Manufacturing Process (KME-404)

Riser Design

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Riser Design

Lesson Objectives

In this chapter we shall discuss the following:

Solidification of casting

Chvorinov rule Functions

of riser Types of riser

Methods for riser design

Solidification of Casting

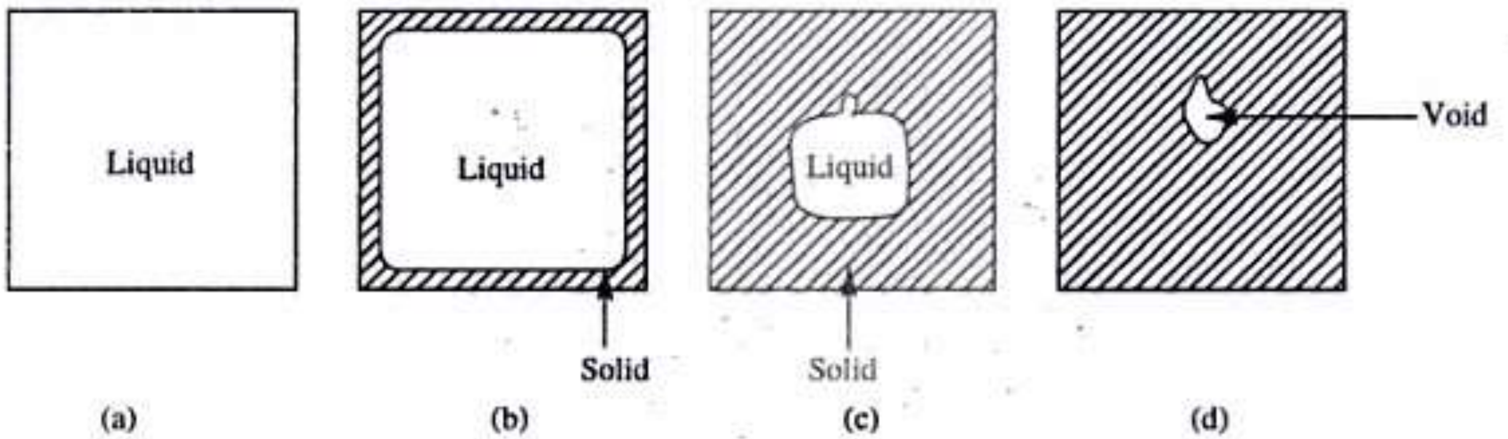
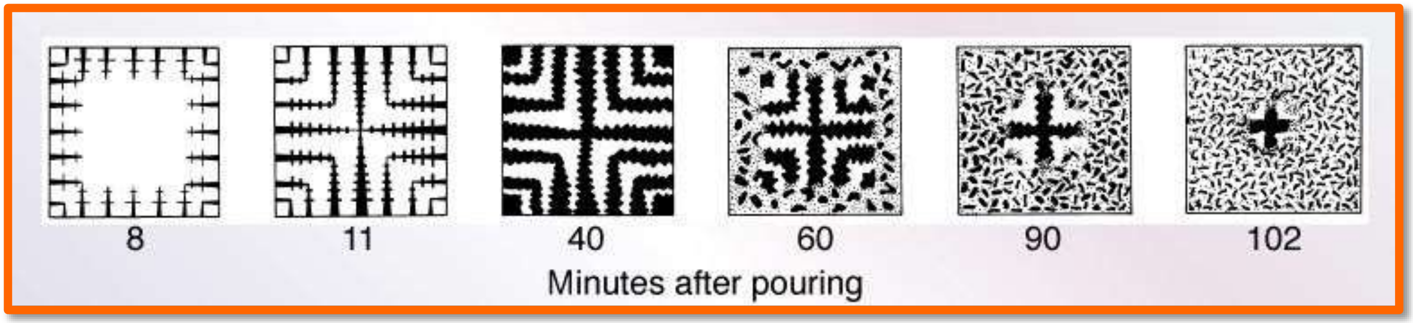


Fig. 12.1 Solidification of cube casting

- During solidification metal experience shrinkage which results in void formation.
- This can be avoided by feeding hot spot during solidification.
- Riser are used to feed casting during solidification.

Solidification of Iron & Carbon Steels



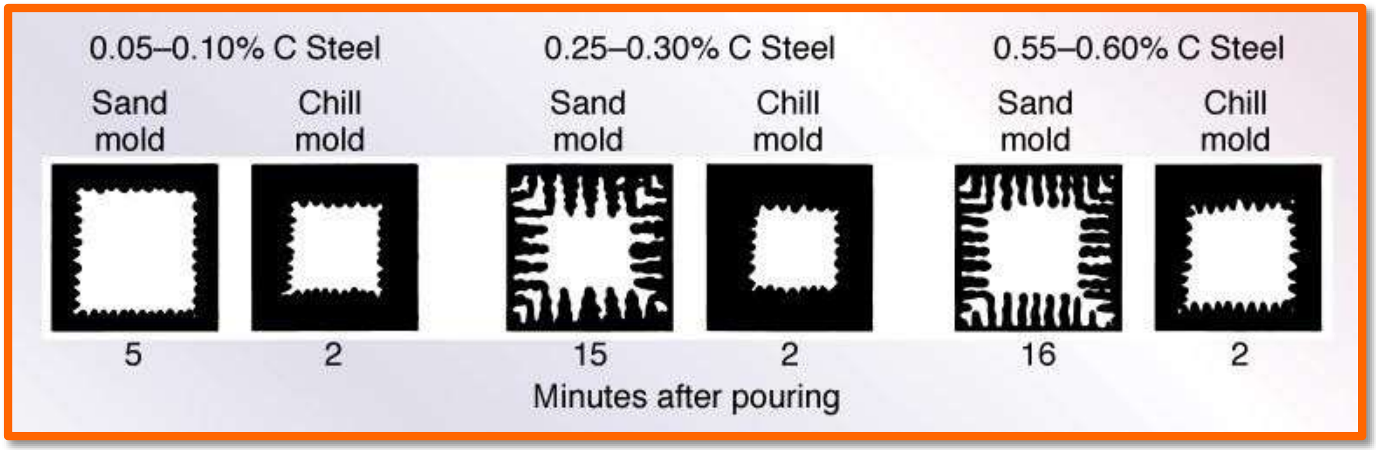


Figure 10.5 (a) Solidification patterns for gray cast iron in a 180-mm (7-in.) square casting. Note that after 11 minutes of cooling, dendrites reach each other, but the casting is still mushy throughout. It takes about two hours for this casting to solidify completely. (b) Solidification of carbon steels in sand and chill (metal) molds. Note the difference in solidification patterns as the carbon content increases.

What Are Risers?

- Risers are added reservoirs designed to feed liquid metal to the solidifying casting as a means for compensating for solidification shrinkage.
- **Riser must solidify after casting.**
- Riser should be located so that directional solidification occurs from the extremities of mold cavity back toward the riser.
- Thickest part of casting – last to freeze, Riser should feed directly to these regions.

Why Risers?

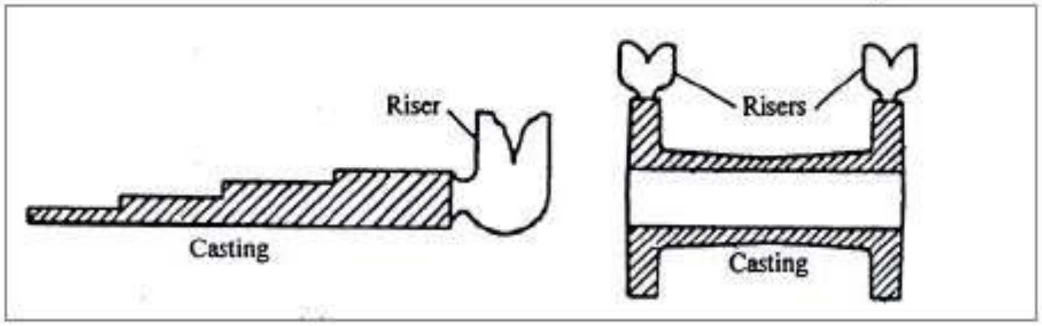
- The shrinkage occurs in three stages,

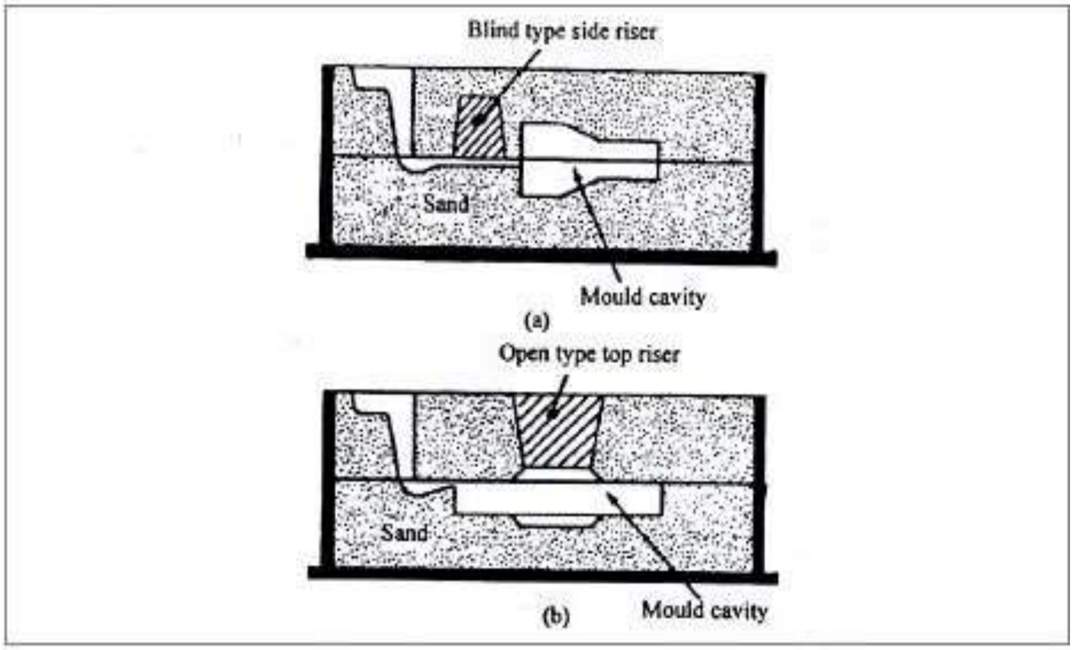
1. When temperature of liquid metal drops from Pouring to Freezing temperature
2. When the metal changes from liquid to solid state, and
3. When the temperature of solid phase drops from freezing to room temperature

- The shrinkage for stage 3 is compensated by providing shrinkage allowance on pattern, while the shrinkage during stages 1 and 2 are compensated **by providing risers.**

Riser Location & Types

- **Top riser**
  - Riser located on the casting
- **Side Riser**
  - Riser located next to the casting
- **Blind risers**
- **Open Riser**





Solidification Time For Casting

- Solidification of casting occurs **by loosing heat from the surfaces** and **amount of heat is given by volume of casting** .
- **Cooling characteristics** of a casting is the ratio of **surface area to volume**.
- Higher the value of cooling characteristics **faster is the cooling of casting.**

Chvorinov rule state that **solidification time is inversely proportional to cooling characteristics.**

Solidification time

$$t_s = K\left(\frac{V}{SA}\right)^2$$

Where

Ts = Solidification time

SA = Surface area

V = Volume of casting

K = mould constant

- A cylindrical riser must be designed for a sand-casting mold. The casting itself is a steel rectangular plate with dimensions 7.5 cm x12.5 cm x 2.0 cm. Previous observations have indicated that the solidification time for this casting is 1.6 min. The cylinder for the riser will have a diameter-to-height ratio as 1.0. Determine the dimensions of the riser so that its solidification time is 2.0 min.
- V/A ratio = (7.5 x 12.5 x 2) / 2(7.5x12.5 + 12.5x2 + 7.5x2) = 187.5 / 267.5 = 0.7

$$\gamma = \frac{t_s}{(\frac{V}{A})^2} = 1.6/(0.7)^2 = 3.26 \text{ min/cm}^2$$

For riser: $D/H = 1$ and $t_s = 2$ min; $V = \pi D^2H/4$; $A = \pi DH + 2\pi D^2/4$

From $D/H = 1 \Rightarrow D = H$ then

$V = \pi D^3/4$; $A = \pi D^2 + 2\pi D^2/4 = 1.5\,\pi D^2$

So, $V/A = D/6$.

Now by Chvorinov's rule, $2.0 = 3.26\,(D/6)^2 \Rightarrow$

$D = 4.7$ cm and $H = 4.7$ cm (riser dimensions)

Note that the volume of the riser in this problem is $V = \pi/4\,(4.7)^2\,(4.7) = 81.5\ cm^3$, which is just 44% of the volume of the cast plate, though its solidification time is 25% longer.

Methods of Riser Design

- *Following are the methods for riser design:*

1. *Caine's Method*
2. *Modulus Method*
3. *NRL Method*

Caine's Method

- Caine's equation $$X = \frac{a}{Y - b} - c$$

Where
X = Freezing ratio
Y = Riser volume / Casting volume
A, b and c = Constant

Freezing ratio $$X = \frac{SA_{casting} / V_{casting}}{SA_{riser} / V_{riser}}$$

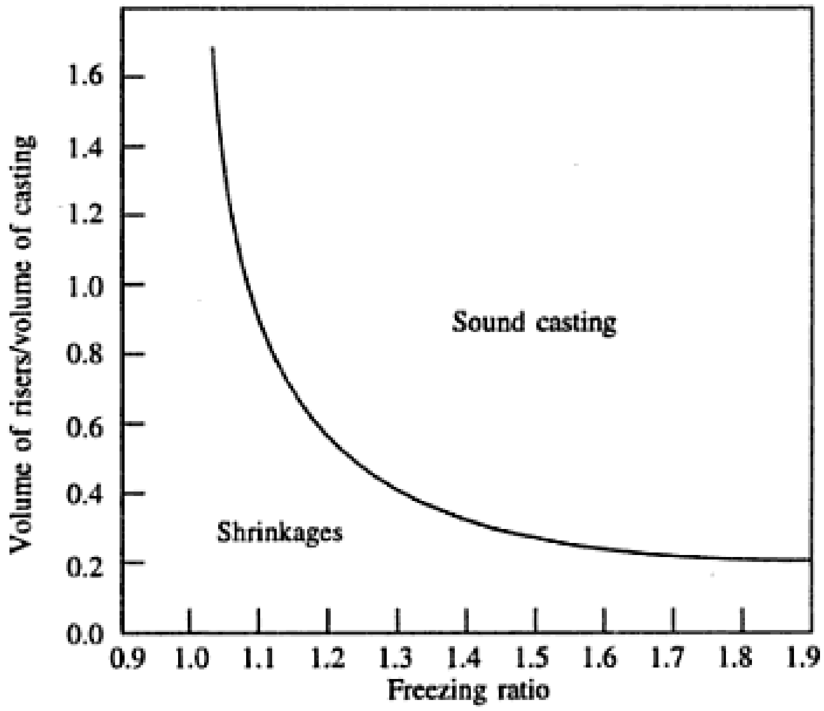


Fig. 12.2 Caine's equation

Constant For Caine's Method

- *Values of constants are given in table:*

	a	b	c
Steel	0.10	0.03	1.00
Aluminium	0.10	0.06	1.08
Cast iron, brass [12.2]	0.04	0.017	1.00
Grey cast iron [12.3]	0.33	0.030	1.00
Aluminium bronze	0.24	0.017	1.00
Silicon bronze	0.24	0.017	1.00

Example:1

Example 12.1 Calculate the size of a cylindrical riser (height and diameter equal) necessary to feed a steel slab casting 25 × 25 × 5 cm with a side riser, casting poured horizontally into the mould.

Volume of the casting = 25 × 25 × 5 = 3125 cm^3

Surface area of the casting = 2 × 25 × 25 + 4 × 25 × 5 = 1750 cm^2

$$\text{Volume of the riser} = \frac{\pi \times D^3}{4} \quad (9)$$

where D is the riser diameter.

$$\text{Surface area of the riser} = \pi \times D^2 + \frac{\pi \times D^2}{4} \quad (10)$$

$$= 1.25\,\pi\,D^2 \quad (11)$$

$$\text{Freezing ratio, } X = \frac{1750 / 3125}{1.25\,\pi\,D^2 / 0.25\,\pi\,D^3} = 0.112\,D \quad (12)$$

$$Y = \frac{\text{Volume of riser}}{\text{volume of casting}} = \frac{0.25\,\pi\,D^3}{3125}$$

$$= 0.000251\,D^3$$

Substituting this in the Caines's equation for steels

$$0.112\,D = \frac{0.10}{0.000251\,D^3 - 0.03} + 1.0$$

On simplification, we get

$D^4 - 8.9286\,D^3 - 119.52\,D = 2490$

By trial and error, we get

$D = 11.44$ cm ≈ 12 cm

Modulus Method

Modulus is the inverse of the cooling characteristic (surface area/ Volume) and is defined as

Modulus = **Volume / Surface area**

In steel casting riser with height to diameter ratio of 1 is generally used.

Volume of cylindrical riser = $\frac{\pi D^3}{4}$

Surface area = $\frac{\pi D^2}{4} + \pi D^2$

The modulus of such a cylindrical riser, M_r would be

$$M_r = 0.2\ D$$

Since $M_r = 1.2\ M_c$

$$D = 6\ M_c$$

where M_c = modulus of the casting.

For sound casting modulus of riser should be greater than the modulus of casting by a factor of 1.2. Therefore $M_r = 1.2\ M_c$

$$D = 6\ M_c$$

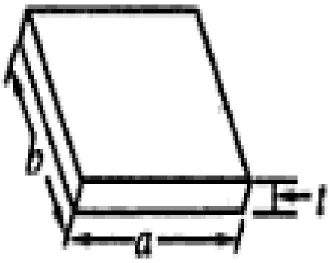
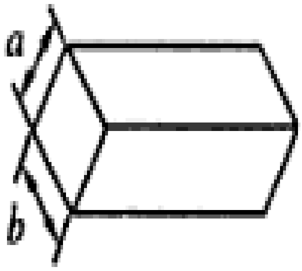
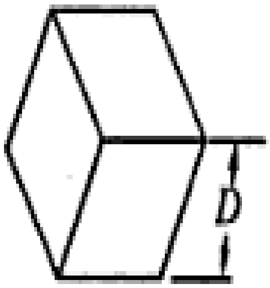
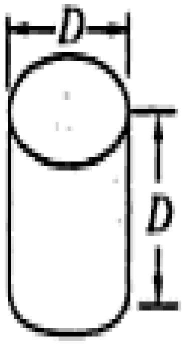
On simplification

Considering contraction of metal

$$D^3 - 5.46\ M_c\ D^2 - 0.05093\ V_c = 0$$

where V_c = volume of the casting.

MODULI OF SIMPLE SHAPES

	Shape		Modulus, M_c
Plate		$a \leq 5t$	$0.5t$
Disc		$d \leq 5t$	$0.5t$
Long bar			$\frac{a \times b}{2(a+b)}$
Cube			$\frac{D}{6}$
Cylinder			$\frac{D}{6}$

NRL Method

- NRL stand for Naval research Laboratory.
- NRL method is essentially a simplification of Caine's method.
- In this method shape factor is used in place of freezing ratio.

Shape factor

$$= \frac{\text{Length} + \text{Width}}{\text{Thickness}}$$

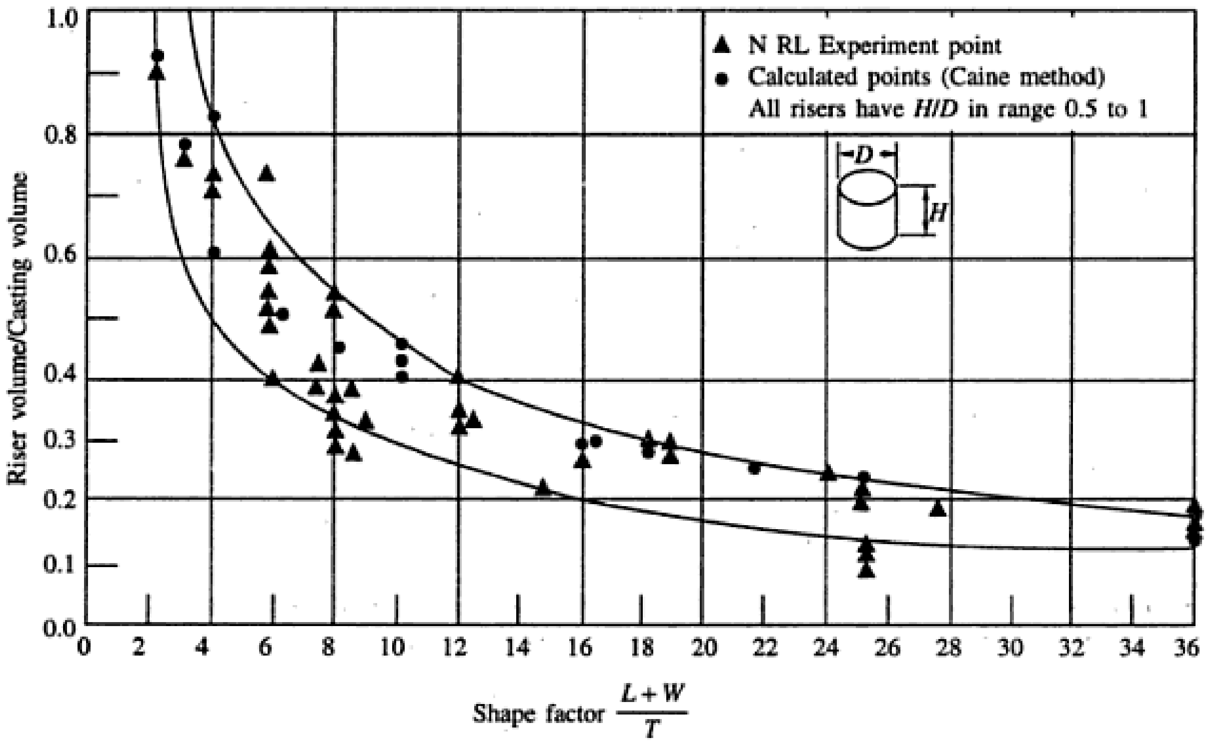
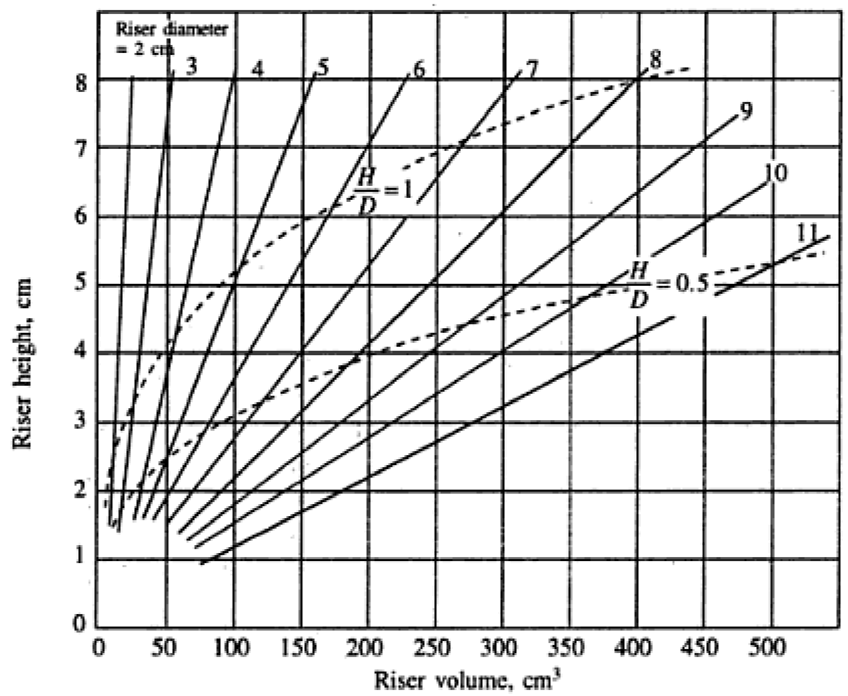
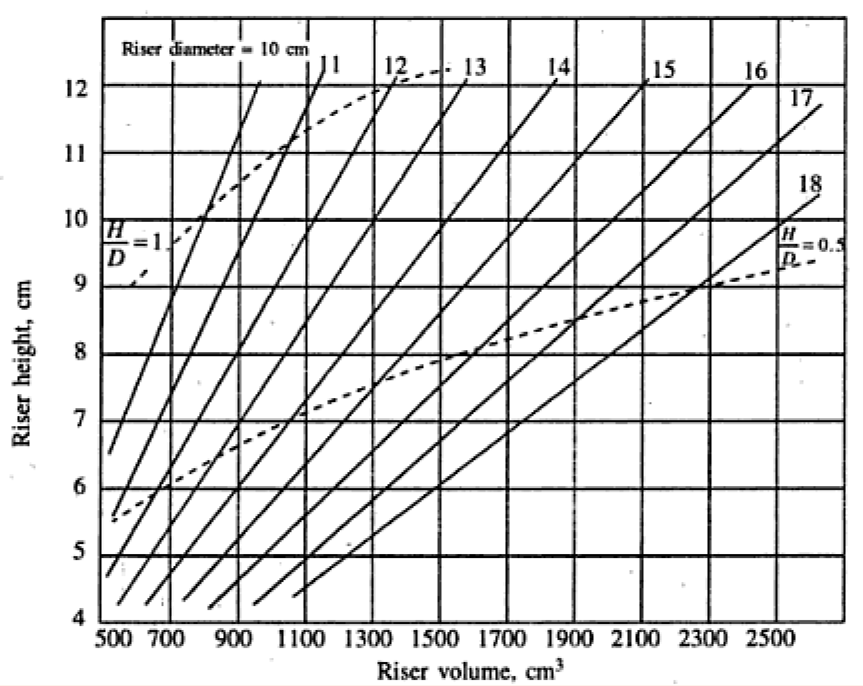


Fig. 12.7 Riser volume selection chart

NRL Method

- Ratio of riser volume to casting volume can be obtained from graph shown below.
- After obtaining riser volume riser diameter and height can be obtained.
- Use H/D = 1 for Side riser and H/D =0.5 for Top riser



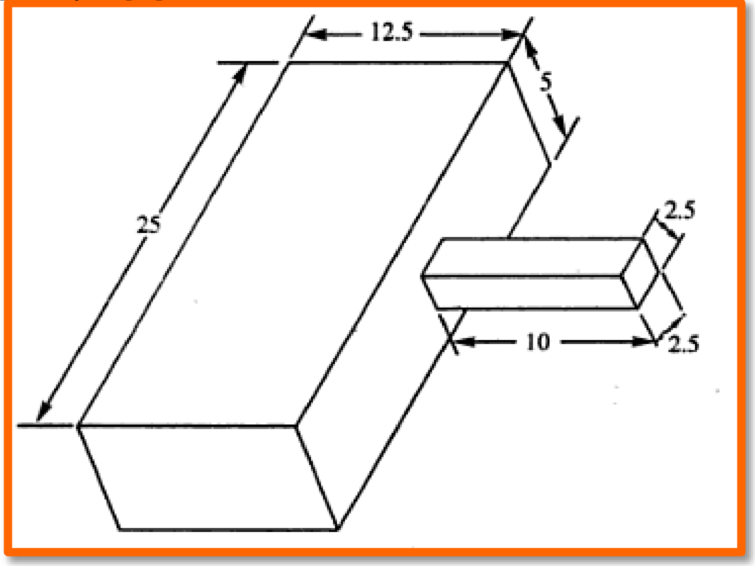


Example:2 Design a suitable riser for the given casting

Solution: Neglecting branch first calculate shape factor

Shape factor = (Length + Width)/ Thickness

= (25+ 12.5)/5 =7.5



Volume of casting V_C = 25 x 12.5 x 5

= 1562.5 cm^3

Volume of riser V_R = 0.575 x V_C

= 0.575 x 1562.5

= 898.43 cm^3

Volume of riser V_R = 2.5 x 2.5 x 10

= 1562.5 cm^3

This is a plate feeding bar with a **thickness ratio of 0.5**, hence from **figure 4.30 (PN Rao)**, **we get parasitic volume as 30 %**

Hence riser volume = 0.30 x 62.5 + 898.43 = 917.2 cm^3

Riser diameter D = 10.53 cm

Choke Area

$$A = \frac{W}{d\, t\, C \sqrt{2 g H}}$$

- Choke area is the main control area which meters the metal flow into mould cavity.
- Normally choke area happens to be at the bottom of the sprue so sprue should be designed first.
- Having sprue bottom as the choke area help in establishing proper flow in the mould easily and early.
- Choke area can be calculated by Bernoulli's equations
- $Q = AV$
- $W = \rho AV$
- Choke area $A = W/ \rho V$

$= W/ \rho\sqrt{2gH}$

$= W/ \rho\, t\, c \sqrt{2gH}$

where A = choke area, mm^2
W = casting mass, kg
t = pouring time, s
d = mass density of the molten metal, kg/mm^3
g = acceleration due to gravity, mm/s^2
H = effective metal head (sprue height), mm
C = efficiency factor which is a function of the gating system

Effective Sprue Height

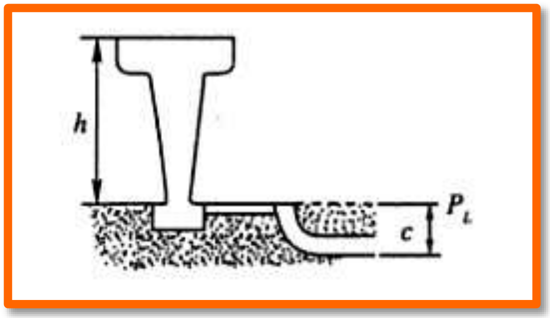
- Effective sprue height H, of a mould depends on the casting dimensions and type of gating system.
- It can be calculated using following relations:

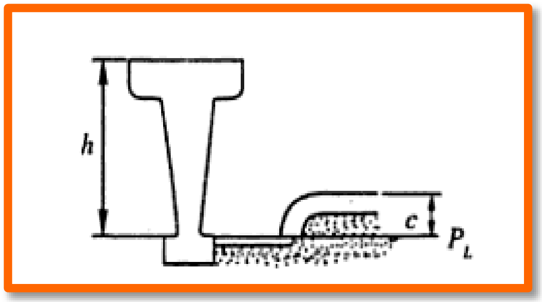
Top gate, $H = h$

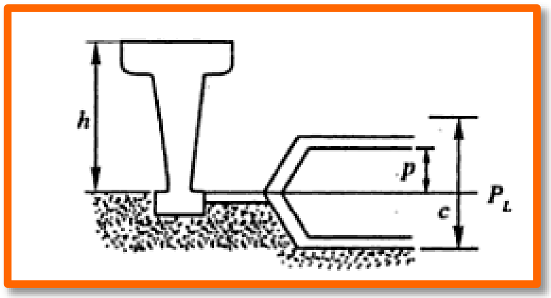
Bottom gate $H = h - \frac{c}{2}$

Parting gate $H = h - \frac{p^2}{2c}$

Values of h, P and c are shown in for various gating system







Where

h =Sprue height

p = Height of mould cavity in cope

c = Total height of mould cavity

Efficiency Coefficient For Gating Systems

Type of system	*Tapered choked sprue*	*Straight sprue runner choke*
Single runner entering runner	0.90	0.73
Two runners with multiple ingates, no bends in runners	0.90	0.73
Two runners with multiple ingates, 90° bends in runners	0.85	0.70

Pouring Time

- Time required for filling a mould is pouring time.
- Too long pouring time – Higher pouring temperature
- Too less pouring time – Turbulent flow & defective casting.
- It depends on casting material, complexity of casting, section thickness and casting size.
- Pouring time is calculated by **empirical formulas** obtained by experiments which differ from one material to another and one casting to other.
- For non ferrous material, **long pouring time would be beneficial** since **they lose heat slowly** and also **tend to form dross** if metal is poured too quickly.

Pouring Time

Grey cast iron, mass less than 450 kg

Pouring time, $t = K\left(1.41 + \frac{T}{14.59}\right)\sqrt{W}$ s

where

$K = \frac{\text{Fluidity of iron in inches}}{40}$

T = average section thickness, mm

W = mass of the casting, kg

Grey cast iron, mass greater than 450 kg

Pouring time, $t = K\left(1.236 + \frac{T}{16.65}\right)\sqrt[3]{W}$ s

Steel castings

Pouring time, $t = (2.4335 - 0.3953 \log W)\sqrt{W}$

(5) Copper alloy castings [11.6]

$$\text{Pouring time, } t = K_2 \sqrt[3]{W} \text{ s}$$

K_2 is a constant given by

Top gating	1.30
Bottom gating	1.80
Brass	1.90
Tin bronze	2.80

Russian practice [11.7]

(6) Intricately shaped thin walled castings of mass up to 450 kg

$$\text{Pouring time, } t = K_3 \sqrt[3]{W'} \text{ s}$$

where W' = mass of the casting with gates and risers, kg

K_3 = a constant as given below

T, (mm)	K_3
1.5 to 2.5	1.62
2.5 to 3.5	1.68
3.5 to 8.0	1.85
8.0 to 15.0	2.20

(7) For castings above 450 kg and up to 1000 kg

$$\text{Pouring time, } t = K_4 \sqrt[3]{W'T} \text{ s}$$

where K_4 is a constant given by

T, (mm)	K_4
up to 10	1.00
10 to 20	1.35
20 to 40	1.50
above 40	1.70

Example

Example 11.1 Calculate the optimum pouring time for a casting whose mass is 20 kg and having an average section thickness of 15 mm. The materials of the casting are grey cast iron and steel. Take the fluidity of iron as 28 inches.

Grey cast iron

$$\text{Pouring time, } t = K\left(1.41 + \frac{T}{14.59}\right)\sqrt{W} \text{ s}$$

$$= \frac{28}{40}\left(1.41 + \frac{15}{14.59}\right)\sqrt{20} = 7.632 \text{ s}$$

Steel

$$\text{Pouring time, } t = (2.4335 - 0.3953 \log W)\sqrt{W} \text{ s}$$

$$= (2.4335 - 0.3953 \log 20)\sqrt{20} = 8.5825 \text{ s}$$

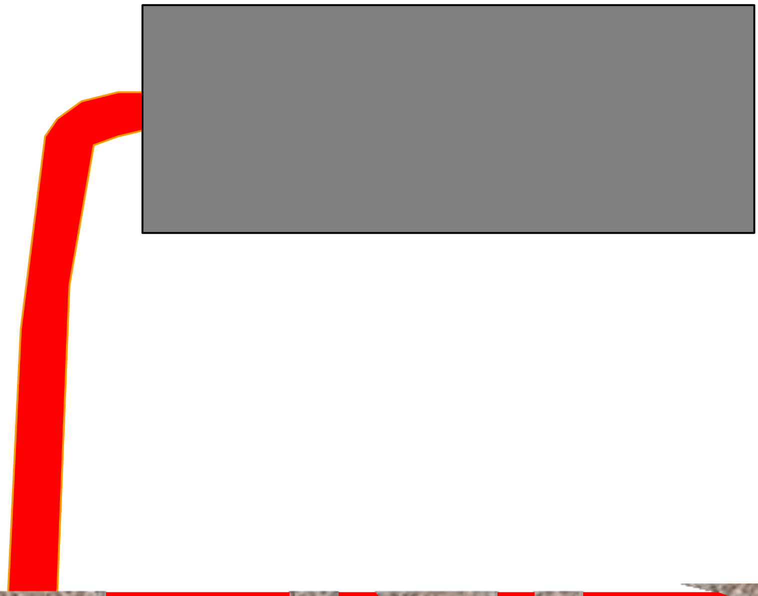
Example 11.2 Calculate the optimum pouring time for a casting whose mass is 100 kg and a thickness of 25 mm. Fluidity of iron is 32 inches. Calculate both for cast iron and steel.

Grey cast iron

$$\text{Pouring time} = \frac{32}{40}\left(1.41 + \frac{25}{14.59}\right)\sqrt{100} = 24.988 \text{ s}$$

Steel

$$\text{Pouring time} = (2.4335 - 0.3953 \log 100)\sqrt{100} = 16.429 \text{ s}$$



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