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Investigation for Surface Quality Improvement of Barrel Finished FDM Patterns Based Vacuum Moulding

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Abstract - In this paper investigations have been made for surface quality improvement of barrel finished fused deposition modelling (FDM) pattern based vacuum moulding (VM) components. VM master pattern was prepared using p-430 grade abs on fdm setup (uPrint-SE), whose surface finish was improved by using barrel finishing (BF) process. The controllable parameters of bf and vm process (namely: media weight, cycle time, vacuum pressure and grain size of refractory sand) were studied at three levels by using taguchi L9 orthogonal array to find out their effects on dimensional accuracy of the final casting. Aluminium 6063 alloy was used for preparing VM components.

Keywords: Fused deposition modelling, Barrel finishing, Surface finish

I.INTRODUCTION

BF is one of the techniques that require lesser time and cost input for finishing of ABS parts. For surface quality improvement of FDM based patterns, barrel Finishing (BF) is the most widely used technology and is also suitable for complex geometries. Every part can be machined including holes, non-symmetric cavities, and parts need not to be fixed [Boschetto, A. et al., 2007]. BF operation consists in loading a charge along with components to be finished, media, water, and compound within a rotating barrel (See Figure1). Depending upon charge composition, adequate rotating speed must be chosen to obtain specific motions, namely rolling and cascade [Henein et al., 1983]. The kinematic is characterized by two regions: passive region and active layer [Mellmann., 2001]. Within the former, the charge has a rigid motion and is carried upwards by the barrel walls until a movement angle is reached [Duran, 2000]. At this stage the charge collapses and a motion in form of avalanches takes place; within this active layer the components and the surrounding media have a relative motion so a delicate abrading action is performed [Boschetto, A., Veniali, F., 2009]. Here the peaks are the only one that cut away from the parts without plastic deformation and the valleys are not affected by the machining [Boschetto et al., 2013]. For BF process not only shape, size, number of faces, edges of media but also the content of abrasive used is of great importance [Cariapa, V. et al., 2008].

Fig. 1 Barrel finishing machine

FDM is an additive manufacturing technology commonly used for modeling, prototyping, and production applications. It is one of the RP techniques that manufactures product in medium volumes effectively in shorten cycle times, material costs and capital equipment for processes [Anita et al., 2001]. FDM machine (seer Figure2) commercially manufactures parts of Acrylonitrile-Butadiene-Styrene (ABS) material by layer-by-layer deposition on a platform. The master patterns produced by FDM are then used for vacuum moulding. The sand grain shape, size and distribution produce a pronounced effect on dimensional accuracy for Al-4%Cu alloy castings made by VM process [Gaindhar, J.L. et al., 1985]. The compaction ratio, bulk density and permeability also shows better results for VM process than conventional sand moulding [Jain, C. K. and Gaindhar, J. L. 1986]. The reported literature has outlined the hybridization of FDM and BF for controlling of roughness surface of the components. The present research work is the combination of FDM, BF and VM process and is mainly related to surface quality improvement of VM specimens casted by Al-6063 (by using barrel finishing on FDM patterns in the pre stages of production and then used for VM). For this case study standard geometry of cubical shape of 34mm sides was taken as a benchmark (see Figure3)

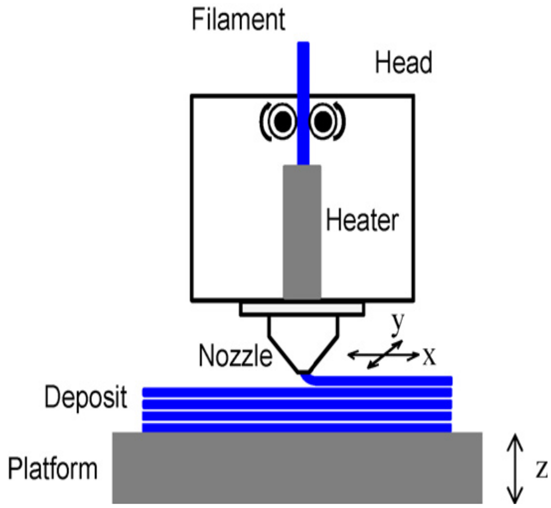

Fig. 2 A manufacturing process to construct a physical model by FDM.

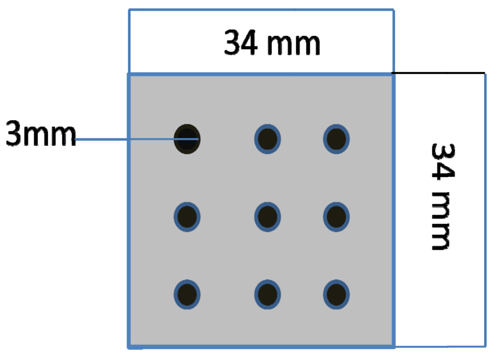

Fig. 3 Benchmark dimensions

II.EXPERIMENTATION

Before conducting final experimentation, pilot experiments were conducted for controlling the levels of input parameters. For the present study, four parameters (two each of BF and VM) have been optimized using Taguchi's optimization technique L9 orthogonal array (see Table1). Four parameters were: media weight, finishing cycle time and vacuum pressure, sand grain size. In this research work, TVBF120STD PU barrel finishing machine was used with diamond shaped media and sodium bicarbonate abrasive. It has been observed that by increasing the media weight above 20 Kg, makes no further improvement on the surface quality of the FDM pattern as it turns into more media loss. Media weight used less than 10 kg was not suitable too, as avalanche motion was not produced which was necessary for material removal. So on the basis of pilot experimentation; three levels selected for media weight which are 10, 15 and 20 Kg. Similarly for other parameters, different levels are selected on the basis of pilot experiments and are tabulated in Table 2. Total 27 (9×3 repetitions) numbers of experiments were conducted by using Taguchi's optimization technique.

TABLE 1 INPUT PARAMETERS

A	B	C	D
Media weight (Kg)	Cycle time (hrs)	Vacuum pressure (mm of hg)	Sand grain size

TABLE 2 CONTROL LOG FOR EXPERIMENTATION

S. No.	Media weight (Kg)	Cycle time (Hr)	Vacuum pressure (mm of Hg)	Sand grain size (AFS)
1	10	2	300	50
2	10	3	350	60
3	10	4	400	70
4	15	2	350	70
5	15	3	400	50
6	15	4	300	60
7	20	2	400	60
8	20	3	300	70
9	20	4	350	50

The dimensional accuracy test of VM components was performed using digital vernier caliper. It should be noted that dimensional accuracy was measured as deviation (i.e. to maximize dimensional accuracy, deviation has to be minimum). Here deviation is difference in dimensions of the cast components from the actual patterns produced on the FDM machine. Deviation was observed at two stages: first at the pre-finishing stage which was measured as the difference in dimensions of FDM pattern before and after BF and second was measured after final casting as the difference in dimensions of cast component and the finished pattern as shown in Table 3. So the final deviation was a difference of change in dimension at the two stages. Based on control log of experimentation (refer Table 2), three sets of experiments were made as D1, D2 and D3 for measurement of dimensional accuracy. The results of deviations are shown in Table 4.

TABLE 3 OBSERVATIONS OF DEVIATION (ΔD) AFTER EACH STAGE

S. No.	Deviation after BF	Deviation after casting	Final deviation
1	0.12	0.65	0.53
2	0.13	0.48	0.35
3	0.14	0.37	0.23
4	0.1	0.42	0.32
5	0.09	0.31	0.22
6	0.09	0.58	0.49
7	0.07	0.32	0.25
8	0.12	0.43	0.31
9	0.12	0.45	0.33

TABLE 4 OBSERVATIONS OF FINAL DEVIATION (ΔD)

S. No.	Δd (mm)		
	D1	D2	D3
1	0.53	0.52	0.54
2	0.35	0.36	0.34
3	0.23	0.24	0.22
4	0.32	0.31	0.33
5	0.22	0.23	0.21
6	0.49	0.50	0.48
7	0.25	0.24	0.26
8	0.31	0.32	0.30
9	0.33	0.34	0.32

III. RESULTS AND DISCUSSION

Based upon result shown in Table 4, Figures 4 and 5 shows S/N ratio for dimensional accuracy and data for means respectively (for smaller the better type case).

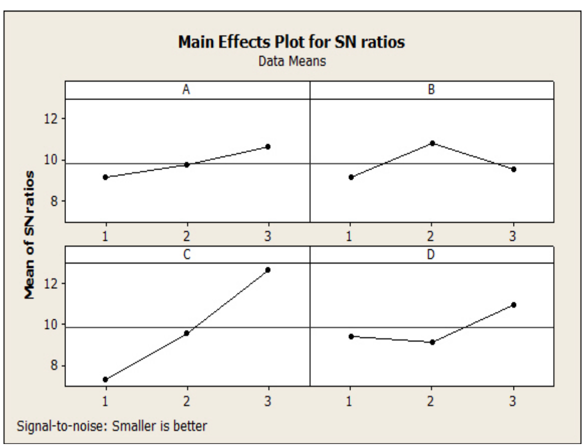

Fig. 4 S/N ratio graph for deviation

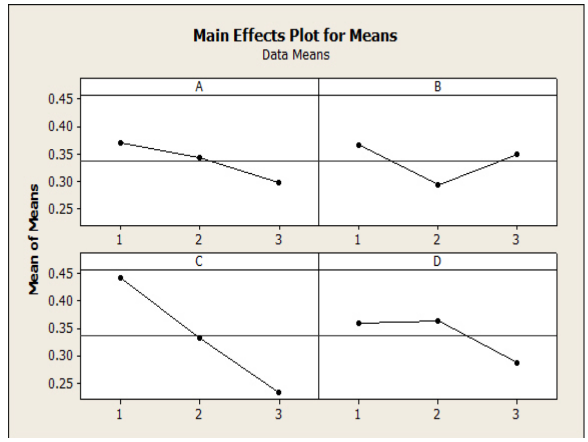

Fig. 5 Means graph for deviation

As observed from the Figure4 the optimized settings for dimensional accuracy is obtained as:

- Media weight–20kg because as media weight increases, more amount of media and abrasive comes in contact which results in more material removal from the pattern and when casting is done on that pattern it results in less deviation from the actual size of the pattern.
- Cycle time–3hours because at 2hours of processing, the amount of material removed from the surface was less which results in more deviation on casting whereas at 4hours of processing, the media loss (due to rubbing against each other) was more and results, in attachment of wooden dust to the FDM pattern and in more deviation on casting. So it has been observed that best result was found at 3hours at which material removal rate was more and results in less deviation on casting.
- Vacuum pressure–400mmhg because as the vacuum pressure increases the compaction in the sand increases which results in tight mould and acquires the shape of the pattern more accurately, therefore results in less deviation from the actual size of the FDM pattern.
- Sand grain size–70 because as the mesh number increases, the grain becomes finer. So 70 grain size is the finest among the selected sizes and adhere the shape of the pattern more precisely so as to give less deviation.

Based upon Table4, Table 5 shows percentage contribution of input parameters for dimensional accuracy. The confirmatory experiment has been conducted on the optimized setting obtained from S/N ratio graph for different parameters and found out that percentage improvement in dimensional accuracy is 66%. These results are valid for 95% confidence level and are in line with the observations made by other investigators.

TABLE 5 PERCENTAGE CONTRIBUTION OF INPUT PARAMETERS FOR DIMENSIONAL ACCURACY

Parameter	Media weight	Cycle time	Vacuum pressure	Sand grain size
Dimensional accuracy	5.83%	7.99%	76.14%	10.04%

IV.CONCLUSIONS

Improvement in dimensional accuracy has been successfully observed by introducing BF in between FDM and VM process as a pre-finishing process. The results suggest that media weight, cycle time, vacuum pressure and sand grain size significantly affects the dimensional accuracy. The best parameter setting for dimensional accuracy is: media weight-20Kg, cycle time-3hours, vacuum pressure-400mm/Hg and sand grain size-70 respectively. This study may be further carried out with more number of input parameters and their levels.

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