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FORMULA SHEET

for

GATE -ME METAL CASTING

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METAL CASTING

1.1 CASTING:

- Casting is a process in which molten metal flows by gravity or other force into a mould where it solidifies in the shape of the mould cavity.
- Term is also applied to the part that is made by this process.
- The sequence of operations involved in casting are:
  - Pattern Making
  - Mould and core making
  - Melting and Pouring – Furnaces and solidification
  - Casting – shakeout, removal of risers and gates.
  - Heat Treatment
  - Cleaning and finishing – fettling
  - Inspection, defects, pressure tightness, dimensions

Casting Terms:

- **Flask:** This holds the sand mould intact according to position
  - Drag – lower moulding flask.
  - Cope – Upper moulding flask
  - Cheek – Intermediate moulding flask used in the three-piece moulding. Made of metal for long term use.
- **Pattern:** It is a replica of the final object to be made with some modifications.
- **Parting Line:** it is the dividing line between the two moulding flasks that makes up the sand mould.
- **Bottom Board:** Used at the start of the mould making process. First, the pattern is kept on the bottom board and sand particles sprinkled on it and then the remaining is done in the drag.
- **Pouring Basin:** Funnel shaped cavity at the top of the mould into which the molten metal is poured. it reduces the eroding forces of the liquid metal stream coming directly from the furnace.
- **Strainer:** A ceramic strainer in the sprue removes dross.
- **Splash Core:** A ceramic splash core placed at the end of the sprue also reduces the eroding force of the liquid metal stream.
- **Skim Bob:** It is trap placed in a horizontal gate to prevent heavier and lighter impurities from entering the mould.
- **Sprue:** A passage through which the molten metal from the pouring basin reaches the mould cavity.
- **Runner System:** It has channels that carry the molten metal from the sprue to the mould cavity.

- **Gate:** It is an actual entry point through which molten metal enters the mould cavity.
- **Core:** It is used for making hollow cavities or otherwise defines the interior surface of the castings.
- **Chaplet:** It is used for supporting cores inside the mould cavity to take care of its own weight and overcome the metallostatic forces
- **Chill:** This is a metallic object which is placed in the mould to increase the cooling rate of castings to provide uniform or desired cooling rate.
- **Riser:** It is a reservoir of molten metal provided in the casting so that hot metal can flow back into the mould cavity when there is a reduction in volume of metal due to solidification.

1.2 PATTERN:

Pattern is a replica of an object to be made by the casting process with some modifications. The size of patterns is slightly greater than the casting by an amount called allowances.

Pattern Allowances:

- Shrinkage allowance
- Machining allowance or finishing allowance
- Draft or taper allowances
- Distortion allowance
- Shake or rapping allowance.

Classification of Patterns:

Various types if patterns depending upon the complexity of the job, the number of castings required, and the moulding procedure adopted are there.

- Single piece pattern.
- Split pattern or two-piece pattern.
- Gated pattern.
- Cope and drag pattern.
- Match plate pattern.
- Loose piece pattern.
- Follow board pattern.
- Sweep pattern.
- Skeleton Pattern.

Pattern Materials:

The selection of pattern material is based on the following factors:

- Production quantity.
- Dimensional accuracy required.
- Moulding process.
- Size and shape of the casting

  Wood, metals, plastics, and polyurethane foam are generally used materials.

Moulding Materials

Variety of moulding materials:

- Moulding sand
- System sand
- Rebounded sand
- Facing sand
- Pasting sand
- Core sand

Required Processing Properties of Moulding Materials

Refractoriness: It is the ability of the moulding material to withstand high temperatures of the molten metal so that it does not cause fusion.

Green strength: The green sand should have enough strength so that the constructed mould retains its shape where green refers to moisture contained in the sand.

Dry Strength: It should retain the mould cavity and at the same time withstand the metallostatic forces when the sand is in dry condition.

Hot Strength: At high temperature, the strength of sand that is required to hold the shape of the mould cavity.

Permeability: The ability of sand to allow the gas to pass through the mould. It depends on size and shape of grains, moisture content and degree of compaction.

Adhesiveness: Ability of moulding sand to adhere to the surface of moulding boxes.

Cohesiveness: Ability of sand particles to stick to each other. it increase with increase in clay and decreases with increase in grain size.

Mould Hardness: It is the hardness of the mould which is measured similar to Brinell hardness test.

Types of Moulding Sands:

Based on its Origin: Natural sand, Synthetic sand, and special sands.

Based on Initial Conditions: Green sand, dry sand, loam sand, facing sand and parting sand

Moulding Sand Composition:

Main ingredients of moulding sand: Silica grains, clay water and additives.

Silica Sand (Silica Grains):

- Silica grains form the major portion of the moulding sand (96%) and rest being other oxides such as alumina, sodium ($Na_2O + k_2O$) and magnesium oxide ($MgO + CaO$).
- Impurities (Oxides) should be minimum because it affects the fusion point of the silica sands.

1.3 CLAY:

Used as binding agent and this is mixed with the moulding sands to provide strength because of their low cost and wider utility.

Types of Clay:

- Kaolinite or fire clay ($Al_3O_32SiO_22H_2O$)
- Bentonite ($Al_2O_34SiO_2H_2O_nH_2O$)
- Southern bentonite
- Calcium as adsorbed ion
- Low dry strength but higher green strength

Water:

- Develops plasticity and strength.
- Amount of water used should be property controlled.
- Usual percentage of water is from 2-8%

Additives:

Coal dust: Used for providing better surface finish to the castings.

Saw Dust or Wood Flour:

- It widens the range of water that can be added to get proper green strength.
- It reduces the expansion of defects while improving the flowability of the moulding and.

Starch and Dextrin:

- Organic binding materials used with mould and core sands.
- Increase resistance to deformation, skin hardness and expansion defects such as scab.

Iron Oxide:

- Improves surface finish, decreases metal penetration, reduces burn-on, increases the chilling effect of the mould.
- It decreases green strength and permeability while improving the hot strength.
- It reduces collapsibility and makes the shake-out of the mould difficult.

Permeability:

- Permeability is expressed in terms of permeability number.
- The standard permeability test is to measure time taken by a 2000 cm^3 of air at a pressure typically of 980 Pa to pass through a standard sand specimen confined in a specimen tube.
- The standard specimen size is 50.8 mm in diameter and a length of 50.8 mm.

$$\text{Permeability Number } P = \frac{v \times H}{p \times A \times T}$$

Where, v = volume of air = 2000 cm^3

H = height of the sand specimen = 5.08 cm

p = air pressure (g/cm^2)

A = cross-sectional area of sand specimen

T = time in minutes for the complete air to pass through.

Green Compression Strength:

- Tests are carried out on the universal sand strength testing machine.
- It refers to the stress required to rupture the sand specimen under compressive loading.
- The standard specimen put on the strength testing machine and the force required to cause the compression failure is determined.

Green Compression Strength:

- Tests are carried out on the universal sand strength testing machine.

- It refers to the stress required to rupture the sand specimen under compressive loading.
- The standard specimen put on the strength testing machine and the force required to cause the compression failure of determined.

Green Shear Strength:

- Test is carried out on the universal sand strength testing machine with a different adapter fitted in the universal machine so that the loading can be made for the shearing of the kind sample.
- Stress required to shear the specimen along the axis is then represented as the green shear strength.

Dry Strength:

The standard specimen dried between 105°C and 110°C for 2 hrs, which is used for testing.

Mould Hardness:

- A spring-loaded steel ball with a mass of 0.9 kg is indented into the standard specimen prepared.
- The depth of indentation can be directly measured on the scale which shows units 0 to 100.
- When no penetration occurs reading is 100 which means hardest mould.

Sand Preparation:

The preparation of sand is thoroughly mixing of its various ingredients. In the mixing process, the clay is uniformly enveloped around the sand grains and moisture is uniformly distributed which is done by muller machine.

Method of Preparing Sand Mould:

- The degree of ramming increases the bulk density or the mould hardness.
- Increased ramming increases strength.
- Permeability of green sand decreases with the degree of ramming.

Factors	Permeability	Strength
Increase of grain fineness number	Decreases	Increases
Clay content	Decreases	Increases
Moisture content	Reaches a maximum and then decreases	Reaches a maximum and then decreases
Degree of ramming	Decreases	Increases

Defects In Castings:

The defects in casting may arise due to the defects in one or more of the following:

- Design of casting and Pattern
- Moulding sand and design of mould and core

- Metal composition
- Melting and pouring
- Gating and risering

Pouring Metal Defects:

- **Mis-runs:** When the metal is unable to fill the cavity completely and thus leave unfilled cavities.
- Cold Shuts: When two metal streams while meeting in the mould cavity do not fuse together properly-discontinuity or weak spot in the casting.

⇒ **Causes of Above Two Defects:**

- By lower fluidity of the molten metal or when the section thickness of the casting is too small.
- When the heat removal capacity is increased such as in the case of green sand mould.

⇒ **Remedy**

- Increase the fluidity of the metal by changing the composition or raising the pouring temperature.
- Improving the mould design.

Heating and Pouring:

The heat energy required is the sum of

- The heat to raise the temperature to the melting point.
- The heat of fusion to convert it from solid to liquid and
- The heat to raise the molten metal to the desired temperature for pouring.

$$H = \rho v\{c_s(T_m - T_o) + H_f + c_l(T_p - T_m)\}$$

$H =$ Total heat required to raise the temperature of the metal to the pouring temperature.

$\rho =$ density

$c_s =$ weight specific heat for the solid metal.

$T_m =$ melting temperature of the metal.

$T_o =$ Starting temperature

$H_f =$ Heat of fusion

$c_l =$ weight specific heat of the liquid metal

$v =$ volume of metal being heated.

Pouring: Introduction of molten metal into the mould, including its flow through the gating system and into the cavity is a critical step in the casting process.

Factors affecting the pouring operation includes pouring temperature, pouring rate and turbulence.

1.4 GATING DESIGN:

The liquid metal that runs through the various channels in the mould obeys the Bernoulli's theorem which states that the total energy head remains constant at any section.

$$h + \frac{p}{\rho g} + \frac{V^2}{2g} = \text{constant}$$

Where, $h =$ Potential head, m

$p =$ pressure, p_a

$V =$ liquid velocity, m/s

$\rho g =$ Specific wt. of liquid, N/m^3

g = Gravitation constant, m/s^2

But as the metal moves though the gating system, a loss of energy occurs because of the friction between the molten metal and the mould walls.

Law of continuity says that the volume of metal flowing at any section in the mould is constant.

$$Q = A_1V_1 = A_2V_2$$

Where, Q = rate of flow, m^3/s

A = area of x – c/s, m^2

V = velocity of metal flows, m/s

1.5 SOLIDIFICATION AND COOLING:

Pure Metals:

Solidify at a constant temperature equal to its freezing point, which is same as its melting point.

Solidification Time:

- It is the time required for the casting to solidify after pouring.
  - Local solidification Time: Actual freezing takes time during which the metal's latent heat of fusion is released into the surrounding mould.
  - Total solidification time: Time taken between pouring and complete solidification.
- Dependent on the size and shape of the casting by an empirical relationship (Chvorinov's rule).

$$T = C_m \left(\frac{V}{A}\right)^N$$

T = total solidification time, min

v = volume of the casting cm^3

A = Surface area of the casting, cm^2

n = Exponent taken to have a value = 2

C_m = Mould constant (min/cm^2)

Shrinkage:

Shrinkage occurs in three steps:

1. Liquid contraction during cooling prior to solidification.
2. Contraction during the phase change from liquid to solid- solidification shrinkage.
3. Thermal contraction of the solidified casting during cooling to room temperature.

Directional Solidification:

In order to minimize the damaging effects of shrinkage, it is desirable for the regions of the casting most distant from the liquid metal supply to freeze first and for solidification to progress from these remote regions towards the risers. It is attained by locating sections of the casting with lower v/A ratio away from the riser. Freezing will occur first in these regions and the supply of liquid metal for the rest of casting will remain open until these bulkier sections solidify.

Another way to encourage direction solidification is to use chills.

Internal Chills are small metal parts inside the cavity before pouring so that the molten metal will solidify first around these parts.

External chills are metal inserts in the walls of the mould cavity that can remove heat from the molten metal more rapidly than the surroundings sand in order to promote solidification.

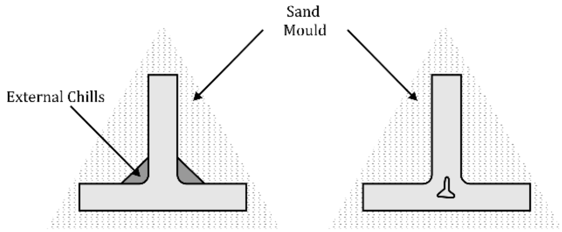


Fig: (a) External chill to encourage rapid freezing of the molten metal in a thin section of the casting and (b) The likely result if the external chill is not used.

Riser Design:

- Riser is used in a sand-casting mould to feed liquid metal to the casting during freezing in order to compensate for solidification shrinkage.
- To function, the riser must remain molten until after the casting solidifies.
- The riser represents the waste metal that will be separated from the cast part and remelted to make subsequent castings. It is desirable for the volume of metal in the riser to be minimum. Since the geometry of the riser is normally selected to maximize the V/A ratio, this tends to reduce the riser volume as much as possible.
- Different forms of riser:
    - **Side Riser:** Attached to the side of the casting by means of a small channel.
    - **Top Riser:** Connected to the top surface of the casting.
    - **Open Riser:** Exposed to the outside at the top surface of the cope, allowing more heat to escape, promoting faster solidification.
    - **Blind Riser:** Entirely enclosed within the mould.
- Design of riser is such that the time taken for solidification of liquid metal in the riser should be more than the time taken for solidification of liquid metal in the cavity.

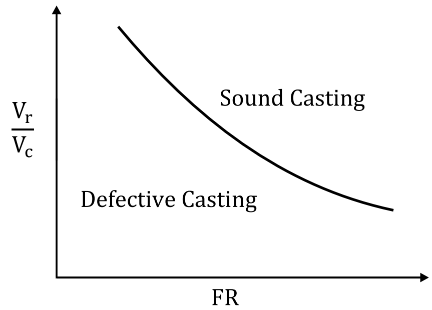
$$(T_s)_{riser} \geq (T_s)_{casting}$$

Riser can be designed by using four methods:

1. Caine's method
2. Modulus method
3. Navel research Method
4. Shrinkage volume consideration method.

Method of Riser Design

1. **Caine's Method:**



X = Freezing ratio (FR)

$$\Rightarrow FR = \frac{\left(\frac{V}{A}\right)_{riser}}{\left(\frac{V}{A}\right)_{Casting}}$$

$v = \text{Volume}$

$A = \text{Surface Area}$

$$\gamma = \frac{v_{riser}}{v_{casting}}$$

$$X = \frac{a}{\gamma - b} + c$$

2. **Modulus Method:**

$$\text{Modulus} = m = \frac{\text{Volume}}{A}$$

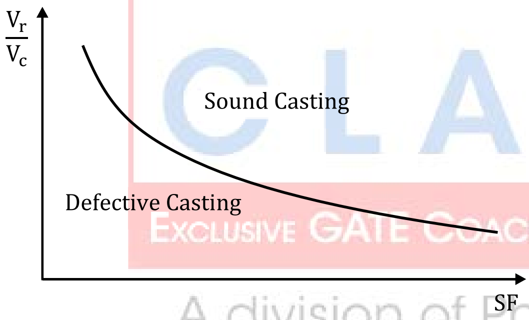
$A = \text{Surface Area}$

$M_{riser} = 1.2\ M_{casting}$

3. **Naval Research Method:**

$$\text{Shape factor (SF)} = \frac{L + W}{T}$$

$L = \text{Length}, W = \text{Width}, T = \text{Thickness}$



Geometry	SF
Cube	2
Sphere	2
Cylinder	2(H = D)

4. **Shrinkage Volume Consideration Method:**

a. Volume of Riser ≥ 3 times precent shrinkage of volume of casting.

b. $\text{time})_{Riser} \geq \text{time})_{casting}$

$$\left(\frac{V}{A}\right)_{riser} \geq \left(\frac{V}{A}\right)_{casting}$$

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