Proceedings of the 72nd World Foundry Congress
21-25th May 2016, Nagoya, Japan

Critical Analysis of Rapid Prototyping assisted Investment casting for Medical Implants

Dheeraj S. Bhiogade[1], Sanjay Randiwe[1], Dr. A. M. Kuthe[2]
[1] Ph.D scholars, Department of Mechanical Engineering (CAD-CAM), India
[2] Professor, Department of Mechanical Engineering, India
Visvesvaraya National Institute of Technology, Nagpur, Maharashtra, India,

Medical applications are some of the most interesting applications of the rapid manufacturing using rapid prototyping (RP) technologies. Produce RP model of the organ structure, which is very useful for diagnosis, surgery planning, training, and development of custom implants. The paper presents the rapid manufacturing process i.e. Casting using ABS polymer pattern & investment casting process for SS316L alloy femur implant. Simulation programs (AutoCAST-X) are used to achieve sound, high quality castings in first attempt. Also the procedure for design of casting system for any intricate shapes has been elaborated, thus foundry engineer facing difficulty. RP pattern based investment casting overcomes the conventional wax pattern process along with validated & optimized process.

With the use of computer software the mold filling and solidification has assured the quality of castings with a higher degree of confidence, and reduces the cost of rejects & major improvements being realized in the areas of controlling shrinkage porosity defects.

Keywords: *Rapid prototyping, Investment casting, Rapid manufacturing, Custom implants, Simulation.*

1. Introduction

The product development from the conceptualization stage to the finish product, numbers of stages involved such as CAD, analysis, casting simulation, optimization, pattern/mold making, melting & pouring of metal, inspection & testing. A dominant technology for producing tailor made product is rapid prototyping (RP). Fused deposition modeling (FDM) is an additive technology suite for producing prototypes and final parts with complex geometries using ABS (Acrylonitrile Butadiene Styerne) [1, 2]. RP has proved be a cost-effective and time-efficient approach for development of products [4, 5]. Worldwide, metal called stainless steel is extensively used, now it also used in human body as prosthesis (implant) [3].

In the one of the study indicated regarding the shell cracking during the burnout process of investment casting, when the invested shell is not strong enough to resist the exerted forces due to thermal expansion. From FEA, the predicted rupture temperature is 350° C, at which the induced stress exceeds the Modulus of rupture (MOR) of the ceramic and thus fractural cracking occurs [6]. In this study procedure for avoiding the mold cracking during burn out process was demonstrated.

2. Methodology of rapid-prototyping

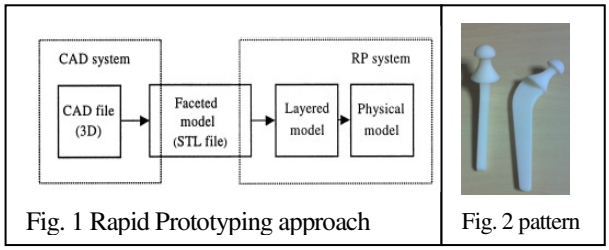

Fig. 1 Rapid Prototyping approach

Fig. 2 pattern

Fig. 1 shows the block diagram of pattern development approach, & finished and cleaned RP pattern shown in fig.2.

3. Methodology of rapid manufacturing/Rapid casting

3.1 Steps involved in rapid casting process are

a. Pattern was developed using RP technology & used for investment casting.
b. Baking of mould & complete evaporation of RP pattern was inside of muffle furnace.
c. Metal melting & pouring.
d. Finished casting after solidification.

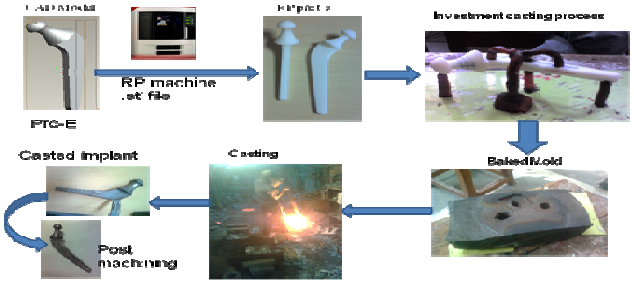

Fig. 5 Rapid manufacturing process for Implants

4. Experimentation

The investigated temperature increasing pattern inside muffle furnace for complete evaporatiton of RP pattern as shown in Table 1:

Table 1: The investigated temp. increasing pattern

Sr. No.	Temperature in (^{0}c)	Status of ABS-Plastic Material
1	At 100 ^{0}Cat 15 min	Solid form
2	At 127 ^{0}C at 15 min	Start to melt
3	At 200 ^{0}C at 15 min	Melting start
4	At 300 ^{0}C at 15 min	Melting continue
5	At 350 ^{0}C at 15 min	Melting complete
6	At 400 ^{0}C at 15 min	Smoke out start
7	At 500 ^{0}C at 15 min	Vaporization start
8	At 500 ^{0}C at 30 min	Vaporization continues at 30 min. Smoke continue
9	At 500 ^{0}C at 40 min	Evaporates completely

5. Mould making

Materials and accessories required for Molding are; vibrator, zirconium sand (biosint extra powder), biosole liquid, muffle furnace, RP-ABS polymer part.

Table 2: Technical data for zirconium sand

Mixing ratio	100 g powder :15 ml liquid
Total expansion	0.95 % - 1.65 %
Mixing time under vacuum	60 second
Processing time span	3 – 5 min.
Compression strength	According to concentration of the expansion liquid between 15 and 20 MPa

Formula for number of packets required for making mould (found from small experiment)

From 1 packets made =287cc volume of net block

Then for 1 cc volume of block = (1/287) packets

Then we can say for any volume of $(\pi/4*d2*h)$ block

Net Volume of sand material= Volume of block-Volume of pattern (sample)

$= \pi/4*d2*h - \pi/4*D2*H$ … if sample were cylinder.

No. of packets required to be is

$$(N) = \frac{\text{Net Volume of sand material}}{287}$$

A ceramic block, which shape is depends upon the RP part, makes a block with minimum sand material and optimum shell thickness, made by poured coat of agitated ceramic slurry (zirconium sand slurry) & allowed to dried under controlled conditions within 30 min. After the blocking process completed baked in muffle furnace for complete burnout of pattern by ramping the temp. up to 500^{o}C according to investigated temp. increasing pattern as per table 1. Backing process sinters the ceramics block and cause invested RP model to be burned out.

5.1 Block Washing

To remove ash and ceramic dust, the block was washed with a forceful air by blower & by water. The water stream is allowed to enter one gate and exit through another gate or a vent or riser. During washing, the water is agitated by shaking the block vigorously.

5.2 Casting

The completed block is now ready to receive the molten alloy. The block is preheated, and the alloy is cast into it according to the foundry's operational procedures.

Fig.6 Actual femur implant casting along with radiograph

Conclusion

- Complete vaporizion of ABS pattern obtained by varying the temp. up to 500 ^{0}C in stages.
- Changes in time & temperature profile of baking was susceptible to crack, residue or half burn.
- If shell thickness reduces, mould may damage due to the forcees of molten metal.
- With the help of simulation data the casting process was improved & ease in manufacturing of complex shapes.
- The study is much helpful for tailor made implants casting in order to overcome the defects.

References

[1]R. Patil, S. M. Kumar, E. Abhilash :IJEIT, Volume 1, Issue 4, April 2012

[2] A. Pranjal, B. Prof. A. M. Kuthe :Proceedings of the 5thMESI Conference – Zaragoza – June 2013.

[3] Roger A :Dairy food & environmental sanitation ,vol.20,No.7,Pg. no. 506-517.

[4] S. Jauhar, K. M. Asthankar & A.M. Kuthe :(AMEA) 181 Vol. 2, No. 3, 2012, ISSN 2167-6380 Copyright © World Science Publisher, United States

[5] D.S. Ingole , A.M. Kuthe: Emerlad Group Pub. Ltd', 2009.

[6] W.L.Yao, Ming C. Leu: MCB University Press',1999.