Shell mold casting

The process was invented in Germany by Dr. Croning, hence it has also been named as the Croning process. In this process the silica sand is mixed with phenolic resin along with a curing agent. The process has a major limitation which is in the form of separation of the sand and resin at the end. The process however has low strength, the curing rate is slow, dusty and the sand resin mixture tends to become heterogeneous. In-order to overcome these issues, Novolak phenolic resin dissolved in alcohol is used and the sand is warm coated with it.

By using this technique, better strengths were achieved with lower resin addition along with excellent curing characteristics with lesser dust problems. Over the years, various new coating techniques have been started and this has helped in improving the quality of the resin coated sands. The Shell process, in many ways is simple to operate than many other competitive processes. The versatility of the process enables it to be used for all types of metals both ferrous & nonferrous e.g. cast iron, s.g. iron, carbon steel, high alloys., stainless steel, manganese steel, aluminum & copper alloys.

The main application of shell process is in the mass production of near to net shape castings particularly in the small & medium range. Shell process has been widely accepted for producing the casting for automobile and hydraulic applications, wherein the accuracy and surface finish is the prime requirement.

The main steps to prepare the shell mould are: Figure: (1)

1- The moulds and cores are fitted over the dump box which prepared by mixing the dry free flowing fine sand (100-150 mesh) with thermosetting resins /epoxy binder.
2- Next this box is inverted such that, the sand-resin mixture falls on the hot pattern pattern made of metal (e.g. aluminum or steel), which is heated to between

3- 175°C-370°C, and coated with a lubricant, e.g. silicone spray. The process may be repeated to get a thicker shell.

4- .This cures a layer of the mixture to a certain extent and forms a hard shell. Once the desired thickness of shell is achieved, the box is rotated back to its original upside position. The excess sand then falls back into the box, thus forming a shell over the pattern. The obtained thickness depends on the temperature and the time of contact of sand-mixture. The required shell thickness for casting depends on the temperature of the pouring metal and complexity of the final casting. It may range from 2-8 mms.

5- To complete the curing process, the sand shell along with the metal plate is heated and baked to cure it in an oven for some calculated time.

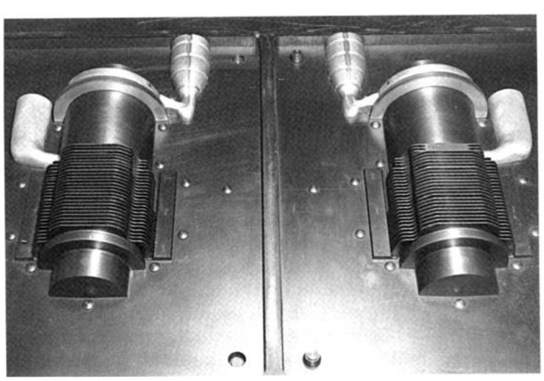
6- The obtained shell mold from this process is removed from the pattern.

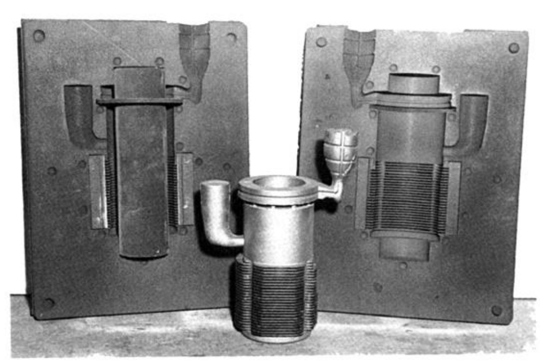
7- If the pattern is of two pieces then the other half of the shell is also prepared the same way. Two halves of the shells prepared are placed together after inserting the core, if any, to make the assembly of the mould.

8- The assembly the two portions (cope and drag) of the shell mold is joined together to form the mold then placed in a molding flask and some sand particles or metal backing shots is placed all around the shell mould assembly in a box for support purpose to add stability to the shell and to give its the sufficient strength.

9- Now the shell mould is fully ready for pouring the liquid metal.

10- When the metal solidifies, the shell is broken to get the part.





Metal Patterns Product

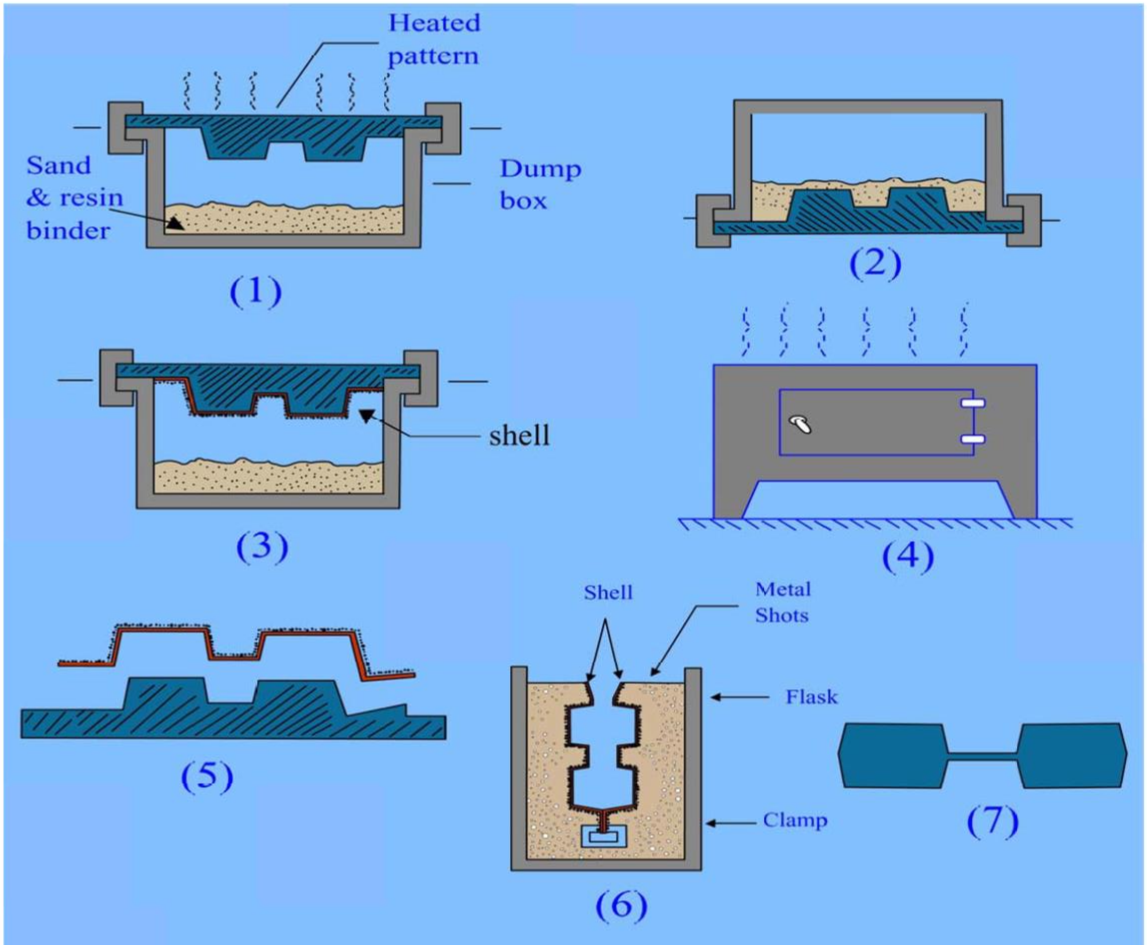


Figure (1): The shell mould casting process sequence

Advantages:

The shell process has several unique properties which makes it an important process in the foundries. These properties can be briefed as:

- **Excellent Surface Finish**: Shell sand process has the ability to produce castings with excellent surface finish and capacity to produce very fine detail.
- **Better Dimensional Accuracy**: The process has an ability to produce castings to tight dimensional tolerances. Due to this characteristic,

machining allowance can be reduced which ultimately helps in reduction of the fettling and finishing costs. The shell process accommodates easily deep drawer patterns with less tapers than conversional production processes.

- **Hollow Cores:** With the shell sands hollow cores and thin profile moulds can be possible. This characteristic gives economics in sand usage & ease of handling. Hollow cores increase the permeability hence usage of very fine sands is also possible.
- **Sand to Metal Ratio:** This is a unique process that gives hollow cores and thin walled moulds, which results in substantial weight reduction and material savings. The normal sand to metal ratio is 1:1 which is much lower than other processes.
- **Ease of Handling:** The molds and cores made by shell molding have exceptional resistance to damage during storage and handling. They have a very high resistance to humidly and can be easily stored for long periods.
- **Resistant to Moisture Pickup:** The shell process has higher resistant to moisture and can be stored in humid conditions for months together. The resin used in shell molding process is very stable and moisture resistant.
- **Excellent Flow-Ability:** The dry coating on sand, gives better flowability and blowing ability compared to processes based on wet sand mixes. This property helps in producing intricate cores and moulds which can be blown to a greater density. e.g. cores for water jacket.
- **Less Inclusions & High Thermal Stability:** The shell sands are less prone to erosion by molten metal due to higher thermal stability of the phenolic resins. This unique characteristic helps in reducing defects like non-metallic burn-in and scabs etc.
- **Lesser Pattern Wear:** As most of the patterns are made from cast iron, very little or no-wear is observed which results in higher pattern life. This helps

in producing large number of castings without much difficulty.

- **Longer Shelf Life:** When properly stored, the shell sands have an indefinite shelf life hence these sands can be stored and used as needed in the foundry.

- Low labor cost,
- Low machining cost,
- High productivity,
- Requires expensive machines

Disadvantages

- High Cost of The Process: Phenolic resins used for the shell process is very costly. The percentage of resin usage is also very high as compared to other processes. Hence this process requires very tight control of the shell thickness else the competitiveness of the process will be sacrificed.
- High Tolling Cost: The shell process is thermoset in nature thereby requiring higher curing temperatures. The patterns used are of cast iron with smooth surfaces which have very low expansion coefficient.
- Cycle Time: Comparatively cycle time required for shell process in more than either cold box or Co2 processes.
- Limited Casting Weight: The shell molding process in best suited for use in small, intricate and light weight castings. The process can be effectively used for casting weights up to 80 kg.

Parameters affecting the quality of Shell mold casting:

- Pattern: Dimensional Accuracy, Surface finish and Draft requirement.
- Additive: Type, Function of additive, properties.
- Alloy: Pouring temperature, Pouring time and Type of Alloy.
- Sand: Type: Silica, Zircon, Size, Size distribution and grain shape.
- Resin and Catalyst: Type of resins, catalysts and costs.
- Curing: Temperature and time.

The Sand material

The dry free flowing sand used in the shell mould must be completely free of clay content. The grain size of the sand used in shell molding is generally in the range of 100- 150 mesh, as the shell casting process is recommended for castings that require good surface finish. However, depending on the requirement of surface finish of the final casting, the grain size of the sand can be ascertained. Also, if the grain size is very fine, it requires large amount of resins, making it expensive.

The Resin and Catalyst materials

The resins most widely used, are the phenol formaldehyde resins, which are thermosetting in nature. Combined with sand, they give very high strength and resistance to heat. The resin initially has excess phenol and acts like a thermoplastic material. In order to develop the thermosetting properties of the resin, the coating of the sand is done with resin and a catalyst (Hexa-methylene-tetramine, known as Hexa). The measure of resin is 4-6% of sand by weight, the catalysts 14-16% of sand by weight. The curing temperature of the resin along with the catalysts is around 150o C and the time required for complete curing is 50 – 65 seconds. The sand composition to be used in making various casting of different materials can be seen from the relevant standards.

The resins available are of water-bourn, flake, or the granular types. The specifications of liquid, flakes or powder resins can be obtained from IS 8246-1976, IS 11266-1985, and IS 10979-1981 respectively.

The resin sand mix aggregate can be prepared by the following three ways.

1- **Hot coating process:** in hot coating process the curing of resin takes place due to the combined effect of heat as well as chemical action of the resin with the catalyst. Once the curing is done, the cured sand is cooled at 40-50 degree centigrade to prevent the lumps and agglomerates and to improve the flow-

ability.

2- **Warm coating process:** In this process, different resin formulation (liquid solvent solution) is used and curing takes place at around 80 degree centigrade. The process is simpler than hot coating but the quantity of resin consumed is larger.

3- **Cold coating process:** In this process, the sand is first mixed with catalysts, then the resin mixed with alcohol is added to the aggregate. The amount of resin requirement is highest in comparison to the amount required in hot and warm coating processes.

The Phenol-Formaldehyde Resins:

In manufacturing the shell sand, phenol, formaldehyde resin is used as a binder. The form of resin may be liquid or flake type. Liquid resin is nothing but is a resin dissolved in alcohol. Liquid resin is used for manufacturing shell sand by either warm air process or by ignition process, whereas solid or flake resin is used for hot coating process. Most of Indian manufacturers of shell sand use liquid resin, because of the easiness of resins of the process. The following properties of resins are generally checked as a acceptance criteria.

1- Liquid Resins

- Clarity
- Viscosity
- Specific Gravity
- Solid content
- PH value
- Coated sand properties at certain percentage of the resin.

2- Solid Resins

- Softening point

- Flow rate
- Particle size

The Hexa Catalyst material

The phenol formaldehyde resins are thermoplastic in nature and require a formaldehyde donor to cure at a certain temperature. Thus after blending of the resin and the catalyst, it becomes thermo-set in nature and thus the formation of shell molds and cores is accomplished. The catalyst used is a blend of hexa methylene tetra-amine and a lubricant. Lubrication helps in the flowability of shell sands. Hexa catalyst is available in the form of a fine powder.

Use of Additives

Additives may be added to the sand aggregate to further enhance the surface finish of the casting or two improve the strength of the mould or to develop the resistance to thermal cracking and distortion. The recommended additives are coal dust, manganese dioxide, calcium carbonate, ammonium boro-fluoride, lignin and iron oxide. To improve the flowability of the sand and to permit easy removal of shell from the pattern plate, some lubricants are added in the resin sand aggregate. The common lubricants used for such purpose is calcium or zinc stearate.