Different Process Parameters Affecting the Additive Manufacturing: A Review

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Abstract:

Using the FDM technology for prototyping in fields like aerospace and medicine has brought to light the significance of dimensional precision in manufactured models. Layer thickness, raster width, infill pattern, etc. are only few of the many process parameters that might affect the dimensional accuracy of FDM-printed items. In order to understand the individual effect of each process parameter and to determine the optimal levels of each parameter based on the material types, this study aims to conduct a comprehensive literature review of publications that investigated the effect of process parameters on the dimensional accuracy of FDM printed parts. Material types such as ABS, PLA, and others were summarized alongside an evaluation of 29 publications that examined the impact of three process parameters: layer thickness, extrusion temperature, and component orientation. 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 $90^{O}$is 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. In order to fully grasp the impact of each process parameter on the dimensional accuracy of FDM printed parts, it is necessary to take into account the influence of confounding variables.

Keyword: Process Parameters, Additive Manufacturing, Fused deposition Modelling, Dimensional Precision

Introduction:

Fused deposition modelling, or FDM, is one of the most popular ways to use additive manufacturing to make prototypes because it is cheap. In general, FDM is a way to make parts by extruding thermoplastic materials layer by layer to print a model from the top down or the bottom up [1]. Figure 1 shows how the FDM printing process uses the bottom-to-top method. The filament is heated and forced through the printer nozzle and onto the printer plate. 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. Still, there hasn't been much research done on how each parameter affects the different types of resin, such as ABS, PLA, and other resins. The goal of this study is to look at the effects of three parameters—layer thickness, extrusion temperature, and part orientation—in detail, as well as to figure out how the type of material affects the best level of process parameters. The most important thing that this paper adds is a better understanding of how each process parameter affects the dimensional accuracy of FDM parts made from different materials like ABS, PLA, and other resins.

One of the most critical factors determining the overall quality of prototypes is the accuracy of the sizes of FDM-printed models, as these impacts the outcomes of prototype studies [3]. Layer thickness, extrusion temperature, raster width, printing speed, infill pattern, 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 ABS, PLA, and other resins. The purpose of this research is to determine how different materials affect the optimal level of process parameters by analysing the effects of layer thickness, extrusion temperature, and component orientation. Understanding how each process parameter influences the dimensional accuracy of FDM parts created from various materials like ABS, PLA, and other resins is the most significant contribution of this study.

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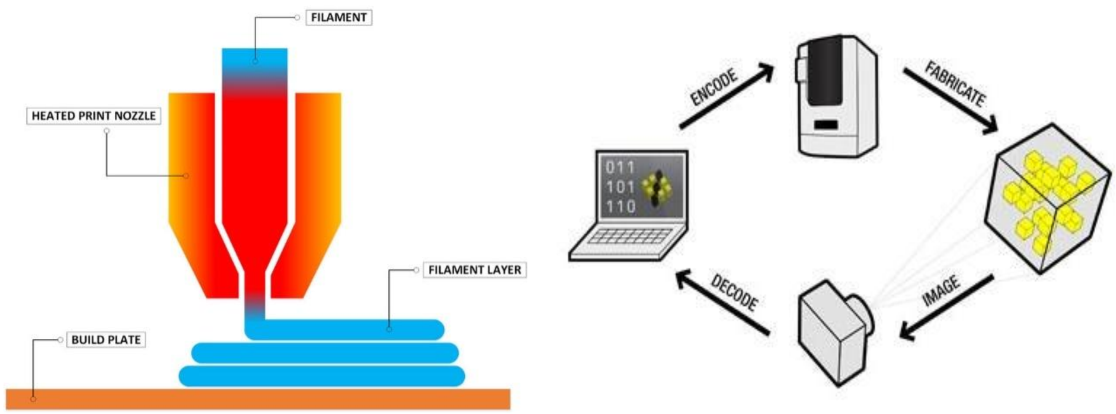

Fig. 1: Working principal of 3D printer [Cao, Marmik]

2. 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.

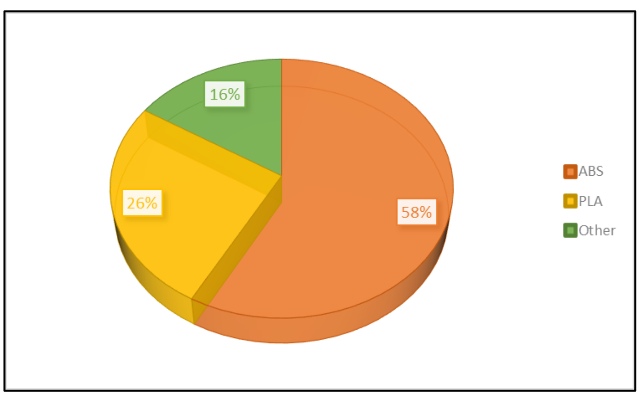

Fig. 2: Research related to Layer thickness

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

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Material	**Reference**	**Layer thickness (mm)**	**Conclusion**
ABS	8	0.1	Printed cube specimen were bigger in term of volume than CAD model
ABS	6	0.2	Printed cube specimen were smaller in term of volume than cad model
ABS	9	0.2	Studied the accuracy of helical surface
ABS	11	0.25	Studied the shrinkage of plate like model with various geometrical shapes viz. cone, rectangle, cylinder and pyramid.
ABS	16	0.178	The length and width dimensions shrink whereas thickness of part increases.
PLA	5	0.1	The length shrinks whereas width and thickness increase.
PLA	17	0.2	The optimal combination of process parameter was found to be 0.2 mm layer thickness, 80mm/s print speed hexagonal building style
PLA	20	0.2	The effect of the layer thickness might depend on part geometry since diameter dimensions are more accurate with higher layer thickness.

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. Dimensional accuracy of FDM printed parts is affected by several factors, the most significant of which are the layer thickness parameter (14%) and the part orientation (13.11%) [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 ABS, PLA, and other resins. In Fig. 3 we see a breakdown of the proportion of publications for each researched resin type.

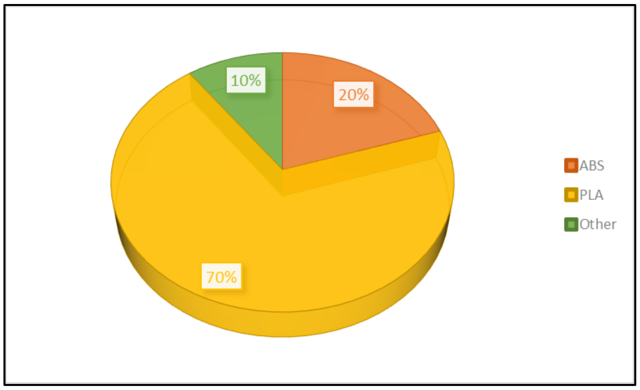

Fig. 3: Research related to Part Orientation

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

Material	**Reference**	**Part orientation (°)**	**Conclusion**
ABS	8	0	Printed part were bigger than the CAD model
ABS	6	30	Printed part was smaller than the CAD model. The contribution of the parameter to dimensional accuracy was only 2.5%.
ABS	13	0	Part orientation affects mostly length dimension accuracy of the printed parts
ABS	14	0	The length and width shrink, whereas thickness of the part increases
ABS	25	89.122	The optimal part orientation for the length dimension is 17 , while for the width and thickness dimensions it is 90°
PLA	26	90	Stair-like model was investigated. The total average deviations of parts using 0°and 90°part orientation were 0.24785 mm and 0.17465 mm, respectively.
PLA	28	90	Horizontal hollow slots (30 mm 10 mm) were studied. The percentage error of 4.33% was observed using 0°orientation and this value decrease to 0.07% for 90°.
Nylon	29	30	Printed parts (1000 mm3cube specimen) were bigger than the CAD model

4. Extrusion temperature effect

When trying to extrude a material, the extrusion temperature is critical because, on the one hand, if it's too cold, the material will have a high viscosity and be difficult to extrude, and on the other hand, if it's too hot, the substance 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 percentage of published works organized by their primary source material.

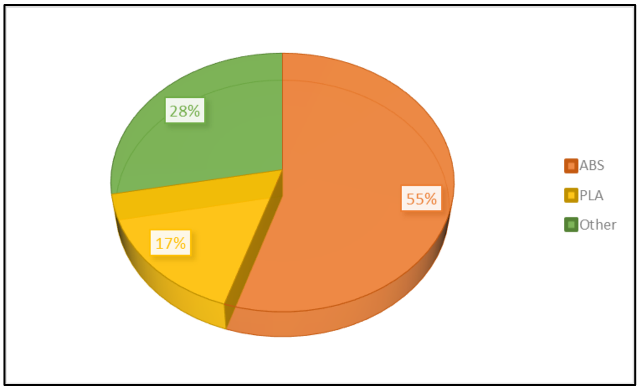

Fig. 4: Research related to Part Orientation

Material	References	Extrusion temperature (^{O}C)	Conclusion
ABS	11	235	The dimensional accuracy was addressed in terms of part shrinkage and results were based on the mean values of maineffects plot for shrinkage
ABS	23	220	The direct relationship between the extrusion temperature and width of the parts was observed
PLA	5	175	The length shrinks, whereas width and thickness dimensions' increase. Above 185^{O}C the length deviation decreases
PLA	20	180	Optimal extrusion temperature also depends on geometry of the part. For example, cylindrical parts more accurate with 220^{O}C
PLA	19	190	The model reduced in thickness dimension and increased in length and width. Minimum deviations in terms of length and width were recognized for 190^{O}C, whereas in thickness dimension for 200^{O}C

PLA	25	90	The part shrinks in length (-0.1005%) and width (-0.104%), increases in thickness (2.15%). The length dimension is more reliable between 215^{O}C 235^{O}C, while the consistency of accuracy for width starts from 205^{O}C
PLA	26	90	No significant effect at higher temperatures (210^{O}C, 220^{O}C, and 230^{O}C) in terms of length and width dimension of square part (30 mm X 30 mm X 15 mm) with an inner shell feature

5. Conclusions

In conclusion, it was discovered that external factors like the part shape, resin type, and the exact dimension of the parts are more likely to determine the individual effects of the layer thickness, extrusion temperature, and part orientation. 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 length, width, and thickness of the pieces also play a role in the precision of the printing process.

Second, research has shown that raising the extrusion temperature reduces dimensional accuracy. What this means is that there is a linear relationship between the extrusion temperature and the dimensional deviance. However, there is a certain temperature beyond which the rise in dimensional deviations becomes minimal. The limiting 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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