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Estimation of Cost for producing an Exhaust Fan through Injection Moulding and Comparison with Rapid Tooling

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***Abstract*—Injection Moulding is one of the widely used methods to produce plastic parts. Cost is one of the predominant factors that affect the selection and usage of a particular technology. This paper provides an insight on manufacturability and cost estimation for injection moulding tool required to make an exhaust fan. The cost thus arrived by conventional means is compared with the cost associated with the use of Rapid Tooling technology.**

***Keywords*—Injection Moulding, Cost, Manufacturability, Estimation, Exhaust Fan, Rapid Tooling.**

I. Introduction

Injection moulding is one of the most common processes used to produce plastic parts. It is a cyclic process of rapid mould filling followed by cooling and ejection. The material, which is generally available as grains or powder, is plasticized in an injection unit and injected into a clamped mould under high pressure [1]. In Injection Moulding Industry greater degree of competence is required to estimate the cost associated with a system, which determines the selling price and profit margin for the product because it is carried out from toolmakers point of view rather than end use of product or process involved. Ferreira and Alves had tried to validate the integration of reverse engineering and rapid tooling technologies in foundry process [2]. Yarlagadda and Wee had made an attempt to design, develop and evaluate the performance of mould inserts for injection moulding by using a powder sintering process [3]. Ferreira et al. had proposed a methodology to integrate reverse engineering with additive rapid prototyping and tooling techniques in order to manufacture EDM electrodes by reducing lead-time and the associated costs [4]. Luo and Tzou had developed the direct metallic Rapid Tooling system by optimizing the process parameters of laser cladding so as to fabricate the mould inserts in order to produce ABS parts of high quality [5]. Rahmati and Dickens had evaluated the rapid tools (built by Stereolithography process) to analyze the maximum number of successful injections and quality of performance [6].

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Ahn had presented the researches related to the application of laser assisted metal rapid tooling process to manufacture moulding and forming tools [7]. Efforts have been made by Nagahanumaiah et al. to build a methodology for process selection and manufacturability evaluation of computer based rapid tooling for producing injection moulds [8]. Attempts were made by Folgado et al. to develop a model so as to have the lowest life cycle cost in the manufacture of injection moulds [9]. Liou et al. had developed a solution to the problem of de-molding destruction by presenting a heat-generable mold insert for micro injection molding [10]. This paper proposes a methodology on manufacturability of the mould and estimation of cost required to make the mould both by conventional tooling process and rapid tooling process.

II. Methodology

The details of exhaust fan are shown in figures 1(a) and 1(b). The core and cavity of mould tool to make the exhaust fan is designed as per HASCO standards by providing shrinkage allowance of 1.25%, draft angle of 1^0 along core side and 1 mm radius in all sharp corners [11]. Vericut 6.2.1 is used to generate the NC code and study the manufacture of mould and its allied difficulties therein.

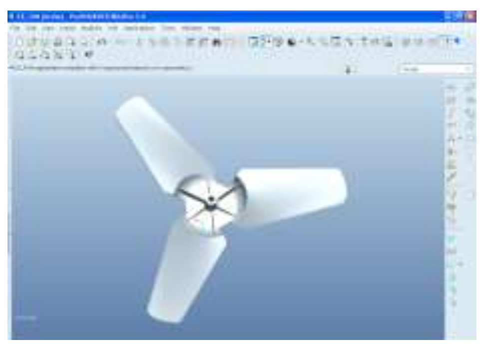

Fig. 1(a). 3D CAD Model of an exhaust fan

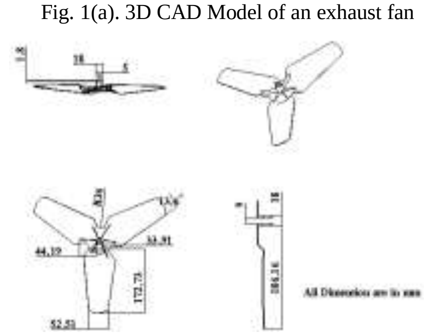

Fig. 1(b) 2D drawing of exhaust fan

The Cavity and Core of mould so designed are shown in figures 2(a) and 2(b) respectively. The cavity work piece before NC machining is depicted in figure 3. The roughing view of the cavity is shown in figure 4. The finishing play path of Cutting tool for Cavity is shown in figure 5. The work piece of core before NC machining is depicted in figure 6. The roughing view the core is displayed in figure 7. The finishing view of the play path of cutting tool for core is displayed in figure 8.

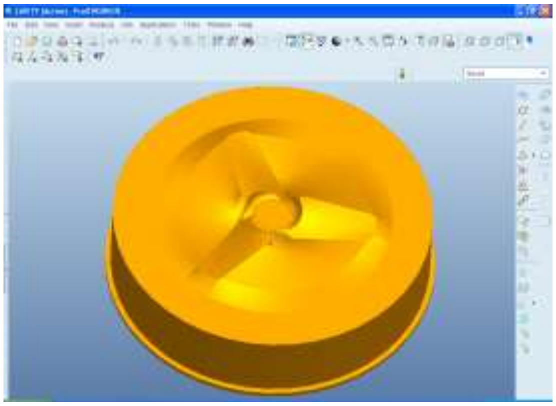

Fig. 2(a) Model of Cavity

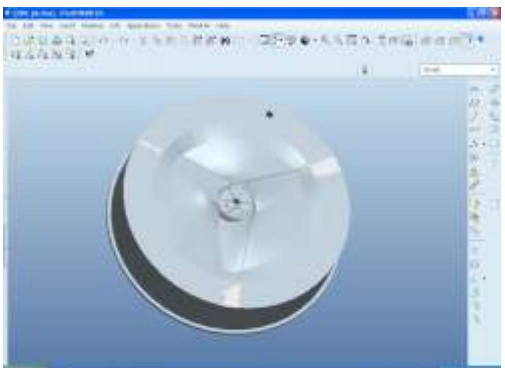

Fig. 2(b) Model of Core

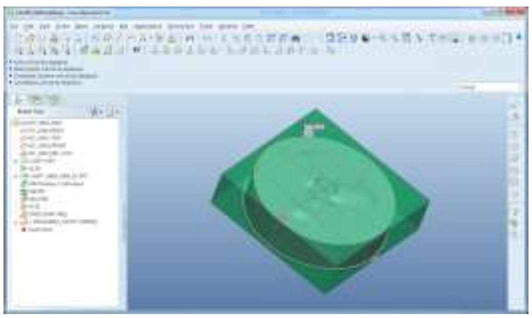

Fig. 3 Cavity Work piece

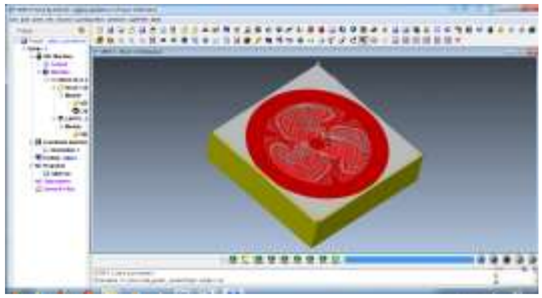

Fig. 4 Roughing view of the Cavity

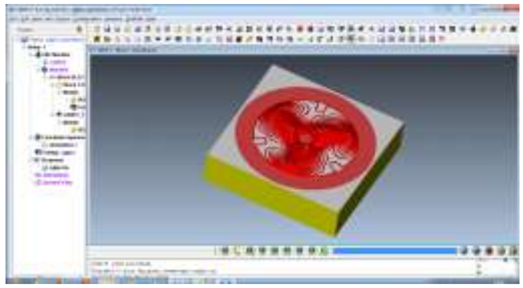

Fig. 5 Finishing view of the Cavity

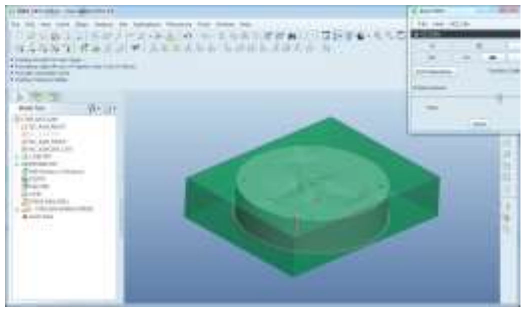

Fig. 6 Core Work piece

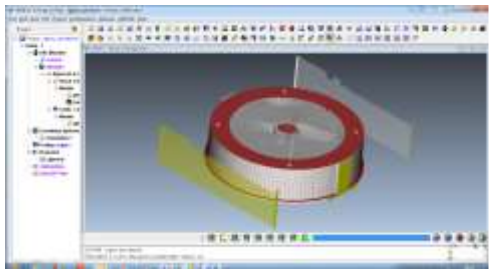

Fig. 7 Roughing view of the Core

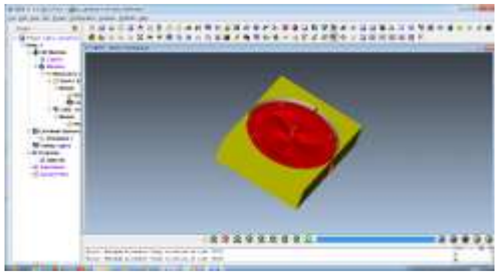

Fig. 8 Finishing view of the Core

III. Estimation of Cost

A. *Estimation of cost for conventional tooling*

The bill of materials required to fabricate a mould with its associated cost is furnished in Table 1. The processing cost required to make an entire mould assembly is shown in Table 2. Further Table 3 shows the total cost associated with the conventional tooling system.

B. *Estimation of cost for Rapid Tooling*

The cost for making a mould by Rapid Tooling depends upon several factors viz. additive manufacturing technique adopted, layer thickness, orientation; build time, tessellation file with triangles/facets, size of the mould, cooling channels etc. Hence two commercially available techniques which are widely used in the industry for short volume of production is demonstrated in this paper. They are Stereolithography (SLA) and Fused Deposition Modeling (FDM). Moreover the cost of Rapid Tooling depends upon build time, immaterial of the complexity of the mould unlike conventional tooling. Therefore the build time for these techniques is determined based on which the cost is calculated. Rapid Tooling time depends on the material to be built, not the material to be subtracted as the case of conventional machining process. Hence the external dimensions of the mould are reduced for bringing down the usage of material and cost as the tool is for low volume of production quickly. For large volumes of production and the situation where time is not a rigid constraint, conventional process is economical. The build times shown in Table 4 may seem to be high, albeit it is very low when compared to the days or weeks of time required to make a conventional mould by the skilled personnel. Table 5 shows the cost parameters involved in Rapid Tooling.

A generic cost model for rapid tooling to estimate the cost is given in equation (1). The labor costs shown in Table 5 are with reference to the organizations based at Bengaluru, India as on the date of studies performed and may vary from place/country. Furthermore the total cost calculated comprises of risk of 15% and a transportation cost of INR 2000 for both core and cavity.

IV. Conclusion

An injection mould tool is designed for fabricating exhaust fan. The manufacturability of exhaust fan is studied using Vericut software after generating the CNC manufacturing program to make the mould using conventional process of machining. A methodology for arriving at the tooling cost for manufacturing exhaust fan is depicted. The estimated costs of mould using conventional machining process and Rapid Tooling (SLA and FDM) are compared. Even though the three costs were nearby, the urgency of the mould, volume of production and quality required are the factors that determine the implementation of rapid tooling process. For low volume of parts to be produced quickly, Rapid tooling is the most feasible process immaterial of the complexity of part design.

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Table 1. Individual component cost

S No	PART DESIGNATION	MATERIAL DETAILS (All the dimensions are in millimetres)	PRICE (INR)
1	Core plate	796x796x150mm=741.33kg Material used is EN28	Rs.174212/-
2	Cavity plate	796x796x150mm=741.33kg Material used is EN28	Rs.174212/-
3	Core back plate	796x796x40mm=198.95kg Material used is mild steel	Rs.13263/-
4	Cavity back plate	796x796x20mm=99.47kg Material used is mild steel	Rs.6632/-
5	Ejector plate& retainer plate	600x600x18=50.868kg Material used is mild steel	Rs.3392/-
6	Ejector pins	Qty-3 Material used is OHNS	Rs.1200/-
7	Push Back pins	Qty-4 Material used is EN8	Rs.1200/-
8	Guide pillar and guide bush	Qty-8 Material used is carbon steel	Rs.8000/-
9	Grids	796x100x85mm length Qty-2 Material- EN8	Rs.7000/-
10	Sprue bush	Material- EN8	Rs.600/-
11	Dowel Pins	Dia 20x150 pins	Rs.500/-
		MATERIAL COST	Rs.390211/-
		+20% Allowance	Rs. 78042/-
		TOTAL MATERIAL COST	Rs. 468253/-

Table 2. Processing cost required for making an entire mould assembly

S.No	PROCESS	Cost in INR
1	Primary machining	Rs. 7,500
2	Machining of Core	Rs. 25,000
3	Machining of Cavity	Rs. 30,000
4	Cylindrical grinding of Guide pillar	Rs. 5,000
5	Heat treatment for core, cavity, runners, overflows	Rs. 30,000
6	Polishing for core, cavity, runners	Rs. 25,000
7	Chrome plating for core, cavity in pattern area	Rs. 3,000
	TOTAL	Rs. 125500

Table 3. Total Mould Cost

S.No	Particulars	Cost in INR
1	Material cost	Rs. 468253
2	Machining cost	Rs. 125500
3	Transportation	Rs. 2000
4	Risk (15% of material & machining cost)	Rs. 89063
	TOTAL	Rs. 684816

Table 4 Build Time for Rapid tooling

RP machine	Manufacturer	Material	Layer thickness (mm)	Build rate (mm^3/min)	Reference	Build time (hours)
SLA 5000	3D Systems	SLA 5530	0.10	1092	[12]	28.62
FDM 250	Stratasys	ABS (P400)	0.25	300	[12]	104.17

A generic cost model for rapid tooling to estimate the cost is given in equation (1) below [12].

$$C_T = (T_{pre} + T_{post})C_{labour} + T_{build}C_{build} + (1 + \frac{lp}{100})W_{part}C_{part\_mat} + (1 + \frac{ls}{100})W_{sup}C_{sup\_mat} \quad (1)$$

where, C_T is the total cost involved using Rapid Tooling in Indian Rupees (INR), T_{pre} is the pre-processing time before building a part (h), T_{post} is post-processing time, (such as support removal), in building a part (h), C_{labour} is labour cost rate (INR/h), T_{build} is build time (h), C_{build} is machine hour rate (INR/h), l_p is percentage of part material loss, W_{part} is the weight of the part material (kg), C_{part_mat} is rate with which part material is procured (INR/kg), l_s is the percentage of support material loss, W_{sup} is the weight of the support material (kg), and C_{sup_mat} is the cost of the support material (INR/kg).

Table 5 Cost parameters for Rapid Tooling

RT process	T_{pre}	T_{post}	C_{labour}	T_{build}	C_{build}	l_p	W_{part}	C_{part_mat}	l_s	W_{sup}	C_{sup_mat}	C_T
SLA	2	3	2000	28.62	2000	5	35	4000	60	15	2000	605152
FDM	1	2	1000	104.17	1000	5	30	3500	50	10	2500	588316