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Experimental Investigations for Use of ABS Replicas in Investment Casting Applications

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Abstract – **In the present research work effort has been made to study the use of acrylonitrile butadiene styrene (ABS) replicas in investment casting (IC) applications. The study starts with selection of the component for industrial application with an idea of improvement in dimensional accuracy (Δd) of the component. The input parameters are part orientation in fused deposition modeling (FDM), number of layers, layer combination and type of materials in IC. The study highlights the percentage contribution of different input parameters on Δd for ABS replicas in IC.**

Keywords: **Fused deposition modeling, Investment casting, Dimensional accuracy, Part orientation, No. of layers, Slurry layer's combination, Metal type.**

I. Introduction

Casting industry is a vital segment of the manufacturing sector, and continues to produce intricate parts with curved surfaces, blends, internal features and varying thickness, in the widest range of size and weight, in virtually any metal or alloy, in an economical manner [1]. A large number of casting processes are available today, with sand and IC accounting for over 80% of total casting production [2]. Today, nearly 60 RP processes are available, producing parts in over 70 materials including polymer blends, paper, ceramics and metals [3]. Depending on the material, these parts can be directly used as patterns for sand casting, or as consumable patterns for IC [4-6]. FDM is one of the RP process which works on the principle of additive method [5]. In FDM process the part is fabricated by deposition of layers. This process is able to quickly fabricate complex-shaped, 3D parts directly from computer-aided design models. The key idea of this technology is based upon decomposition of 3D computer models data into thin cross-sectional layers, followed by physically forming the layers and stacking them up; "layer by layer technique" [7-8].

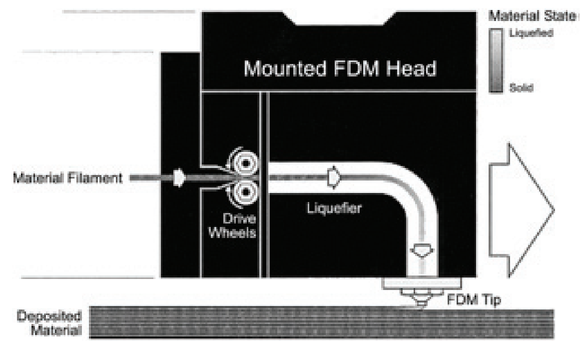

Fig. 1 Schematic of FDM [4]

A plastic filament or metal wire is unwound from a coil and supplies material to an extrusion nozzle which can turn the flow on and off as shown in Fig.1. The process detail of the combination for both FDM and IC process is shown in Fig. 2.

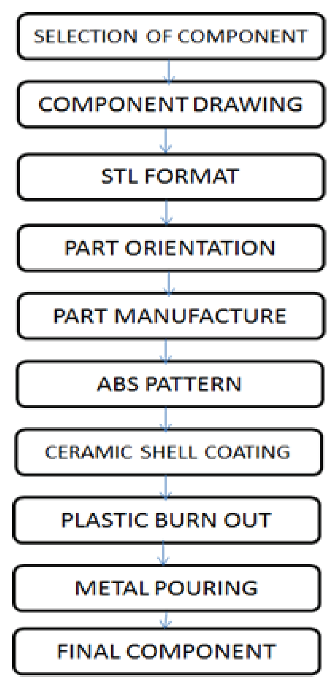

Fig. 2 Schematic of Process [4]

The literature reviews reveal that lot of work (experimental and theoretical) has been reported on FDM and IC process independently. But hitherto very less has been reported on application of ABS replicas (prepared by FDM machine) for IC application. So in the present work, it is proposed to study the effect of process parameters of FDM and IC for sound casting (as regards to **Δ**d of final component). For the present study an industrial component has been selected. The detailed drawing for the component has been made using solid works (CAD software). The drawing has served as the input to the FDM machine and a tree for IC process has been generated. The Taguchi optimization approach has been applied to study the process parameters. Following are the objectives of study:-

- To investigate the use of ABS replicas in IC applications.
- To develop a model for better '**Δ**d' based upon Taguchi approach.

II. Design of Experiments

Before going for the final experimentation, pilot experiments were conducted in order to analyze the contributing parameters and their levels. For the present study, one parameter of FDM and three parameters of IC were studied in pilot experimentation and their ranges for best outputs were fixed. Basically, in the pilot experimentation for FDM it was found that the horizontal (0°) orientation of the component gives the better results as regard to material and time consumption (Ref. Table1) and for IC it was found that the mould requires 7-9 numbers of refractory layers (Ref. Table II).

Table I Orientation Results

Position	Material Consumed ($inch^3$)		Time (Hrs.)
	Support	Model	
0°	0.98	1.191	3:14
30°	2.501	1.161	5:52
45°	2.60	1.20	6:03
60°	1.47	1.22	3:36

Breakdown of the mould was occurred during the metal pouring in case of number of layers lesser than 7 because the pouring pressure of the metal is not sustainable to the mould and weight of mould was increased as in case of more than 9 numbers of layers. Further in the three levels of layer combination, primary and secondary combinations were kept fixed while the tertiary layer combinations were varied. The primary coating was made with the finest refractory followed by coarse one. Aluminum, gun metal and brass were used for the present research work. These three metals were selected for the present work because components are casted commercially with these metals, and they have industrial applications in marine, petroleum industry and distilled water discharge pipe line respectively. Final experiments were conducted under the constraint of processing parameters and their levels (as shown in Table II) by following Taguchi L9 O.A. (Ref. Table III). The dimensions of patterns assembly tree are shown in Fig. 3.

Table II Three Levels and Three Parameters

S. No.	No. of Layers	Layer Combination	Type of material/ Melting Temp.
1	7	1+3+3	Aluminum (680°C)
2	8	1+3+4	Brass (900°C)
3	9	1+3+5	Gun Metal (950°C)

[*Note: 1+3+3 signifies one primary layer, one secondary layer and three tertiary layers. Similarly in case of 1+3+4 and 1+3+5, tertiary layer are varied accordingly while primary and secondary layers remains unchanged]

Table III Modified Control Log For Experimentation

S. No.	No. of layers	Layer Combination	Type of material
1	7	1+3+3	Aluminum
2	7	1+3+3	Brass
3	7	1+3+3	Gun Metal
4	8	1+3+4	Brass
5	8	1+3+4	Gun Metal
6	8	1+3+4	Aluminum
7	9	1+3+5	Gun Metal
8	9	1+3+5	Aluminium
9	9	1+3+5	Brass

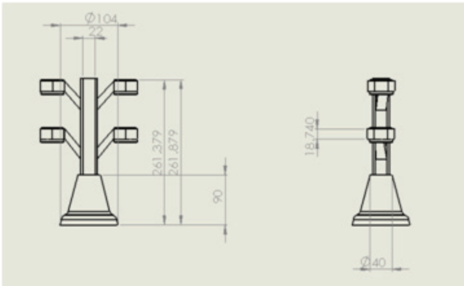

Fig. 3 Schematic of component

III. Results and Discussion

Based upon Table III, three repetitions of experiment were made as R1, R2 and R3 for measurement of **Δ**d. The **Δ**d is basically the amount by which the metal component shrinks or changes its dimensions after casting. The dimensions of ABS patterns is measured and that of the final casted products. The difference in both sizes gives the Δd as given in Table IV.

Table IV Observations of Final Experimentation for (ΔD)

S. No.	Δd (mm)		
	R1	R2	R3
1	0.37	0.36	0.38
2	0.09	0.09	0.1
3	0.25	0.24	0.23
4	0.15	0.14	0.16
5	0.28	0.27	0.28
6	0.37	0.36	0.38
7	0.29	0.3	0.28
8	0.31	0.3	0.32
9	0.14	0.15	0.16

Table V shows the variation of S/N ratio and Δd w. r. t. to no. of layers. Fig. 4 shows the highest value of the S/N ratio and Δd w. r. t. to no. of layers and gives the best setting.

Table V Variation Of S/N Ratio, ΔD W. R. T. To No. of Layer

S. No.	S/N Ratio	Δd
1	13.87093	0.234444
2	12.08626	0.265556
3	12.46123	0.25

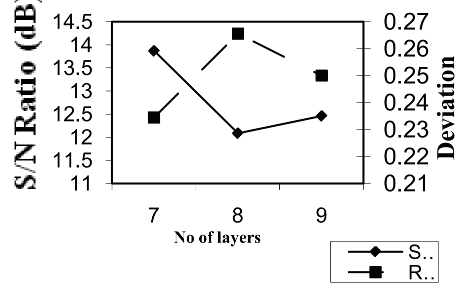

Fig. 4 S/N ratio and Δd w. r. t. to no. of layers

Table 6 shows the variation of S/N ratio and Δd w.r.t. to layer combination. Fig. 5 shows the highest value of the S/N ratio and Δd w. r. t. to layer combination and gives the best setting. Table VII shows the variation of S/N ratio and Δd w. r. t. to type of metal. Fig. 6 shows the highest value of the S/N ratio and Δd w.r.t. type of material/ melting temperature. Based upon Fig.4-6 confirmatory experiments were conducted for Δd. Table VIII shows optimized results as per confirmatory experiments. These results are valid at 95% confidence level and are in line with observations made by other investigators [6-10].

Table VI Variation Of S/N Ratio and ΔD W. R. T. to Layer Combination

S. No.	S/N Ratio	Δd
1	13.87093	0.234444
2	12.08626	0.265556
3	12.46123	0.25

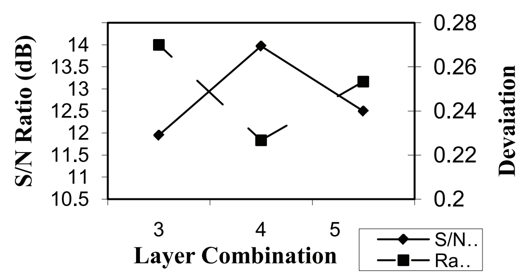

Fig. 5 S/N ratio and Δd w. r. t. to layer combination

[*Note: Layer combination 3 signifies 1+3+3, 4 signify 1+3+4 and 5 signifies 1+3+5].

TABLE VII VARIATION OF S/N RATIO, ΔD W. R. T. TO TYPE OF MATERIAL/ MELTING TEMPERATURE

S. No.	S/N Ratio	Δd
1	9.145819	0.35
2	17.83962	0.131111
3	11.43298	0.268889

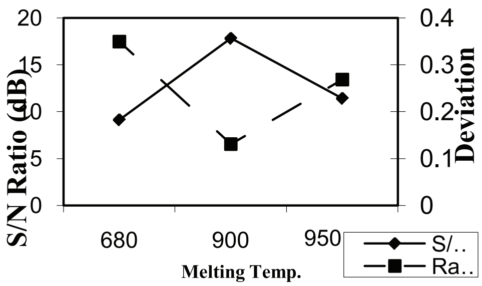

Fig. 6 S/N ratio and Δd w.r.t. type of material/ melting temperature

TABLE VIII OPTIMIZED RESULTS AS PER CONFIRMATORY EXPERIMENT

S. No.	No. of layers	Layer Combination	Type of material	Δd (mm)
1	9	1+3+5	Aluminum	0.29
2	7	1+3+3	Brass	0.08
3	7	1+3+3	Gun Metal	0.24

Fig. 7 shows pie chart of percentage contribution for Δd in present case study of combination of FDM and IC.

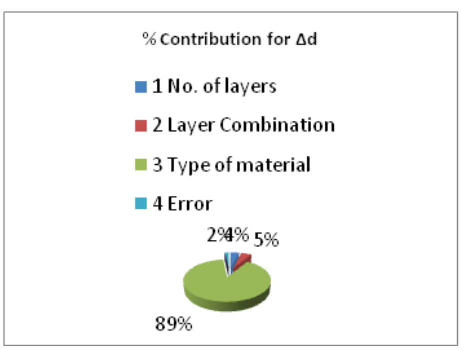

Fig.7 Pie Chart for contribution of Δd

III. CONCLUSIONS

The component has been successfully prepared by combining FDM and IC process. The result suggests the input parameters, i.e. no. of layers, layer combination, melting temperature affects the Δd. The optimum parameters of dimensional accuracy for aluminum are 9 no. of layers with combination 1+3+5 and for brass is 7 no. of layers and combination 1+3+3 and for gun metal is 7 no. of layers and combination 1+3+3. The confirmatory experiment has been conducted and percentage improvement in dimensional accuracy for aluminum is 6.6%, for brass 11.11% and for gun metal 4% respectively.

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