Selection criteria for investment casting equipment

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ABSTRACT

Investment casting is a specialized foundry process, in which a shell is built over a wax pattern where the shell is used as a mold and the molten metal as a cast. The major equipment required for this process are: Furnaces for melting, shell firing and preheating, core debinding and sintering; injection molding machine, autoclave, finishing and fettling equipment, inspection and quality control equipment, shell room equipment, cluster room equipment, die design and fabrication equipment, air cooling and material movement equipment. The process is an NNS (Near-Net Shape) casting process producing high quality products. It uses raw materials like highly reactive metals and alloys, wax, colloidal silica, ceramic sand and preformed cores. The criteria for selecting equipment in various shops depends on the process and the raw materials used. The capacity of the equipment should be enough to feed intermediate products in sufficient numbers for the next stage. The time schedule in each shop is different. A foundry can decide on the degree of automation in each shop, balancing higher quality against increased cost. Similarly, the decision to use centralized AC or air-cooling will depend on the cost factor. The paper discusses the selection criteria for each shop of the investment-casting foundry.

Key words: Casting; ceramics; heat treatment.

INTRODUCTION

The process of investment casting consists of investing a shell over a wax pattern, removing the wax from the shell and pouring the molten metal into the cavity formed. In case of hollow castings, the wax is injected over a preformed core placed in the die. It consists of three intermediate products- preformed core, wax tree and shell-all of which can be used only once. It is a precision or an NNS casting process, where very little machining is done to the final casting, whereas in other manufacturing processes, extensive machining is done to arrive at the final product.

Process steps and sections

Investment casting foundry can be broadly divided into different sections.

Die design and fabrication

For a hollow investment-cast product, wax pattern dies, sprue, pouring system dies and core dies are required. Since the process is used for making complicated shapes, CAD/CAM programs and CNC machines can do the die design and fabrication.

Core making shop

Preparation of a core involves injecting a ceramic + organic dough into a core die, removing the binder and firing the core to get adequate strength.

Pattern shop

Wax pattern are injected over a preformed core. Components of feeding and risering system like pouring cup, central sprue, runners, ingates, risers are either injected or poured into dies.
Clustering section

In this section, wax patterns are joined to a common feeding system to prepare a wax cluster or a wax tree. The equipment used in this section is nothing more than soldering rod.

Shell room

In this section, a shell is built or invested over the wax tree. There are two general methods. Allowing slurry contained in a flask to set around the wax tree makes a block shell. In the second process, the shell is built in several steps. The wax tree is dipped in air-hardening slurry and then stuccoed with sand particles. Slurry tanks have to be rotated constantly to prevent premature gelling of the slurry. Each dipping-stuccoing cycle is followed by extensive drying on drying stands for 24-30 hours. This process can be accelerated by the use of blowers.

Dewaxing room and shell firing sections

In these sections, wax is removed from the shells and fired, normally in two stages, to impart sufficient handling strength and remove the last traces of the wax.

Melt-room, fettling room and finishing

Melt room is equipped with a melting furnace and a shell-preheating furnace. Fettling room requires a host of workshop machines for shell knockout, sprue cutting, sand-blasting, trimming etc. A pressure vessel is also required to dissolve out and remove core particles by concentrated alkalis.

Heat-treatments

Some alloys like superalloys can be subjected to heat-treatment by solutioning + ageing. They may also be subjected to hot isostatic pressing (if costs permit) to reduce the defects and improve strength.

Inspection, auxiliary equipment and Selecting the capacity

Investment castings are subjected to rigorous inspection and testing. A foundry may require auxiliary or supporting equipment for material movement. The capacities should be designed such that there is a smooth, uninterrupted flow of material from one section to the next.

Major equipment required

The major equipments required are furnaces, wax injection machines, autoclave/pressure vessels, workshop machinery, shell room equipment, cluster-room equipment, inspection and auxiliary equipment.

Furnaces

The entire investment casting plant is designed around melting furnace. Induction furnaces are usually used as melting furnaces. If the alloy to be cast is highly reactive, then vacuum or protective atmospheric furnace has to be used. For Directionally Solidified (DS) and single crystal casting, a two chamber or three chamber furnace is selected. Specially designed graphite susceptors must be used to get uniform heating all over the height of the shell. Induction furnaces used in investment casting are usually cold wall type. Shell is withdrawn by a smooth, programmable mechanism. A DS furnace can also be used for conventional casting. It comes with various degrees of sophistication and automation. For non-reactive alloys, fuel-fired furnace can be used. A separate primary melting and refining furnace with various degrees of sophistication can be used. Preparation of master alloys can be done in this furnace. Some foundries prefer to purchase remelt bars and master alloys from suppliers. Shell firing furnaces can be fuel-fired or electric. The furnace (with oxidizing atmosphere) must be equipped with efficient venting system to expel the gases evolved due to wax decomposition. Depending on the capacity, same furnace can be used for preheating and final firing or two separate furnaces can be used. Molten metal is usually poured in a hot shell to prevent misruns. A separate preheating furnace can be used for this purpose. If pouring under vacuum is desired, then a hot shell is removed and kept in the mold chamber. Some foundries may prefer to withdraw a hot shell from the shell-firing furnace and directly pour molten melt into it.

In the preparation of preformed cores, furnaces are required for debinding and for sintering. Now-a-days some manufacturers are offering combined furnaces. The heating rate and the rate of gas expulsion from the debinding furnace are most critical. Some furnaces are offered, which
control the temperature continuously to adhere to the set rate of gas expulsion. Binder is removed by decomposition as well as thermal oxidation. The cores are sintered at 1000-1200°C to get adequate handling strength. They are fragile and of complicated in shape, so the firing must be done by supporting the cores on setters or embedding them in a suitable ceramic bed to prevent warping. The sintering temperature and the degree of sintering must be chosen so as to control the firing shrinkage, since this affects the final dimensions of the casting.

**Injection machines**

Injection machines are required for wax and core injection and are of critical importance. Most of the foundries use a separate low melting wax (usually without fillers) for injecting feeding system components.

**Autoclaves/pressure vessels**

Although the universal choice is steam dewaxing, some foundries use furnace dewaxing. Heat transfer of the wax is controlled by the pressure and temperature of the steam and the rate at which it is admitted. Hence, modern dewaxing autoclaves are quick locking and quick-pressurizing type.

**Workshop machinery**

These are required for die fabrication, fettling and finishing operations. Investment casting is a NNS technology involving little or no machining on most of the surfaces. The dies must be produced with a high degree of precision. Dies can be conveniently produced by CNC machining. Fettling operations consist of shell knockout, shell material shakeout, cutting of the feeding system, finishing the final casting etc. Shell knockout can be done manually. Depending on the complexity of the castings, cutting machines with more and more sophistication can be used. For finishing operations, fine grinding machines have to be used to get the requisite surface finish on all the surfaces.

**Shell room machinery**

This consists of slurry tanks, stuccoing units, drying stands etc. Slurry made up of ceramic flour suspended in air-hardening colloidal silica or ethyl silicate. Slurry tanks are rotating and the stirrer is stationary. Stirrer blades should be designed to give optimum stirring, without causing entrapment of air bubbles. The diameter of the slurry tank should be designed as per the diameter of the shells being produced. Stuccoing units are either of sand-raining type or of fluidized bed type. If sand particles are in different size ranges for different coats, then it is often advantageous to use a number of sand-raining machines, each charged with sand in different size ranges. Many large-scale foundries, especially those catering to the needs of the aircraft industry, have gone in for robotic shell making. But for a jobbing foundry having a wide product mix these are not advisable. The temperature & the humidity of the shell room should be controlled to have a uniform drying. Larger foundries go for a centralized AC and smaller ones use blowers, air-coolers, driers and humidifiers. During the application of final coats and drying, air-blowers are employed to speed up drying. In case of block shells, the wax tree is mounted in a flask, which is immersed in an aqueous slurry of silica + plaster. The slurry is allowed to set in the flask by applying vibrations.

**Cluster room**

This is a highly skilled job requiring the simplest of equipment (usually nothing more than a soldering rod). Patterns are clustered together around a central pouring cup, sprue and runners. The joints have to be flawless.

**Inspection room**

Investment castings are tested for dimensional accuracy, surface finish, defects like surface flaws, porosity, inclusions etc. Dimensions are checked against gauges. Aircraft foundries often have coordinate measuring machines. These check whether the dimensions and curvatures are within the tolerance limits or not and give a yes-no decision. Surface is inspected by dye penetrant test under ultraviolet light. Aircraft foundries go for conventional and microfocus radiography for each casting. Surface roughness (or fineness) is an important parameter. Aircraft foundries go for destructive mechanical testing and microscopic examination of test-pieces cast along with the patterns.

**Auxiliary equipment**

Depending on the volume of production, foundries go for sophisticated equipment for material movement, charging and discharging –
both raw material and intermediate products. Plant layout should be such as to facilitate smooth, uninterrupted movement of material and products. Each section of the foundry has a host of auxiliary equipment like washing stands, storage bins, overhead crane etc.

CONCLUSIONS

Depending on the peculiarities of the investment casting process, equipment with special features is often required. Traditional furnaces, injection machines, autoclaves etc, have to be modified to include these features.

REFERENCES