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Investment Casting Process: Advance and Precise Casting Technique for Complex Product Design

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Abstract

With the times changing and world getting more focused towards superior quality, manufacturers have started looking for better processes so as to make better product. Casting industry has shifted focus towards better casting techniques of which investment casting is of prime consideration. Literature available for investment casting is limited and not enveloped properly in one title. This paper aims at providing detailed description of the Investment Casting technique, its importance as casting process and its applications. Further this paper discusses comparison of Investment casting with conventional methods, its advantages and drawbacks.
Keywords: Investment Casting, Precision Casting, Casting Techniques.

I. Introduction

The technique of investment casting is both one of the oldest and most advanced of the metallurgical arts [1]. Investment castings are at work in the fiery combustion chambers of jet aircraft and in the sub-zero vacuum of space [2]. Yet, the root of this technology, the cire –perdue or "lost wax" method dates back to at least the fourth millennium B.C. The artists and sculptors of ancient Egypt and Mesopotamia used the rudiments of the investment casting process to create intricately detailed jewellery, pectorals and idols. Remarkably, civilizations as diverse as China's Han Dynasty, the Benin Kingdom in Africa and the Aztecs of pre-Columbian Mexico employed similar techniques. The cross-cultural adoption of this complex process implies a great degree of commerce and communication in antiquity. In Renaissance Europe, the Italian Sculptor, goldsmith and author, Benvenuto Cellini, cast his bronze masterpiece "Perseus and the head of Medusa" using the lost wax process. Cellini detailed his achievement in his famous autobiography, one of the classics of world literature. The investment casting technique was largely ignored by modern industry until the dawn of the twentieth century, when it was "rediscovered" by the dental profession for producing crowns and inlays. The first authenticated record of the use of investment casting in dentistry appears in a paper written by Dr. D. Philbrook of Council Bluffs, Iowa in 1897.However, the true significance of this process was not realized until Dr. William H. Taggart of Chicago published his research in 1907.During World War II, with urgent military demands overtaxing the machine tool industry, the art of investment casting provided a shortcut for producing near-net-shape precision parts and allowed the use of specialized alloys which could not readily be formed by alternative methods.

Investment Casting Process

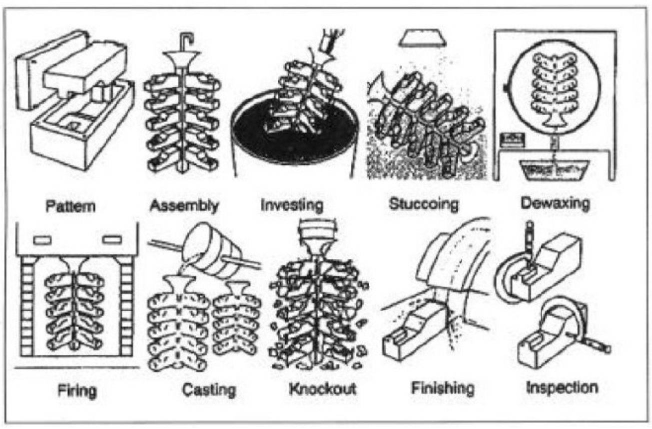

Figure 1: Progress in Investment Casting, Source: Ram Prasad, Aero Metals Inc., USA

The figure 1 shows the progress in investment Casting. The investment casting process proved practical for many military components and during the post war period it expanded into many commercial and industrial applications where complex metal parts were needed, however, the process was still relatively obscure [3]. It was in this period that Hitchiner Manufacturing Co., Inc. was founded. In the decades that followed, many innovations such as the shell process, the steam autoclave, conveyorization, automation, and robotics have modernized and transformed the process.In today's world, investment castings touch all of our lives. When we fly on an airplane, drive an automobile, play golf, use a utility tool, power tool or hand tool, we are using investment castings. Once thought of as suitable only for low volume, high cost applications, investment casting has evolved into a technology capable of producing quantities of millions of pieces per year, at costs rivalling those of less flexible and desirable methods.

1. Pattern box:
The investment castings process begins with fabricating the injection die. It can often require several months of lead time. The metal die must make allowance for shrinkage of both wax and later the metal casting, about 0.011 to 0.015 in. per in. total. [4]
2. Wax pattern and gating system:
Then comes fabrication of a sacrificial pattern with the same basic geometrical shape as the intended finished cast part. Patterns are normally made of investment casting wax that is injected into a metal wax injection die. Waxes employed are blends of beeswax, carnauba, ceresin, acrawax, paraffin, and other resins usually obtained as proprietary mixtures. The wax is injected into the mould at 150 to 170 F and at a pressure of 500 to 1000 psi.
3. Assembling:
Once a wax pattern is produced, it is assembled with other wax components on a central wax stick, called a sprue, to form a casting cluster or assembly.
4. Pre- coating/ Dipping/ Investing:
The entire wax assembly is then dipped in a ceramic slurry. A typical slurry consists of 325-mesh silica flour suspended in ethyl silicate solution of suitable viscosity to produce a uniform coating after drying.
5. Coating/ Stuccoing:
Then pouring of the investment- moulding mixture around the pattern is coated. The moulds are then allowed to air set. The dipping and stuccoing process is repeated until a shell of ~6-8 mm (1/4-3/8 in) is applied.
6. DE waxing:
Once the ceramic has dried, the entire assembly is placed in a steam autoclave to remove most of the wax. Wax is melted out of the hardened mould by heating it in an inverted position at 200 to 300 F. The wax may be reclaimed or reused.
7. Pre- heating/ Burn out / Firing:
The remaining amount of wax that soaked into the ceramic shell is burned out in a furnace. The moulds are heated from about 1600 to 1900 F for ferrous alloys and 1200 F for aluminium alloys. The burnout and preheating cycle must completely eliminate wax and gas-forming material from the mould.
8. Gravity pouring:
When the mould is at temperature, the metal is gravity-poured into the sprue. Air pressure may then be applied to the sprue to force-fill the mould cavity.
9. Finishing
The casting is allowed to cool. Once the casting has cooled sufficiently, the mould shell is chipped away from the casting.Next, the gates and runners are cut from the casting.After minor final post processing (sandblasting, machining), the castings - identical to the original wax patterns - are complete and ready for shipment.

II. Advantages and Limitations of Investment Casting

- The biggest advantages of investment casting are that it is possible to produce a very wide variety of products across different industries.[5]
- Many Intricate forms with undercuts can be cast.
- A very smooth surface is obtained with no parting line.
- Allows high dimensional accuracy. Tolerances as low as .003in (.076mm) have been claimed.
- Very thin sections can be produced by this process. Metal castings with sections as narrow as .015in (.4mm) have been manufactured using investment casting.
- The finished piece will need no welding or assembling, you save on time and cost that would be required using other methods.
- Certain un-machinable parts can be cast to preplanned shape.
- Practically any metal can be investment cast.
- It may be used to replace die casting where short runs are involved.
- Parts of the investment process may be automated.
- An example of a larger-sized product that can be made using investment casting is turbine blades with complex shapes for power generation industries. The blades can be single-crystal, directionally solidified, or conventional equi-axed blades. The firearm industry is another example of where investment casting is used, but for smaller precision parts. Some of these parts include firearm receivers, triggers, and hammers.[6]

- Investment casting is a complicated process and relatively expensive.
- Is usually limited to small casting, and presents some difficulties where cores are involved.
- Investment castings require very long production-cycle time compare to other casting processes.[7]
- Holes cannot be smaller than 1/16 in. (1.6 mm) and should be no deeper than about 1.5 times the diameter.
- This process is practically infeasible for high-volume manufacturing, due to its high cost and long cycle times.[8]
- For hollow parts, like competition kettle bells, we could not make the whole parts totally, after casting, we still need to weld the bottom and then powder coating.[9]
- Many of the advantages of the investment casting process can be achieved through other casting techniques if principles of thermal design and control are applied appropriately to existing processes that do not involve the shortcomings of investment castings.[10]

III. Comparison of investment casting with other casting Process

Concepts	**Sand casting**	**Die casting**	**Investment casting**
Description	Process that mixes raw sand, clay and water, which is then compacted around a pattern to create a mold. Most common type of molding, suitable for any production volume, and typically a low-cost option.	Method in which molten metal is forced into a metal die under pressure. This process is suitable for repeatability of medium- to high volume, intricate or close-tolerance parts.	Casting process in which wax replicas are coated with a slurry mix of ceramic refractory and sand, allowed to dry, and then heated to extract the wax, leaving behind a near-net-shape cavity. Capable of creating shapes that are small or intricate components. Widely used to eliminate additional machining expense.
Metals	Most Castable Metals	Aluminum, Zinc, Magnesium, &Copper	Most Castable Metals
Size range	All sizes per foundry capabilities	Typical max mold area = 3 ft2	0.1 to 100 lbs
Tolerances	0-3" = 0.03" per in. + 0.005" per in. for each additional in. Across parting line add 0.020" to small castings, 0.090" to large castings	0.0015" per in. Not less than 0.002" on any one dimension. Across parting line add 0.010"	+/-0.005" per in. up to 3" add 0.002" per in. over 3"
Relative cost	Low	Low	High
Surface Finish	Ferrous: 420-900 RMS Aluminum: 175-350 RMS Copper Base: 300-560 RMS	20-90 RMS	60-120 RMS
Minimum Section Thickness	Ferrous: 0.250-0.375" Non-Ferrous: 0.125-0.250"	Aluminum:0.050- 0.080" Zinc & Mag.: 0.025- 0.040"	Carbon Steel: 0.090" Stainless Steel: 0.125" Aluminum: 0.030"
Ease ofCasting ComplexDesigns	Fair to Good	Good	Best

IV. Applications

- Aircraft engines, air frames, missiles.
- Machine tools&Hand tools [11]
- Agricultural equipment
- Metalworking equipment
- Automotive Oil well drilling and auxiliary equipment
- Bailing and strapping equipment
- Optical equipment
- Bicycles and motorcycles
- Packaging equipment
- Pneumatic and hydraulic systems
- Communications Pumps
- Sports gear and recreational equipment
- Textile equipment
- Electrical and Electronics equipment
- Diesel engines,fuel systems and Stationary turbines

- Guns and small armaments
- Wire processing equipment
- Prosthetic appliances, Dentistry and dental tools

V. Conclusion

Investment Casting is also called as Precision Casting or Lost Wax Casting or Cire –perdue. With the help of precision casting process casting product can be carried out more precise which leads to less finishing time which saves the unnecessary efforts of the workers. Better dimensional accuracy reduces the rejection rate. Compare to sand casting mould making take more time but cooling of the casting takes less time, in comparison Investment casting process is time consuming because of its 3 or 4 phase coating process. Initial cost is high because of pattern box making and mould making steps requires skilled operators and cool environment, which makes the process expensive compare to sand casting. So it is preferable to use Investment Casting, when small size products are needed to be casted in large quantity.

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