Investment casting (lost wax process)

The investment casting process, which is commonly referred to as the "lost wax method", originated in and around the fourth millennium B.C. It is evidenced through the architectural works found in the form of idols, pectorals and jewelry in remains of the ancient Egypt and Mesopotamia.

This process has been used since ancient times to make jewellery – therefore it is of great importance to HK. It is also used to make other small (few grams, though it can be used for parts up to a few kilograms). The steps of this process are shown in the figure (1) below.

An advantage of this process is that the wax can carry very fine details – so the process not only gives good dimensional tolerances, but also excellent surface finish; in fact, almost any surface texture as well as logos etc. can be reproduced with very high level of detail.

Investment Casting Types

–Flask type

–Shell type

The basic steps of the shell investment casting process are:

1. Preparing the heat-disposable wax, plastic or polystyrene patterns in a metallic die of the required shape of castings. Each and every casting requires a pattern to be produced. Wax or polystyrene is made used as the injecting machine.
2. Assembly of large number of the prepared patterns onto a gating system (attached to a wax sprue centrally).
3. "Investing," (covering) the pattern assembly by immersed in refractory slurry which completely surrounds it builds the shells at room temperature forming the mold.

4. The mold is further heated, so that the pattern assembly melt and the wax flows out, leaving the required cavity behind.
5. The metal in molten state is poured into the formed mold.
6. Once the metal solidifies, the shell is removed (knocked out).
7. Fettling (cutting off) of the pouring basin and gates followed by finishing operations to get the desired dimensional tolerances and finish.

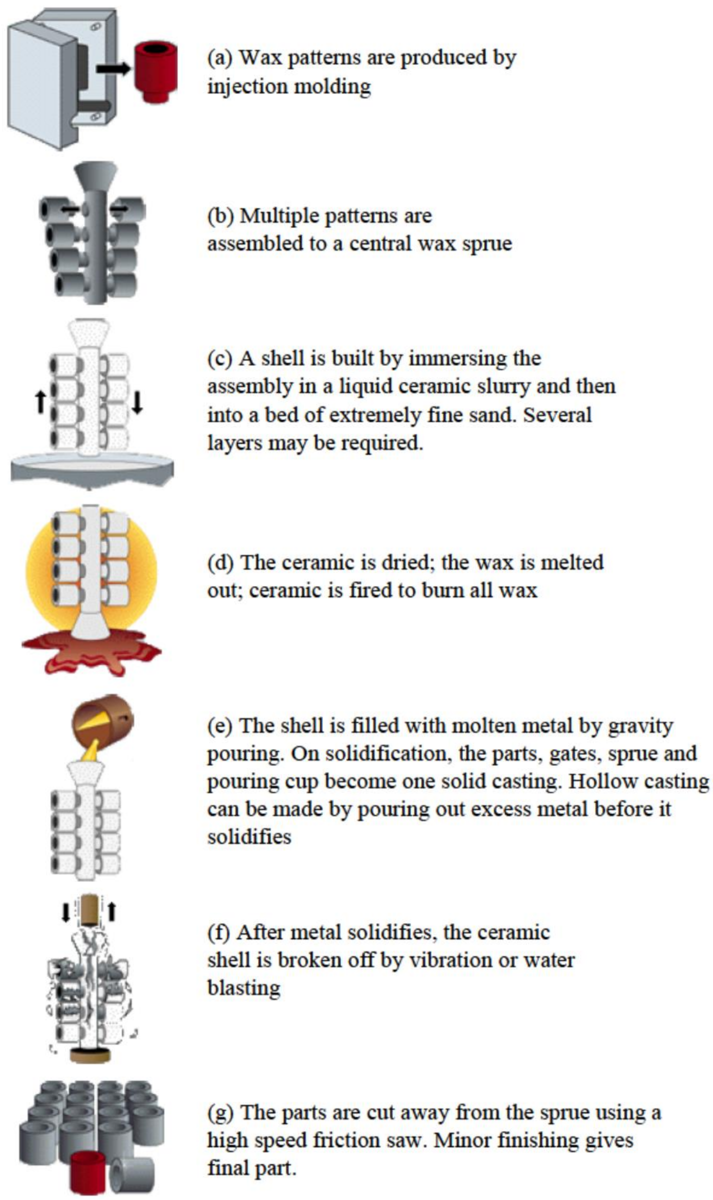
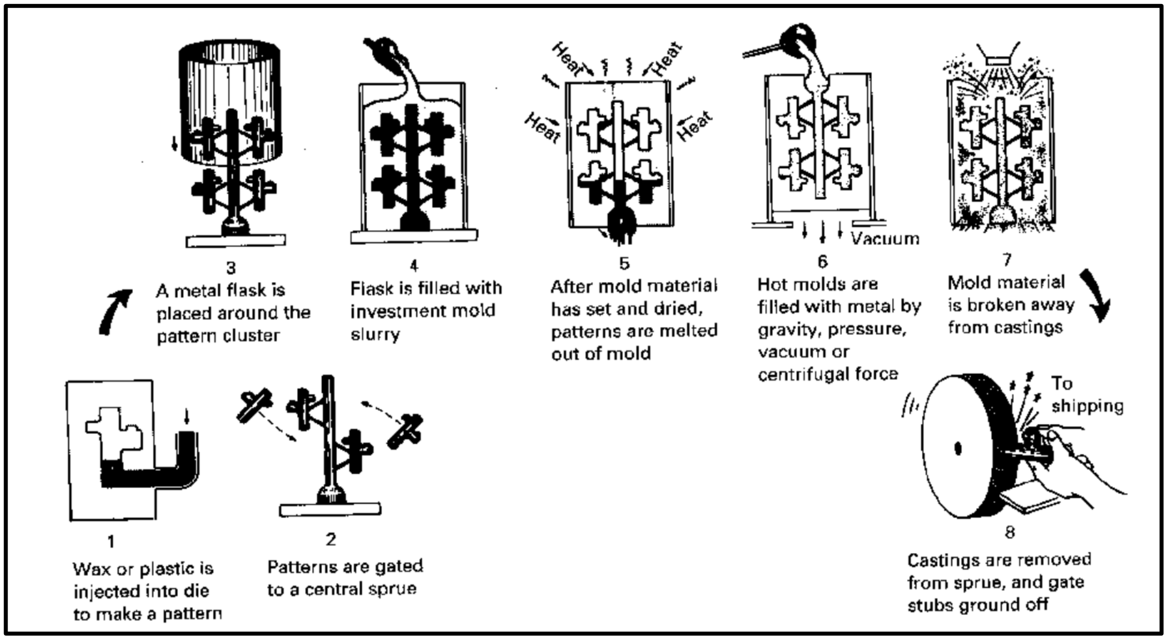


Figure 1. Steps in the investment casting process [source: www.hitchiner.com]



Investment Flask Casting

Advantages

- Complex shapes that are difficult to produce by other casting methods are very easily possible to be produced by this method.
- Thin cross sections and intricacies can be made by this process.
- Finish machining is considerably reduced or eliminated on the castings made by this process, making it economical in cost.
- The process has no metallurgical limitations.
- This process produces castings with excellent surface finish.
- Closed dimensional tolerances and intricate geometries are easily obtained.
- A single process gives good surface finish.
- Alloys with higher melting points can also be easily cast.

Disadvantages

- Expensive process due to the cost of ceramics and pattern (wax cost).

- As the shells are delicate, the process is limited by the size and mass obtained.
- Making intricate and high quality pattern increases the process costs.
- Expensive process since it uses the wax, which increases the cost.
- The cross section of molds being thin, the process is limited by size and mass of casting.
- The quality of the pattern determines the quality of the casting.
- Removal of the wax from the mold again adds up time and cost.

Applications

- Aircraft: Turbine blades; carburetor and fuel-pump parts; cams; jet nozzles; special alloy valves.
- Chemical Industries: Impellors; pipe fittings; evaporators; mixers
- Tool and Die: Milling cutters; lathe bits; forming dies; stamping dies; permanent molds etc.
- General and Industrial applications: cloth cutters, sewing machine parts; welding torches; cutter, spray nozzles; metal pumps; etc.

Ceramic Shell Investment Casting Process (CSIC)

Ceramic Shell Investment Casting (CSIC) is one of the near net shape casting technologies. The process is based on expendable wax patterns for producing joint-less moulds that are required for near net shape castings.

The main difference between investment casting and ceramic shell investment casting is that, in the former process, before dewaxing the wax pattern, it is immersed in a refractory aggregate. Whereas in the ceramic shell investment casting, a ceramic shell gets built around the tree assembly through repeated

dipping of the pattern into slurry (refractory material such as zircon with binder).

After getting the required thickness of cross section, the tree assembly is de-

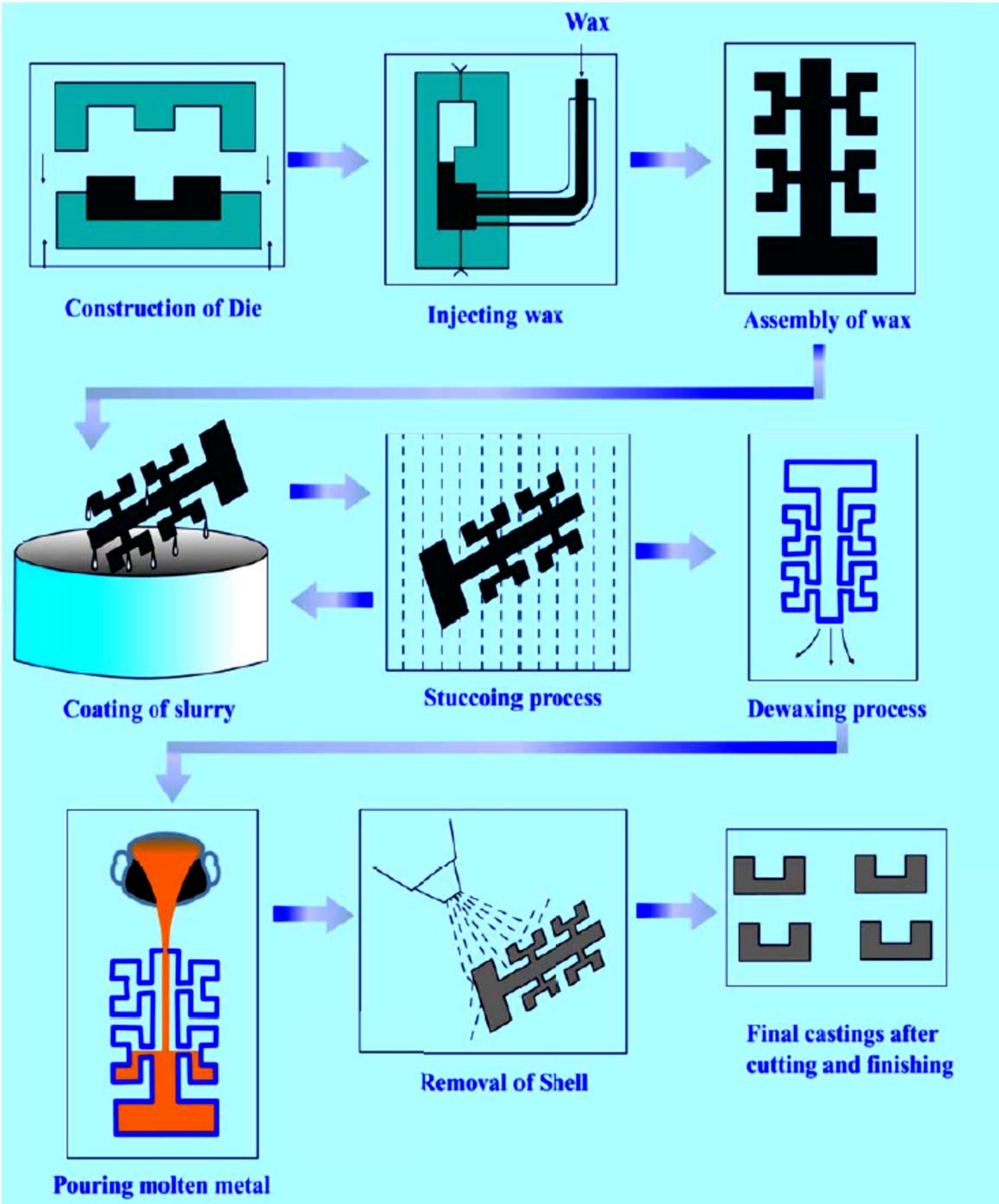


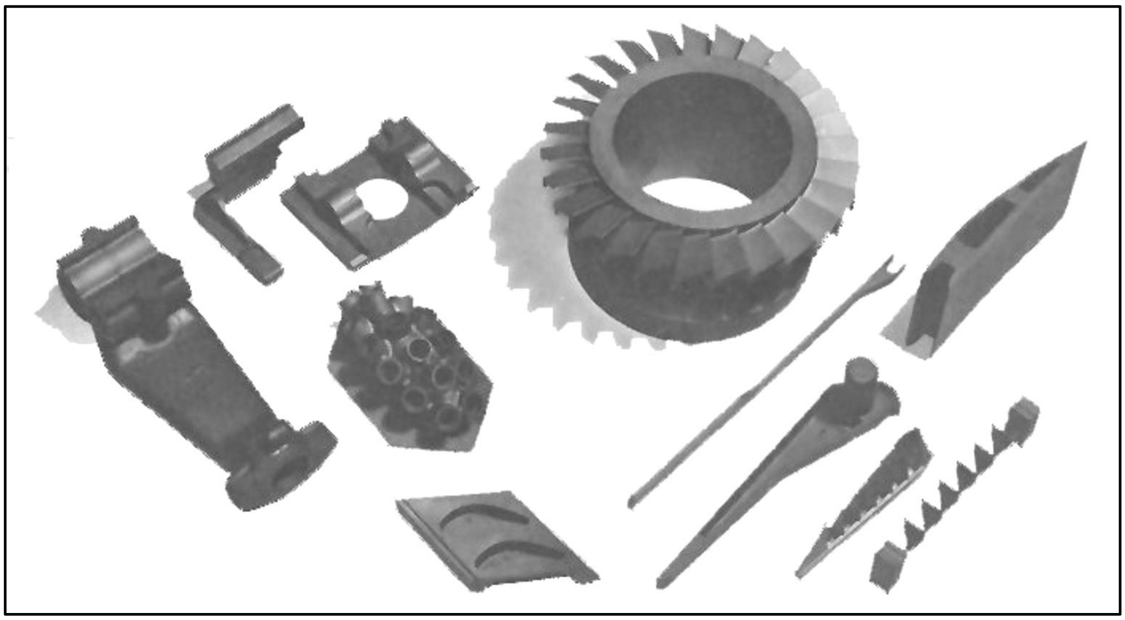
Fig. 2.7.1: The Basic Steps of the Ceramic Shell Investment Casting Process

waxed. The shell obtained is further immersed in a refractory coating and the metal is poured into it.

In this process, a wax pattern/assembly is first dipped into a ceramic slurry bath for its primary coating. Thereafter, the pattern is withdrawn from the slurry

and is manipulated to drain of the excess slurry to produce a uniform coating layer. The wet layer further stuccoes through sprinkling the relatively coarse ceramic particles on it or by immersing it into such fluidized bed of particles. The ceramic coating is built by successive dipping and stuccoing process. This procedure is further repeated till the shell thickness as desired is obtained.

Upon completion, the entire assembly is placed into an autoclave or flash fire furnace at a high temperature. In-order to burnout out any residual wax, the shell is heated to about 982oC which helps to develop a bonding of high-temperature in shell. Such molds are stored for future use wherein they are preheated for removing the moisture content from it and then, molten metal can be poured into it.



Investment Casting – Products

Shaw Process

Slurry like mixture is poured over the pattern. The mixture contain of:

–Refractory aggregate

–Hydrolyzed ethyl silicate

–Jelling agent

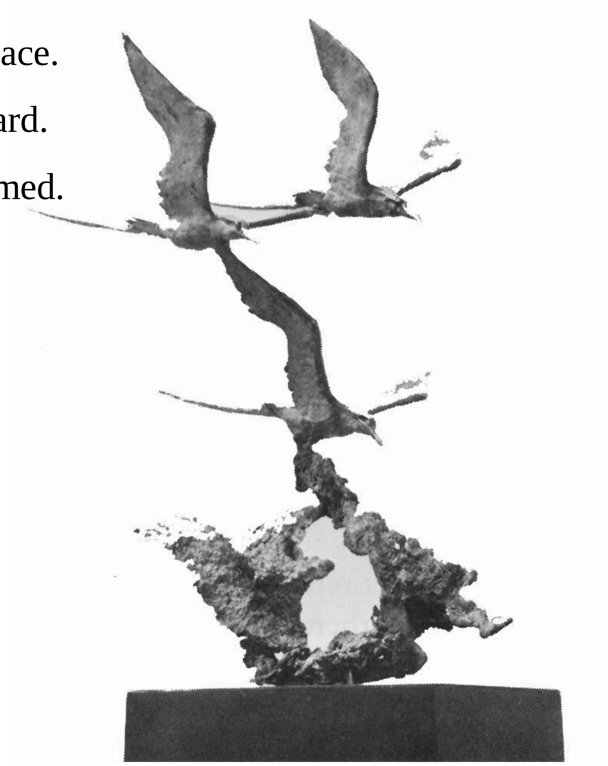
- Mixture sets in a rubbery jell so that the pattern can be stripped from the mold. Mold has sufficient strength to return its original shape.

- The mold is ignited to burn off the volatile elements in the mix.
- It is then brought to a red heat in a furnace.
- This firing makes the mold rigid and hard.
- At the same time, micro-cracks are formed.

  They provide

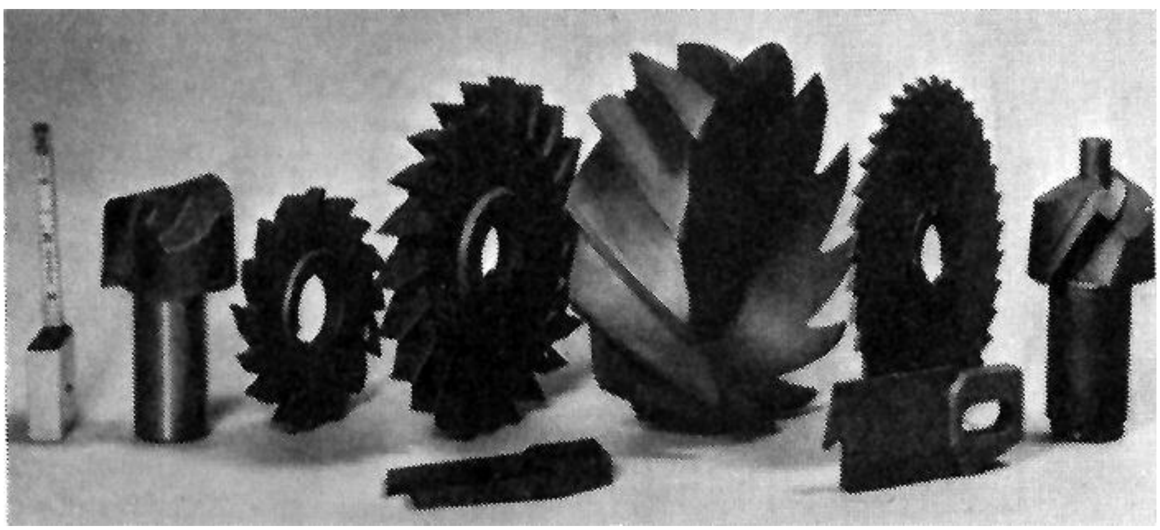
  –Excellent permeability

  –Good collapsibility



Shaw Process – Properties

- Casting of all sizes,
- Produces excellent surface finish,
- Excellent detail,
- High dimensional accuracy,
- Cheaper than investment casting



Shaw Process – Products

Wax Preparation, Blending and Process Parameters in CSIC

The pattern material selection is most important point in the ceramic shell investment casting (CSIC) process. The patterns are prepared through injecting wax into the die. The patterns thus made should be fracture-resistant and distortion free such that part accuracy is maintained.

The key demand for tighter tolerances from CSIC process is to calculate and control the shrinkage of pattern material in order to improve the accuracy of products. The shrinkage characteristics of waxes and its influence on the final dimensions of casting are of great fundamental importance in getting high-quality castings; minimizing product cost and scrap.

Numerous factors can affect the degree to which contraction in dimension can occur while taking into account wax pattern accuracies obtained through such patterns from the die.

There are four types of waxes and wax blend composition (bees wax, paraffin wax, carnauba wax and montana wax,) with different melting temperatures (58.2°C to 83.8°C) can be used to make the pattern suitable for use in investment and ceramic shell investment castings. The physical properties of the various waxes are given in the table (1) below:

Table (1): Wax properties

Wax	Color	Melting Point (Degree Centigrade)	Density (gm/cc)
Bees Wax	White	58.2	0.97
Paraffin Wax	White	58.5	0.94
Carnauba Wax	Black	81.9	0.99
Montana Wax	Brown	83.8	1.02

The form of each of the above wax is solid at room temperatures. The recommend blend / mix of waxes for the best dimensional and surface properties of

the pattern are in the following ratio (weight ratio): Paraffin: Bees: Montana: Carnauba: 10: 6: 3: 1.

Process Parameters affecting the Quality of Wax Pattern

In-order to identify the process parameters which affect the quality of wax patterns an Ishikawa cause and effect diagram is constructed, as shown in Fig. 9.8.1. It indicates that the following process parameters have an effect on the quality of the wax patterns (dimensional accuracy and surface roughness) made from the dies.

- Wax composition, wax temperature in the injection machine and temperature of the wax injection. (nozzle temperature)
- Die temperature, die lubrication, die venting, die surface
- Sprue design, injection pressure and wax flow rate
- Holding time, injection time, dwell time and post-injection cooling

Pattern Die

A typical three step pattern used for making the mould by CSIC Process is shown in Fig. 2.8.2. A die made of aluminum is shown in the photograph in fig. 2.8.3. It can be prepared for the production of wax patterns in CSIC process. The photograph of the wax pattern which inturn will be removed from the die, is shown in Fig. 2.8.4.

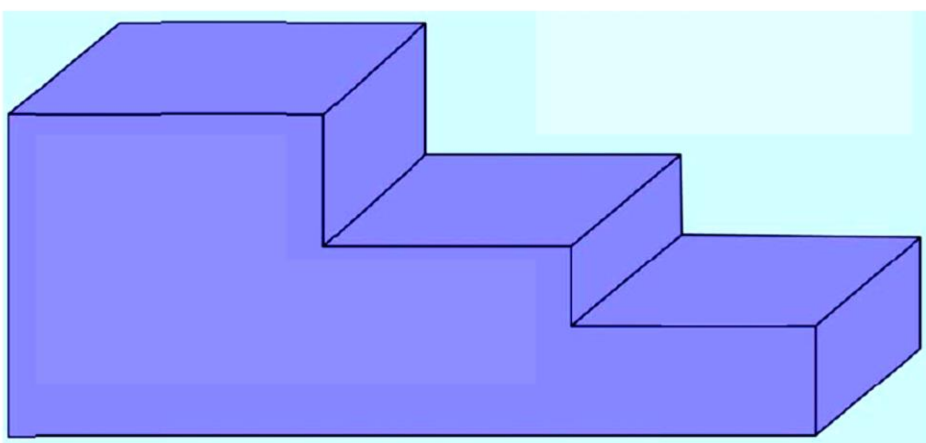


Fig. 2.8.2 The Pattern

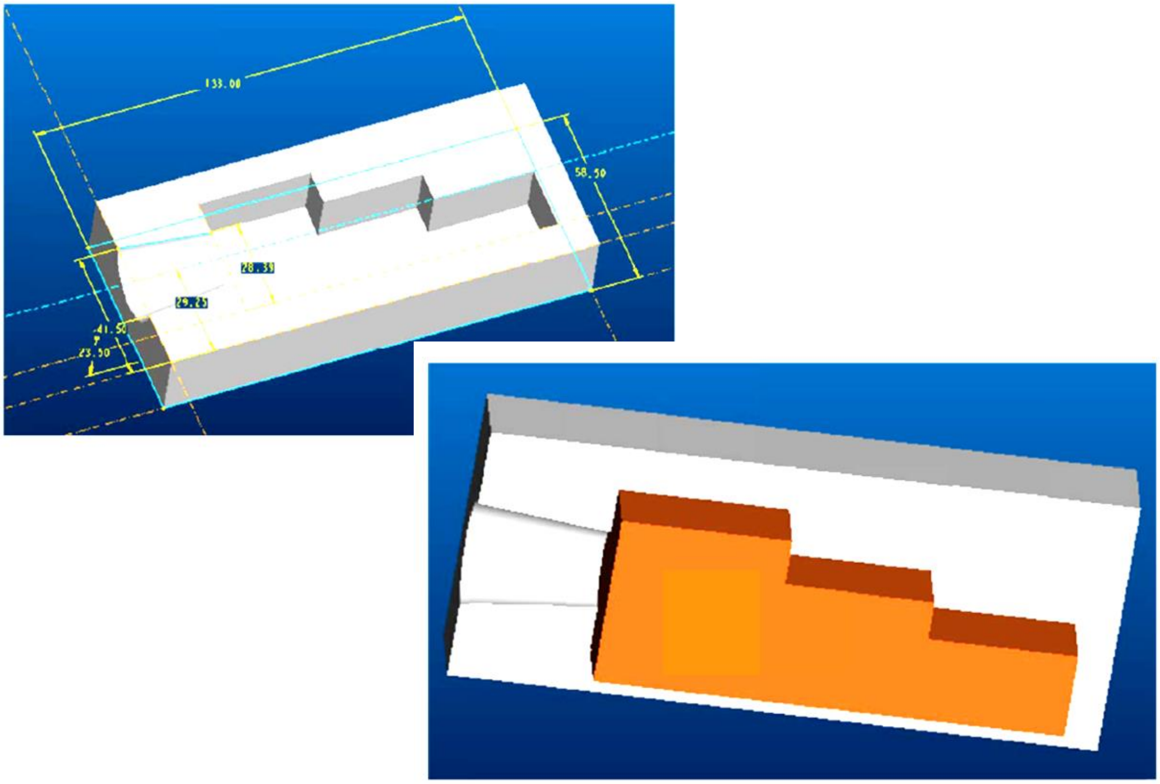


Fig. 2.8.4 Photograph of Wax Pattern to be removed from the die

Wax Injection Machine

A wax injector is a machine which makes use of an earlier conditioned wax and injects it into a die in-order to produce a wax pattern. An injection machine was designed and fabricated at I.I.T. Roorkee and is shown in Figure 2.8.5. The machine has three basic components:

- The heating unit,
- The injection unit and
- The die clamping system

This machine performs the following essential functions:

- A Jacket provided for heating and melting of the wax occurs in an aluminum reservoir tank with provision for slow speed stirring
- Injecting of the liquid wax from the brass cylinder under pressure into a closed mold

- Maintaining the injected wax under pressure for a specified time to prevent the back flow of liquid wax and to compensate for decrease in the volume of melt while solidification

Through these basic three functions, the mechanical and thermal inputs of the injection equipment are coordinated in-line with the basic properties and behavior of the wax under process.

The injection process includes some other sub-processes such as feeding of the brass cylinder through an aluminum reservoir gravimetrically, use of a control valve and controlling temperature with thermostat during melting, conditioning and injection to ensure high pattern quality. A temperature control is made use for controlling the temperature during wax injection in the set-up.

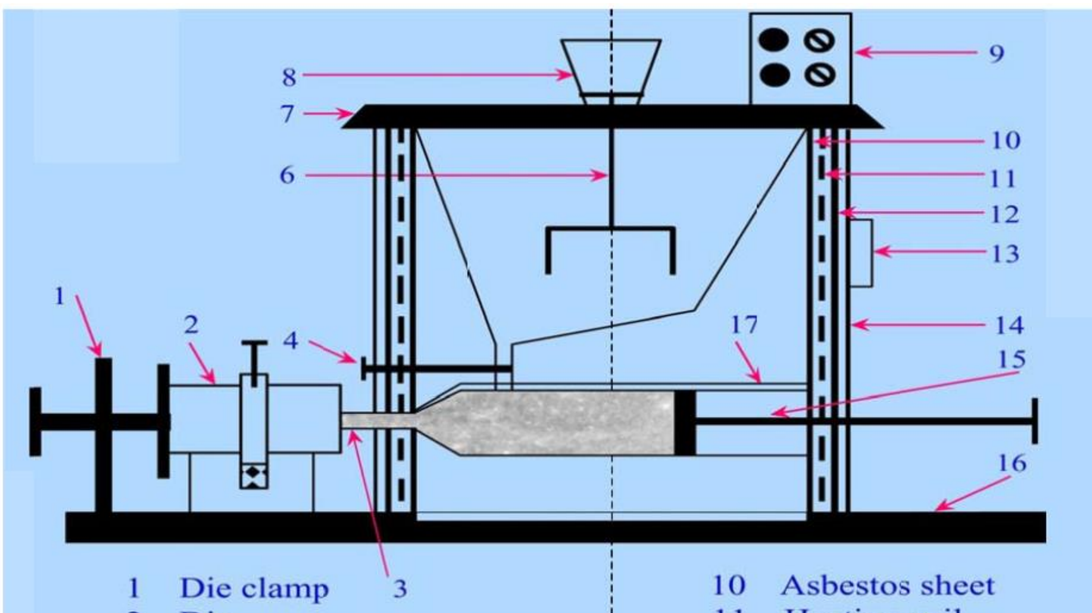


Fig.2.8.5 Schematic sketch of the wax injection machine

Parameters Affecting the Quality of Castings Produced by CSIC process

To identify the process parameters that affect the quality of the castings produced by CSIC process, Ishikawa cause and effect diagram is constructed, as shown in Fig. 2.8.6. The Ishikawa cause-effect diagram depicts that the following parameters can affect the quality of the casting (dimensional accuracy, surface roughness, mechanical and metallurgical properties) made by the CSIC process.

- Wax Pattern: Wax temperature, Die temperature, Pressure and Wax Viscosity
- Stucco: Type, Composition, Size and Size Distribution
- Alloy: Pouring temperature, Pouring time and Type of Alloy
- Ceramic Slurry: PH value, density and viscosity
- Mould: Firing temperature, Dewaxing temperature