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A Review on Process Parameters of Additive Manufacturing

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Abstract – *The importance of dimensional accuracy in produced models has been highlighted by the use of FDM technology for prototyping in industries such as aerospace and medical. Several process factors, such as layer thickness, raster width, infill pattern, etc., can impact the dimensional accuracy of FDM-printed objects. The goal of this research is to conduct a systematic literature review of studies that examined the impact of process parameters on the dimensional accuracy of FDM printed parts. This will allow us to better understand the effect of each parameter individually and to find the optimal levels of each parameter based on the material types. The effects of layer thickness, extrusion temperature, and component orientation on common materials like ABS and PLA were outlined, along with a review of 29 related papers. Tables summarized the key findings from each study, revealing the optimum value for each process parameter and describing the articles' respective methods. Layer thickness levels between 0.1 and 0.2 millimetres are recommended for ABS and PLA parts, whereas higher layer thickness values are typically associated with greater precision for ASA and Nylon parts. The extrusion temperature is determined to be optimally low, and this parameter is also less sensitive to variations in the material being used. With regards to part orientation, it has been determined that 0 degrees is best for ABS printed parts while 90Ois best for PLA printed parts. Furthermore, additional factors like the geometry of the part, the type of resin, and the varying dimensions of the part are likely to affect the ideal level of each process parameter. It is important to account for the impact of confounding variables when trying to understand the effect of each process parameter on the dimensional accuracy of FDM printed items.*

Keywords- Additive manufacturing, ABS, FDM, PLA. ASA

I- INTRODUCTION

Additive manufacturing techniques like Fused Deposition Modeling (FDM) are widely utilized to create prototypes because of their low cost. In general, FDM is a method of manufacturing components that involves printing a model from the bottom up or the top down by extruding layers of thermoplastic materials [1]. Bottom-up construction is used in the FDM printing

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process, as seen in Figure 1. After being heated, the filament is extruded via the printer's nozzle and onto the build platform. When the model cools down to room temperature, the printed layers harden. FDM (Fused Disposition Modeling) technology has been used more and more in medicine, cars, and the aerospace industry in recent years [2, 3]. Since aerospace prototyping is used to study how models act when fluids move through them, there is a high demand for the overall quality of models.

The accuracy of the sizes of FDM-printed models is one of the most important things that determine the overall quality of prototypes because it affects the results of prototype studies [3]. It has been found that different printing parameters, such as layer thickness, extrusion temperature, raster width, printing speed, infill pattern, etc., have a big effect on the accuracy of the dimensions [4]. Most of the studies have looked at different combinations of process parameters to find the best set of parameters for making FDM parts with better dimensions. There is still a lack of data on how each parameter impacts unique resin types like ABS, PLA, and others. The study's overarching objective is to determine how different materials impact the optimal range for three process parameters: layer thickness, extrusion temperature, and component orientation.

This paper's greatest contribution is a more nuanced comprehension of how various process parameters influence the dimensional accuracy of FDM components fabricated from ABS, PLA, and other resins.

One of the most critical factors determining the overall quality of prototypes is the accuracy of the sizes of Fused Diffused Method-printed models, as this impacts the outcomes of prototype studies [3]. Extrusion temperature, layer thickness, raster width, infill pattern, printing speed, etc. are only few of the printing characteristics that have been discovered to significantly impact dimensional accuracy [4]. Studies have mostly focused on identifying the optimal set of process parameters for producing FDM parts with improved dimensions. In spite of this, there is a lack of data on the effects of each parameter on PLA, ABS, and other resins. The purpose of this research is to determine how different materials affect the optimal level of process parameters by analyzing the effects of extrusion temperature, layer thickness, and component orientation. The most important takeaway from this research is an understanding of how different process parameters affect the dimensional accuracy of FDM components made from different materials including ABS, PLA, and other resins.

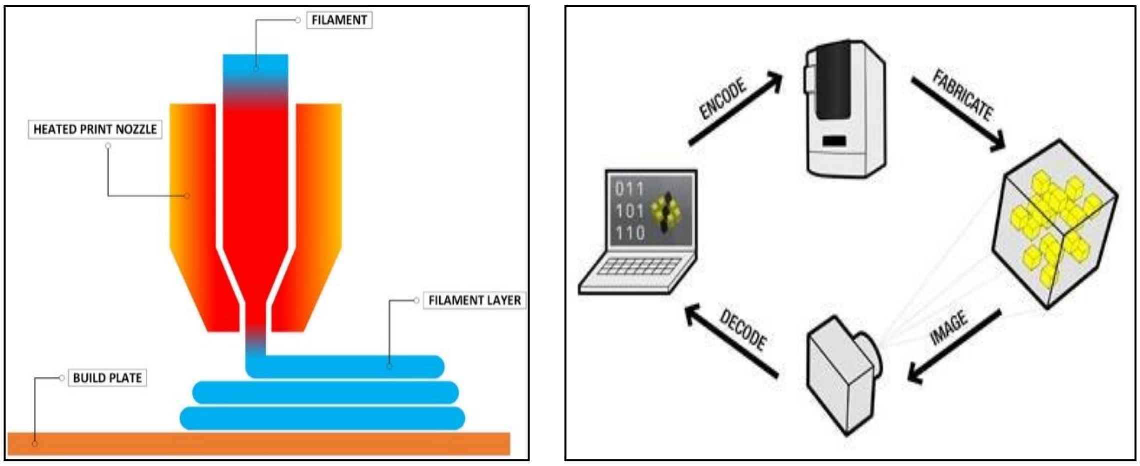

Fig. 1: Working principal of 3D printer [3]

LAYER THICKNESS EFFECT

According to literature study, the accuracy of an FDM-printed part is dependent on several factors, including layer thickness, part orientation, and shell thickness [6]. The findings of an ANOVA analysis [7] emphasized its significance (12.23% contribution), second only to the raster width parameter. The layer thickness is

determined to be directly proportional to the part dimension (r = 0.352) [7]. This indicates that greater dimensional discrepancies occur when thicker layers are used to create larger pieces. Table 1 is a summary of 19 publications that explore the impact of layer thickness on the dimensional accuracy of FDM components for a variety of materials, including ABS, PLA, and other resins. ABS resin was employed in more than 50% of the trials that were analysed. Figure 2 displays the distribution of evaluated articles across resin types
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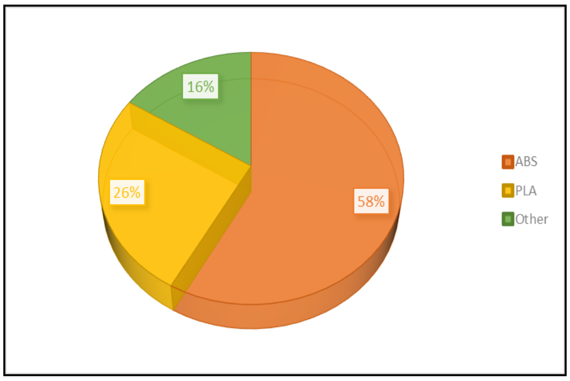

Fig. 2: Research related to Layer thickness

Table 1: The summery of research article discussing effect of the layer thickness on dimensional accuracy.

Material	**Reference**	**Layer thickness (mm)**	**Conclusion**
ABS	8	0.1	The printed cubes have more volume than the digital model.
ABS	6	0.2	The volume of the printed cubes was less than that of the CAD models.
ABS	9	0.2	Studied the accuracy of helical surface
ABS	11	0.25	We looked at the effects of several geometric forms on a plate-like model's shrinking viz. cone, rectangle, cylinder and pyramid.
ABS	16	0.178	The part's thickness grows while its length and breadth decrease..
PLA	5	0.1	The part's thickness grows while its length and breadth decrease.
PLA	17	0.2	It was determined that a 0.2-millimeter layer thickness, an 80-millimeter-per-second print speed, and a hexagonal architectural style produced the best results.
PLA	20	0.2	While diameter dimensions are more precise with increased layer thickness, the effect of the layer thickness may rely on the shape of the component.

3. PART ORIENTATION EFFECT

In this section, we'll look into the research done on how part orientation affects the precision with which FDM parts are sized. The layer thickness parameter (14%) and the component orientation (13.11%) are the two most influential elements on the dimensional accuracy of FDM printed parts [8]. Part orientation, as used in this publication, is the angle at which the printed object is tilted with regard to the X-Y plane. Table 2 displays the evaluated literature divided into categories based on the materials used in the studies, such as PLA, ABS, and other resins. In Fig. 3 we see a breakdown of the proportion of publications for each researched resin type.

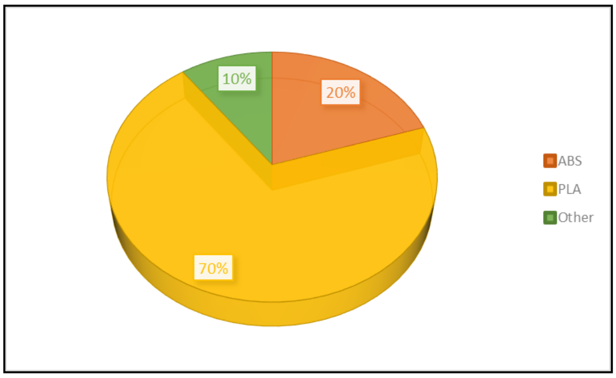

Fig. 3: Research related to Part Orientation

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Table 2 The summery of research article discussing effect of the part orientation on dimensional accuracy.

Material	Reference	Part orientation (^{O})	Conclusion
ABS	8	0	The printed parts were much larger than the CAD version.
ABS	6	30	The 3D printed component was more compact than the CAD model. The parameter only improved dimensional precision by 2.5% at most.
ABS	13	0	Printing accuracy is mostly affected by orientation in terms of the length dimensions of the pieces.
ABS	14	0	The part's length and width are decreasing, but its thickness is growing.
ABS	25	89.122	For the length measurement (17), 90^{O} is the best orientation, and for the width and thickness dimensions (both 90^{O}).
PLA	26	90	Models resembling stairs were studied. Both the 0^{O} and 90^{O} component orientations had average total variations of 0.24785 mm and 0.17465 mm, respectively.
PLA	28	90	Researchers looked at two different widths of horizontal hollow holes (30 mm and 10 mm). At a zero-degree orientation, the error rate was 4.33 percent, but it dropped to 0.7 percent at a ninety-degree angle.
Nylon	29	30	The 3D printed pieces (a 1000 mm^3 cube specimen) were significantly larger than the CAD model.

4. EXTRUSION TEMPERATURE EFFECT

The extrusion temperature is important because, on the one hand, if the material is too cold, it will have a high viscosity and be difficult to extrude, and on the other hand, if the material is too hot, it will be fluid and dripping may occur. That's why it's crucial to adjust the extrusion temperature appropriately for the printing material. In this section, ABS, PLA, and other resins were tested separately to see how extrusion temperature affected the dimensional accuracy of FDM printed objects. There is a brief overview of the items under consideration in Table 3. Figure 4 displays the ercentage of published works organized by their primary source material.

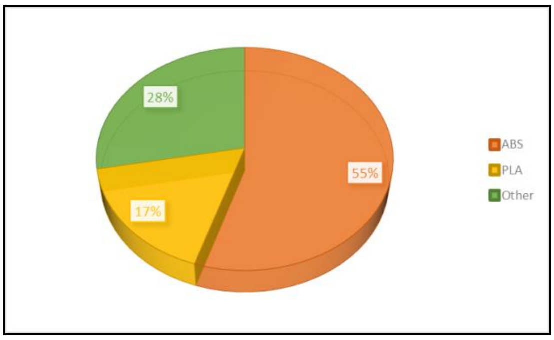

Fig. 4: Research related to Part Orientation

Material	References	Extrusion temperature (^{O}C)	Conclusion
ABS	11	235	The average values of the main effects plot for shrinkage were used to draw conclusions about the dimensional correctness of the parts.
ABS	23	220	It was found that the extrusion temperature had a direct correlation with the breadth of the components.
PLA	5	175	Reduced in length while growing wider and thicker. Length discrepancy lessens above 185 degrees Celsius.
PLA	20	180	The shape of the component also affects the ideal extrusion temperature. For instance, 220 degrees Celsius results in more precise cylinders.

PLA	19	190	The model's length and breadth were enlarged, but its thickness was decreased. The smallest length and breadth variations were seen at 190^{O}C, while the smallest thickness variation occurred at 200^{O}C.
PLA	25	90	The component gets thinner (2.15%) but shorter (-0.1005%) and narrower (-0.104%). While the length dimension is more consistent between 215OC and 235^{O}C, the breadth dimension begins to show consistent accuracy around 205^{O}C.
PLA	26	90	There was no noticeable change in the length or breadth of a square portion (30 mm 30 mm 15 mm) with an inner shell feature when heated to 210^{O}C, 220^{O}C, or 230^{O}C.

5. CONCLUSIONS

In conclusion, It was shown that the specific impacts of the layer thickness, extrusion temperature, and part orientation are more likely to be determined by external factors such as the part form, resin type, and exact size of the parts. To begin, research has shown that FDM items made from ABS or PLA resins benefit most from layer thicknesses between 0.1 and 0.2 millimetres. With ASA and nylon, thicker layers (about 0.3 mm) are preferable. This indicates that there may be a range of ideal layer thicknesses suitable for various materials. The width, length, and thickness of the pieces also play a role in the precision of the printing process.

Second, studies have indicated that a rise in extrusion temperature leads to less precise dimensions. This implies that the dimensional deviation is proportional to the extrusion temperature. Above a certain temperature, however, the increase in dimensional deviations essentially stops. The maximum and minimum temperature has a value that varies from material to material. PLA material was discovered to be the primary focus of research into the effect of extrusion temperature. This could be because PLA undergoes less shrinkage than ABS. Research indicates that between 180 and 220 degrees Celsius is the best extrusion temperature range for PLA components. In addition, when using PLA material, printed samples typically exhibit positive variations in width and thickness, whereas length shrinkage occurs. Finally, the ideal angle for part orientation varies with both the type of material and the size of the printed pieces. Researchers have found that ABS parts benefit most from a 0 orientation, while PLA and ASA resins perform best at a 90 orientation. What's more, the influence of the part orientation parameter on the parts' length, width, and thickness was found to vary from article to article. The length and width of the printed items were found to be most affected by this setting. This concludes that the kind of material, its composition, and the geometry of the part are as essential as the effect of process parameters for the dimensional accuracy of printed parts. In addition, the best values for each process parameter may vary depending on the part's length, width, and thickness. As a result, the material, shape, and dimension of the component being manufactured are more likely to be traded off to determine the ideal process level. Optimal process parameters, component geometry, and dimensions are all factors that might be studied further to see how they affect the dimensional accuracy of FDM-printed parts.

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