EFFECTIVE UTILIZATION OF USED DEPOSITION MODELING TECHNOLOGY

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This paper deals with basic knowledge and problems in area of Fused Deposition Modelling (FDM) technology operation focused on used material testing and operation optimization from economical aspects of view. It belongs to progressive methods of model creation based on geometry obtained from CAD environment with application possibilities in different industrial spheres.

KEYWORDS

rapid prototyping, fused deposition modeling, materials for rapid prototyping

1 INTRODUCTION

Rapid Prototyping (RP) of physical parts or otherwise known as solid freeform manufacturing or desktop manufacturing or layer manufacturing technology, represents the new phase in the evolution of prototyping. The invention of this series of Rapid Prototyping methodologies is described as a watershed event because of the tremendous time savings, especially for complicated model. Through the parts (individua components) are relatively three times as complex as partsmade in 1970s, the time required to make such a part now averages only three weeks. Since 1988, more then twenty different rapid prototyping techniques have emerged. Rapid Prototyping is the automatic construction of physical objects using additive manufacturing technology. The first techniques for Rapid Prototyping became available in the late 1980s and were used to produce models and prototype parts. Today, they are used for a much wider range of applications and are even used to manufacture production-qualityparts in relatively small numbers. The use of additive manufacturing for Rapid Prototyping takes virtual designs from computer aided design (CAD), transforms the mintothin, virtual, horizontal cross-sections and then creates successive layers until the model is complete. The primary advantage to additive fabrication is its ability to create almost any shape or geometric feature. [Novakova-Marcincinova L. 2014b, Novak-Marcincin J. 2012, Rimar 2016]

2 MATERIAL PROPERTIES OF FUSED DEPOSITION MODELLING TECHNOLOGY

Stratasys Fused Deposition Modelling (FDM) is a typical RP process that can fabricate prototypes out of ABS plastic. To predict the mechanical behaviour of FDM parts, it is critical to understand the material properties of the raw FDM process material, and the effect that FDM build parameters have on anisotropic material properties. This chapter characterizes the properties of ABS parts fabricated by the FDM 1650 and realized by researchers of Gyeongsang National University Jinju (Korea) and University of California, Berkeley (USA) [4].

Using a Design of Experiment (DOE) approach, the process parameters of FDM, such as raster orientation, air gap, bead width, colour, and model temperature were examined. The FDM machine possesses a second nozzle that extrudes support material and builds support for any structure that has an overhang angle of less than 45° from horizontal as a default. If the angle is less than 45°, more than one-half of one bead is overhanging the contour below it, and therefore is likely to fall. The machine deposits material in a directional way that results in parts with anisotropic behaviour. Experiments were performed in which the effect of several process parameters on the mechanical behaviour of FDM parts was examined.

Fig. 3 shows magnified views of the fractured surfaces of the specimens. The Axial ([0°]12) specimens showed tensile failure of individual fibers resulting in the highest tensile strength among the FDM specimens. However, this strength was lower than that of the injection moulded ABS partially because the gaps between fibers reduced the effective cross sectional area. The Transverse ([90°]12) specimens resulted in the lowest tensile strength because the tensile loads were taken only by the bonding between fibers, and not the fibers themselves. The Cross specimen ([0°/90°]6) consisted of a layer of fibers oriented in the 0° direction, followed by a layer in the 90° direction. The resulting failure load for this pattern, as might be expected, fell between the [0°]12 and [90°]12 specimens. The Criss-cross ([45°/-45°]6) specimen showed shear failure along the 45° line in the macroscopic view but the microscopic view revealed the repeated failures of individual fibers by shearing and tension. Note that the oval shape of the fibers is determined by the Quickslice software settings for road width and slice height. [Plancak, M 2009, Novakova-Marcincinova L. 2013a]

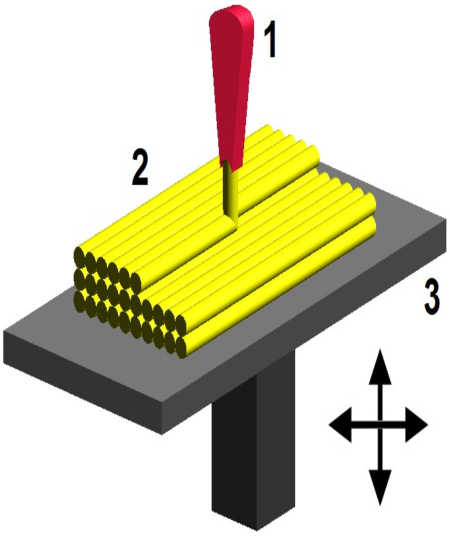

Figure 1. Fracture surfaces of [0°]12 and [45°/-45°]6 specimen [4]

3 PRINCIPLE OF FUSED DEPOSITION MODELING

Fused Deposition Modelling (FDM) was developed by Stratasys in Eden Prairie, Minnesota. In this process, a plastic or wax material is extruded through a nozzle that traces the part's cross sectional geometry layer by layer. The build material is usually supplied in filament form, but some setups utilize plastic pellets fed from a hopper instead. The nozzle contains resistive heaters that keep the plastic at a temperature just above its melting point so that it flows easily through the nozzle and forms the layer. The plastic hardens immediately after flowing from the nozzle and bonds to the layer below. Once a layer is built, the platform lowers, and the extrusion nozzle deposits another layer. The layer thickness and vertical dimensional accuracy is determined by the extruder die diameter, which ranges from 0.013 to 0.005 inches. In the X-Y plane, 0.001 inch resolution is achievable. A range of materials are available including ABS, polyamide, polycarbonate, polyethylene, polypropylene, and investment casting wax.

For better orientation of user in process of setting of suitable parameters during the preparation of printing there was algorithm elaborated which accumulates all factors and steps that lead to selection of most suitable variant. All the attempts were realized as a part of preparation stage for printing on UPrint machine that utilize FDM technology to build the prototype. This technology, developed by Stratasys, uses the software program to orient the model and generate building slices. Printer dispenses with basic building material and support material which is used if necessary for creation of holes, cavities, drafts, etc. Each material has its own nozzle. Creation of particular prototype layers with use FDM method is shown in Fig.2. [Novakova-Marcincinova, L. 2013c, Novakova-Marcincinova, L. 2012, Novakova-Marcincinova. E. 2017, Balara 2018, Janekova 2014, Monkova 2013, Mrkvica 2012, Panda 2016, Panda 2011a]

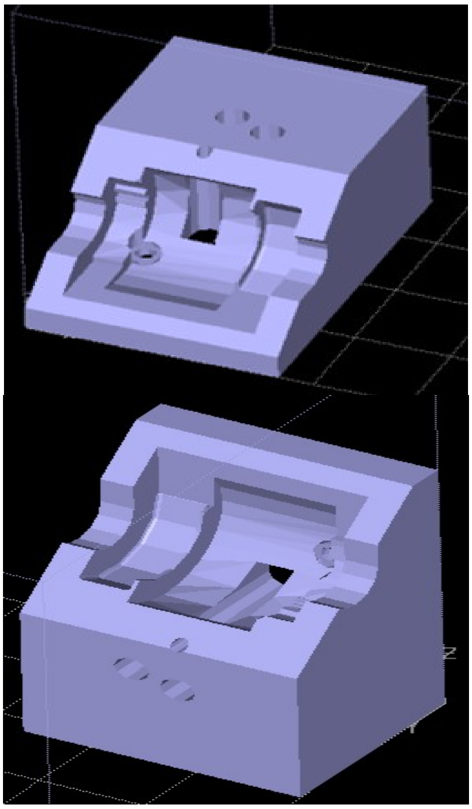

Figure 2. Application of Fused Deposition Modelling technology

3.1 *Optimal Economical Operation of Fused Deposition Modelling Method*

Fused Deposition Modelling method is one of methods that uses special computer format STL. From historical point of view it is the work of developers who establish this format as output data form obtained after digitalization with 3D scanner. Polygon surfaces also known as facets represents areas for volume description. Model in STL format created in some three dimensional CAD software has surface constituted from number of triangles. Number and size of triangles defines the preciseness of curvature of particular model surfaces. [Novakova-Marcincinova L. 2013a][Plancak, M 2009]

Nowadays all CAD software products provide functions and tools necessary for export of created models in STL format that is further used in FDM process. User of 3D technology can change spatial orientation according to his requirements. They should be based on functionality and corresponding quality of complicated surfaces (complex surfaces, planar surfaces under angle, cavities, holes) and also on expected proportion of used basic and support material with focus on economical matters. In most cases automatic mode can be chosen for definition of model position but in that case it is barely justified or explained on the base of functionality of some part surfaces. Next parameter that is important from the viewpoint of final quality and price is definition of thickness of single printed layer. With this parameter there is also related style of model and support material addition as two basic building substances used for prototype production. Material can be build as one unit or particular layers can be printed in grid with lower density what reduces the printing price. Factor of input data quality, factor of suitable software and physical part orientation and factor of relevant density and building layers style are most problematic aspects in process of FDM operation. On the Fig. 3 are presented different possibilities of produced part orientation from quality and production time point of view. [Plancak, M 2009, Novakova-Marcincinova L. 2013b, Jurko 2016, Prislupcak 2014,Panda 2011b]

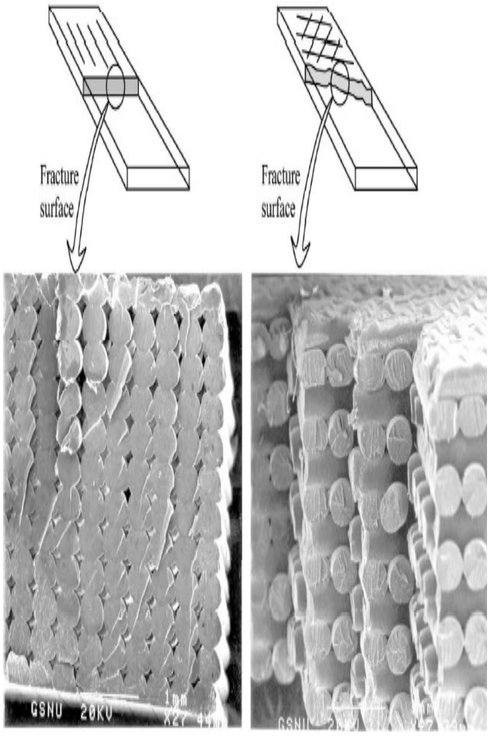

Figure 3. Different part orientation from quality and production time point of view

Following example of preparation of FDM production process describes the problems solved by previously mentioned parts. Model created in Pro/Engineer was exported in STL format and imported into Catalyst software. First the model was oriented as it can be seen on Fig. 4 left, while setting the quality of building material to value Solid a consequently to Sparse-high density and Sparse-Low density. After keeping the parameter of support material on Basic level we obtained data written in Tab. 1. In another situation 3D model was applied to working board with different orientation. In this case the material parameter was also changed from Solid to Sparse-high density and Sparse-low density. Results are obtained in Tab. 2. [Novakova - Marcincinova L. 2012a]

Model 1	**Solid**	**Sparse high**	**Sparse Low**
Model (cm^3)	231,23	176,75	96,53
Support (cm^3)	10,05	10,04	10,05
Time (h)	7:22	7:12	5:07

Table 1. Output values of material usage

Model 2	**Solid**	**Sparse high**	**Sparse Low**
Model (cm^3)	231,01	177,15	98,2
Support (cm^3)	11,9	11,9	11,9
Time (h)	8:13	8:15	6:05

Table 2. Output values of material usage and printing time for 1st model orientation printing time for 2nd model orientation

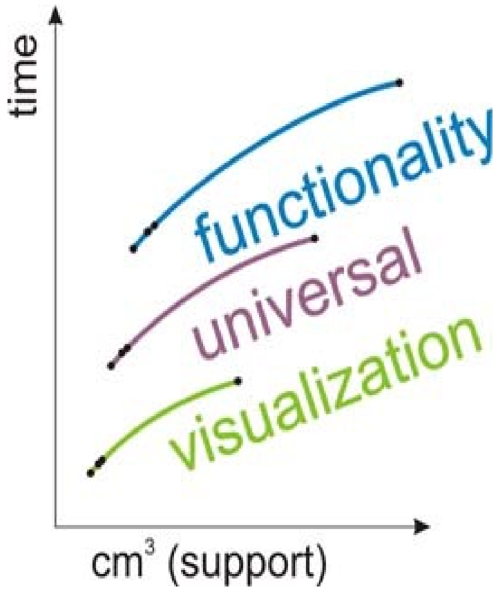

Figure 4. Dependencies of printing time on used material

Presented Fig. 4 is graphical expression of changes in support material application style based on values from previous tables. Curves describe dependence of printing time on usage level of support material. Areas expressing the character of printing from the viewpoint of its economy are situated between these curves. User can decide for concrete category according to expected or requested application field of printed part. [Novakova - Marcincinova L. 2012a, Olejarova 2016,Pandova 2016]

4 CONCLUSIONS

This paper was focused on optimization of RP preparation and operation processes. It described the steps that lead to selection of suitable settings. There are presented output values obtained from production software. By the Rapid Prototyping processes realization can be produced parts from different common and special materials. For the best operation of selected rapid prototyping technologies in manufacturing practice is needed to realize tests of various applications and uses, based on an average rating of the materials and operation settings used in the specific processes. Chapters are focused on optimization of Rapid Prototyping preparation and operation process. There also is algorithm that leads to selection of suitable RP operation settings. Utilization of algorithm is presented on case of part production with use of UPrint device and Catalyst software, system created for utilization of Fused Deposition Modelling (FDM) technology.Assets for the future could lie in possibility of having all the necessary information at once and thus to make the right decision on proper settings variant based on real facts. Realization of such innovation can be achieved through generation of database that would process and archive all output data after production of part models. Relations would be observed between chosen parameters of basic and support material, times of production and quality, all including economical aspects. This supportive database system would together with software philosophy based on described steps for selection of suitable parameters assure maximal economy while keeping comfort and effective way of selection.

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