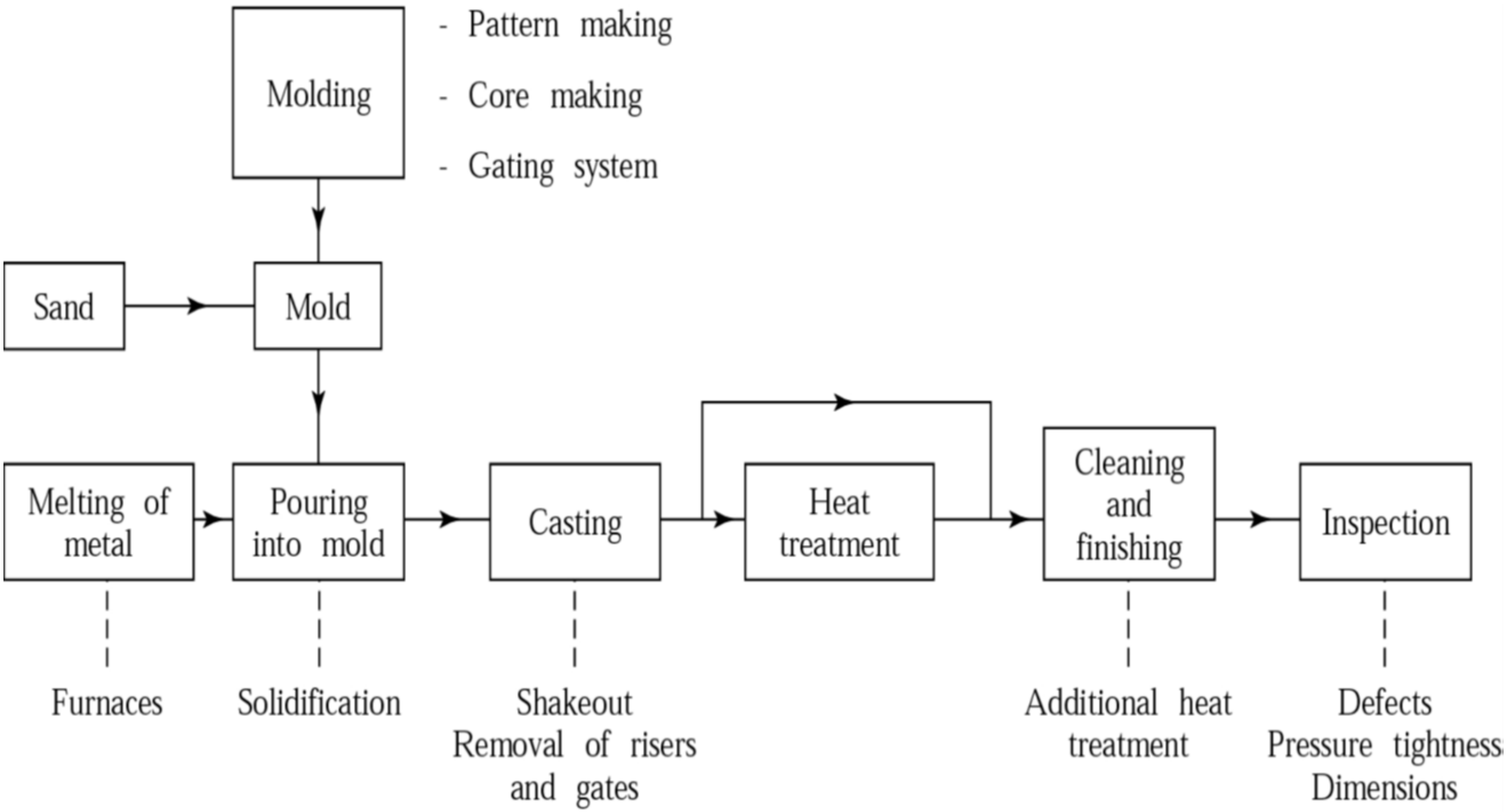
SAND CASTING

4.1. 1: SAND CASTING

- Sand casting is the most widely used casting process, it utilizes expendable sand molds to form complex metal parts that can be made of nearly any alloy.
- Because the sand mold must be destroyed in order to remove the part, hence it has low production rate.
- The sand casting process involves the use of a furnace, the pattern and sand mold.
- Nearly any material can be casted by this method.

SAND CASTING STEPS



- A line diagram showing sand casting steps

APPLICATION OF SAND CASTING

- A wide range of parts can be cast using this process ranging from a couple grams to several tons.
- Some smaller sand cast parts include components as gears, pulleys, crankshafts, connecting rods, and propellers.
- Larger applications include housings for large equipment and heavy machine bases.
- It is also common in producing automobile components, such as engine blocks, engine manifolds, cylinder heads, and transmission cases.

EXAMPLE

- A SIX CYLINDER ENGINE BLOCK

EXAMPLE

- Alloy steel manifold

ADVANTAGES

i. **Design flexibility: T**he size and weight of parts can range. are only limited by molten metal handling and supply.
ii. **Wide range of materials:** Nearly **a**ll types of engineering alloys can be cast as long as it can be melted.
iii. **High melting temperature**: Materials with higher melting temperatures can be cast because sand is resistant
iv. **Complex shapes**: Features with geometrical complexity are possibly manufactured because sand is flexibly molded.
v. **Cheapest method:** Sand is very inexpensive, low tools and equipment cost to manufacture near net shape components.
vi. **Short lead time** – Hence ideal for short production runs

DISADVANTAGES OF SAND CASTING

i. **Low strength**: Due to high porosity compared to a machined part.
ii. **Poor dimensional accuracy**: Due to shrinkage and surface finish.
iii. **Poor surface finish**: Due to internal sand mould wall surface texture.
iv. **Defects unavoidable**: Quality variations such as shrinkage, porosity, pouring defects, surface defects.
v. Post processing: Machining operation often required if tighter tolerance needed to interface with other mating parts

FOUNDRY SAND

- The typical foundry sand is a mixture of fresh and recycled sand, which contains 90% silica (SiO_2),3% water, and 7% clay.
- The *grain size* and *grain shape* are very important as they define the surface quality of casting and the major mold parameters such as strength and permeability:
- Bigger grain size results in a worse surface finish
- Irregular grain shapes produce stronger mold
- Larger grain size ensures better permeability

FOUNDRY SAND

- The grain size and grain shape are very important as they define the surface quality of casting and the major mold parameters such as strength and permeability.
- Bigger grain size results in a worse surface finish, however larger grain size ensures better permeability.
- Irregular grain shapes produce stronger mold.
- The quality of the sand that is used also greatly affects the quality of the casting.

SAND PROPERTIES

i. Cohesiveness - Is the strength of the sand to retain a given shape after the pattern is removed.

- Casting sand must have the property of bonding and hence maintaining the shape of the cavity.

ii. Chemical inertness - The sand must not react with the metal being cast.

- This is especially important with highly reactive metals, such as magnesium and titanium.

SAND PROPERTIES

iii. Permeability - Ability to allow venting of trapped gases.

- during the pouring process many gases are produced, such as Hydrogen, Nitrogen, carbon dioxide, and steam, which must leave the mold otherwise casting defects, such as blow holes and gas holes, occur in the casting.
- For each cubic centimeter (cc) of water added to the mold 16,000 cc of steam is produced.
- Higher permeability can reduce the porosity of the mold. Lower permeability can result in better surface finish.
- Permeability is determined by the size and shape of grains.

SAND PROPERTIES

iv. Refractoriness – The thermal stability of casting sand to withstand the high temperature of the liquid metal being cast without breaking down. Ability to resist damage, such as cracking, from the heat of the molten metal. Some sands only need to withstand 650 $^{\circ}$ C if casting aluminum alloys, whereas steel needs a sand that will withstand 1,500° C. Sand with too low refractoriness will melt and fuse to the casting.

SAND PROPERTIES

v. Collapsibility - Ability of the sand to compress during solidification of the casting. If the sand cannot compress, then the casting will not be able to shrink freely in the mold and can result in cracking.

- Similarly Collapsibility refers to the ability of the sand to be easily stripped off the casting after it has solidified. Sands with poor collapsibility will adhere strongly to the casting. Special additives can be used to improve collapsibility.

SAND PROPERTIES

vi. Cost - Not any sand can be used for casting, hence to obtain the property casting sand cost must incurred.

- Thus the location of the foundry with regard to the sand availability may be cost effective.

vii. Reusability - Ability of the sand to be reused for future sand molds.

SAND PROPERTIES

viii. Surface finish - The size and shape of the sand particles defines the best surface finish, with finer particles producing a better finish.

- However, as the particles become finer (and surface finish improves) the permeability becomes worse.

ix. Flowability - The ability for the sand to flow into intricate details and tight corners without special processes or equipment.

SAND PROPERTIES

x. Availability - The availability of the sand is very important because for every ton of metal poured, three to six tons of sand is required. Although sand can be screened and reused, the particles eventually become too fine and require periodic replacement with fresh sand.

- The organic free clean silica sand can be obtained from river basin or fresh water lakes like Lake Victoria.

TYPES OF SAND

- In large castings it is economical to use two different sands, because the majority of the sand will not be in contact with the casting, so it does not need any special properties.
- The sand that is in contact with the casting is called facing sand, and is designed for the casting on hand.

TYPES OF SAND

- This sand will be built up around the pattern to a thickness of 30 to 100 mm. The sand that fills in around the facing sand is called backing sand.
- This sand is simply silica sand with only a small amount of binder and no special additives.

TYPES OF SAND

i. Silica Sand

- Silica (SiO_2) sand is the sand found on a beach and is also the most commonly used sand. It is made by either crushing sandstone or taken from natural occurring locations, such as beaches and river beds.
- The fusion point of pure silica is 1,760 $^\circ$ C, however the sands used have a lower melting point due to impurities.

SILICA SAND

- For high melting point casting, such as steels, a minimum of 98% pure silica sand must be used; however for lower melting point metals, such as cast iron and non-ferrous metals, a lower purity sand can be used (between 94 and 98% pure).
- Silica sand is the most commonly used sand because of its great abundance, and, thus, low cost (therein being its greatest advantage).

SILICA SAND

- Its disadvantages are high thermal expansion, which can cause casting defects with high melting point metals, and low thermal conductivity, which can lead to unsound casting.
- It also cannot be used with certain basic metals because it will chemically interact with the metal, forming surface defects.
- Finally, it releases silica particulates during the pour, risking silicosis in foundry workers.

OLIVINE SAND

- Olivine is a mixture of orthosilicates of iron and magnesium from the mineral dunite.
- Its main advantage is that it is free from silica, therefore it can be used with basic metals, such as manganese steels.
- Other advantages include a low thermal expansion, high thermal conductivity, and high fusion point.
- Finally, it is safer to use than silica.

CHROMITE SAND

- Chromite sand is a solid solution of spinels.
- Its advantages are a low percentage of silica, a very high fusion point (1,850 °C), and a very high thermal conductivity.
- Its disadvantage is its costliness, therefore it's only used with expensive alloy steel casting and to make cores.

ZIRCON SAND

- Zircon sand is a compound of approximately two-thirds zirconium oxide (Zr_2O) and one-third silica.
- It has the highest fusion point of all the base sands at 2,600 $^{\circ}$ C, a very low thermal expansion, and a high thermal conductivity.

ZIRCON SAND

- Because of these good properties it is commonly used when casting alloy steels and other expensive alloys.
- It is also used as a mold wash (a coating applied to the molding cavity) to improve surface finish.
- However, it is expensive and not readily available.

CHAMOTTE SAND

- Chamotte is made by calcining fire clay (Al_2O_3-SiO_2) above 1,100 ° C. Its fusion point is 1,750 ° C and has low thermal expansion.
- It is the second cheapest sand, however it is still twice as expensive as silica
- It is usually used when casting large steel workpieces.

CHAMOTTE SAND

- Its disadvantages are very coarse grains, which result in a poor surface finish.
- It is limited to dry sand molding.
- Mold washes are used to overcome the surface finish problems.

OTHER MATERIALS

- Modern casting production methods use other different types of casting materials that can manufacture thin and accurate molds such as those used in egg cartons.
- But this cannot be fully covered because the techniques and the knowledge exposure differs among different manufacturers.

BINDERS

- Binders are added to a base sand to bond the sand particles together (i.e. it is the glue that holds the mold together).

BINDERS

i. Clay and water

- A mixture of clay and water is the most commonly used binder.
- There are two types of clay commonly used: Bentonite and Kaolinite, with the former being the most common.

BINDERS

ii. Oils

- Linseed oil, marine oils and other vegetable oils used to be as binders,
- However due to their increasing cost, they have been mostly phased out.
- The oil also required careful baking at 100 to 200 °C to cure (if overheated, the oil becomes brittle, wasting the mold).

BINDERS

iii. Resins

- Resin are natural or synthetic high melting point gums.
- The two common types used are urea formaldehyde (UF) and phenol formaldehyde (PF).
- PF resins have a higher heat resistance than UF resins and cost less.

BINDERS

- There are also cold-set resins, which use a catalyst instead of a heat to cure the binder.
- Resin binders are quite popular because different properties can be achieved by mixing with various additives.

BINDERS

- Other advantages include good collapsibility, low gassing, and they leave a good surface finish on the casting.
- MDI (methylene diphenyl diisocyanate) is also a commonly used binder resin in the foundry core process.

BINDERS

iv. Sodium silicate

- Sodium silicate [Na_2SiO_3 or (Na_2O) (SiO_2)] is a high strength binder used with silica molding sand.
- To cure the binder, carbon dioxide gas is used, which creates the following reaction:

$$Na_2O\ (SiO_2) + CO_2 <=> Na_2CO_3 + 2SiO_2 + \text{Heat}$$

BINDERS

- The advantage to this binder is that it can be used at room temperature and is fast.
- The disadvantage is that its high strength leads to shakeout difficulties and possibly of hot tears in the casting.

ADDITIVES

- Additives are added to the molding components to improve: surface finish, dry strength, refractoriness, and "cushioning properties"

i. Reducing agents

- Up to 5% of reducing agents, such as coal powder, pitch, creosote, and fuel oil, may be added to the molding material to prevent wetting

REDUCING AGENTS

- (prevention of liquid metal sticking to sand particles. thus leaving them on the casting surface), improve surface finish, decrease metal penetration, and burn-on defects. These additives achieve this by creating gases at the surface of the mold cavity, which prevent the liquid metal from adhering to the sand.
- Reducing agents are not used with steel casting, because they can carburize the metal during casting.

ADDITIVES

ii. Cushioning materials

- Up to 3% of "cushioning material", such as wood flour, saw dust, powdered husks, peat, and straw, can be added to reduce scabbing, hot tear, and hot crack casting defects when casting high temperature metals.

CUSHIONING MATERIALS

- These materials are beneficial because burn-off when the metal is poured creates tiny voids in the mold, allowing the sand particles to expand.
- They also increase collapsibility and reduce shakeout time.

ADDITIVES

iii. Cereal binders

- Up to 2% of cereal binders, such as dextrin, starch, sulphite lye, and molasses, can be used to:
  - increase dry strength (the strength of the mold after curing)
  - Improve surface finish.

CERIAL BINDERS

- Cereal binders also improve collapsibility and reduce shakeout time because they burn off when the metal is poured.
- The disadvantage to cereal binders is that they are expensive.

ADDITIVES

iv. Iron oxide

- Up to 2% of iron oxide powder can be used to prevent mold cracking and metal penetration, essentially improving refractoriness.
- Silica flour (fine silica) and zircon flour also improve refractoriness, especially in ferrous castings.
- The disadvantages to these additives is that they greatly reduce permeability.

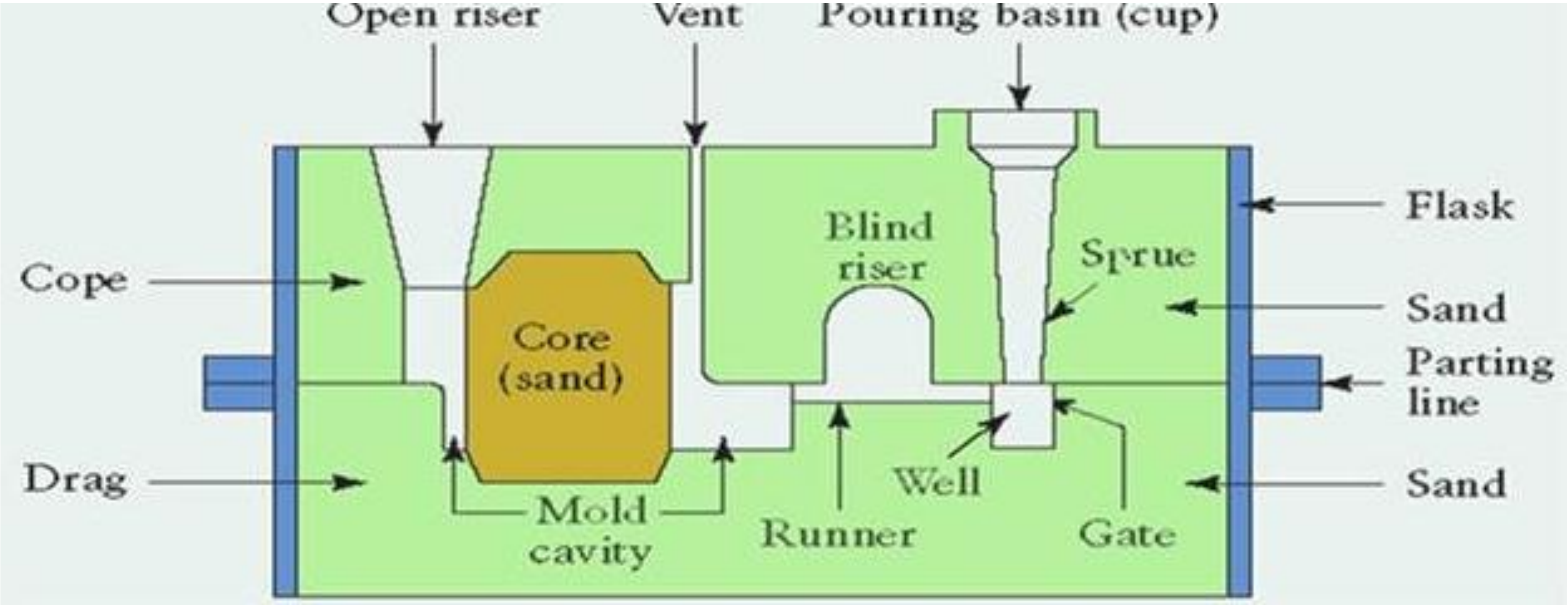
ADDITIVES

v. Parting compounds

- To get the pattern out of the mold, prior to casting, a parting compound is applied to the pattern to ease removal.
- They can be a liquid or a fine powder (particle diameters between 75 and 150 micrometres.
-

PARTING COMPOUNDS

- Common powders include talc, graphite, and dry silica.
- common liquids include mineral oil and water-based silicon solutions.
- The latter are more commonly used with metal and large wooden patterns.



THE END

THANK YOU FOR YOUR ATTENTION