

Investment casting using Rapid Prototyping

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Abstract

Today's rapid product development and global market conditions set demands for companies to adjust quickly to new conditions and to constantly adopt new technologies. It is a necessity of the hour to bring about a revolution in manufacturing industry from mass production manufacturing to tailor made manufacturing in which products are manufactured according to the desire of the customer. For that new time efficient manufacturing processes are being developed and rapid prototyping is one of them. Rapid prototyping methods is used for making a prototype or pattern for casting a product. This paper gives an insight into the investment casting process assisted by rapid prototyping and further 3d printing techniques.

Keywords: Investment casting, rapid prototyping, 3D printing.

Nomenclature: I.C: Investment Casting, STL: Stereolithography, 3D printing: three dimensionl printing.

1. Introduction

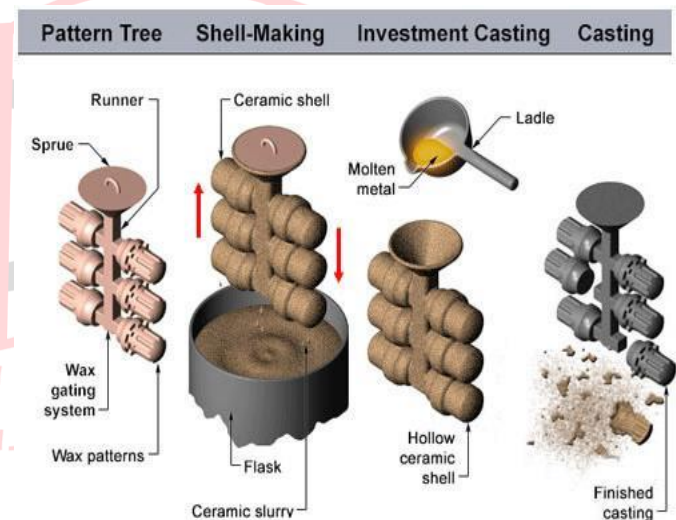
In casting industry there is always a competition to reduce production cost, to shorten timelines and to increase productivity and quality. Along with this environmental protection should also be taken into consideration. Investment casting offers an economical method for mass production of complex shaped metal parts. However, high tooling cost and longer timeline associated with fabrication of metal molds causes a major problem. As the production of I.C wax sacrificial patterns, result in cost justification problems for customized single castings of small and medium quantity production. Rapid prototyping techniques can reduce the cost associated with single part or small quantity production as they can be applied to the fabrication of I.C patterns containing complex and intricate designs with significant cost and time savings technologies. The meaning of prototype technology, as its definition, is simply a technology to assist the manufacturing of new products for demonstration, and to test geometry and dimensions. By this method, there is no need to prepare patterns and dies by traditional method of casting.

2 .Rapid prototyping for investment casting

2.1 Investment Casting

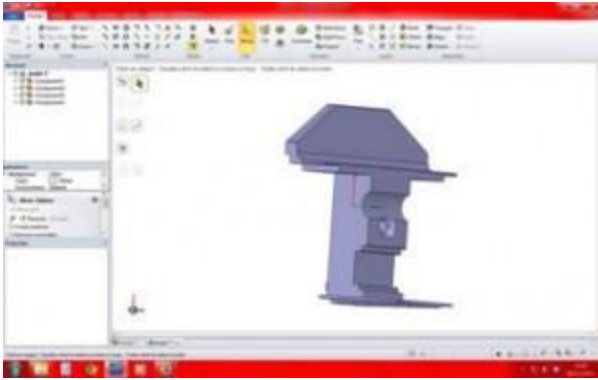
Investment casting is a manufacturing process in which a wax pattern is coated with a refractory ceramic material. Once the ceramic is hardened, its internal geometry takes the shape of the casting. The wax is melted and taken out and molten metal is poured into the cavity. The metal solidifies within the ceramic mold and then the metal casting is broken out. This manufacturing process is also known as lost wax casting. (The Shrinkage of wax, shrinkage of ceramic material invested over the wax pattern and shrinkage of metal casting should be taken in consideration in investment casting.) Conventionally, the investment

casting process are accurate though time consuming, so an alternative method which can reduce the process time cycle is needed. One of the possible answer to such demands on product development is the use rapid prototyping method.



2.2 Rapid prototyping

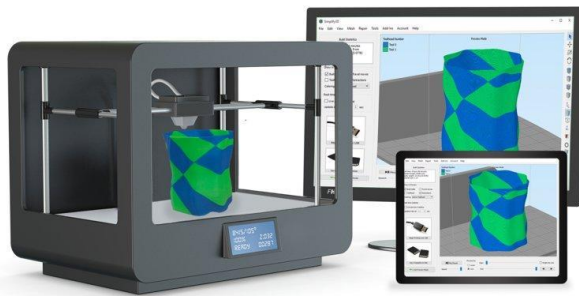
Rapid prototyping is essentially a method used to fabricate a scale model of an assembly or a physical part by the usage of three dimensional computer aided design data. (It provides 3D visualization for digitally rendered images.) Using this technique a wide range of innovative ideas can be transformed into perfectly functioning end user products. This construction of parts is done using "additive layer manufacturing" technology or in other words using 3D printing. Various 3D printing technologies like SLS, SLA, DMLS, CJP and FDM are used for this prototyping.



2.3 3D Printing:

The process in which material is joint or solidified under computer control to create a three dimensional object with material being added together such as powdered grains or liquid molecules being fused together is referred to as 3D printing. Objects of almost any shape or geometry can be produced using digital model data from an electronic data source or a 3D model.

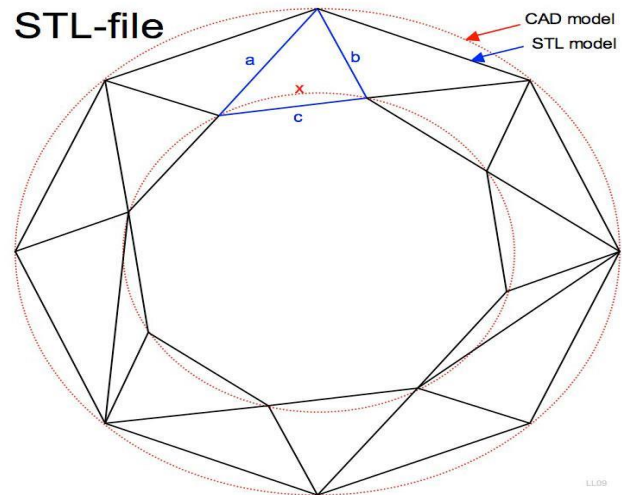
In a 3D printing process a whole object is turned into thousands of tiny little slices then makes it from the bottom up slice by slice. These layers stick together to form a solid object. 3D printers can create moving parts like wheels and hinges as a part of the same object.



2.3 Steps involved in Investment Casting using Rapid prototyping:

1. Standard software models for computer aiding such AUTOCAD, SolidWorks, Pro/Engineer, Catia, etc. are used for the definition of three dimensional CAD models.
2. To create STL file: it is the standard format used for the rapid prototyping which presents the three dimensional surface as a set of planar triangles. It is impossible to obtain accurately curved surface due to triangle planarity. This problem can be solved by increasing the number of triangles or reducing their size.

STL-file



3. Appropriate algorithms are created by cutting layers or models by height or size .layer density, i.e. their distance depends on the desired accuracy and can range from few hundredth of millimeter to several millimeters.
4. Appropriate devices such as 3D printers are used to create physical layers. This process is repeated for several layers, starting from lowest layer till top final layer.
5. After creating the model, residue materials are removed and if necessary the model is grinded, polished or varnished. This is known as post processing. Thus, a pattern for casting is formed.
6. Next, A ceramic shell is created around the Rapid prototype pattern using ceramic slurry, to form the necessary mold for casting.
7. The required gating systems and vents are implemented in the mold as per the design of the pattern.
8. The metal is poured inside the mold.
9. The burnout of the casting tree depends on the material used for making the pattern. In this process the casting mold is usually kept inside a furnace set at an appropriate temperature (depending on cast material) and the pattern is allowed to melt out of the mold cavity. Sometimes, this burnout is carried out in a two-step process-
 - a. De-waxing
 - b. Pattern burnout.
10. Appropriate cleaning or washing method is followed after the burnout to cleanse the casting clean of the pattern residue.
11. The final step before obtaining the casting is plugging the vent holes, which were previously open to aid the burnout process.

Thus a finished product is obtained by using the combination of rapid prototyping and investment casting.

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Materials used:

Following is a brief of some of the materials used for making the pattern using rapid prototyping technique.

1. **Polycarbonate (C₁₆H₁₈O₅):** the patterns created by using polycarbonate are quite porous. Exact level of porosity for the patterns vary with build parameters, but this is generally not a critical factor in using the patterns for investment casting. Though they must be sealed prior to dipping in ceramic slurry. When the wax is molten and the pattern heats to the temperature of wax (about 190° F) negligible distortion has been observed in the pattern.
2. **TrueForm PM™:** TrueForm PM™ does not need to be dipped in wax to seal the surface before shelling unlike polycarbonate. These patterns are approximately 70% dense. Patterns made from this material have excellent feature definition, surface finish and are significantly more accurate than patterns made from polycarbonate.

Advantages:

Rapid prototyping's role is to construct the master model that in turn is used to produce the pattern.

1. Investment casting using rapid prototyping requires less time as compared to conventional investment casting.
2. As with investment casting, rapid prototyping minimizes the cost.
3. Rapid prototyping modelling is advantageous in getting more complex geometries fairly quickly with less manpower.
4. More accuracy is achieved using rapid prototyping and 3D printing.
5. Rapid prototyping only uses the material needed to create the item being produced. Conventional investment casting process generates a lot of waste by discarding the

extra material not used for the manufacturing of the pattern. 3D printing uses every part of every material used in the process.

Market Growth:

Nowadays, a number of investment foundries are competing in the market not only are they finding that they can compete effectively against machining, they are making better margins than before on high volume orders on which they build their business.

Very few people anticipated that the most significant impact of additive fabrication technologies on the already established manufacturing process was to give it a new life in markets like never before.

One of the primary drivers for this market is the capability of rapid prototyping equipment to increase effectiveness and the product development process. Prototyping enables the production of reliable and cost effective products and reduces the need for multiple prototypes and analysis time.

Conclusion:

When we talk about customized products manufactured as per the demands of the consumer, one cannot leave any room for faults. Whereas in rapid prototyping process, the simulations and the casting design is already done in the software and one has to follow the design as mentioned by the software report and the process suggested by the customer. Also parts which are intricate in shape and are required in small quantities, the same process can be utilized where there is no tension of core or cope and drag or ramming of sand where there is a chance that the pattern might be damaged.

Fabrication of hard and complicated tooling is not required for rapid prototyping. The accuracy and surface finish on the pattern manufactured using this process has a significant impact on the advancement in casting industry. Beginning with wax and progressing to polycarbonate, this process can now produce accurate patterns with very good surface finish, requiring very little hands-on post processing thus reducing both fabrication time and cost of pattern fabrication.

References:

1. Pranjal Jain, A.M. Kuthe (2013), Feasibility study of manufacturing using rapid prototyping: FDM approach, The Manufacturing Engineering Society International Conference, MESIC 2013.
2. Jin-wu Kang and Qiang-xian Ma (2017), The role and impact of 3D printing technologies in casting, China Foundry, vol. 14 no. 3.
3. www.shellcast.com, Reducing lead time with rapid prototyping.
4. www.wikipedia.org, Investment Casting.

5. www.wikipedia.org, 3D printing.
6. www.wikipedia.org, Rapid prototyping.
7. Clinton L. Atwood, Michael C. Maguire, Michael D. Baldwin, Brian T. Pardo (1996), Rapid Prototyping: A paradigm shift in investment casting.
8. C. W. Lee, C. K. Chua, C. M. Cheah, L. H. Tan, C. Feng, (2003), Rapid investment casting: direct and indirect approaches via fused deposition modelling, The International Journal of Advanced Manufacturing Technology January 2004, Volume 23, Issue 1-2, pp 93-101
9. www.ppcpinc.com, Investment casting advantages and disadvantages.
10. www.efunda.in, Rapid prototyping: an overview.
11. Bralla, J.G. (ed.) (1986), Handbook of Product Design for Manufacturing, McGraw-Hill (New York).
12. www.stratasysdirect.com, 'Technical application guide for rapid prototyping pattern.' By stratasys 3D printers and production systems.

