Module-9: ADVANCED METAL CASTING PROCESSES:

Lecture No -10

Process Parameters and Steps in Shell molding

In this process the moulds and cores are prepared by mixing the dry free flowing sand with thermosetting resins and then heating the aggregate (mixture of fine sand (100-150 mesh) and thermosetting resins) against a heated metal plate. Due to the heat, the resin cures, which causes the sand grains to get bonded with each other and it forms a hard shell around the metallic pattern. The inside portion of the shell is the exact replica of the pattern against which the sand aggregate is placed before heating. The shape and dimension of the inside portion of the shell thus formed is exactly the same as that of the pattern. 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. The assembly of the shell is then placed in a molding flask and backing material is placed all around the shell mould assembly to give its assembly the sufficient strength. Now the shell mould is fully ready for pouring the liquid metal.

Sand

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.

Resin and Catalyst

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 150^{o} 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.

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.

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.

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.

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.

Liquid Resins

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

Solid Resins

- Softening point
- Flow rate
- Particle size

Hexa Catalyst

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 flow-ability 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.

Steps in Preparing the Shell Mould:

The steps to prepare the shell mould are shown in Figure 9.10.1.

1. A match plate metal pattern comprising the cope and drag is heated to the required temperature and fitted over the box containing the mixture of sand and thermosetting resin
2. Next this box is inverted such that, the sand-resin mixture falls on the hot pattern. This cures a layer of the mixture to a certain extent and forms a hard shell.
3. 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.
4. To complete the curing process, the sand shell along with the metal plate is heated in an oven for some calculated time.
5. The obtained shell mold from this process is removed from the pattern.
6. Now the two portions (cope and drag) of the shell mold are thereby assembled and some sand particles or metal shots are used in a box for support purpose to add stability to the shell and the pouring is done.
7. After it gets cooled the finished casting along with sprue is taken out and fettling is done.

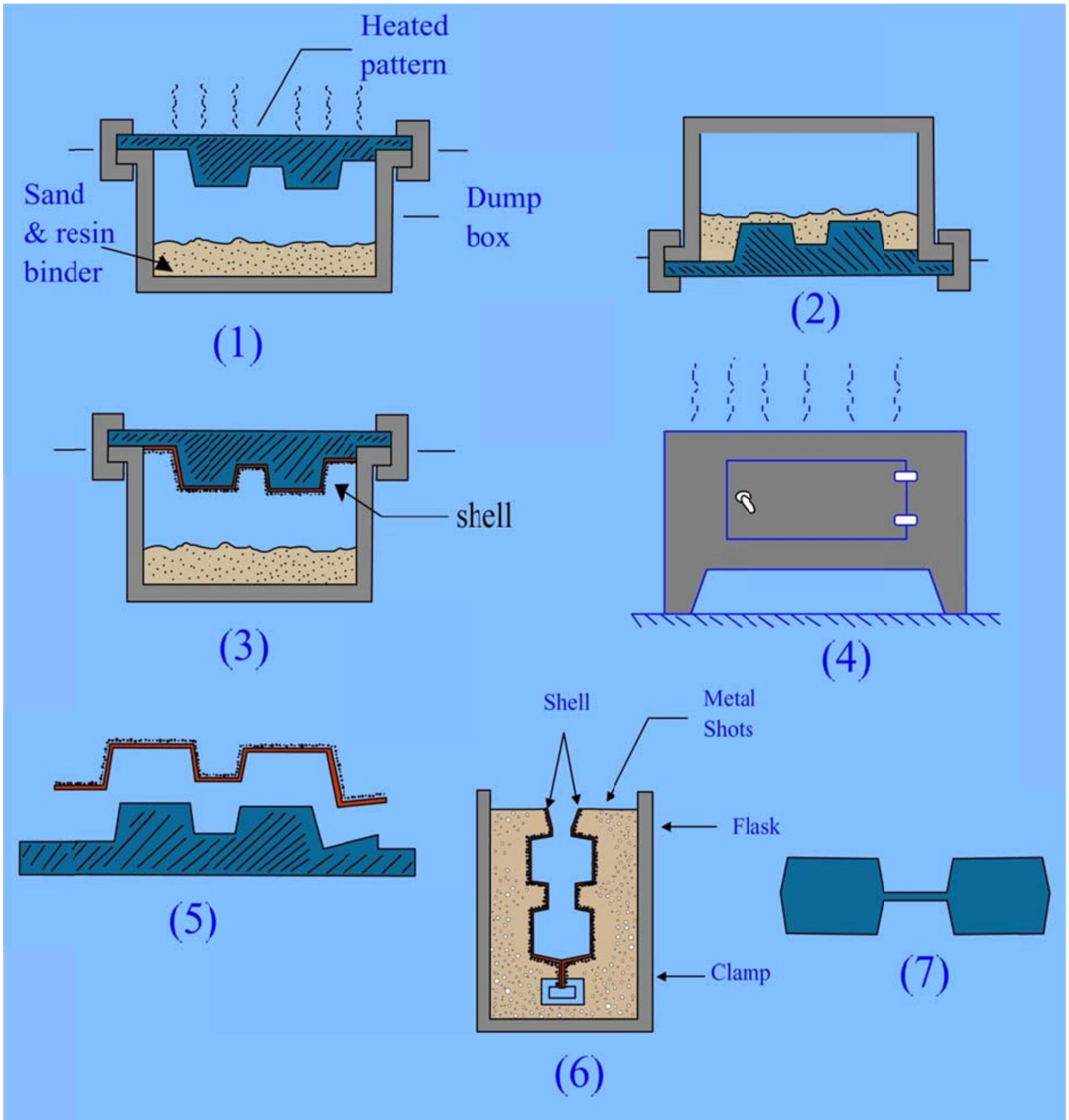

Fig. 9.10.1 Process Sequence of Shell Mould

Parameters affecting the quality of castings produced by Shell Mould Process

To identify the process parameters that affect the quality of the castings produced by shell molding process, Ishikawa cause-effect diagram has been constructed, as shown in Fig. 9.10.2. It is indicated through the Ishikawa cause-effect diagram that the following process parameters can affect the casting quality (dimensional accuracy, surface roughness, mechanical and metallurgical properties) made by shell molding process.

- 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.

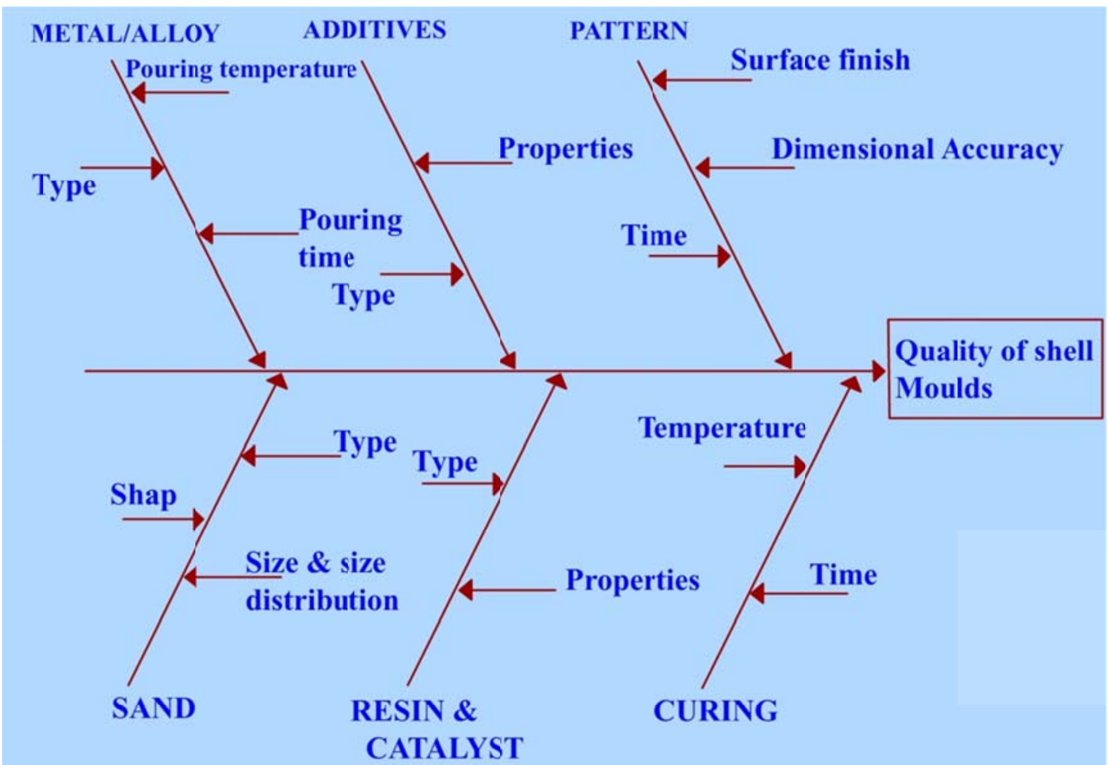

Fig.9.10.2 Process parameters affecting the shell molding process