EXPERIMENTAL TECHNIQUE TO MINIMIZE THE MODEL MATERIAL REQUIREMENT FOR THE TURBINE SHAFT IN RAPID PROTOTYPING (FDM)

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ABSTRACT -- Rapid Prototyping (RP) is regarded as layered manufacturing or solid free form fabrication. Here, from the data of Computer aided design (CAD), physical modeling of a new product is designed. The special tooling or significant process engineering are not used in rapid prototyping. Prototyping process helps in the conceptualization of a design. It is customary to fabricate a prototype and to test it; before the commencement of its starting of actual manufacturing. Rapid Prototyping (R P) is a generative or additive manufacturing method. In Fused Deposition Modeling process of Rapid Proto-typing, the component is built by deposition of layers contoured in a (x – y) plane two dimensionally. The third dimension (z) results from single layers being stacked up on top of each other, but not as a continuous z- coordinate. The 3 D- CAD model is designed for the Shaft with many design features; with Autodesk Inventor software. Many experiments are conducted on Fused Deposition Modeling (FDM) Rapid Prototyping machine and the actual components are manufactured by changing the orientation of the component. Every time, the requirement of the model material (or build material) is calculated. The optimum orientation is experimentally investigated to manufacture the Turbine Shaft component, with the condition of minimum requirement of model material.

Keywords --Rapid Prototyping, F D M, Layer Resolution, CATALYST Software, AUTODESK Software, Model material and Support material.

1. INTRODUCTION

In the present days, digital prototyping is being widely used for the product development in different areas and by many companies. The main challenge comes after the product has been digitally prototyped, and tested for the real world, under virtual conditions; and then in the manufacturing of the real prototype. The challenges include how to maintain sufficient level of the limits, fits, tolerances, time and costs (tooling design and manufacturing), time for producing the component for the first time, and many other factors that are involved in the manufacturing process.

The lead time required to make a prototype of a product will be reduced by this rapid procedure, since the process engineering time and tooling requirements are avoided. The advantages of rapid prototyping have made it suitable for the global market requirements such as fast manufacturing, and highly engineered products. Technologies like Rapid Tooling (RT) and Rapid Manufacturing (RM) attempt to overcome many of the present deficiencies in the fabrication of final end- use parts using RP technologies. One of the major benefits of RP/ RT/ RM is the capability to manufacture parts quickly. Rapid manufacturing is defined as the ability to manufacture a product, direct from CAD data input, without human intervention or skill. This procedure of transforming CAD data, directly into the final product is also called as direct manufacturing. The limitations for the present RM processes are material variety and properties, processing speed, dimensional accuracy, surface finish, repeatability, geometry capabilities and cost effectiveness.

For the purpose of prototyping, Rapid Prototyping or Additive Manufacturing technique is being used. In this method, addition of material is used in order to build the machine component or the part, which under manufacturing. In the process of adopting the Rapid Prototyping Technology, Fused Deposition Modeling is one of the important processes that is being currently used by many Research Institutes and Industries for the process of developing the prototypes for the first time to ensure their designs, to follow the manufacturing considerations, and to test the components in the laboratory under a large number of conditions.

In this FDM process, one of the main considerations is to minimize the Model material of the product that has a great effect on the product in terms of reduction in the design phase time, reduction in cost of manufacturing, increase of the surface finish and accuracy with which the product is being built. The Turbine Shaft, which has several design features, is taken as work piece in the present experiments. This Turbine Shaft has several operations such as facing, plain turning, step turning, drilling, key way milling, grooving, thread cutting, etc. In this paper, several experiments are conducted to predict the optimum orientation for the Turbine Shaft work piece; in order to reduce the requirement of the model material. Also, similar experiments can be conducted on F D M machine, for other complex parts such as Rotors of the turbines, spur and helical gears, impellers, threads, all types of bio medical applications, etc. Best orientation can be estimated; with a condition to minimize the requirement of the model material.

II. THE PROTOTYPING PROCESS

1.1 Principle

There are a number of methods in the Rapid Prototyping process. The abbreviation for Fused Deposition Modeling is F D M. This is the other major technology and also widely used technique after Sterio-lithography. F D M builds up the product in thin layers of thermo plastic wire like filaments. There is no need for liquid photopolymers, powders and lasers.

1.2 Process Description

In the F D M technique, filaments of heated thermo plastic are extruded from a tip that moves in the x – y plane. The controlled extrusion head deposits very thin beads of material on to the build platform to form the first layer. The platform is maintained at a lower temperature, so that the thermo plastic quickly hardens. After the platform lowers, the extrusion head deposits a second layer upon the first layer. Supports are built along the way, fastened to the part either with a second weaker material or with a perforated junction. Build materials include A B S (Acryto Nitrile Butadine Styrene), elastometer (96 durometer), Polycarbonate, Polyphenol sulfone and investment casting wax. As the nozzle is moved over the table in the required geometry, it deposits a thin bed of extruded plastic to form each layer. The plastic hardens immediately after being released from the nozzle and bonds to the layer below. The entire system is contained within a chamber at a temperature just below the melting point of the plastic.

Several materials are available for the process including A B S and investment casting wax. A B S offers good strength and more recently polycarbonate and poly (phenyl) sulfone materials have been introduced which extend the capabilities of the method further in terms of strength and temperature range. Support structures are fabricated for overhanging geometries and are later removed by breaking them away from the object. A water soluble support material which can simply be washed away is also available.

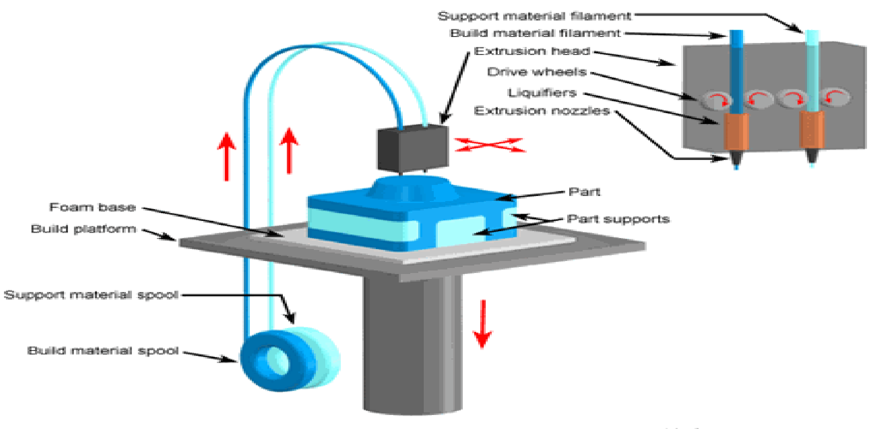

Fig 1: Process of Fused Deposition Modeling.

1.3 Fused Deposition Modeling Process

F D M method is user friendly and the operation is quite. F D M operation is fast for the production of small parts on the order of a few cubic centimeters or those that have tall and thin factors. It may be slow for the components with wide cross sections.

1.4 Advantages of FDM Process

The advantages of FDM process include the following. i. Quick and generation of components at low cost ii. Different colors are available. iii. There is no worry of possible exposure to toxic chemicals, lasers or liquid polymer bath. iv. The system does not waste material during or after producing the model. v. Materials can be changed quickly.

1.5 Limitations of FDM Process

The limitations of FDM process are listed below. i.Restricted accuracy due to the shape of the material used. ii. Supports may be required. iii.Part strength is weak perpendicular to build axis. iv. Temperature fluctuations during production could lead to delamination.

1.6 Applications of FDM process

Rapid Prototyping process or Additive Manufacturing process is extensively applied in Defense, Research organizations, Machine Tools, Air Crafts, Aerospace Technology, Automotive Industries, Bio- Medical applications, etc. F D M process has wide range of engineering applications. i. Model for operation and functional part testing. ii. Design model for assessing the final appearance and geometry of a complex part. iii. After assembling the parts, the working of complete products can be evaluated. iv. This process is applied in Investment casting and Injection molding.

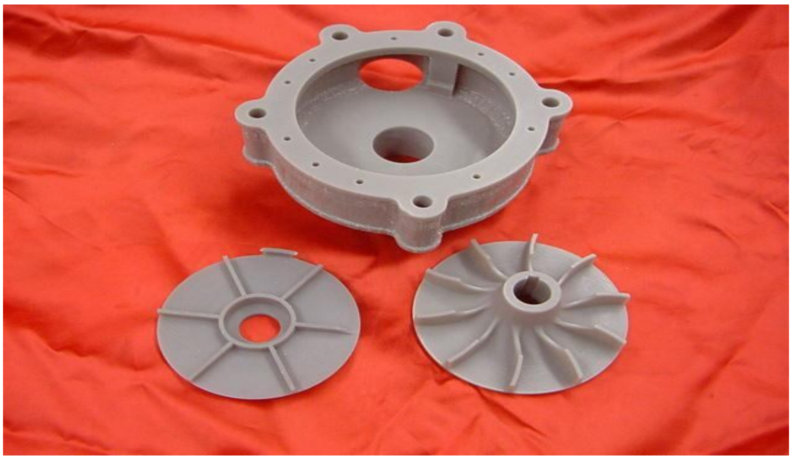

Fig 2: Complex parts, each made by F D M

II. STATEMENT OF THE PROBLEM

Due to the increasing types and complexity of materials that is being used for the process of FDM with some materials there arises the problem of the cost of the materials, which directly relate to the increase in the overall operational costs. Also, if the model material is more, it results in excess electrical power consumption. In addition, it leads to thermal wear on the machine. This aspect has direct relation to the manufacturing cost and the maintenance cost. It results in more time consumption also.

III. SOLUTION

A defined orientation or a correct position of the work piece in F D M machine has to be implemented to solve this problem, and to get the optimal accuracy. Also, the defined orientation results in the consumption of least model material to get the product having exact dimensions and with specified accuracy. The present experiments are conducted on Fused Deposition Modeling machine, Stratasys make, USA. This F D M machine is provided with a pre- processing software called Catalyst, which will be useful for processing the 3 D- CAD model. This CAD model will be imported for producing a complex component or part. In the present work, a Turbine Shaft with several manufacturing features is designed and it is tested in different orientations, in order to get minimum model material requirement.

IV. EXPERIMENTAL SET UP

The Turbine Shaft is designed using ‘Autodesk Inventor’ software, and it is converted into ‘.stl’ format. It is loaded to the ‘Catalyst’ software of F D M machine. Experiments are conducted on this software with different orientations of the part for minimum requirement of the model material. In order to compare the results of the Catalyst software, the Shaft components are practically fabricated on F D M machine in different orientations for the minimum requirement of model material. The results are verified. The results are presented below.

In the present experimental work, the Turbine Shaft example is shown in two orientations to the axis of the component. i. Horizontal position and ii.Vertical position, for the minimum requirement of model material. The experiments are conducted with two different layer resolutions. Similar type of the experimental work can be extended to complex parts such as gas turbine Rotors, blades, air craft parts, impellers, etc, where we find reduction in the model material usage will have great impact on the overall cost of manufacturing the components.

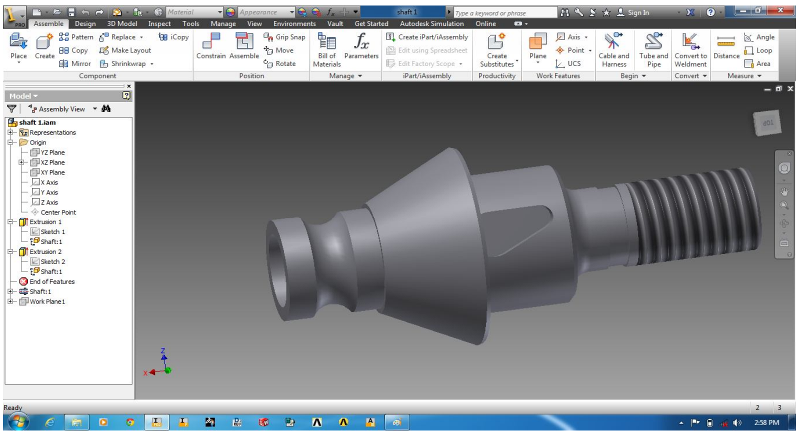

Fig 3: Turbine Shaft component

5.1 Case I: Turbine Shaft in Horizontal axis Position

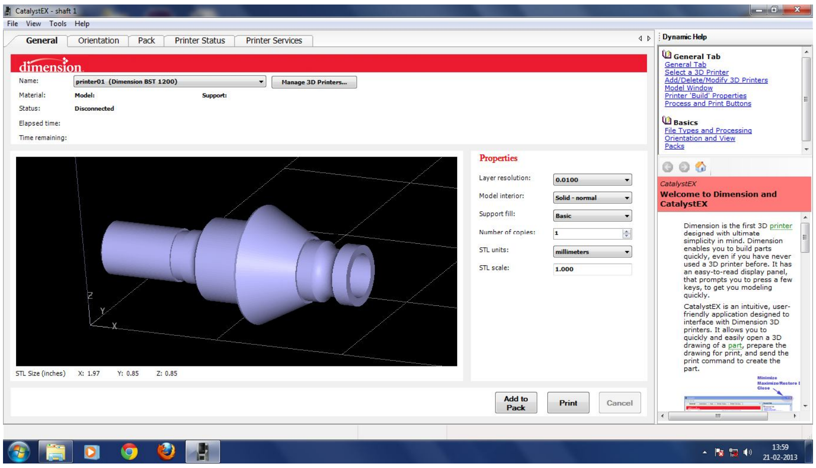

Fig 4: Shaft in Horizontal axis position

Table 1. Model material for different layer thicknesses when the Turbine Shaft is in horizontal axis position

Model Material (in^3)	Layer Thickness, In.
0.39	0.010
0.38	0.013

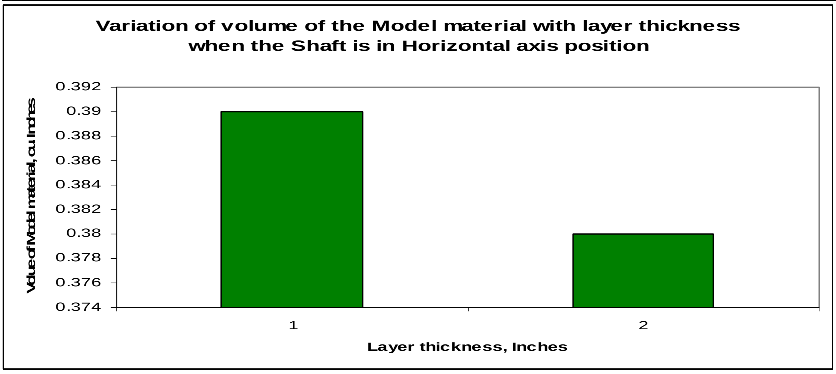

Fig 5: Variation of volume of Model material with layer thickness when the Turbine Shaft is in horizontal axis position

1.2 Case II: Turbine Shaft in Vertical axis position

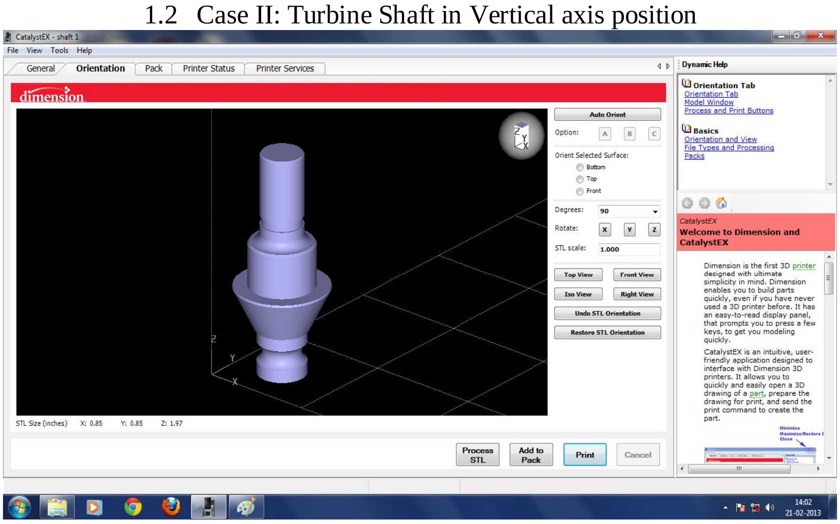

Table 2. Model material requirement when the Turbine Shaft is in vertical axis position

Model Material (in^3)	Layer Thickness In.
0.41	0.010
0.40	0.013

Fig 6: Turbine Shaft in Vertical axis position

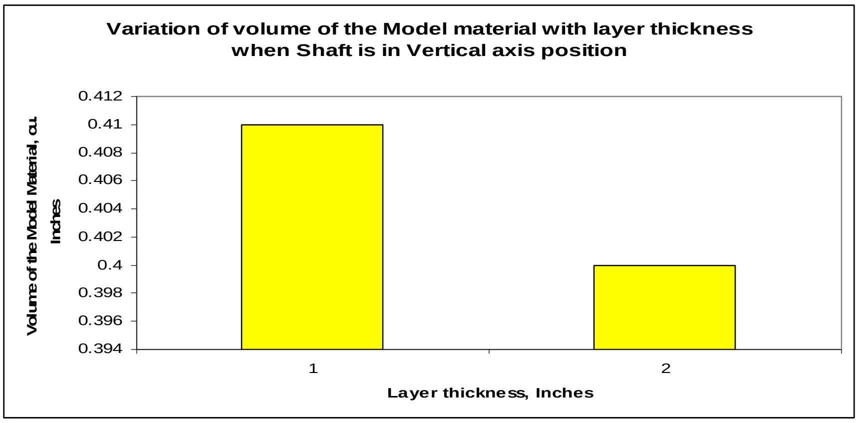

Fig 7: Variation of volume of Model material with layer thickness when the Turbine Shaft is in Vertical axis position

V. CONCLUSIONS

The main objective of the above experimental work is to find out the orientation of the component in the space and setting the layer resolution in order to get minimum model material requirement in F D M machine. i. After simulating the Turbine Shaft and ii. After conducting practical experiments on F D M machine, it is concluded from the graphs that placing the Turbine Shaft in the horizontal axis position and selecting layer thickness of 0.013 inches, minimum model material requirement of 0.38 cubic inch is resulted for the building of the component. In the present work, the Turbine Shaft is analyzed for the prototyped part, which is 1 / 10 th of the original size. So, the model material requirement may seem to be less value here. But, if the same turbine Shaft is to be manufactured on full size, then the requirement of the model material will become a major issue and important factor.

VI. REFERENCES

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