Prototype Development of a Mobile Phone Skin

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Abstract— Rapid prototyping being one of the most novel manufacturing techniques is chosen as the field of study due to its wide range of applications such as in the consumer products, automotive, aerospace and medical industries. To increase the processing efficiency of the prototype fabrication, optimization of the orientation, is required. The surface roughness, production time, and support area are taken as the parameters for the optimization. Particle swarm optimization algorithm was carried out and the results were verified by the fabrication of the part. Thus the prototype development is attained by the increase in processing efficiency and decrease in the cost. The prototype development increases visualization capability during the early phases of design and useful in detecting errors in previous design to rectify. In the present highly competitive market, project cost and risk is reduced drastically.

I. INTRODUCTION

The fabrication orientation in rapid prototyping has always been a keen area of interest for research. Various theories have been already established for optimizing the fabrication orientation of rapid prototyping part. The current topic of interest being similar to the optimization of the fabrication orientation various literatures on the same topic were referred. This research aims for the development of the prototype by optimizing the work done. The prototype is fabricated by fused deposition modeling in different building orientations and different factors are considered to optimize the process.

Aijun li etal stipulated an approach for the selection of optimum fabrication orientation for the fused deposition modeling and has defined a way for the optimization of production time and support area and surface roughness. The optimized fabrication orientation was obtained by Particle swarm optimization algorithm [1].

Jibin Zhao etal worked out an optimizing model based on the input parameters of support area and fabrication time and staircase effect. Genetic Algorithm can efficiently solve the problem for determination of part-building orientation and the problem of optimization of scanning direction also in RP [2]. Here also the authors have considered the similar factors as that of the previous journal referred. But instead of Particle swarm algorithm they have applied Genetic algorithm to explain the Process. Genetic algorithm is comparatively easier than the PSO Algorithm. Jibin Zhao has put forward a theory for optimizing a model based on the different parameters of, support area production time, and staircase effect. The general satisfactory degree function is constructed and then the multi-objective optimization theory was employed based on the principle of general satisfactory degree. By solving the function employing genetic algorithm the optimum part-building orientation is obtained. This method can effectively resolve the part-building orientation in RP experimentally [3]. The Journal paper is mathematically sound and explains the core of the paper pretty clearly. The PSO algorithm also has some advantages and disadvantages. For the research purpose some of the papers were referred and in his study Ioan Cristian Telea has analyzed the particle swarm optimization algorithm using some homogeneous results from the dynamic system theory. The parameters are selected graphically and the guidelines for the same were found out. The exploitation and exploration concepts were illustrated and discussed [4]. The papers explains how the particle swarm algorithm can be simplified by opting either exploration or exploitation by a vigorous sampling of the solution space for a strong location of the optimum globally, but for that a large number of objective function evaluations need to be done or, by favoring the exploitation which will result in a quick conjunction but to a possibly non-optimal solution. Not surprisingly, the best choice appears to depend on the form of the objective function. The paper though mathematically very good and defines the problem wonderfully. The application of the same in the current research is not needed and the area of the same paper is too wide to be included in the same.

Searching for more parameters to be included for the Research this paper has four more parameters included. In their paper Chen yh etal have formulated fuzzy variables based on seven factors depending upon the STL file .The candidate building orientations were ranked based on the fuzzy multi criteria decision method. Satisfactory results were shown when the experiment was done with two examples [5] and unlike the reference [1-2-3] the journal paper covers much more parameters or factors affecting the optimisation of the process for the FDM process such as support needed area height of CG, base plane size, skewness of CG, number of stock layers, volume of removed material and inaccessible volume. But apart from introducing the parameters the proper mathematical explanations about the same are not given and the paper seems to be lacking proper explanations.

II. EXPERIMENTAL HYPOTHESIS

The Main objective of rapid prototyping, by the Fabrication of the prototype, for the designer is to evaluate and thereby reducing the production time and increasing the processing efficiency. As the defects produced in the designs can be minimized to a large extent by the manufacture of the prototype and thus the production time is reduced drastically. So if the time taken to fabricate the prototype also is the minimum then the Maximum efficiency can be attained. The prototype once fabricated has to have the dimensional properties or as the scaled version of the original counterpart. Then the design can be evaluated for its design features and the beauty and the surface finish of the part can be evaluated. The support area also plays a major role in determining the accuracy and the production time of the part. The support area needs to be minimal, as much time will be consumed for the manufacture of the support area also. So an optimum support area also has to be found out for the increased efficiency of the rapid prototyping part. Hence the chief aim of this research is to minimize the production time, surface roughness and support area in such a way that it will not conflict with each other. As to reduce the surface roughness the machine needs more time to fabricate. So these objectives have a conflict with each other. The Model prototype development can be attained by the effective implementation of the objectives.

III. METHODOLOGY

Prototype development is done by the multi objective optimization done by taking support area, surface roughness of the fabricated part and the fabrication time required and the optimum model for fabrication orientation is proposed.

A. Optimization of support area

Support area of the fabricated part is the material from the forming platform to the base support of the material. The quality and integrity of the fabricated part is greatly influenced by the support area. Support needs to be added for those surfaces which has the vector pointing downwards and which are at a small angle with the negative Z-axis, similar to the triangular facets

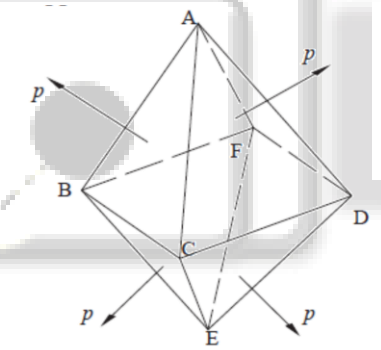

Fig. 1: Triangular facets division

$$Am = 0.5 \left\{ \begin{vmatrix} a2-a1 & b2-b1 \\ a3-a1 & b3-b1 \end{vmatrix} + \begin{vmatrix} b2-b1 & c2-c1 \\ b3-b1 & c3-c1 \end{vmatrix} + \begin{vmatrix} c2-c1 & a2-a1 \\ c3-c1 & a3-a1 \end{vmatrix} \right\} \hat{}0.5$$

The model for optimization of support area is:

$$f_1(d) = \min \sum_{m=1}^{\infty} A_m |d.p_m|.\delta \quad (1)$$

d is the unit vector for fabrication orientation and δ is a threshold function.

Where $\delta = |1,\ d.p_m < 0$, $\delta = |\ 0,\ d.p_m > 0$

B. Production time optimization

Time to build the part includes time for scanning and time for preparing. The time taken for scanning is independent of the direction in which the part is built. The total number of layers has an effect on the preparing time; the total height of the part building direction is also dependent on number of layers. Therefore the part building time can be reduced if the height of part building direction is minimized. Thus the problem of optimization is stated as follows:

$$f_2(d) = \min \sum_{i=1}^{n} \sum_{j=1}^{3} \max(\text{d.Aj}) - \min(\text{d.Aj}) \quad (2)$$

Where Aj is vector of each vertex of a triangular facet.

C. Surface roughness optimization model

The triangular facet's angle of the m[th] , θ is determined by Fabrication orientation d

$\theta = \psi\ (d,m)$

$$R_{av} = \frac{\sum Ra_m A_m}{\sum A_m}$$

Where Ra_m is the roughness of the m[th] triangular facet and A_m is the area.

$$f_3(d) = min \sum_{m=1} Ra_{av} \quad (3)$$

D. Particle swarm optimization algorithm.

The PSO algorithm is according to the research results on the flock of flying birds. Bird flocking in 2-D space is simulated and implemented by PSO. The current position and velocity is represented in XY axis by V_x and V_y. Any change in the position can be identified by the information of velocity and position. An objective function is optimized by bird flocking. The best value of each agent so far is depicted by (p_{best}) and its XY position. The personal experiences of each agent are represented by this. In the group the best value so far is known to each agent. The agent tries to renew its current position always: the present positions (x, y), the present velocities (V_x, V_y), the detachment between the current and the p_{best} position, the detachment between the current position and g_{best}. The concept of velocity represents this change in values.

E. Surface roughness measurement

Roughness of a surface is an extent of the texture or smoothness of the surface. The vertical non-conformity of the ideal surface and the real surface is depicted by roughness. The smoothness and the roughness of the surface are determined by the magnitude of deviation of this value. Roughness is the high frequency, short wave length constituent of a measured surface. The fractional coefficients of the rough surfaces are often higher than the smooth surfaces. Roughness is often a considered as a good indicator of the performance of any mechanical element, as the irregularities on the surface may or may not form nucleation sites which may result in corrosion and crack. The increase in roughness is not desirable and the decrease in it also demands more time and cost. The surface roughness is decreased at the cost of increasing its manufacturing cost as the material needs to be undergone through more number of processes. Roughness can be measured using contact or non-contact methods. Contact method is when a measurement stylus is dragged across the surface to measure the surface roughness.

IV. RESULTS AND DISCUSSIONS

The optimal solution for the multi objective function was found out using Particle swarm Optimization algorithm.

A. Simplification of variables

Suppose the unit vector of the object to be fabricated is $d=x_i+y_j+z_k$, Then $x_i^2+y_j^2+z_k^2=1$.Given β is the angle between vector d and Z-axis while α is the angle between the X axis and projection of vector d in XOY plane . Then x, y, z is expressed as follows.

$$\begin{cases} x = \sin\beta \cdot \cos\alpha \\ y = \sin\beta \cdot \sin\alpha \\ z = \cos\beta \end{cases}$$

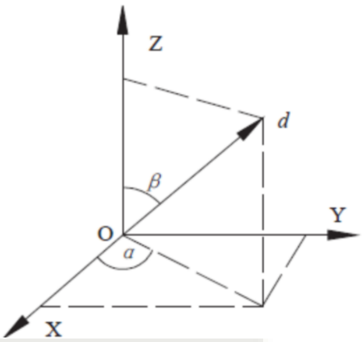

Fig. 2: Fabrication orientation unit coordinate vectors

Here α varies from 0 to 2π whereas β varies from –π/2 to π/2.

The three objectives have to be satisfied by one fabrication orientation. The formula for the same is

$S(\alpha,\beta)=f1(\alpha,\beta).s1+f2(\alpha,\beta).s2+f3(\alpha,\beta).s3$ (4)

Where *s*1, *s*2 and *s*3 are the extents of profile on different

Indicators, and *s*1+*s*2+*s*3=1

The main objective is to find out the optimum solution of *S*(*α*,*β*), so $F_{fit}(\alpha,\beta)$ is used as the fitness function.

$F_{fit}(\alpha,\beta)=C_{max}-S(\alpha,\beta)$ (5)

Where C_{max} is the maximum value of S (*α*,*β*), Compiling the automatic optimization program and setting parameters, to find the optimum solution of *α* and *β*.

The cad solid model was prepared in the solid works software and was converted into the STL file format and which was later fed into the CATALYST EX software. The mobile phone skin was fabricated in two different orientations at first to get well versed with the fabrication techniques and to check the results. The axis was rotated by 90 degrees each time and the fabrication was done.

While the model fabrication along y axis the machine got struck twice as the support volume of the part was not sufficient to hold the model in the correct position as a result the fabrication had to be aborted both the times. The inferences from the rapid prototyping were that if the part fabricated is too small in volume and if the support area is small then there is a chance that the part may get displaced from the forming platform resulting in the process abort. The fabrication time and the support volume of the part can be found out from the software itself. The software shows how much time is left for the process to be completed and how much material is used for the process. Whereas the surface roughness values of the fabricated part were measured using Roughness testing machine and the values were obtained.

Model no	Axis of orientation	Production time	Support material
1	X axis	17 min	.183 in^3
2	Y axis	64 min	.216 in^3

Table. 1: values of parameters in different orientations

Sl no	Texture of surface	Ra_1	Ra_2	Ra_{avg}
1	Rough (top surface)	4.51	4.48	4.495
2	Smooth (bottom surface)	1.25	1.32	1.285

Table. 2: surface roughness values of prototype

Fig. 3: Prototype fabricated

V. CONCLUSION

The mobile phone skin was fabricated in different orientations and the production time, support material and surface roughness were noted. These parameters were found to have the most influence on the quality of the prototype. The optimization of the fabrication orientation with PSO algorithm was done. The prototype was fabricated in different angles and was found to have optimized values of the three parameters chosen. The pso algorithm is applied in an effective way to optimize the part fabrication.

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