# Optimization of Process Parameters of ABS Material Made by Fused Deposition Modeling - A Review

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*Abstract*— This paper has presented a brief review for optimizations of the parts manufactured by FDM method. Fused deposition modeling is one of the RP process that produced prototype from plastic material by lying track of semi molten plastic filament on to a platform in a layer wise manner from bottom to top. The quality of FDM parts are highly depends upon various process parameters of FDM process. The effect of each process parameter such as Layer Thickness, Orientation, Raster Angle, Raster Width and Air Gap on the Dimensions, Surfaces Roughness and Mechanical Properties are analyzed using different methods.
***Key words:*** ABS, Fused Deposition Modeling

## I. INTRODUCTION

Rapid Prototyping (RP) can be defined as a group of techniques used to quickly fabricate a scale model of a part or assembly using three-dimensional computer aided design (CAD) data. Since the introduction of the first commercial rapid prototyping (RP) machine widely known as Stereo lithography in 1986, a wide range of RP machines have been commercialized, and many more newer systems continue to be developed in various parts of the world. In addition to prototypes, RP techniques can also be used to make tooling (referred to as rapid tooling) and even production-quality parts (rapid manufacturing). For small production runs and complicated objects, rapid prototyping is often the best manufacturing process available. RP techniques that are currently commercially available, including Stereo lithography (SLA), Selective Laser Sintering (SLS), Laminated Object Manufacturing (LOM), Fused Deposition Modeling (FDM), and Ink Jet printing techniques.

Fused deposition modeling (FDM) is one of the RP systems that produced prototype from plastic materials by lying tracks of semi molten plastic filament on to a platform in a layer wise manner from bottom to top. FDM is the most widely used rapid prototyping technology. The FDM technology is marketed commercially by Stratasys Inc. (USA), which also holds a trademark on the term. In this process a plastic filament or metal wire is unwound from a coil and supplies material to an extrusion nozzle which can turn on and off the flow. The nozzle is heated to melt the material and can be moved in both horizontal and vertical directions by a numerically controlled mechanism, directly controlled by computer-aided manufacturing (CAM) software. The model or part is produced by extruding small beads of thermoplastic material to form layers as the material hardens immediately after extrusion from the nozzle. A "water-soluble" material can be used for making temporary supports while manufacturing is in progress. This supports can easily remove from the parts.

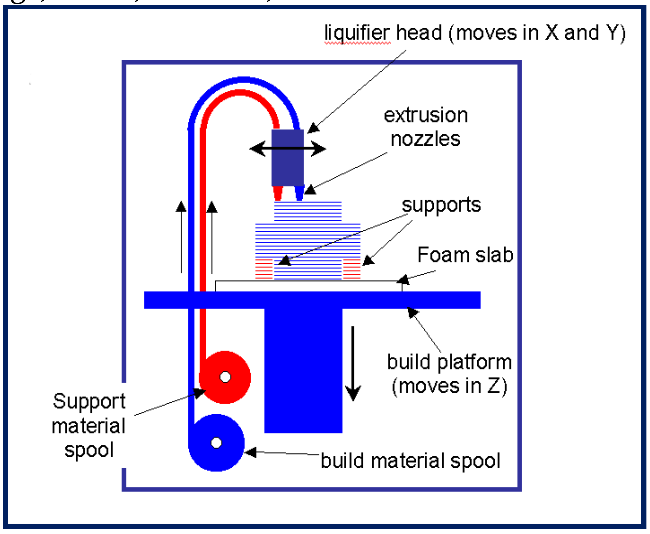


Fig. 1: Fused deposition modeling process principle

### A. Main Process Parameters:

*1) Orientation:*

Part builds orientation or orientation referrers to the inclination of part in a build platform with respect to X, Y, Z axis. Where X and Y-axis are considered parallel to build platform and Z-axis is along the direction of part build.

*2) Layer thickness:*

It is a thickness of layer deposited by nozzle and depends upon the type of nozzle used.

*3) Contour width:*

The width of contour deposited by nozzle

*4) Raster Angle:*

It is a direction of raster relative to the x-axis of build table.

*5) Shrinkage factor:*

Shrinkage factor applied in the x, y, and z direction.

*6) Air Gap:*

It is the gap between two adjacent raster on same layer.

## II. LITERATURE REVIEW

Sandeep Raut et al.[1] In FDM, one of the critical factor is to select the build up orientation of the model since it affects the different areas of the model like main material, support material, built up time, total cost per part and most important the mechanical properties of the part. The effect of built orientation on the mechanical properties and total cost of the FDM parts was investigated. The responses considered in this study are mechanical property of FDM produced parts such as tensile and bending strength. Test specimens were fabricated on Stratasys FDM type rapid prototyping machine coupled with CATALYST software and ABS as main material.

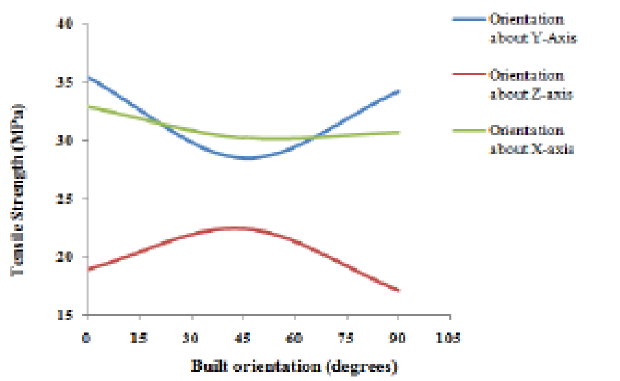


Fig. 2: Tensile test: Tensile strength versus Built orientation

As shown in fig 2. It can be seen from the graph that tensile strength value is maximum for the specimen fabricated about y-axis and shows a maximum value of 35.45MPa at 45° built orientation. But the x-axis the tensile strength value is almost constant with a maximum value of tensile strength of 33 MPa at 0°built-up orientation and z-axis show low tensile strength value 22.51 MPa at 45° built-up orientation.

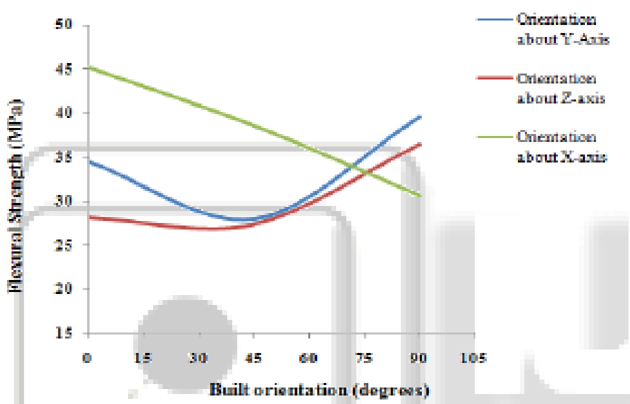


Fig. 3: Bending test: Flexural strength versus Built orientation

As shown in fig 3. The specimen fabricated about Y and Z-axis the flexural strength value decreases up to 45°built up orientation and then increases with built up orientation. But in X-axis with increase in built orientation the flexural strength value decreases. It was found that about y-axis at 0° built up orientation FDM parts has good tensile strength and minimum cost and about x-axis 0° built up orientation FDM parts has good flexural strength and medium cost.

Farzad Rayegani et al.[2] Presented the functional relationship between process parameters and tensile strength for the FDM process has been developed using the group method for data modeling for prediction purposes. An initial test was carried out to determine whether part orientation and raster angle variations affect the tensile strength. It wasfound that both process parameters affect tensile strength. The negative air gap significantly improves the tensile strength. Smaller raster widths also improve tensile strength. The zero part orientation maximum tensile strength is obtained. Increased raster angle also improves tensile strength. The maximum tensile strength is obtained at part orientation is zero, raster angle 50°, raster width 0.2034mm and negative air gap-0.0025mm.

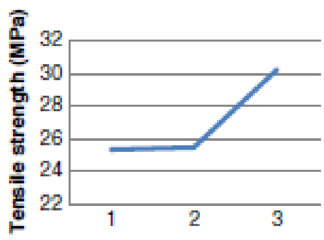


Fig. 4: Part Orientation
[1 (90°), 2 (39°), 3 (0°)]

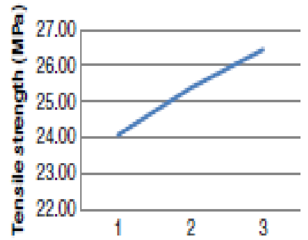


Fig. 5: Raster Angle
[1 (0°), 2 (30°), 3 (45°)]

From the fig 4 & 5. It was observed that there is no outright linearity for the tensile strength measured for the three orientations and raster angle. Tensile strength is increase in part orientation is 0° as the part orientation is increase the tensile strength will decrease. Similarly as the raster angle increase the tensile strength increase.

A. Bagsik et al.[3,4] have worked on the mechanical properties of FDM samples built up with the FDM process were analyzed depending on the build direction. The influence orientation and the tool path generation of manufactured parts based on the mechanical data is analyzed. The tensile tests show different strength and strain characteristics that depend on the given structure and as a result of the build direction. The best results were achieved for all directions by using a negative raster air gap. The thick specimen has better mechanical properties in X and Z directions 81Mpa and 43Mpa. But the thin specimen improves the tensile strength 67Mpa in Y-direction. The results show that the geometry of the sample parts, independent from their build direction, does not conform to the nominal geometry. The test specimens built in X-direction obtain the maximum strengths is 63Mpa as compared to Y and Z-direction. But the compressive strength of specimens built up in XY-direction is lower than that of specimens built up in Z-direction. The compressive strength is 97Mpa. The tip is change regularly for good result.

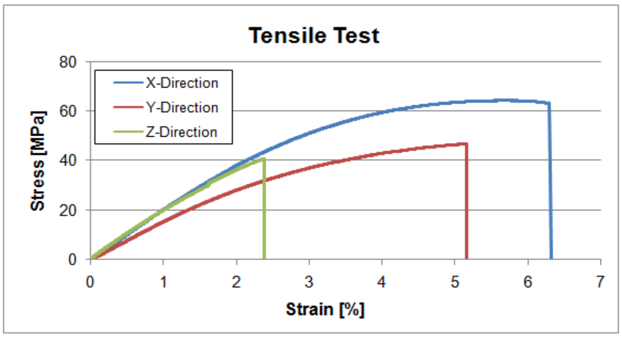


Fig. 6: Compare of Stress-Strain Curves from different Build Directions

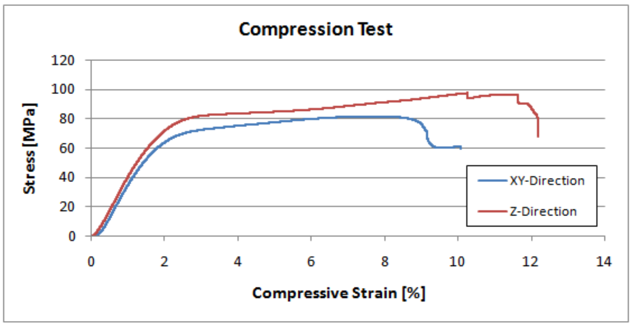


Fig. 7: Compare of Stress-Strain Curves from different Build Directions

From the fig 6 and 7. It was observed that the test specimens built in x-direction obtain the maximum strengths. After reaching the maximum stress the specimens break. The average tensile strength is 63MPa, the elongation at break 6.4%. The tensile strength of samples built in Y and Z direction is lower than the tensile strength of samples built in X-direction. Specimens built in Z-direction have an average compressive strain at 12% and the compressive strength is 97MPa. The compressive strength of specimens built up in XY-direction is lower than that of specimens built up in Z-direction.

L.M. Galantucci et al.[5] have analyzed and compared the mechanical properties and the surface quality of treated and untreated FDM parts with a solution of 90% dimethylketone and 10% water. Tensile and bending properties have been investigated by designing and performing four Central Composite Designs (CCDs) of experiments. The treatment can be used to dramatically improve the surface finish of ABS prototypes. A general tendency was observed where greater immersion times and lower raster widths resulted in lower tensile strength. The specimen should be dissolve in chemical so it reduces the roughness and increasing the compactness of the structure in tensile test. In bending tests the general improvement is of the flexural strength.

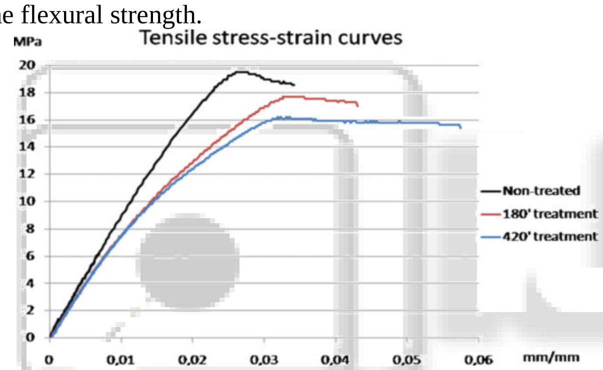


Fig. 8: Tensile Stress Strain Curves For Treated And Untreated Specimens.

Where the tensile stress–strain curves are shown for treated and untreated specimens, with a raster angle equal to 0 and a raster width equal to 0.479 mm. The increased maximum displacement and decrease of the maximum stress with a longer treatment time are evident. Also response surfaces analysis has pointed out an overall reduction of the tensile strength.

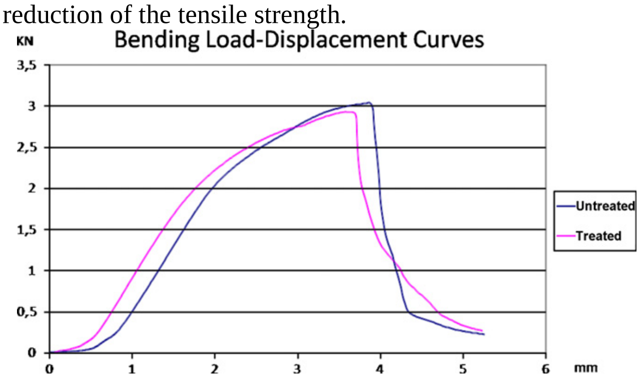


Fig. 9: Load-displacement curves for bending test on turbine blades.

Untreated and treated blades have been compared and two examples are reported in the Fig 9. It can be seen that there is a very low reduction of the maximum load and a very similar behavior. The test shows how, for this functionally complex part, the treatment proves to be very useful to improve surface roughness while preserving the same flexural behavior.

Anoop Kumar Sood et al.[6,7] have studied the influence of important process parameters viz., layer thickness, part orientation, raster angle, air gap and raster width along with their interactions on dimensional accuracy of Fused Deposition Modeling (FDM) processed ABSP400 part. It was observed that shrinkage is dominant along length and width direction of built part. But the positive deviation from the required value is observed in the thickness direction. Optimum parameters setting to minimize percentage change in length, width and thickness of standard test specimen have been found out using Taguchi's parameter design. They were used artificial neural network for prediction purpose. They conclude that for minimizing percentage change in length higher layer thickness 0.254 mm, 0 orientation, maximum raster angle 60°, medium raster width and 0.004 air gap will give desire results. On the other hand lower value of layer thickness 0.127mm, orientation 0, raster angle 0° and higher value of raster width and minimum value of air gap 0.004 will minimize percentage change in thickness of test specimen. The grey Taguchi method was used to fabricate the part in such a manner that all the 3 dimension i.e. length, width and thickness show minimum deviation from actual value. the maximization of grey relational grade shows that layer thickness of 0.178 mm, part orientation of 0 degree, raster angle of 0 degree, road width of 0.4564 mm and air gap of 0.008 mm produce improved part dimensions. Impact strength is improving at higher value of raster, strength increases with the increase in orientation. Zero air gap will improve the diffusion between the adjacent raster but may also decreases the heat dissipation as well as total bonding area.

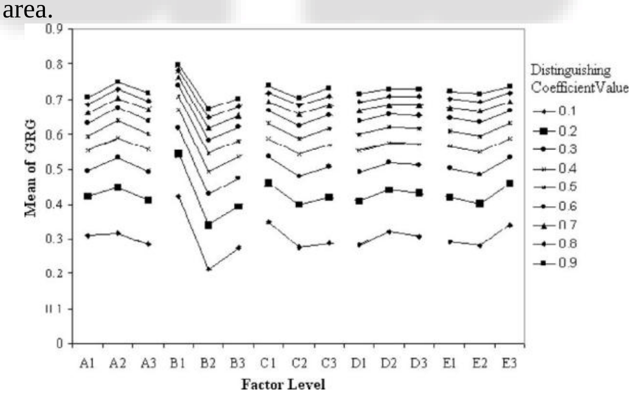


Fig. 10: Sensitivity analysis for different distinguishing coefficients.

Result of sensitivity analysis (Fig. 10) shows that different values of distinguishing coefficient give same factor level.

Mostafa Nikzad et al.[8] have introducing a new composite material for the FDM process. The new composite materials involving ABS and metals. The experiments have been conducted to characterize the thermal, mechanical, and rheological properties. The analyses have been carried out to investigate main flow parameters such as temperature, pressure drop and velocity using two CFD software, two-dimensional and three-dimensional analysis. The entrance velocity of filament at a rate of 0.001 m/s is maintained along the tube until it gets to the nozzle tip. The melt flow speed in the center is the highest while lowest at the wall due to no-slip condition. The results obtained by both of the analyses have been compared and show a very good correlation in predicting the flow behavior.

B.H. Lee et al.[9] have perform the experiments for finding out the optimal process parameters of Fused deposition modeling rapid prototyping machine to achieve maximum flexibility of ABS prototype. For design of experiments Taguchi method was used. The process parameters such as air gap, raster angle, raster width and layer thickness each of at three levels is selected for the study. L9 orthogonal array was selected for design of experiments. The analysis of variance used to investigate the process parameters to achieve the optimum elastic performance of ABS prototype. It was found that for 10°angle of displacement, air gap produces maximum contribution on throwing distance, for15° angle of displacement, raster angle and layer thickness demonstrate almost equal maximum contribution on throwing distance. For 20° angle of displacement, layer thickness gives the highest contribution on throwing distance. From the results it was found that layer thickness, raster angle, raster width and air gap significantly affect the elastic performance of the compliant ABS prototype.

R. Anitha et al.[10] have studied the effect of various process parameters i.e. layer thickness, road width and speed deposition of fused deposition modeling part. These process parameters influence the quality characteristics of the FDM parts. Taguchi method was used for design of experiments.L18 orthogonal array was selected for experiments. The result shows that the layer thickness is effective to 43.37% at 95% without pooling. On the other hand the layer thickness is effective to 51.57% at 99% with pooling. The layer thickness is most effective at 0.3556mm, the road width at 0.537mm and the speed of deposition at200mm.

P. M. PANDEY et al.[11] have studied the orientation for part deposition as it affects part surface quality, production time and the requirement for support structure and cost in the RP processes. They used Multicriteria Genetic Algorithm to determine optimal solutions for part deposition orientation for the two contradicting objectives i.e. surface roughness and built time. The minimum average part surface roughness can be obtained at maximum production time. On the other hand the minimum production time with maximum average part surface roughness. The best surface roughness was obtained at 240.001 angles about the axis 0.034, 0.369, and 0.289and the minimum production time at 89.97 about axis 0.749, 0.011, and 0.009.

## III. CONCLUSION

This paper has presented a brief review of the application of FDM technique for optimizations of the manufactured parts are analyzed. FDM is the most widely used rapid prototyping technology. The effect of each process parameter such as Layer Thickness, Orientation, Raster Angle, Raster Width and Air Gap on the Dimensions, Surfaces Roughness and Mechanical Properties are analyzed. Hardness increases with a decrease in layer thickness. In x and y-axis at 0° built up orientation FDM parts has good flexural strength and tensile strength. Negative gap, smaller raster width, zero part orientation, and increased raster angle improve tensile strength.

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