FOUNDRY SECTION

FEEDER DESIGN

Aim Design riser for a Steel Casting for the given casting drawing by

a) Chvorinov's Method
b) Caines Method

When molten metal enters a mould cavity, its heat is absorbed by and transferred through the mould wall. In case of pure metals and eutectics, the solidification proceeds layer-by-layer starting from the mould wall and proceeds inwards. As the front solidifies, it contracts in volume, and draws molten metal from the adjacent (inner) layer. When the solidification front reaches the innermost region or the hot spot, there is no more liquid metal left and a void called shrinkage cavity is formed. This is avoided by attaching a feeder designed to solidify later than the hot spot. The shrinkage cavity shifts into the feeder. The solidification phenomenon helps in predicting the type and location of shrinkage defects, and in overcoming them successfully by appropriate design of feeders.

A binary eutectic solidification of a general alloy is shown in Figure 1.

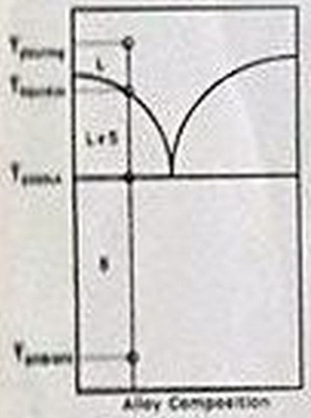

Figure 1.

Here we pour the molten metal at a temperature $T_{pouring}$. As temperature falls the vertical line touches the ***liquidus*** line (all points above this are in liquid state) and the corresponding temperature is $T_{liquidus}$. Next the vertical line touches the ***solidus*** line (all points below this are totally solid) and the corresponding temperature is $T_{solidus}$. Metal shrinks between temperatures $T_{pouring}$ and $T_{liquidus}$. This shrinkage is known as ***Liquid shrinkage***. The shrinkage between temperatures $T_{liquidus}$ and $T_{solidus}$ is known as ***Solidification shrinkage***. The shrinkage for temperatures between $T_{solidus}$ and $T_{ambient}$ is known as ***Solid shrinkage***. Usually metal has enough fluidity during liquid shrinkage and solidification shrinkage. Therefore, during these two, contraction, stages feeders are used to compensate the shrinkages. Solid shrinkage is compensated by the ***contraction*** allowance provided in the patterns.

Once the metal is poured into a mould the portion of metal which comes in contact with moulding material looses heat rapidly and solidifies. The solidification process in a stepped mould cavity is shown in Figure 2.

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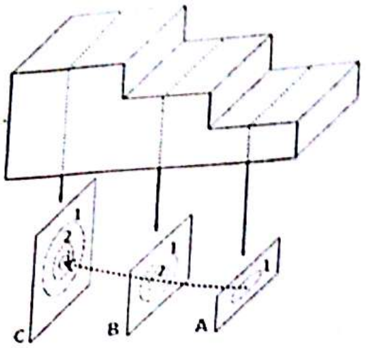

Figure 2

Three sections are considered at three places each passing through the middle of a step. Metal in these sections are assumed to solidify from the periphery towards the centre. Such type of solidification is known as ***Progressive Solidification***. Each section is analysed after 1, 2 and 3 minutes of pouring. It can be seen that even after 3 minutes of pouring some area in section C remain molten whereas sections A and B have solidified by that time. Consequently no shrinkage can be found in sections A and B whereas some shrinkage is expected in section C. The last point to solidify in these sections is joined by a dotted line which shows the direction of solidification from thinner to thicker section. This type of shrinkage which refers to the sequence of solidification of different regions of the casting: ideally starting from thin regions at one end, followed by adjacent thicker regions, and finally ending at the thickest region usually the feeder. A three dimensional comparison of these two type of solidifications are shown in Figure 3 below.

Figure 3

The solidification characteristics of castings are governed by three factors: freezing range (F), thermal gradients (G), and cooling rate (R).

Freezing range is the difference of $T_{liquidus}$ and $T_{solidus}$ of the alloy/metal. Short range freezing range behave like pure metals and eutectics, and the solidification proceeds layer-by-layer. The grains are columnar and grow in a direction perpendicular to the mould wall. In long range freezing alloys, the solidification is initiated at a large number of points, and the grains grow in size until the neighbouring grains hinder them.

Thermal gradient between two points is the difference in temperature per unit distance. Thin castings and points near the mould wall are characterized by high gradients, whereas the middle regions of thick castings have low gradients. A higher difference in section thickness of neighbouring regions enhances the thermal gradient between them. The feed metal primarily moves along the direction of the maximum thermal gradients to compensate for volumetric contraction during solidification. Poor gradients, especially at an isolated hot spot, cause shrinkage porosity.

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Cooling rate is the fall in temperature at a location over a time period. Cooling rates are higher in the beginning and decrease as the solidification progresses. Also the cooling rates are higher at mould bottom where the metal is in contact with the mould than at the top. Higher cooling rates generate finer grains. The grain size affects the strength and hardness of the casting.

Feeding Principles

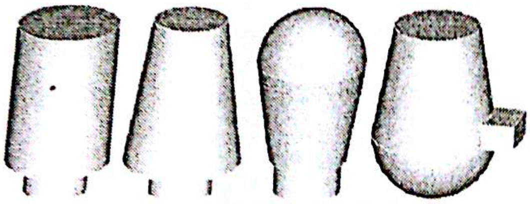
- Feeder must solidify after casting:
- Sufficient feed metal: There should be sufficient feed metal in the feeder as it itself also solidifies while the casting solidifies.

$\eta_{feeder} V_{feeder} > \alpha(V_{casting} + V_{feeder})$, where

η	feeder efficiency(about 15%)
α	solidification contraction (3-5%)
V	volume

Shapes of the feeder

- The ideal shape of the feeder should be one which has got highest volume to surface area ratio.



- Accordingly sphere is the most ideal shape but because of moulding difficulties it is impractical.
- Feeders are generally cylindrical or tapered in shape.

- Feeder location w.r.t. casting
  - Top feeder: gravity feed with chances of undercut.
  - Side feeder: Hotter and easier to mould and fettle.

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Position of the feeder

- If there is only one major hotspot in the casting, the feeder must be connected to the casting face closest to the hot spot.
- If two or more isolated hot spots are located far apart then each hot spot may require a devoted feeder.
- When a feeder is placed above the hot spot then it is known as ***Top feeder*** whereas if it is placed on a side it is called ***Side feeder***.
- A top feeder is more effective because of the additional effect of gravity. On the other hand the side feeders can remain molten for a longer period implying that a smaller feeder can be used.
- Feeders may also be classified as ***Open*** or ***Blind***, depending on whether the top of the feeder is open to atmosphere or not.
- In sand casting open feeders loose more heat than blind feeders so are less efficient compared to blind feeders.
- In metal moulds it is reverse, open feeders are more efficient than blind feeders since heat transfer by conduction through the metal mould is greater than beat transfer by convection through air.
- Open feeders are also called ***risers*** since the liquid metal can be seen rising in them, serving as useful indicators that the mould has filled completely.
- Blind feeders also require an opening to the atmosphere, to enable feed metal flowing down to the hot spot. This is ensured placing a special core called ***william core*** above a blind feeder named so after the inventor.
- Feeder must be connected to a flat surface rather than a curved face of the casting for ease of fettling.

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Chvorinov's Method of Riser Design

Chvrorinov analysed that $t = k\left(\frac{V}{A}\right)^2$ where

k is a function of liquid metal characteristics as well as mould characteristics.
V = Volume
A = Exposed Surface area
Basic assumption of riser design according to Chvorinov is

$t_R > t_C$ where t_R = solidification time of Riser and t_C = Solidification time of Casting

i.e. $\left(\frac{V}{A}\right)_{Riser} > \left(\frac{V}{A}\right)_{Casting}$

Shape of the Riser = Cylindrical with height = H; Diameter = D
H/D ratio should be 1.5 to 2.0

$A_{Riser} = \frac{\pi D^2}{2} + \pi DH$ for Blind Riser

$A_{Riser} = \frac{\pi D^2}{4} + \pi DH$ for Open Riser

$\left(\frac{V}{A}\right)_{Riser}$ = 1.1 to 1.2 times $\left(\frac{V}{A}\right)_{Casting}$

Procedure

1 Calculate the volume and exposed surface area of the casting from the drawing
2 Decide a proper position for the rise
3 Decide the type of riser Blind or Open
4 Consider a H/D ratio for the riser
5 Determine D and H of Riser

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Caines Method of Riser Design

The formula used for riser design in this method is

$$X = \frac{a}{Y - b} + C_1 \qquad \text{equation 1}$$

Where

$$X = \frac{(A/V)_{Casting}}{(A/V)_{Riser}} \qquad \text{equation 2}$$

Where A = exposed surface area

$$A_{Riser} = \frac{\pi D^2}{2} + \pi DH \quad \text{for Blind Riser}$$

$$A_{Riser} = \frac{\pi D^2}{4} + \pi DH \quad \text{for Open Riser}$$

V = volume

$$Y = \frac{V_{Riser}}{V_{Casting}}$$

a = Freezing Characteristics coefficient = 0.1 for steel
b = liquid to solid contraction = 0.03 for steel
C_1 = relative freezing rate of riser and casting = 0.8 for insulating sleeve

Procedure

1 Calculate $(A/V)_{Casting}$
2 Consider riser to be cylindrical with H/D = 1.5 to 2.0 where H and D are height and diameter of the riser respectively.
3 Decide the position and type of riser
4 Calculate $(A/V)_{Riser}$ in terms of D
5 Calculate Y
6 Equate equations 1 & 2 to find D
7 Find the height of the riser

Compare the size of the riser calculated by the tow methods and limitations of each