A Review on Parameter Optimization of Fused Deposition Modeling Process

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Abstract— Fused deposition modelling (FDM) is a fast growing rapid prototyping (RP) technology due to its ability to build functional parts having complex geometrical shapes in reasonable build time. The dimensional accuracy, surface roughness, mechanical strength and above all functionality of built parts are dependent on many process variables and their settings. In this study paper an effort is made to review the investigation on various process parameters like layer thickness, part build orientation, raster angle, raster width, flow rate and feed rate of machine has been studied along with the various technique to optimized thus parameters.
Key words: Fused Deposition Modeling, Parameter Optimization

I. INTRODUCTION

Fused Deposition Modeling (FDM) common extrusion-based AM technology. A FDM machine consists of a heated build chamber equipped with an extrusion head and a build platform. Consequently, the machine does not use a laser. The extrusion head provides the material deposition in the x-y area according to the contour of the actual layer. It is a plotter-type device.

The build material is a prefabricated filament that is wound up and stored in a cartridge from which it is continuously fed to the extrusion head. The cartridge has a build-in sensor that communicates with the material management system of the machine. In the head, the material it is partly molten by an electric heating system and extruded through a nozzle that defines the string diameter that nearly equals the layer thickness.

Usually, string diameters range from 0.1 mm to 0.25 mm. The platform moves in z-direction and defines the layer thickness, as the material is squeezed on the top of the partly finished part. The process needs support. They are made by a second nozzle that extrudes another plastic support material simultaneously with the build material.

After deposition, the pasty string (of the build material as well as of the support material) solidifies by heat transfer into the preceding layer and forms a solid layer. Then the platform is lowered by the amount of one-layer thickness and the next layer is deposited. The process repeats until the part is completed.

There are many plastic materials available for FDM processes, including engineering materials such as ABS, PC-ABS, and specialty grades for medical modeling. Some machines are restricted to only a limited number of different materials. There is a big variety of colors available, amongst it even translucent, black, and white qualities. Because the color is linked to the filament, it cannot be changed during the build process.

Typical part properties resemble those of plastic injection molded parts; however, they tend to show anisotropic behavior that can be reduced by properly adjusted build parameters. The parts are either used as concept models, functional prototypes, or as (direct manufactured) final parts.

FDM parts show typical surface textures that result from the extrusion process. According to the layer thickness and the orientation of the part in the build chamber, these textures are more or less visible. Therefore, the positioning (orientation) in the build chamber has a big influence on the appearance of the part. [1]

II. STUDIES RELATED TO FDM PROCESS

O. A. Mohamed [2] Define the process parameters Layer thickness refers to the thickness of the layer processed by the nozzle tip. The layer thickness depends on the material used and tip size. Air gap is the gap between two raters on the same layer. Raster angle refers to the angle of the raster pattern with respect to the x axis on the bottom part layer. Specifying the raster angle is very important in parts that have small curves. The raster angles typically allowed are from 0 to 90. Build orientation refers to the way in which the part is oriented on the build platform with respect to X, Y, Z axes. Road width is the width of the material bead used for the rasters. Larger values of road width will build a part with a stronger interior. Smaller values will require less production time and material. Number of contours is the number of contours built around all outer and inner part curves. Additional contours may improve perimeter part walls.

A.K. Sood, R.K. Ohdar [3] Process parameters considered are layer thickness, orientation, raster angle, raster width, and air gap. The response surface plots involving interaction terms are studied and reason behind the observation can be summarized as follows.

1) Number of layer in a part depending upon the layer thickness and part orientation. If number of layer is more, it will result in high temperature gradient towards the bottom of part.
2) Small raster angle is not preferable as they will result in long raster which will increase the stress accumulation along the direction of deposition resulting in more destruction and hence weak bonding.
3) Thick raster result stress accumulation along the width of part and have effect as the long raster.
4) Zero air gaps will improve the diffusion between the adjacent rasters but may decrease the heat dissipation as well as total bonding area.

G. S. Bual, Parlad kumar [4] Literature related to various surface finish techniques has been reviewed. It has been found that there are various methods to improve surface finish of FDM parts. The surface finish can be improved by choosing suitable build orientation of the part. It can also be increased by reducing the layer thickness of build material. However, it will increase the build time. Some authors have reported that proper setting of FDM machine parameters may lead to better surface finish. It has been found that the surface finish can also be improved by using some post processing techniques. Out of post processing techniques, chemical treatment has been used successfully by some researchers to produce a very good surface finish.

To improving surface finish can be divided into three categories, namely:

1) Optimization of build orientation

Experiments were conducted using a fractional factorial design with two levels for layer thickness and three levels for orientation factor. The authors concluded that for 20 and 45 degrees built orientation the roughness value is directly proportional to the layer thickness but for 70 degree built orientation roughness value is decreased as the layer thickness is increased.

2) Slicing strategy (layer thickness).

In general, a thinner slice layer produces better surface finish but it will increase the build time. Many researchers have found that the layer thickness significantly influences the surface finish.

3) Fabrication parameters optimization

The surface finish also depends upon a number of process parameters of the FDM machine. With proper adjustment of the build parameters, quality can be significantly improved without incurring additional expenses.

P. Vijay, P. Denial, K. V. D. Rajesh [5] Whatever may be the manufacturing process, an absolutely smooth and flat surface cannot be obtained. The machine elements or parts retain the surface irregularities left after manufacturing the surface of a part is its exterior boundary and the surface irregularities consist of numerous small wedges and valleys that deviate from a hypothetical nominal surface. These irregularities are responsible to a great extent for the appearance of a surface and its suitability for an intended application of the component is usually understood in terms of surface finish, surface roughness, and surface quality.

Factors Affecting the Surface Finish:

- Vibrations.
- Material of the work piece.
- Type of machining.
- Rigidity of the system consisting of machine tool, fixture, cutting tool and work.

This paper presents an experimental design technique for determining the optimal surface finish of a part built by varying Build Orientation, Layer Thickness and keeping other parameters constant using the Fused Deposition Modeling (FDM) process. The design investigates the effect of these parameters on the surface finish.

Yu-an Jin Hui Li, Yong He Jian-zhong Fu [6] Presents a new approach to characterize the surface profile of objects fabricated with FDM, a low-cost and promising additive manufacturing technique. The mathematical models for both the top surface and the side surface are developed to quantitatively study the surface profiles. Critical process parameters are categorized into pre-process parameters and fabrication process parameters to investigate their impacts on the surface profiles. Results from the experiments validate the feasibility and effectiveness of the proposed surface profile models and indicate that good quality top surface can be achieved by coordinating the speed of filament driving motor and the axis driving motors synchronously, and the quality of side surface can be guaranteed by adjusting the stratification angle and the layer thickness appropriately. Based on the comparison between experimental results and analytical values, several optimization approaches for process parameters and conclusions are demonstrated to enhance the surface quality. Therefore, much more desirable surface can be achieved in FDM after investigating the surface profile.

P. Sreedhar, C. Mathikumar Manikandan, G. Jothi [7] The work described in this paper has identified how far the surface roughness varies across a full range of surface angles show in figure 2.6. FDM test parts were fabricated to verify the proposed surface roughness expression. Empirical and computed roughness data were acquired by measuring the test part and implementing the proposed expression. By comparison between the measured data and computed values, the validity of the proposed expression was proved.

Results from the experiments validate the feasibility and effectiveness of the proposed surface profile models and indicate that good quality top surface can be achieved by coordinating the speed of filament driving motor and the axis driving motors synchronously, and the quality of side surface can be guaranteed by adjusting the stratification angle and the layer thickness appropriately.

R.I Campbell, H.S. Lee [8] Showed that between about 45 deg. and 180 deg. there was range in which the surface roughness was predictable. However, on upward facing surface that were within 45 deg. of being horizontal measured value showed considerable variation.

For several RP processes, the surface roughness varies across the full range of surface angles. It has been demonstrated that for the majority of the system there is at least of angles in which the surface roughness can be reasonably well predicted. However, for the 3D printer the very random result demonstrated that there is no range in which the surface roughness can be closely predicted. The other main conclusion to draw from the experimental work is that for some systems, the stair-stepping effect does not appear to be the main factor in the determining surface roughness. In particular, upward facing surfaces on the actual built part and most surfaces on the FDM and 3DP parts displayed much lower surface roughness apart for reducing layer thickness.

Further, surface roughness visualisation algorithm has been developed and implemented with a commercially available cad package. The user has been given ability to accurately predict the surface roughness of an RP model before it has been build. Comparison can be made between the capabilities of different RP techniques. Area of the unacceptable surface roughness can be investigated in an attempt to eliminate them. When optimum orientation has been determined, it can be used during RP build process.

L.M Galantucci, F. Lavecchia, G. percoco [9] The roughness of FDM prototype is analyzed. Process parameters have affect the Ra. In particular, the slice height and the raster width are important parameters while the tip diameter has little importance for surface running either parallel or perpendicular to the build direction.

The main effect plot shows the average value at each level of all factor considered. When varying the tip dimension, the response variable Ra remains virtually same while the raster width affects the top surface; also slice height important factor. In particular slice height also affect the top surface due to the altered width of filament.

Vijay. Nidagundia, R. Keshavamurthyb, C.P.S. Prakashc [10] Process parameters were optimized for FDM process using Taguchi's L9 orthogonal array. Significant process parameters were identified using analysis of variance. For ultimate tensile strength; 0.1mm layer thickness, 0-degree orientation angle and 0-degree fill angle. For dimensional accuracy; 0.1 mm layer thickness, 0-degree orientation angle and 0-degree fill angle. For surface roughness; 0.1mm layer thickness, 0-degree orientation angle and 0-degree fill angle. For manufacturing time; 0.3mm layer thickness, 0-degree orientation angle and 0-degree fill angle are the process parameters found to be optimum and significant.

Manmadhachary A., Ravi Kumar Y., Krishnannd L. [11] In the paper fast Fourier Transform (FFT) interpolation algorithm is introduced to improve accuracy of curves. Traditionally the STL model is developed from the constructed 3D surface model, but in this method surface creation are avoid and the interpolated point were directly converted into triangulation by the Delaunay triangulation algorithms. Number of steps are reduced to construct STL model, as a result increase accuracy is improved. By changing triangulation angle and trimming and filling (material adding) operations are carried out in the STL model with the last no of steps. By applying this algorithm, the dimensional error is reduced by 57% and surface finish increased by 20% is registered. The disturbed edges are reconstructed by addition of material with high triangulation angle.

J. S Chohan, Rupinder Singh, K. S Boparai [12] The non-traditional surface finishing technique has been presented to develop for VS processes. The results of study suggest that the small smoothing durations (30 sec) and repeated cycles (precooling-smoothing-post cooling) can yield excellent surface finish. Further the surface finish has been achieved at optimized VS parameters resolving major hurdle of surface roughness of FDM parts. The interaction among the process parameters was also checked and was found insignificant. It is recommended to avoid over heating of parts by increasing exposure duration which may deteriorate surface texture and dimensional accuracy. The outcomes of study can be useful for production of patient specific implants via VS route which can reduce production time and cost. The investment castings prepared can be used for in-vitro study to validate practical applicability of the process.

III. Conclusion

From the above reviews conclusion can be drawn that the optimization of FDM parameters is necessary to achieve higher quality parts. For improving quality of the fused deposition modeling part surface roughness most significant property. Surface roughness improved by changing various process parameters on it.

– The research has been focuses on minimizing surface roughness of Fused Deposition modeling part by controlling various machining parameters on it.
– For optimum parameter value further aim to established relationship between all the machining parameters taken on modeling FDM part by using algorithmic point of view.

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