A Review on Optimization of Process Peramater of Fused Deposition Modeling For Better Dimensional Accuracy

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***Abstract*—The quality of FDM produced parts is significantly affected by various parameters used in the process. In this present work three important process parameters of the FDM process such as layer thickness, part build orientation and raster width are consider. Their influence on three responses such as percentage change in length, percentage change in width and percentage change in thickness of the test specimens are studied with material of polycarbonate. The powerful Taguchi's method is used for design of experiments because of it can be provide simplification of design plan and reduced the number of experiments runs. Specimens are prepared for dimensional accuracy**.

***Index Terms*— FDM Machine, Layer thickness, Orientation angle, Raster Width, Dimensional accuracy, Taguchi method.**

I. INTRODUCTION

In rapid prototyping, the machine reads in data from a CAD drawing, and lays down successive layers of liquid or powdered material, and in this way builds up the model from a series of cross sections. These layers, which correspond to the virtual cross section from the CAD model, are glued together or fused automatically to create the final shape. The primary advantage to this type of "additive" construction is its ability to create almost any geometry[1]
Steps for rapid prototyping:-

1. Development of a CAD model
2. Generation of standard triangulation language (.STL) file
3. Slicing the .STL file
4. Support Structures
5. Manufacturing
6. Post processing [1]

Fused deposition modeling, which is often referred to by its initials FDM, is a type of additive fabrication or (sometimes called rapid prototyping/rapid manufacturing (RP or RM)) technology commonly used within engineering design. The technology was developed by S. Scott Crump in the late 1980s and was commercialized in 1990. The FDM technology is marketed commercially by Stratasys, which also holds a trademark on the term.

Like most other additive fabrication processes (such as 3D printing and stereo lithography) FDM works on an "additive" principle by laying down material in layers. 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 a computer-aided manufacturing (CAM) software package.

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. Several materials are available with different trade-offs between strength and temperature properties. As well as acrylonitrile butadiene styrene (ABS) polymer, the FDM technology can also be used with polycarbonates, polycaprolactone, polyphenylsulfones and waxes. A "water-soluble" material can be used for making temporary supports while manufacturing is in progress. Marketed under the name Waterworks by Stratasys, this soluble support material is quickly dissolved with specialized mechanical agitation equipment utilizing a precisely heated sodium hydroxide solution [2]

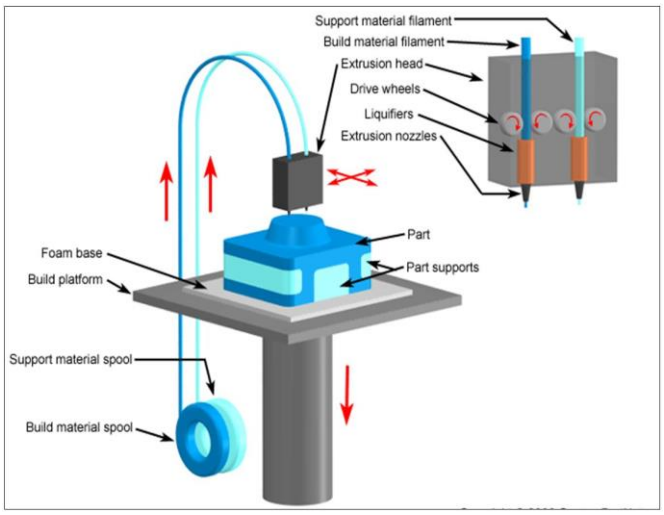


Fig. 1 – Fused Deposition Modeling Machine

Anoop Kumar et al. have studied the influence of important process parameter viz. layer thickness, part orientation, raster angle, air gap and raster width along with their interaction on dimensional accuracy of fused deposition modeling (FDM) process ABS parts. They have observed that the shrinkage is dominant along with the length and width direction of built parts. But the positive deviation from the required value is observed in the thickness direction. Optimum parameter settings 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 (ANN) for prediction purpose. Finally 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. They adopted grey Taguchi method to fabricate the part in such a manner that all the 3 dimensional shows minimum deviation from actual value. Finally 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 will produced overall improvement in part dimensions[3]

Rajal bansal et al. They have studied the primary process parameter of FDM process such as layer thickness ,raster angle and part orientation influence the dimensional accuracy of the part s fabricated using ABS material ,due to shrinkage of the filament the dimension of the CAD model does not match with the FDM process part the shrinkage dominates along length and width of the build part where as positive deviation is observed along thickness direction .influence at each parameter response such as percentage change in length, width ,and thickness of build part are studied using response surface methodology the optimization of process parameter is made by using genetic algorithm and finally they get optimum value of process parameter so the dimensional accuracy is improved .after the experimental work they suggest the optimum combination of process parameter to get the improvement in dimensional accuracy.[4]

Alhubail Mohammad et al. they have conducted the experiments to find out the effect of main FDM process variable parameters. Five important FDM parameters like layer thickness, air gap, raster width, contour width and raster orientation are on their effect quality of surface roughness, dimensional accuracy and tensile strength. They have selected the new ABS M30, bio medical material in order to fabricate the parts, full factorial method was used for design of experiments a number of analytical methods such as regression analysis, analysis of variance were used to determine the influence of the variable FDM process parameter settings. After the experimental work they have found that not all FDM parameter have impact on the proposed response characteristics, they have also conclude that air gap parameters has been proved statistically to influence the surface finish of FDM built parts .building parts with thinner layer may reduce the surface roughness they have also find that negative air gap increase the tensile strength, layer thickness and raster width may prove better dimensional accuracy.[5]

Nancharaiah et al. They have conducted the experiment to determining the optimum surface finish and dimensional accuracy of a part built by the Fused Deposition Modeling (FDM) process. They have found that effect of the process parameters layer thickness, road width, raster angle and air gap on the surface finish and dimensional accuracy. Experiments were conducted using Taguchi's design of experiments with three levels for each factor. From the ANOVA analysis, it was found that the layer thickness and road width affect the surface quality and part accuracy greatly. Raster angle has little effect. But air gap has more effect on dimensional accuracy and little effect on surface quality.[6]

S.K.Panda et al. in this paper they have study the effect of five important FDM parameters such as layer thickness, raster width and air gap .an tensile and flexural strength of test specimen. Experiments have conducted using central composite design and empirical models relating each response and process parameter have been developed the models are validated using analysis of

variance (ANOVA). They have used latest evolution any bacterial foraging algorithm to predict optimal parameters setting of FDM process. After the experimental work they have find out that the layer thickness and orientation angle is highly significant parameters for FDM fabricated parts whereas remaining parameter have little effect.[7]

Ahn et al. have characterized the properties of ABS parts fabricated by the FDM 1650. They were examined the process parameters of FDM such as raster orientation, air gap, bead width, color and model temperature by using design of experiments (DOE). Tensile strength and compressive strength of directionally fabricated specimens were measured and compare with injection molded ABS P400 material. After the experiments they have found that the air gap and raster orientation affect the tensile strength of an FDM parts greatly. Bead width, model temperature and color have little effect. The measure tensile strength of the ABS material with optimum FDM parameter were between 65 to 72 % of the measured of injection molded ABS and the compressive strength ranged from 80 to 90 percent of the injection molded ABS.[8]

K.Thrimurthulu et al. they have attempts towards obtaining an optimum part deposition orientation for fused deposition modeling process for enhancing part surface finish and reducing build time. they have selected this area because of these two concern contradict with each other and generally .compromise made between these two aspect .they have developed model for evolution of average part surface roughness and build time .genetic algorithm was used for optimization. Finally they have determine optimal part deposition orientation for FDM process is very helpful to obtain good surface finish with smaller build up time .the prediction of the develop system are validated with result published earlier and they are in good agreement with each other.[9]

Pulak M. pandey et al. In this paper the authors carried out the improvement in surface finish using staircase machining in fused deposition modeling .four important parameters of FDM such as cutting speed ,build orientation ,rack angle, and angle between cutting edge each of them at two levels are selected .for this study after the experimental work they have seen that stair case machining by HCM is successfully attempted for enhancing surface finish of the FDM parts and they have conclude that surface finish of RP component can be improved by machining of staircase .at last A semi empirical statistical model is developed for surface roughness prediction of FDM parts .it was compare with the experimental data which was have good agreement with it .so they have proved that the model development was valid.[10]

R.anitha et al. They have study of effect of various process parameters of fused deposition modeling on the quality of FDM made part .Taguchi method is used for optimization of both process design and product design .they have selected three important FDM factor such as layer thickness ,road width and speed deposition each of at three level. Taguchi's L18 orthogonal array was selected in order to design the experiments and signal to noise ratio is applied to find out most significant factor on the response characteristics, at last regression analysis was used in order to predict the experimental data. After the experimental work they have found that layer thickness is affected 49.37% without pooling and with pooling it is affected 51.57% at 99% level of significant .road width and speed contribute 15.57%and 15.83% at 99% level of significance according to s/n ratio they have contribute that the layer thickness is the most effective FDM parameter among three, Which affect the output response.[11]

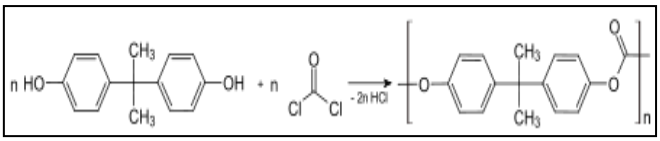
L. M. Galantucci et al. have studied the influence of FDM machining parameter on acrylonitrile butadiene styrene (ABS) prototype surface finish. The surface finish of product after the modification of extrusion parameters has been measured and processed through designed experiment they have also studied the chemical method to improve surface finish of the product. Finally they have found that the slice height and raster width are important parameters while the tip diameter has a little important for surface running either parallel or perpendicular to the build direction. A chemical post processing treatment has been analyzed and yields a significant improvement of the R_a of the treated specimen the proposed chemical treatment is economical, fast and easy to use. When varying the tip dimension, the response variable R_a remains the same while the raster width affects the top surface, also the slice height is an important factor.[12]

B.H. Lee et al. They have done optimization of influence of parameter for production of flexible ABS objects in FDM machine, here they have produced ABS compliant prototype .an orthogonal array, S/N ratio, and ANOVA are employed to investigate the process parameter in order to achieve optimum elastic performance of compliant ABS prototype to get maximum throw distance from prototype. Here four parameters such as air gap, raster angle, raster width and layer thickness each of at three level is selected for the study L9 orthogonal array was selected for design of experiments after the experimental work they have given out optimum combination of parameter for 10 °,15 °,20 °of displacement[13]

II. MATERIAL

Polycarbonates received their name because they are polymers containing carbonate groups(–O–(C=O)–O–). Most polycarbonates of commercial interest are derived from rigid monomers. A balance of useful features including temperature resistance, impact resistance and optical properties position polycarbonates between commodity plastics and engineering plastics. The polycarbonate material is selected to fabricate the part due to its high mechanical strength.

The main polycarbonate material is produced by the reaction of bisphenol A (BPA)andphosgene $COCl_2$. The overall reaction can be written as follows:



The first step of the synthesis involves treatment of bisphenol A with sodium hydroxide, which deprotonates the hydroxyl groups of the bisphenol A.

$(HOC_6H_4)_2CMe_2 + 2\ NaOH \rightarrow (NaOC_6H_4)_2CMe_2 + 2\ H_2O$

The diphenoxide ($(NaOC_6H_4)_2CMe_2$) reacts with phosgene to give a chloroformate, which subsequently is attacked by another phenoxide. The net reaction from the diphenoxide is:

$(NaOC_6H_4)_2CMe_2 + COCl_2 \rightarrow 1/n\ [OC(OC_6H_4)_2CMe_2]_n + 2\ NaCl$

In this way, approximately one billion kilograms of polycarbonate is produced annually.[2]

III. SPECIMEN PREPARATION

With the help of PRO-E software 3D solid model of prototype is modeled and are the converted in to .STL file. STL file is imported to FDM software (Insight ™). the test specimens having dimensions 80 mm x 10 mm x 4 mm have been prepared.. one part per experiment were fabricated by the use of FDM 360 mc machine. Polycarbonate is the material which is used for fabricating the designed part.The mean of the three readings each of percentage change in length, percentage change in width and percentage change in thickness are taken to be the representative value respectively. The line diagram of experimental specimen which is design in **Figure2**. The figure represents actual prototype which is modeled in the FDM 360 mc machine as per experimental plan.

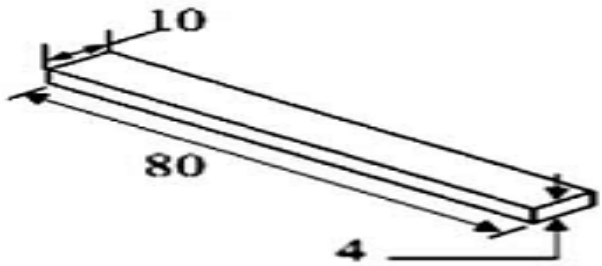


Fig 2 Component design for Dimensional accuracy

IV. DESIGN OF EXPERIMENT

The purpose of Design of experiment is to plan, design and analyze the experiment so that the valid and objective conclusions can be drawn effectively and efficiently.

The design of experiment based on

- Factorial design
- Taguchi method
- Response surface method

Taguchi Approach

The objective of Taguchi's effort is process and product design improvement through the identification of easily controllable factor and their settings, which minimize the variation in product response while keeping the mean response on target. By setting those factors at their optimal levels, the product can be made robust to changes in operating and environmental conditions. Thus more stable and higher quality products can be obtained and this is achieved during Taguchi parameter design stage by removing the bed effect of the cause rather than the cause of the bed effect. Furthermore, since the method is applied in a systematic way at a pre-production stage (off line), it can greatly reduce the number of time consuming tests needed to determine cost effective process conditions, thus saving in costs and wasted products.[14]

V. CONCLUSION

This investigation give information about

1. Influence of parameters on Dimensional accuracy of FDM fabricated part.
2. One best combination of parameters where Dimensional accuracy is very high.
3. Change in Dimensional accuracy as FDM machin parameter is change.

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