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MICRO MOULD FABRICATION FOR PLASTIC COMPONENTS WITH FDM: A REVIEW

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Abstract

Fused deposition modelling (FDM) is commercially used to manufacture intricate shape components and tooling, with high accuracy. In the present work, fundamental principles for micro mould fabrication with FDM, process parameters involved and their affect on dimensional accuracy, and mechanical properties of plastic components are reviewed, for application in manufacturing industry.

Keywords: Fused deposition modelling; Plastic components; Dimensional accuracy; Surface finish.

1. Introduction

FDM is a rapid prototyping (RP) technology that forms three-dimensional objects from CAD generated solid or surface models (Singh, 2010a, Singh, 2011a). In this process, FDM materials like ABS, elastomer, polycarbonate, poly-phenol sulphone and investment casting wax feeds into the temperature-controlled FDM extrusion head, where it is heated to a semi-liquid state (Kumar and Kruth, 2010). The head extrudes and deposits the material in thin layers onto a fixtureless base. The head directs the material into place with precision, as each layer is extruded; it bonds to the previous layer and solidifies. The designed object emerges as a solid three-dimensional part without the need for tooling (Bassoli et al., 2007). The FDM process is shown in Figure 1.

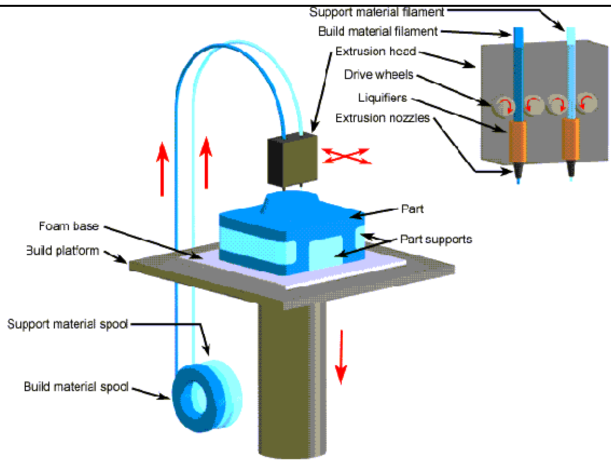

Figure1. Schematic of FDM (Garg, 2011)

FDM process has number of advantages like (Singh and Garg, 2011):

- A good variety of materials available
- Easy material change
- Low maintenance costs
- Thin parts produced fast
- Tolerance of +/- 0.005" overall
- No supervision required
- No toxic materials
- Very compact size
- Low temperature operation

FDM has some limitations also like (Singh and Garg, 2011):

1. Development of seam line between layers
2. Material bumps in case, extrusion head is not moving continuously
3. Requirement of supports
4. Part strength is weak perpendicular to build axis
5. Temperature fluctuations during production could lead to de-lamination

2. Literature Review

FDM is a low cost and reliable technique of 3D printing since past thirty (30) years (Chhabra and Singh, 2011, Singh, 2010b, 2011b). Pham and Gault (1998) discussed a summary of RP technology. The study suggested that there is a requirement for improvement of RP technologies to reduce expensiveness of the final products. Some of the studies have been reported to generate the algorithms in the RP techniques to modify the edges of RP products.(Lam et al., 1998). The proposed route of the RP has been developed the RP products with improved dimensional accuracy and surface finish. Masood et al. (2000) have proposed a mathematical design for optimization of the RP process to reduce the volumetric errors in the RP based products. The study highlighted the use of decision-making theory for selection of build orientation. Nickel et al. (2001) have studies the effects of infill pattern on the residual stress to generate the parts with minimum residual stress. The study is supported by the finite elemental method to investigate the effects of deposition pattern. The results of the study show that deposition angle has impact on part deflection and accuracy.

Anitha et al. (2001) have investigated the characteristics of the FDM printed prototypes. The results of the study highlighted that FDM process parameters have played a crictical role and influenced the strength, surface geometry and dimensional accuracy. Dutta et al. (2001) reviewed the developing fields of layered manufacturing/RP. Three broad topics were considered for study namely: design systems for heterogeneous objects, layered manufacturing processes and the process planning techniques. Several process applications were also outlined in the survey. Some of the studies is focused on the route of comparing the various RP based technologies as per mechanical strength, dimensional accuracy and surface finishes (Upcraft and Fletcher, 2003). These studies highlighted that FDM is one of the promising technology. Gronet et al.(2003) have performed FDM printing with prospective of creating the templates of for preparations of customized acrylic based implants for cranial defects. Thrimurthulu et al. (2004) have proposed the optimal route for 3D printing by FDM considering the part deposition. The study highlighted that average build time and average part roughness can be minimized by selecting the optimal set part build orientation. Lee et al. (2004) utilized ABS models as immediate Investment castings designs for delivering silicone elastic moulds to cast wax IC designs. The focal points inferred incorporate huge measures of expense and time investment funds, moderately exact last castings (normal dimensional mistake 1.5%) with sensible surface quality and the total disposal of hard tooling required in customary IC process.

Masood and Song (2004) developed new metal/polymer composite material successfully and tested it for direct rapid tooling application using the FDM process. Characterisation of this new material displayed desirable mechanical properties, offering fabrication of flexible feedstock filaments for producing functional parts and tooling directly on the FDM system. When comparing of composites made of vast size filler particles with the composites made out of little size filler particles at a similar filler volume content, it has seen that the composite with bigger molecule measure display more prominent elastic modulus and worry than the composite with littler molecule estimate. The composite with littler molecule measure displayed huge ductile prolongation. Use of this new composite material in quick tooling utilizing the FDM framework had appeared great quality parts and infusion forming device additions could be created effectively. Some of researchers highlighted that parts made by FDM have anisotropic properties. From the compression test, it was affirmed that manufacture heading was imperative procedure parameter that influences mechanical properties. Moreover, it was discovered that parts made by FDM had high compressive quality (Lee et al., 2007). Chakraborty et al. (2008) presented an extruder path generation for a new RP technique named “Curved Layer Fused Deposition Modeling” (CLFDM). The prototyping technique employed deposition of material in curved layers in contrast to flat layers as in FDM.

The proposed method would be particularly advantageous over FDM in the manufacturing of thin, curved parts (shells), increase in strength and reduction in the number of layers. Xiaomao et al. (2009) have proposed and tried a powerful and productive help age calculation dependent on cut information. The calculation effectively includes fundamental backings for draping surface as well as for hanging vertexes and edges. It completely used the parts self-bolster capacity and diminished the repetitive backings at most extreme degree. Ahn et al. (2009) defined another methodology for planning the surface unpleasantness of FDM parts. By examination between the deliberate information and figured qualities, the legitimacy of the proposed articulation was demonstrated. Galantucci et al. (2010) contemplated the mechanical properties of FDM models treated with an answer of 90% dimethyl ketone and 10% water have been broke down. The treatment can be utilized to drastically improve the surface completion of ABS models. In states of diminished harshness, a minor decrease of the rigidity was found however a more noteworthy pliability was found. Also, bowing tests uncovered a general improvement of the flexural quality, most likely because of an alternate activity of the arrangement on surfaces worked with various examples or potentially an alternate response of treated fibers to footing and pressure.

3. Discussions

Some researchers have proved that FDM is capable of yielding strong composite parts as bond forms between successive roads and layers due to partial or full melting of the feedstock composite filaments (Kumar and Kruth, 2010, Bassoli et al., 2007, Garg, 2011). Figure 2-4 shows the morphology of ABS plastic material component prepared by FDM.

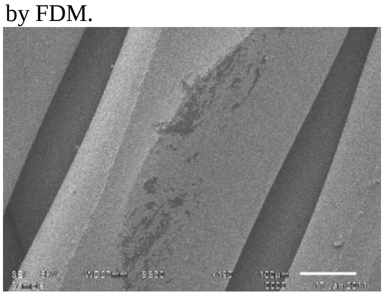

Figure 2. Morphology at the best settings of orientation (Garg, 2011)

Figure 3. Morphology at a rotation of 150 in the X direction (Garg, 2011)

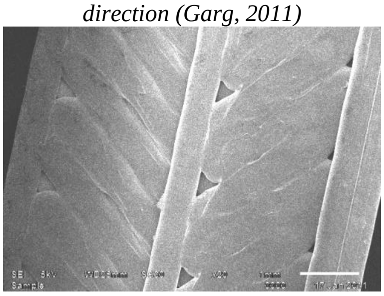

Figure 4. Morphology at a rotation of 300 in the X direction (Garg, 2011)

Morphology uncovered the closeness and consistency of holding between contiguous dots under various introductions. It is seen that display material has not been saved at specific spots and the quantity of spots where the material is left to be kept is diverse under various introductions. It is additionally seen that the span of the un-kept model material likewise fluctuate with the segment introductions. In the present work, the seat mark was distinguished as spanner which is an agent of the hand device industry and fabricated utilizing FDM (Garg, 2011). Hand apparatus industry is an energetic and creating industry which can get advantage from the RP methods. For leading the experimentation, the CAD model of the seat mark (Ref. Figure 5) was made on UNIGRAPHICS programming. The 3D CAD model was changed over into the STL design which was encouraged into the PC connected to the FDM machine for readiness of segment. The 3D demonstrates was changed over into various 2D sees which are appeared in Figure 6.

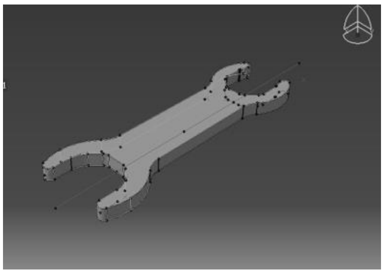

Figure 5. CAD model of benchmark (Garg, 2011)

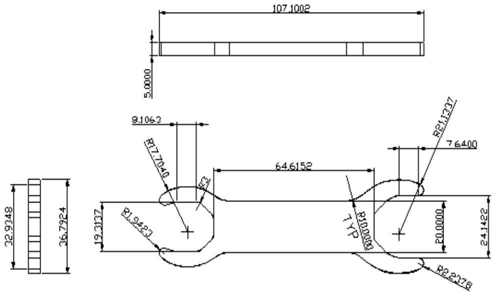

Figure 6. 2D views of benchmark (Garg, 2011)

The machine was cleaned and the seat mark was set in different introductions. In the wake of setting of introductions the part was cut, layer by layer development was done and from that point the segments were cleaned. The best settings were recognized dependent on minimal utilization of help material, show material and the most reduced creation time. The utilization of the material and creation time in various introductions is appeared Table 1.

The morphology of the produced part under various introductions was finished with the Scanning Electron Microscope (SEM) utilizing gold plating. The morphology was checked at the best settings (in view of utilization of model material, bolster material and creation time), at a pivot of 150 to the best settings in the X course and at a revolution of 300 to the best settings in the X bearing. The morphology at the best settings, at 150 and 300 degrees is appeared in Figure 2-4 individually. The investigation of the morphology uncovered that the at the best settings of introduction consistently disseminated grains are watched, which were firmly stuffed when contrasted with the situation of X= 150 and X =300 (Figure 3 and 4) and on this premise it was inferred that the segments created in the level position would be the best for the present contextual analysis.

Table 1- Different orientations of the bench mark (Garg, 2011)

Parameter	Z= 0^0	X=30^0 Y=0^0 Z= 0^0	X=0^0 Y=30^0 Z= 0^0	X=0^0 Y=0^0 Z= 30^0	X=60^0 Y=0^0 Z= 0^0	X=0^0 Y=60^0 Z= 0^0
Model Material (mm^3)	8849	9012.9	9012.9	8849	8849.0	9012.9
Support tmaterial	2294.2	8685.1	11634.8	6227.1	6227.1	5899.3

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(mm^3)						
Time (hours)	0.28	1.29	2.49	1.31	1.34	2.28
Parameter	$X=0^0$ $Y=0^0$ $Z=60^0$	$X=0^0$ $Y=30^0$ $Z=30^0$	$X=30^0$ $Y=0^0$ $Z=30^0$	$X=30^0$ $Y=30^0$ $Z=0^0$	$X=30^0$ $Y=30^0$ $Z=30^0$	$X=60^0$ $Y=60^0$ $Z=60^0$
Model Material (mm^3)	8849.0	8849	9012.9	8849	9012.9	9012.9
Support material (mm^3)	6063.2	11470.9	9176.8	13601.3	13929	5571.6
Time (hours)	2.71	2.21	1.26	2.38	2.39	2.29

The study also highlighted that process capability indices for FDM process is greater than 1 and this is considered to be industry benchmarks, so this process will produce conforming products as long as it remains in statistical control (Garg, 2011). The process lies within +/- 6 sigma and tolerances are well within the tolerance limits as specified by DIN 16901 standards. Further, micro hardness showed that there is little variation in the hardness if taken at the same sample or on different samples which indicated no shift in the process and the process produces components of uniform strength. Sood et al. (2010) determined the functional relationship between process parameters and strength (tensile, flexural and impact) using response surface methodology. The process parameters considered were layer thickness, orientation, raster angle, and raster width and air gap. It was inferred that the quantity of layers in a section relies on the layer thickness and part introduction. In the event that number of layers is more, it will result in high temperature angle towards the base of part. This expanded the dissemination between contiguous raster and quality would improve. However, high temperature angle is additionally in charge of contortion inside the layers or between the layers. Additionally, increment in number of layers likewise expanded the quantity of warming and cooling cycles and therefore lingering pressure gathering increments. This brought about twisting, interlayer splitting and part de-overlay or creation disappointment in this manner lessening the quality. Zero air-gap improved the diffusion between the adjacent rasters but may also decrease the heat dissipation as well as total bonding area. Singh (2011b) highlighted experimental investigations for statistically controlled RM solutions for plastic components using FDM. Final components prepared are acceptable as per ISO UNI EN 20286-I (1995) and DIN16901 standard. The results are in-line with the observations made by other investigators (Singh, 2010b, 2011c). This process ensures rapid production of statistically controlled pre-series technological prototypes and proof of concept at less production cost and time. The study also highlighted that adopted procedure is better for proof of concept and for the new product, for which the cost of production for dies and other tooling is more.

4. Summary

FDM is a relative new RP technique with which parts can be produced accurately and rapidly. It is observed from the literature survey that relatively less work has been reported on FDM as compared to the other RP techniques. Moreover the literature review reveals that research work that has been reported on FDM is on the process development, but very less has been reported on process capability of FDM for specific field applications. So the further research work may be focused on process capability study of FDM for die developments for continuous production. The result of the investigation will be useful to give information to mechanical utilization of the thought about innovation. It will comprehend the procedure bitterly and will likewise change the perspective of industry to receive the procedure. The appropriateness of the procedure will empower the utilization of the procedure at an extensive scale.

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