

PETG (Polyethylene Terephthalate Glycol): Offers a balance of strength, flexibility, and impact resistance. Less brittle than PLA and easier to print than ABS.

Nylon: High tensile strength, toughness, and flexibility. Great for parts that require durability and wear resistance.

VI. CAPABILITY

Material capabilities of 3D printing materials are well-versed by their molecular constructions, and also depend on a material's dispensation during printing. Properties of 3D-printed parts are reliant on their material construction and printing method, and therefore need widespread testing of groupings of material/3D printing parameters to regulate material abilities for a given uses [10]. For occurrence, a part's mechanical retort when made up with FDM is adaptable based on the 3D printed layer width, extrusion temperature, and build angle [11], [12]. The below-given Table 1 provides the summary of restrained mechanical properties of nearly mutual polymer 3D-printed materials established as solid samples. Supplementary proceedings in the table provide background for how testing was carried out to deliver a range of mechanical properties. Material properties contain strength and stiffness associated systems of measurement that are key properties for choosing appropriate materials for mechanical uses.

Table 1 Measured part properties systematized by material

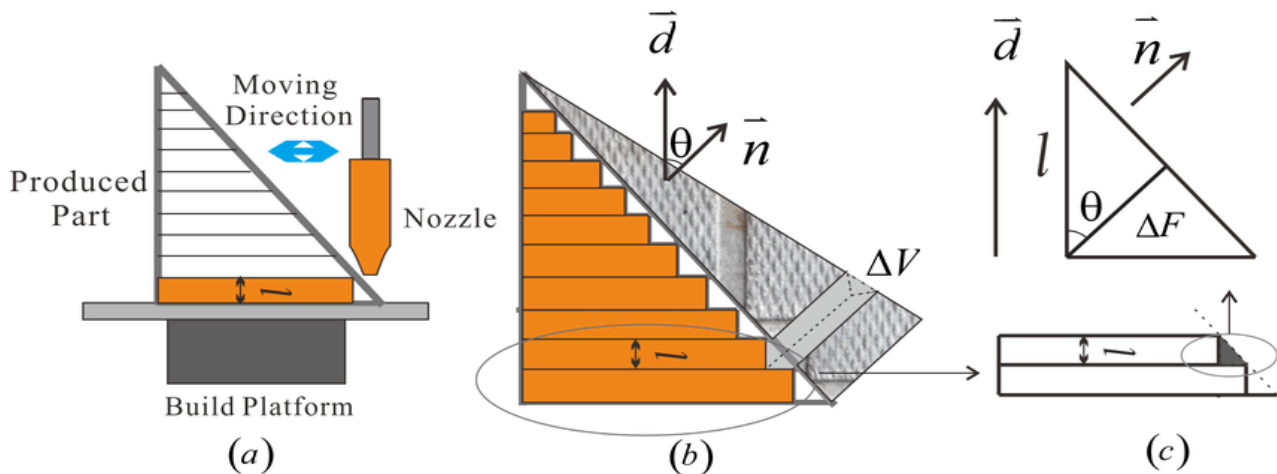
Materials	Measured Properties	Manufacturing Technique	References
Acrylonitrile butadiene styrene (ABS)	Tensile Strength: 25–35 MPa; Elastic Modulus: 1310–1520 MPa; Orientation angle of 0° to 90°	FDM	[11]
Acrylonitrile butadiene styrene (ABS)	Tensile Strength: 25–35 MPa; Layer Width: 0.06–0.12 mm; Nozzle temperature: 200–250 °C	FDM	[12]
Acrylonitrile butadiene styrene (ABS)	Tensile Strength: 32 MPa; Elastic Modulus: 1200 MPa	FDM	[13]
Polycarbonate (PC) and Biomaterial blend	Tensile Strength: 25–55 MPa; Elastic Modulus: 2100 MPa; Nozzle Temperature: 210–240 °C; Orientation angle of 0° to 90°	FDM	[12]
Polycarbonate (PC)	Tensile Strength: 27 MPa; Elastic Modulus: 1500 MPa	FDM	[13]
Polyethylene terephthalate glycol (PETG)	Tensile Strength: 46–60 MPa; Layer width: 0.04–0.1 mm	FDM	[11]
Polycarbonate (PC) and Fossil-fuel blend	Tensile Strength: 28–62 MPa; Elastic Modulus: 1300–1500 MPa; Orientations of 0° to 90°	FDM	[12]
Polylactic acid	Tensile Strength: 265 MPa; Yield Strength: 205 MPa; Elastic Modulus: 4400 MPa	FDM	[14]
Nylon	Tensile Strength: 45–50 MPa; Elastic Modulus: 1250–1350 MPa	Multi-jet fusion	[15]
Acrylic-based material	Elastic Modulus: 1750–2000 MPa; Orientations of 0° to 60°.	Polyjet	[1]
Epoxy-based material	Tensile Strength: 25–45 MPa; Elastic Modulus: 2000–2300 MPa	Stereolithography	[16]

VII. CHALLENGES AND OPTIMIZATION TECHNIQUES

7.1 Adaptive Slicing: Adaptive slicing varies layer thickness based on part geometry to balance surface quality with print speed.

7.2 Chemical Post-Processing: Chemical treatments like acetone smoothing for ABS can enhance surface finish by creating a smoother outer layer.

7.3 Improved Support Structures: Optimizing support structures can reduce material waste while ensuring adequate support for complex shapes during printing.



VIII. CONCLUSION

Fused Deposition Modeling offers a flexible approach to additive manufacturing with significant benefits in cost-effectiveness and design freedom. While challenges remain regarding surface finish and mechanical strength, ongoing research into optimizing parameters and post-processing techniques continues to enhance part quality. Future studies should focus on exploring advanced materials and automation technologies to further improve FDM applications across various industries.

REFERENCES

1. Crump, S.S., "Apparatus and Method for Creating Three-Dimensional Objects," US Patent No. 5,121,329, 1992.
2. Thomas, S., Rajesh, P., "Influence of Layer Thickness on Surface Finish in FDM," *Journal of AM Processes*, 2022.
3. Wang, L., Zhang, Z., "Effect of Infill Density on FDM Part Strength," *Materials Journal*, 2021.
4. O'Brien, C., "3D Printing in Medicine: The Role of FDM in Customized Implants," *Additive Manufacturing*, 2022.
5. Rahman, M.T., et al., "Composite Filaments for Fused Deposition Modelling in Biomedical Applications," *Advanced Healthcare Materials*, 2021.
6. Janarthanan Gopinathan, Insup Noh *Biomaterials research* 22 (1), 11, 2018.
7. Multiprocess 3D printing for increasing component functionality Eric MacDonald, Ryan Wicker *Science* 353 (6307), aaf2093, 2016.
8. Ten challenges in 3D printing William Oropallo, *Les A Piegl Engineering with Computers* 32, 135-148, 2016.
9. History of 3D printing Amanda Su, Subhi J Al'Aref *3D printing applications in cardiovascular medicine*, 1-10, 2018.
10. The impact and application of 3D printing technology Thabiso Peter Mporfu, Cephas Mawere, Macdonald Mukosera *International Journal of Science and Research (IJSR)*, 2014.
11. 3D printing: Printing precision and application in food sector Zhenbin Liu, Min Zhang, Bhesh Bhandari, Yuchuan Wang *Trends in Food Science & Technology* 69, 83-94, 2017.
12. 3D printing—A review of processes, materials and applications in industry 4.0 Anketa Jandyal, Ikshita Chaturvedi, Ishika Wazir, Ankush Raina, Mir Irfan Ul Haq *Sustainable Operations and Computers* 3, 33-42, 2022.
13. Practical 3D printers: The science and art of 3D printing Brian Evans *Apress*, 2012
14. review paper on 3D-printing aspects and various processes used in the 3D-printing Vinod G Gokhare, DN Raut, DK Shinde *Int. J. Eng. Res. Technol* 6 (06), 953-958, 2017
15. *Fabricated: The new world of 3D printing* Hod Lipson, Melba Kurman John Wiley & Sons, 2013.
16. *The 3D printing handbook: technologies, design and applications* Ben Redwood, Filemon Schffer, Brian Garret 3D Hubs, 2017.



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