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Rapid Investment Casting – Road ahead

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Abstract— Rapid product creation is the buzzword of present market. Prototyping market is thriving today. Conventional manufacturing fails to obey the prototyping marketers 'Faster –Cheaper –Better' dictum. The Prototyping market urges to-days' manufacturers to explore technology integration for compliance . Integration of conventional precision casting process with various rapid prototyping technologies is one of the finest logical options opened to the rapid product development research community, in the realm of precision engineering component development. This paper is made on the same theme. Here, SLS technology, the most popular Rapid Prototyping but the least recommended for the stated purpose is selected for experimentation. Equipments used are 1. Dilatometer,2. SLS Sinterstation,3. Precision casting Lab. The test pieces are modelled in Duraform Polyamide powder on SLS machine. Test pieces are tested for its thermal expansion on Dilatometer. A series of tests are carried out on the dilatometer for exploring the possibility of restricting the thermal expansion of Durafrm artifacts. Duraform expansion is compared with one of the recommended investment casting sacrificial pattern material . Interesting observations are made , thermal expansion restricted considerably ie from 2.2 % to0.3% !!!. It is a success on laboratory scale. Hence authors invite RP research community to commercialise the concept suitably, for the benefit of precision casting industry. Authors are working in their RP lab on technology integration in the area of precision components development.

Index Terms— SLS Selective Laser Sintering, RP Rapid Prototyping, RT Rapid Tooling,RM Rapid Manufacturing,IC Investment Casting, Shell Crack,Thermal Expansion .

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1 Introduction

RP is one of finest technologies available to conventional manufacturers for technology integration to reach the dictum ' Faster –Cheaper – Better' [1]. RP products are principally are of 'feel and fit' type and functionally unfit at large. Researches are working on this opportunity to convert RP products into full 'Feel-Fit – Function' artifacts. RT is the bridge between RP and RM . One of the logical and technologically promising alliance feasible in the area of precision engineering components development is between IC and RP. This integration makes their advantages multiply and disadvantages nullified [2],[3].

In the above regard many commercially available RP technologies variants claim capacity to generate patterns for precision component castings,such as SLA –QuickCast[4] , DTM –Cast Form[5], SANDERS - ModelMaker[6], envisiontec .GmbH – ULTRA,PERFACTORY [7],Stratasys-FDM [8],[9],[10] etc. But authors feel the capacity of RP machines to replace the wax is questioned for its high thermal expansion compared to wax, which rupture the shell[11],[12],[13],[14]. Any attempt to counter the potential chance of shell crack would be a support to the precision prototype development community[14]. Authors have made considerable advancement in this realm[15],[16] and this paper is an accidental observation made in the research on the topic and points at one of the possible means to counter the shell crack. This concept would be a lead to the researchers of RP community to explore its practical use on Industry shop floor.

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2 Experiment

2.1 Description

Orton Dilatometer Fig.1 is a versatile piece of equipment designed to measure the thermal Expansion/Percentage Linear Dimensional Change of any solid material (ceramics, glass, metal, polymers etc)as a function of temperature. Standard Orton Dilatometer is a digital, horizontal, single sample bench top system comprised—

Fig 1

-of a furnace with silicon carbide heating element (1600°C), fused quarts sample holder system, thermocouple , sample displacement system (consisting of Probe Rod, Linear Variable Dimensional Transducer and counter weighed pulley.),Control board for furnace and data acquisition with Orton software. Sample holder pushes and position it into furnace . The test temperature range can be set as per the test requirement. Temperature ramp can also be set. The expansion of the sample is probed and transmitted to LVDT, it generates signal corresponding to the change in sample length and continuously sends that signal to the Orton Board Computer along with the thermocouple output.

As a result, the PLC(percentage linear change) Vs. temperature of the test sample is obtained from the display continuously [17]. The readings against each sample can be recorded in the form of a graph or discrete numerals.

2.2 Test Piece Preparation

It was decided to chose SLS RP machine. Here energy source used to fuse the polycarbonate power to required shape is laser. Fig.2 gives its working principle. All the components including the laser system is placed in an oven. The build chamber has a nitrogen rich atmosphere kept at around 150-175°C. This provides safety and help heat balance . The feed piston movement is a measure of the feed powder, build piston movement is a measure of layer thickness and sump piston just collect the excess.

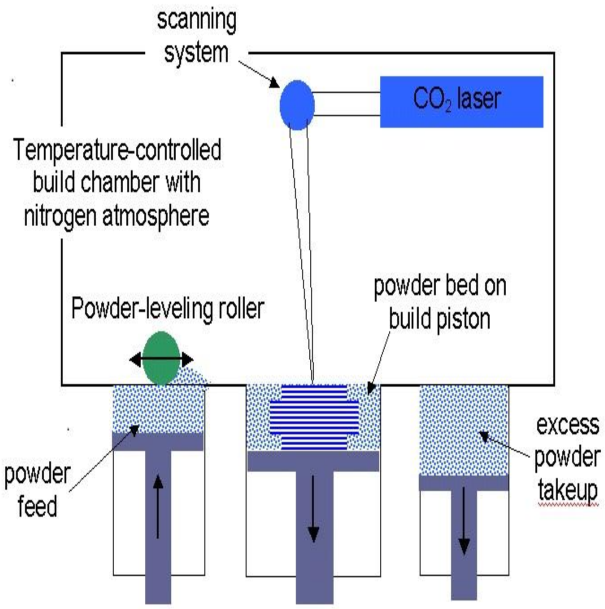

Fig.2

The job spreading the powder true to the thickness of each layer without a spilling is done by the feeder roller mechanism mounted and travelling over the table. Once the bottom most layer(cross section/ slice) is sintered the feed mechanism raises the feed piston and lowers the build piston in the respective chambers exactly by one layer thickness to sinter the second layer of powder. Once all the layers are sintered the part is removed from the excess powder and sent for grit blasting BREAKOUT room and finishing room. [18],[19]. The test samples (12 X 12 mm cylinders) are modelled in CATIA software , converted into STL file and transported into SLS machine. A few operating parameters set on RP machine for generating the test samples are given in the Table 1. Fig 3 shows some test samples generated on SLS RP machine.

Table 1

Sl.No	Settings	Value
1	Laser power	18W
2	Scan spacing	0.12 mm
3	Layer/Slice Thickness	0.1mm
4	Scanning speed	2000mm/s
5	Part bed Temperature	1750 C

The test samples are cleaned, checked for dimension and loaded as per the standard procedures in the Dilatometer set up. There were considerable delays in between the experiments as to maintain the machine and temperature. The respective test result of the samples from the graphical output are recorded.

Fig.3

3 Results

The experimental data and result are recorded as in the Table 2.

Tabble.2

Sample identi-fication	Initial Length Lo mm	Start Temp, oC	End (set) Temp,oC	%linear Change,PLC= ΔL/Lo *100	Remark
SLC 0I	12.22	30	170	2.24	Duraform test bar,Tested from room tem 30C
SLC I	12.22	60	170	1.58	Duraform test bar
SLC II	12.22	100	170	0.87	Duraform test bar
SLC III	12.22	130	170	0.76	Duraform test bar
SLC IV	12.22	145	170	0.51	Duraform test bar
SLCV	12.22	165	175	-	Duraform test bar,Unable to record the reading , machine tripped,as temperature balancing eratic. But expect a reading around 0.3.approximately equal to ABS value.
FDM – ABS	12.22	30	10	0.33	ABS -test bar tested from roomTemp30C

4 Discussion

SLS RP machine is quite much in the RP market and very versatile with respect to its speed , accuracy and precision and ideal for preparing patterns for precision casting . But stamped unsuitable for the stated purpose as thermal expansion of Duraform-its build material is very high ; around 7 to 10 times more than FDM ABS[20]. Hence authors were exploring a possibility of restricting the expansion of Durafom patterns such that it will not rupture the IC shell during its firing.

Fig 4 and Fig 5 show a few revealing examples of shell crack with RP biuld materials,SLS in perticular.It is also helpful to explain the relative magnitude of crack and oviouly the need to forstall it

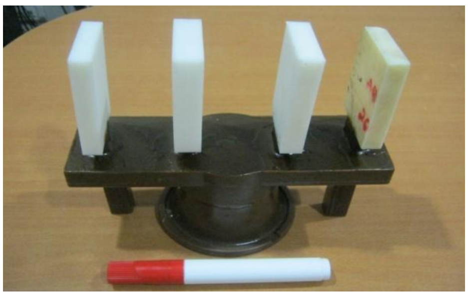

Fig 4

Fig 5

The thermal expansion, referring the Table2, of SLS part has been cut down to around five folds ,ie from 2.22% to 0.51% when the sample SLC IV was tested from 145o C instead of testing from room temp. Still more encouraging is that for sample SLC V at 165oC ,authors expected a value around 0.3% but due to the difficulty arose with balancing the initial –final temperatures the Dilatometer tripped. More over the dilatometer requires a minimum of 21 sets of reading for giving the graphic output. The most interesting part of this work is that the expected PLC value (0.3%) for SLS sample is almost same as that of FDM ABS , which is claimed to be suitable for preparing sacrificial RP patterns for IC.
Here authors like to draw an analogy between the autoclave impact on wax firing and the possible firing cycle for Duraform removal. As we know one threat common and critical to all investment casters is the thermal expansion. The conventional IC plants are concerned with that of wax and ceramic shell. They know the Wax expands a little compared to that of ceramic shell. But at temperature below 40o C wax relative expansion is many magnitudes more than that of shell and the evidently the shell cracking tendency is countered by controlling Time & Pressure* in the auto clave such that wax melted before it expands. RP community knows that autoclave conventional control is not all suitable for removal of RP patterns, however the same logic may be used to restrict the expansion of RP patterns.

Fig 6

Fig 7

Fig 6 and Fig 7 show a revealing example of shell crack with conventional wax, cuased becuase of the uncontrolled firing of the shell.It is also help to understand even wax shell also fails if firing is done in an uncontrolled way.
Obviously this experiment lead us to a very interesting conclusion that one can restrict the thermal expansion of RP pattern to tame it against causing shell cracking that the popular SLS technology with Duraform would be a feeder for Rapid Investment Casting . If realized it will be a break though in RP application. But application of this concept on the foundry shop floor is a challenge . This challenge opens up innumerable opportunities for researchers to work on it. The research community need to model and simulate the firing process of SLS pattern with its ceramic blanket. It is quite an interesting research option and once a scientific firing cycle is established, it would be a priceless contribution to the Indian precision casting industries.

5 Conclusion

The work claims success in restricting the expansion of SLS Durafom from 2.2% to 0.3% when carried out in a controlled atmosphere .But it is also relevant to remember the success made is on laboratory scale . Hence it invites the RP research community to incubate the concept suitably to promote rapid product development precision casting industry - Rapid Investment Casters.

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