MME 345

Lecture **B:09**

The Design of Feeding System

3. Feeding calculations 2: Optimizing shape and placement of feeder

Ref:

[1] P. Beeley, Foundry Technology, Butterworth-Heinemann, 2001
[2] J. Campbell, Castings, Butterworth-Heinemann, 2001
[3] Heine, Loper, Rosenthal, Principles of Metal Casting, Tata McGraw-Hill, 1976

Topics to discuss....

1. Optimizing shape of feeder
2. Optimizing placement of feeder
3. Increasing the efficiency of feeder

1. Optimizing Feeder Shape

- ☐ The shape of the feeder plays an important part in keeping the metal it contains in liquid form. So the feeder should be shaped so that it promotes a slow cooling rate.

  surface area of the casting relative to volume is important in determining the rate of heat transfer from the casting.

- ☐ According to Chvorinov's rule, solidification time of a given shape is proportional to its modulus , i.e., square of its (V/A) ratio

  for a feeder of a given size to have a maximum solidification time, it must have the smallest surface area

- ☐ Amongst all shapes, a sphere has the smallest surface area

  thus a spherical feeder head will remain liquid for the longest period of time amongst all shapes of unit volume

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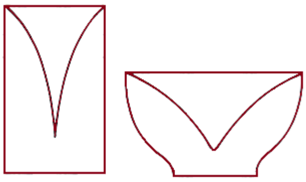
- ☐ Spherical feeder heads
  - **difficult to mould**
  - **cause feeding problems**

  and the last metal to solidify would be near the centre of the sphere, which cannot be used to feed a casting

- ☐ Practicalities dictate the use of cylindrical shapes for most feeders, although hemispherical feeders or a hemispherical base of cylindrical feeder are often used.



- ☐ Besides maximizing freezing time, other factors influencing the shape of a feeder head include

  1. **the timing of the demand for feed metal, affecting the shape of the shrinkage cavity in the head, and**
  2. **the permissible area of junction with the casting: this should be as small as possible to minimize fettling costs**

1.1 Optimising feeder dimensions

- Now the diameter of a cylindrical feeder depends on too many factors. But what about its height?

- Most authorities and researchers agree that the minimum height of a feeder should be **no less than one-half** times its diameter and the maximum height should be **no more than one and a half** times its diameter.

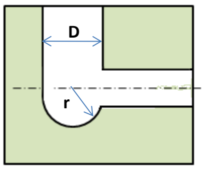
D = 100 mm ➔ H = 50 – 150 mm

This is because of the V/A ratio.
Dimensions outside those limits would make the V/A ratio lower than it is within them.

- These limitations apply to both top and side feeders.

- The top and bottom surfaces of the cylindrical feeders can be made spherical to stay liquid longer. That **bulb**, as it's called, will keep the feeder liquid.

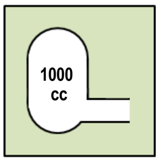
  It has the same diameter as the feeder (i.e., D = 2r)



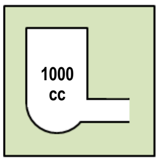
- When we have blind feeder, we can use the same technique on top and bottom of it for the same purpose.

  Which of these two feeders should stay liquid longer?

  The answer is (a).



(a)



(b)

- The **dome**, as we called the top of the blind feeder, has the same dimensions as the bulb i.e., the radius of the dome is one-half the diameter of the feeder.

- ☐ Like feeder, the neck should stay liquid as long as possible.
  That means that the cross-sectional shape of the neck should be circular.

  For thin plate castings, a round neck may be impossible.
  In that cases, we have to use a neck with a square, or perhaps rectangular, cross-section.

- ☐ Even though the neck has a circular section, the longer it is for a given diameter, the more area it will have and the more rapidly it will solidify.

  The feeder neck should never exceeds one-half the diameter of the feeder.

  The diameter of the neck can be determined using the simple formula:

$$D_n = 1.2\,L_n + 0.1\,D$$

D = diameter of feeder
L_n = length of neck
D_n = diameter of neck

- ☐ For a square or rectangular neck, the following formula can be used:

The calculations given in this section are applicable to most common types of iron castings. Similar formulas are available for other cast alloys.

$$L_n = D/3$$

$$W_n = 2.5\,L_n + 0.18\,D$$

$$T_n = 0.6 - 0.8\,T$$

D = diameter of feeder
L_n = length of neck
W_n = width of neck
T_n = thickness of neck
T = thickness of casting

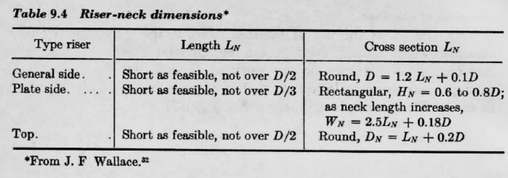


Table 9.4 ***Riser-neck dimensions****

Type riser	Length L_N	Cross section L_N
General side . .	Short as feasible, not over $D/2$	Round, $D = 1.2\,L_N + 0.1D$
Plate side. . . .	Short as feasible, not over $D/3$	Rectangular, $H_N = 0.6$ to $0.8D$; as neck length increases, $W_N = 2.5L_N + 0.18D$
Top. .	Short as feasible, not over $D/2$	Round, $D_N = L_N + 0.2D$

*From J. F Wallace.[32]

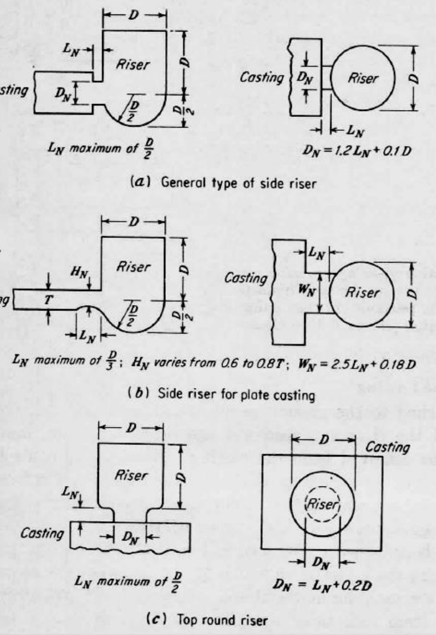


Fig. 9.22 Location of dimensions used in Table 9.4 for three types of risers. (*From J. F Wallace.*[32])

2. Optimizing Placement of Feeder

- Feeder heads are normally placed in direct contact with the heavier sections of a casting, since this enables directional solidification to be maintained throughout freezing.

- In complex castings, the shape is divided into a number of natural zones of feeding, each centred on a heavy section separated from the remainder of the casting by more constricted numbers.
- Each zone is then fed by a separately calculated feeder

- In normal conditions, there will be a limit to how far feed liquid can be provided along a flow path.
- Up to this distance from the feeder, the casting will be sound.
- Beyond this distance, the casting will exhibit porosity.

- For many extended castings feeding range is the limiting factor as appreciable **temperature gradients** are needed for feeding and these are difficult to induce in parallel sections over long distances.

- Examples to obtain castings free from dispersed porosity:

  steels :

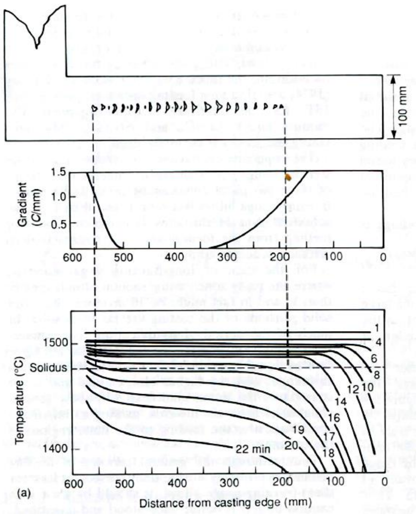
  ~ 0.2–0.4 °C gradients/cm (plate)
  ~ 1.5–2.6 °C/cm (bars)

  non-ferrous alloys :

  ~ 5.5 °C gradients/cm
  ~ 13 °C gradients/cm
  (long freezing range alloys)

  - steep temperature gradients against end walls
  - shallow gradients adjacent to feeder heads
  - isothermal plateau in intermediate regions

  - feeding can only take place over very short distances in such plateau zones and centre line shrinkage generated in remaining areas



temperature distribution in a solidifying steel bar

- When a long bar or a plate is cast without a feeder, a certain length of the casting from each end of the bar/plat is sound.

  this results from the directional solidification that developed at the ends because of faster cooling rate.

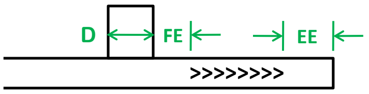
  This is called the **end effect**.

- When a long bar/plate is cast using a feeder at the centre of the casting, a certain distance from the feeder (in any direction) the bar/plat is sound.

  This is called the **feeder effect**.

- The **use of chill** provides a powerful influence in extending the feeding range of heads when placed at intermediate positions of feeders.

  the spacing between feeder heads can in this case be more than doubled, which also greatly increases the casting yield.



F_d = D + 2FE + FE

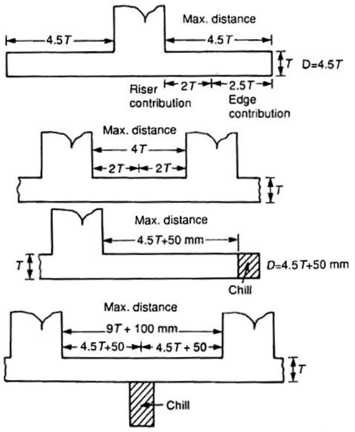


Fig. 6.9 (b): Feeding distances for steel plates cast in greensand.

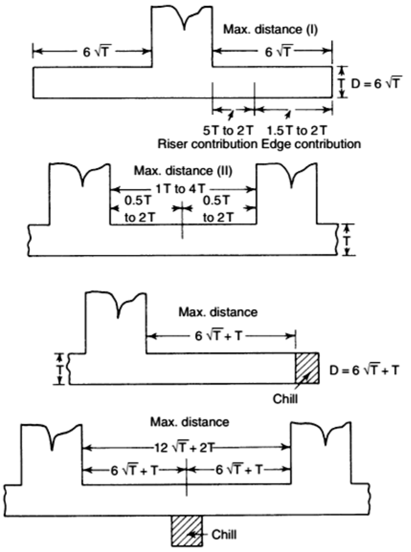


Fig. 3.26: Feeding distance relationships for bars

Summary:

Feeder contribution: $L_d = 2.0\,T$
Edge contribution: $L_d = 2.5\,T$
Chill contribution: $L_d = 50$ mm

Applies for heavy sections only ranging from 50 – 200 mm

Work of Johnson and Loper (1969):

Plate casting: $L_d = 72\,m^{1/2} - 140$ mm
Bar casting: $L_d = 80\,m^{1/2} - 84$ mm

Down to section thickness of 12.5 mm

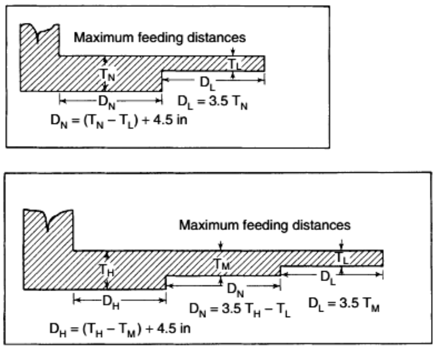


Fig. 3.27: Feeding distance relationships for dual and multiple sections

Work of Bishop et. al, (1969):

When plates joined at their edges to form stepped members (where the conjunction of two plates differing in thickness by a factor exceeding 1.4),

the feeding distance in the thinner or 'parasite' plate is increased, when compared with that when the latter is cast alone.

- ☐ Feeding distance diminishes with increasing **freezing range**.

in extreme case of a gunmetal, satisfactory soundness was attained only with the aid of chills.

For comparison of feeding ranges in different alloys, Flinn introduced the useful concept of 'centreline resistance factor (CRF)'

$$\text{CRF} = \frac{\text{time during which crystals are present at the centre line}}{\text{total solidification time}} \times 100$$

a measure of periods during which metal flow for feeding through a central channel is successively free and obstructed by growing crystals

Table 3.5 Centre line resistance factors of typical alloys cast in sand moulds (after Flinn[54], courtesy of American Foundrymen's Society)

Alloy	*Centre line resistance factor*
Copper (99.8%)	<1
Lead (99.0%)	17
60–40 Brass	26
18.8 Steel (0.2% C)	35
0.6% C steel	54
Monel	64
88/10/2 gunmetal	95
Al 4% Cu	96

CRF ↑ ⇨ Feeding resistance ↑

- ☐ For short-freezing-range alloys, CRF is low, and have increased feeding distance
  - **solidified skin grows from the mould inwards and block the channel for liquid flow**
  - **feeding distance increases with section thickness**
- ☐ For long-freezing-range alloys, CRF is high, and have decreased feeding distance
  - **feeding through the dendritic pasty zone is difficult**

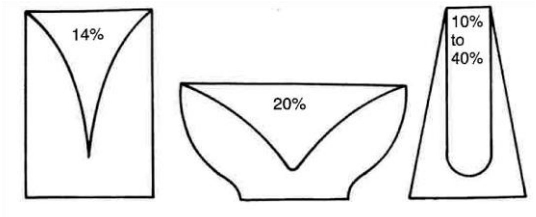
3. Increasing Efficiency of Feeder

- The efficiency of a feeder head may be defined as the amount of feed metal supplied to the casting in relation to the total weight of metal initially present in the head.

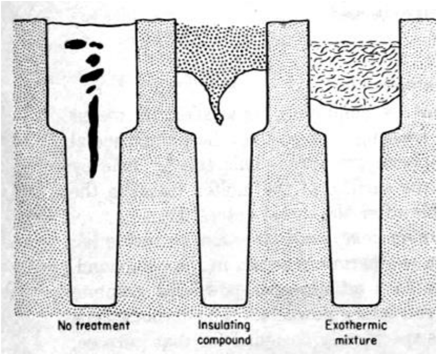
$$\text{Efficiency, } U = \frac{I - F}{I} \times 100$$

I = initial volume of metal in head
F = final volume of metal in head

- The efficiency of a plain feeder head is very low, since solidification proceeds in the head at the same time as in the casting.



- A feeder can be made more efficient by some artificial means to keep the top molten so that the liquid beneath can be exposed to atmospheric pressure.
- These include:
  - use of insulating materials around the feeder head
  - use of exothermic compounds



use of an insulating compound or exothermic mixture in the feeder reduces the piping tendency and decrease the amount of metal required in the feeder

- The net effect of using these artificial means is to **reduce the size of feeder**.
- This also means a **higher casting yield**.

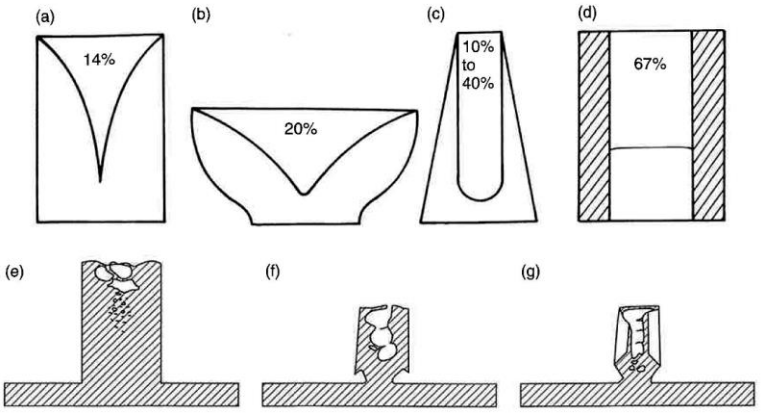


Figure 6.5 *Metal utilization of feeders of various forms moulded in sand. The (a) cylindrical and (b) hemispherical heads have been treated with normal feeding compounds; (c) efficiency of the reverse taper heads depends on detailed geometry (Heine, 1982, 1983); (d) exothermic sleeve (Beeley, 1972). Metal utilization for ductile iron plates with (e) cylindrical sand feeder; (f) insulating feeder; and (g) cruciform exothermic feeder (after Foseco 1988).*

Insulation

- ☐ The use of insulating materials to retard radiation losses from the exposed metal surface is a long established practice.
- ☐ More thorough insulation is now frequently sought by lining the heads with **moulded sleeves** to reduce conductive heat loss through the mould.
- ☐ The materials used derive their low heat diffusivity from porous or granular structures.
  - **Top coverings materials include: dry sand, powdered slag, chopped straw (which first char and then burn away to leave a bulky ash), proprietary anti-piping compounds (contain a certain amount of exothermic material; those used of steel contains carbonaceous matter which becomes absorbed by the metal and locally reduces its freezing temperature)**
  - **pre-formed sleeves for lining materials include: foamed gypsum plaster (to develop high porosity) (for non-ferrous castings), diatomaceous silica and vermiculite (for steel castings).**

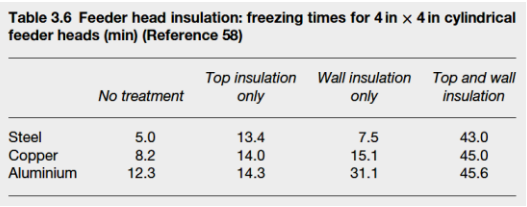


Table 3.6 Feeder head insulation: freezing times for 4 in × 4 in cylindrical feeder heads (min) (Reference 58)

	No treatment	*Top insulation only*	*Wall insulation only*	*Top and wall insulation*
Steel	5.0	13.4	7.5	43.0
Copper	8.2	14.0	15.1	45.0
Aluminium	12.3	14.3	31.1	45.6

Exothermic materials

- Considerable heat is generated by exothermic reaction; in some cases molten metal is also produced.

- Common materials used: **thermit mixture** (fine mixture of aluminium and iron oxide), powdered charcoal or graphite, rice or oat husk, and refractory powder.

Thermit reactions:

$2Al + Fe_2O_3 = Al_2O_3 + 2Fe$; $\Delta H_{298} = -853$ kJ

$8Al + 3Fe_3O_4 = 4Al_2O_3 + 9Fe$; $\Delta H_{298} = -3347$ kJ

- Added in two ways:

1. **Material is added on top of feeder to control feeding. Composition must be compatible with that of the casting.**
2. **Material is mixed with bonding material and water to mould sleeve for lining feeder head. The added substance helps delaying exothermic reacting and extend the period during which heat is generated. This diminishes the danger of contamination, since the exothermic reaction is confined to the mould wall. The period during which heat is generated is controlled.**

Table 3.7 Exothermic feeder heads: comparison of volumes of spheres of a given modulus $M = 1$

Sphere	*Actual diameter* cm	*Equivalent modulus M_E* cm	*Equivalent diameter* cm	*Equivalent volume* cm³	*Volume factor*
Plain	6	1	6	113	1
Exothermic	6	1.43	8.58	330	2.92

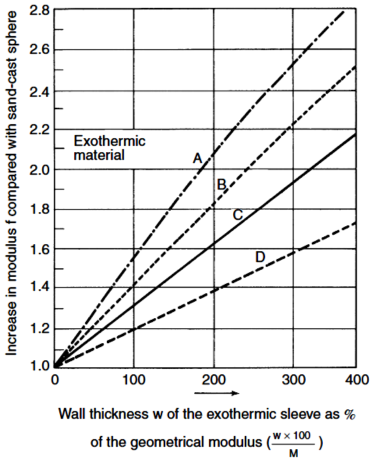


Figure 3.18 Increase in modulus of cast steel spheres due to exothermic mould lining. Sphere diameter 150 mm (from Wlodawer[34]) (courtesy of Dr R. Wlodawer and Pergamon Press Ltd., reprinted from Directional Solidification of Steel Castings (1966))

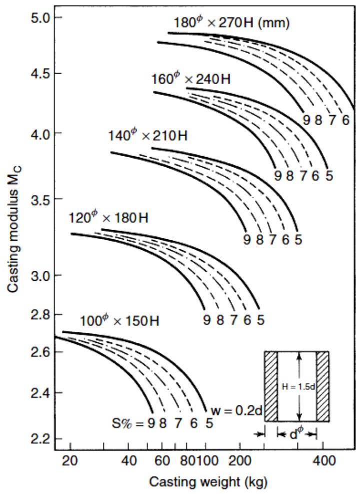


Figure 3.32 Chart for selection of exothermic feeder head dimensions (from Wlodawer[34]) (courtesy of Dr R. Wlodawer and Pergamon Press Ltd., reprinted from Directional Solidification of Steel Castings (1966))

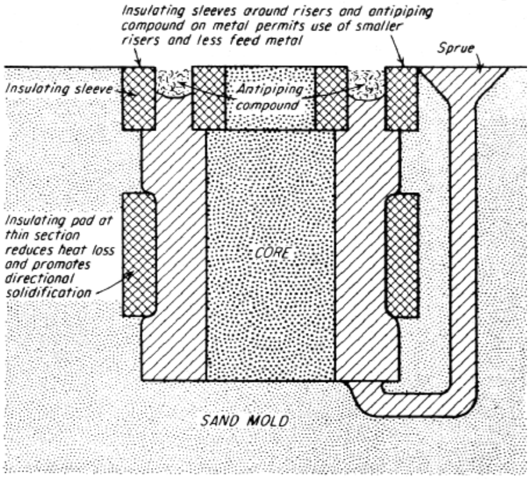


***Fig.* 9.27** **The combination of insulating sleeves around risers and insulating pads at thin sections of a casting increases metal yield and promotes directional solidification.**

- Use of chills, primarily to extend feeding distance, also exert a profound influence on feeding requirements.

By creating an earlier demand for feed metal, the freezing time needed in the feeder head is shortened.

Thus, the reduction in the effective modulus of a wholly or partially chilled casting enables feeder head dimensions to be reduced towards the level at which volume feed capacity governs the size of head required.

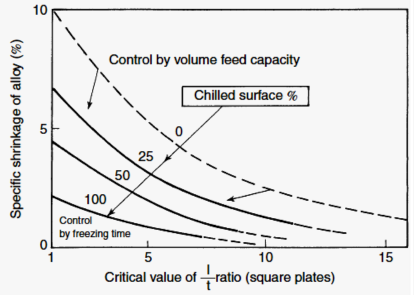


Figure 3.40 Controlling factors in feeder head size: effect of chilling

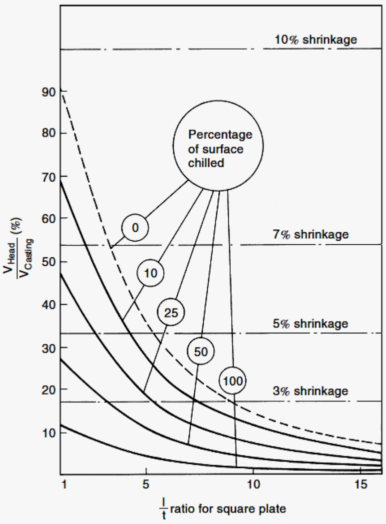


Figure 3.39 Influence of chilling on head volume required to satisfy freezing time criterion (spherical head; plates of various proportions)

Next Class

MME **345**, Lecture **B:10**

The Design of Feeding System

4. Case study in design of a feeding system