

A Framework for Predictive Decision Support System for Additive Manufacturing Techniques: Insights from Material Data

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Abstract

The industrial transformation of today depends heavily on additive manufacturing because of its high resolution and accuracy. The most widely utilized methods are stereolithography (SLA), selective laser melting (SLM), selective laser sintering (SLS), and fused deposition modeling (FDM). Since the advent of additive manufacturing, many new materials have emerged in various formats, such as solid and powder. With the increase in available materials, manufacturers often struggle to choose the right techniques, as there are limited methods and cost considerations to account for selecting the right materials in additive manufacturing (AM) is crucial for improving the performance, cost-efficiency, and the overall success of the final product. The selection involves balancing costs with performance requirements and is essential for achieving the desired performance, ensuring process compatibility, controlling costs, and meeting design and regulatory standards. The research paper focuses on how to choose the appropriate technique for a given material using a prediction decision support system, which has been developed based on the provided material data to have better cost-efficiency.

Keywords: Additive Manufacturing, Material Data, Predictive Decision Support System, Framework

1.0 INTRODUCTION

Due to its efficiency in producing complicated structures, excellent surface polish, and shorter production times, Additive Manufacturing (AM) is a popular choice for prototype and production in many industries. However, with the growth of available materials, the demand for AM is steadily increasing. Product developers often need to test a model before proceeding with

actual development. Selecting the appropriate technique for a given material can be challenging, and developers may struggle to identify the optimal approach. The research paper addresses this issue by developing a predictive decision support system. The system allows developers to input material data and receive recommendations for the most suitable and efficient AM techniques in order to have cost effectiveness.

2.0 LITERATURE REVIEW

Stereolithography (SLA), Selective Laser Sintering (SLS), Selective Laser Melting (SLM), Fused Deposition Modeling (FDM), and Laminated Object Manufacturing (LOM) are the five main additive manufacturing processes. Many materials are used in additive manufacturing, such as metals, polymers, alloys, ceramics, sticky sheets, and metal powders. [1]. Despite the broad range of materials and methods, these techniques share the core principle of building components through a layer-by-layer additive process [2]. Every phase of the additive manufacturing process is essential to guaranteeing that the finished product satisfies quality standards and design requirements. The focus of current research is on large-scale structure production using scalable techniques, bioprinting for medical purposes, and integrating artificial intelligence to enhance printing procedures and material qualities. [3].

Fused Deposition Modeling (FDM) uses thermoplastic polymers supplied as filaments on spools, each typically holding about 500 cubic centimeters of material. The FDM method is popular in affordable 3D printers for individual users and small businesses [4]. Common FDM materials include ABS, ULTEM 9085, polycarbonate (PC), carbon fiber composites, PLA, and PC-ISO, suitable for aerospace, automotive, and wind energy applications [5].

Stereolithography (SLA) employs photopolymer resins that are cured and removed from resin tanks. It precisely aligns optical elements like lenses and mirrors as it scans each layer of the object with a single ultraviolet (UV) laser beam [6]. SLA has the advantage of not requiring stringent control over properties such as surface tension,

viscosity, and volatility, unlike inkjet-based methods [7]. Components are cleaned using isopropyl alcohol (IPA) or other solvents after printing in order to get rid of any remaining uncured resin. [8]. Common SLA materials include Durable Resin, Epoxy Resin, Grey Resin, Tough Resin, Clear Resin, and Zirconia Methylpropane (TMP) [9]. SLA is especially valued in dental applications for its accuracy, resolution, and smooth surface finish [10].

For optimal performance in Selective Laser Sintering (SLS) systems, Particle size distribution (PSD) for the powder should be between 20 and 80 μm [11]. In the SLS process, a laser with carefully controlled energy selectively sinters the powder particles at a molecular level, forming a solid structure without completely liquefying the material. SLS is distinctive among rapid prototyping methods as it can directly manufacture metallic components without the need for a polymer binder [13]. Common materials used in SLS include polyamides, PMMA/PS, titanium, and tungsten carbide [14]. This technique contrasts with methods that involve complete melting, which are typically employed for metals and ceramics [15].

One of the first commercially accessible additive manufacturing processes, Laminated Object Manufacturing (LOM), entails the successive layering and gluing of materials, such as paper, plastic, or metal. As a branch of Selective Laser technologies, LOM uses continuous sheets of paper or polymer tapes, which are layered and laminated to form complex three-dimensional shapes [16]. These layers are precisely cut to correspond with the cross-sections of the intended object, often utilizing lasers or mechanical cutters [17]. Common materials in LOM include adhesive-coated sheets,

aluminum sheets, and natural materials such as sawdust and graphene foams derived from graphite. The method is known for its high accuracy, achieved through thin layer thickness, typically around 0.1 mm [18].

In contrast to selective laser sintering (SLS), a sophisticated powderbed fusion additive manufacturing technology known as selective laser melting (SLM) entirely melts the powdered material. A temperature that is marginally below melting point is maintained for the powder inside the build chamber during the SLM process. A temperature that is marginally below melting point is maintained for the powder inside the build chamber during the SLM process. Despite its significant potential, the widespread implementation of SLM technology in industries is constrained by challenges such as thermal cracking [19]. In SLM, a laser provides the heat necessary to completely melt the powder, unlike the partial melting seen in SLS [21]. This technique primarily uses metal powders, including 18Ni300 maraging steel [12], Inconel 718, and Inconel 625, to produce components that are both highly dense and structurally robust [20]. Top of Form

This research paper focuses on developing a program to select the appropriate additive manufacturing process. The predictive system identifies the most suitable method for a given material. An extensive review of relevant research literature has demonstrated that this proposed system effectively forecasts the appropriate additive manufacturing technique.

3.0 METHODOLOGY

Figure 1: illustrates the suggested system's process.

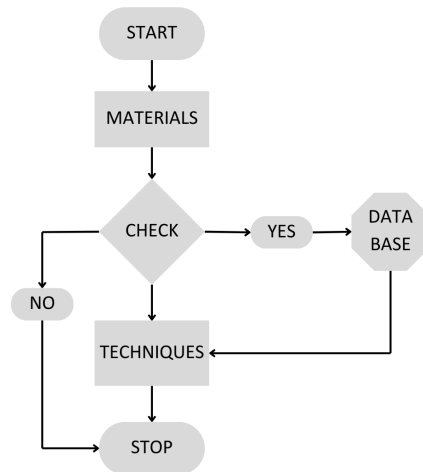


FIGURE 1: Predictive system flow chart.

The process begins with prediction system activation, followed by material selection by product users. If the chosen material is available in the database, the system continues; if not, it terminates the prediction process. Upon confirming material availability, the system searches for suitable manufacturing techniques and retrieves relevant information. The appropriate technique is then displayed, concluding the prediction process. The first step involves identifying materials provided by developers, who choose additive manufacturing techniques based on material availability and feasibility. The focus then shifts to selecting the appropriate additive manufacturing techniques. This study specifically examines These are some of the most popular techniques in additive manufacturing: Selective Laser Sintering (SLS), Laminated Object Manufacturing (LOM), Selective Deposition Modelling (FDM), Stereolithography (SLA), and Selective

Laser Melting (SLM). Matching materials with appropriate additive manufacturing techniques is a critical step that follows material and technique analysis. Each material's unique properties determine its compatibility with specific techniques; for example, solid materials are generally compatible with Fused Deposition Modelling (FDM). A database is previous created with two tables to organize the collected information. The first table lists the additive manufacturing techniques, each with an identification number. The second table details the materials associated with these techniques, linking them through the identification numbers from the first table. Each entry in the second table is tied to a specific technique based on the material's properties.

4.0 RESULTS AND DISCUSSIONS

Fig. 2, 3, and 4 present the different examples for the different inputs from the users. A user interface has been designed for users, which will display a list of materials.



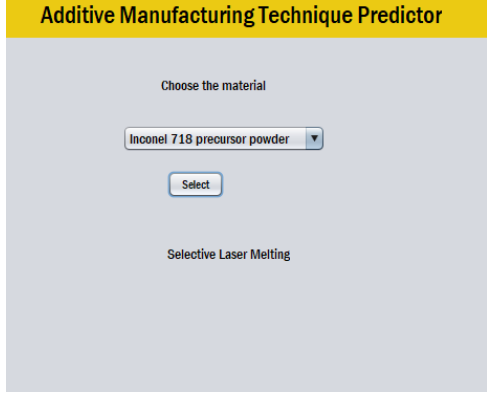
The screenshot shows a web interface titled "Additive Manufacturing Technique Predictor". It features a dropdown menu labeled "Choose the material" with "Zirconia" selected. Below the dropdown is a "Select" button. At the bottom of the interface, the text "Stereolithography" is displayed.

FIG. 2: Example 1 Zirconia material - Stereolithography



The screenshot shows a web interface titled "Additive Manufacturing Technique Predictor". It features a dropdown menu labeled "Choose the material" with "PMMA/PS" selected. Below the dropdown is a "Select" button. At the bottom of the interface, the text "Selective Laser Sintering" is displayed.

FIG. 3: Example 2 PMMA/PS material - Selective Laser Sintering



The screenshot shows a web interface titled "Additive Manufacturing Technique Predictor". It features a dropdown menu labeled "Choose the material" with "Inconel 718 precursor powder" selected. Below the dropdown is a "Select" button. At the bottom of the interface, the text "Selective Laser Melting" is displayed.

FIG. 4: Example 3 Inconel Material - Selective Laser Melting

When a user selects a material from the list, the system will recommend an appropriate additive manufacturing technique. For example, as shown in the fig. 3, if PMMA/PS is selected, the system will suggest Selective Laser Sintering (SLS) as the suitable technique. Top of Form Thus by predicting the appropriate technique for the given material, cost efficiency is improved as inappropriate selection of techniques will end up with increase in cost which involves in material cost because of wastage of materials and manufacturing cost because of high per hour cost in AM.

5.0 CONCLUSIONS

Additive manufacturing is revolutionizing industries through increased accuracy and reduced production time. Despite the technology's widespread availability, manufacturers frequently encounter challenges in selecting the correct materials for each technique. To address this, a predictive decision support system has been developed to determine the most appropriate technique for a given material.

Manufacturers input the material into the system, which then checks the material against a database. If the material is found, the system identifies and displays the suitable manufacturing technique. This process streamlines and enhances the efficiency of production. Additionally, the system includes features for updating the database with new materials or technologies, ensuring ongoing accuracy and adaptability. The system works by allowing manufacturers to input a material, which is then matched against a comprehensive database. Upon finding a match, the system recommends the most suitable manufacturing technique for that specific material and displays it to the manufacturer. This approach simplifies the decision-making process, ensuring that production is both efficient and cost effective.

Beyond merely facilitating the selection process, the system also significantly reduces the time required for manufacturers to choose the appropriate technique, cutting down on costs, material wastage, and overall manufacturing lead time.

REFERENCES

[1] D. Bourell et al., "Materials for additive manufacturing," *CIRP Annals*

- *Manufacturing Technology*, vol. 66, no. 2, pp. 659–681, 2017, Doi: 10.1016/j.cirp.2017.05.009.
- [2] S. Singh, S. Ramakrishna, and R. Singh, "Material issues in additive manufacturing: A review," *Journal of Manufacturing Processes*, vol. 25. Elsevier Ltd, pp. 185–200, Jan. 01, 2017. Doi: 10.1016/j.jmapro.2016.11.006.
- [3] Additive Manufacturing: A Comprehensive Review Longfei Zhou *, Jenna Miller, Jeremiah Vezza, Maksim Mayster, Muhammad Raffay, Quentin Justice, Zainab Al Tamimi, Gavyn Hansotte, Lavanya Devi Sunkara and Jessica Bernat <https://doi.org/10.3390/s24092668>
- [4] R. Melnikova, A. Ehrmann, and K. Finsterbusch, "3D printing of textile-based structures by Fused Deposition Modelling (FDM) with different polymer materials," in *IOP Conference Series: Materials Science and Engineering*, 2014, vol. 62, no. 1. Doi: 10.1088/1757-899X/62/1/012018.
- [5] F. Ning, W. Cong, J. Qiu, J. Wei, and S. Wang, "Additive manufacturing of carbon fiber reinforced thermoplastic composites using fused deposition modeling," *Composites Part B: Engineering*, vol. 80, pp. 369–378, Oct. 2015, Doi: 10.1016/j.compositesb.2015.06.013.
- [6] J. Borrello, P. Nasser, J. C. Iatridis, and K. D. Costa, "3D printing a mechanically-tunable acrylate resin on a commercial DLP-SLA printer," *Additive Manufacturing*, vol. 23, pp. 374–380, Oct. 2018, Doi: 10.1016/j.addma.2018.08.019.
- [7] M. Layani, X. Wang, and S. Mag dassi, "Novel Materials for 3D Printing by Photopolymerization," *Advanced Materials*, vol. 30, no. 41. Wiley-VCH Verlag, Oct. 11, 2018. Doi: 10.1002/adma.201706344.
- [8] C. Riccio et al., "Effects of Curing on Photosensitive Resins in SLA Additive Manufacturing," *Applied Mechanics*, vol. 2, no. 4, pp. 942–955, Nov. 2021, Doi: 10.3390/applmech2040055.

- [9] C. Dall'Argine, A. Hochwallner, N. Klikovits, R. Liska, J. Stampf, and M. Sangermano, "Hot-Lithography SLA-3D Printing of Epoxy Resin," *Macromolecular Materials and Engineering*, vol. 305, no. 10, Oct. 2020, doi: 10.1002/mame.202000325.
- [10] L. N. Khanlar, A. S. Rios, A. Tahmaseb, and A. Zandinejad, "Additive manufacturing of zirconia ceramic and its application in clinical dentistry: A review," *Dentistry Journal*, vol. 9, no. 9. MDPI, Sep. 01, 2021. Doi: 10.3390/DJ9090104.
- [11] M. Schmid, A. Amado, and K. Wegener, "Materials perspective of polymers for additive manufacturing with selective laser sintering," *Journal of Materials Research*, vol. 29, no. 17, pp. 1824–1832, Jun. 2014, Doi: 10.1557/jmr.2014.138.
- [12] M. Anilli, A. G. Demir, and B. Previtali, "Additive manufacturing of laser cutting nozzles by SLM: processing, finishing and functional characterization," *Rapid Prototyping Journal*, vol. 24, no. 3, pp. 562–583, 2018, Doi: 10.1108/RPJ-05-2017-0106.
- [13] J. P. Kruth, X. Wang, T. Laoui, and L. Froyen, "Lasers and materials in selective laser sintering" [Online]. Available: <http://www.emeraldinsight.com/researchregisterhttp://www.emeraldinsight.com/0144-5154.htm>
- [14] P. M., "Additive Manufacturing of Tungsten Carbide Hardmetal Parts by Selective Laser Melting (SLM), Selective Laser Sintering (SLS) and Binder Jet 3D Printing (BJ3DP) Techniques," *Lasers in Manufacturing and Materials Processing*, vol. 7, no. 3. Springer, pp. 338–371, Sep. 01, 2020. doi: 10.1007/s40516-020-00124-0.
- [15] S. F. S. Shirazi et al., "A review on powder-based additive manufacturing for tissue engineering: Selective laser sintering and inkjet 3D printing," *Science and Technology of Advanced Materials*, vol. 16, no. 3. Institute of Physics Publishing, Jun. 01, 2015. doi: 10.1088/1468-6996/16/3/033502.
- [16] B. Dermeik and N. Travitzky, "Laminated Object Manufacturing of Ceramic-Based Materials," *Advanced Engineering Materials*, vol. 22, no. 9. Wiley-VCH Verlag, Sep. 01, 2020. doi: 10.1002/adem.202000256.
- [17] M. Prechtel, A. Otto, and M. Geiger, "Rapid Tooling by Laminated Object Manufacturing of Metal Foil," *Advanced Materials Research*, vol. 6–8, pp. 303–312, May 2005, doi: 10.4028/www.scientific.net/amr.6-8.303.
- [18] Y. Tao, Q. Yin, and P. Li, "An additive manufacturing method using large-scale wood inspired by laminated object manufacturing and plywood technology," *Polymers (Basel)*, vol. 13, no. 1, pp. 1–10, Jan. 2021, doi: 10.3390/polym13010144.
- [19] "Additive manufacturing: Challenges, trends, and applications," Osama Abdul hameed <https://orcid.org/0000-0003-0799-2711>, Abdulrahman AlAhmari <https://orcid.org/0000-0002-3079-0141>, Wadea Ameen, and Syed Hammad Mian
- [20] L. E. Murr et al., "Fabrication of metal and alloy components by additive manufacturing: Examples of 3D materials science," *Journal of Materials Research and Technology*, vol. 1, no. 1. Elsevier Editora Ltda, pp. 42–54, 2012. doi: 10.1016/S2238-7854(12)70009-1.
- [21] Sebastian Thiedea, *, Mathias Wiese, Christoph Herrmann," Upscaling strategies for polymer additive manufacturing: an assessment from economic and environmental perspective for SLS, MJF and DLP" 54th CIRP Conference on Manufacturing Systems, Manufacturing Systems, Faculty of Engineering Technology, Department of Design, Production & Management, University of Twente, De Horst 2, Building 20, Enschede, 7522 LW, The Netherlands