Cornerstone Christian College

Name: ____________________________
Class: ____________________________
Due date: ________________/___/____
Mark: ________/38________________%

Year 9 Mathematics 2016. Topic 5, Measurement and Geometry Investigation

The Feeding of Castings

You are to investigate the calculation of casting modulus and feeder size.

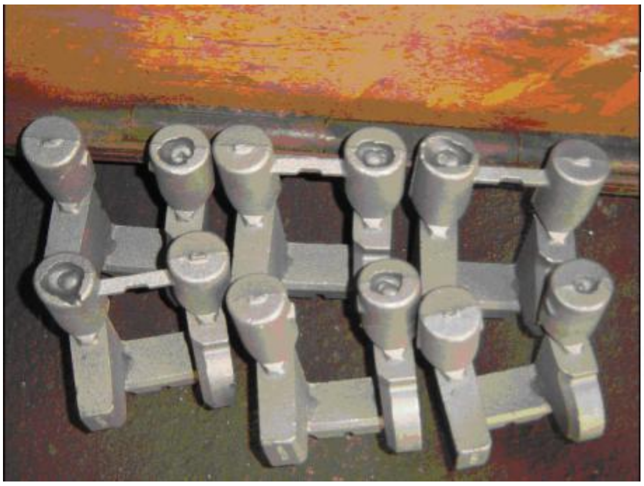
This investigation is worth 5% of your year grade.

Assessed:
Calculate the surface area and volume of cylinders and solve related problems (ACMMG217) (analysing nets of cylinders to establish formulas for surface area), (connecting the volume and capacity of a cylinder to solve authentic problems)
Solve problems involving the surface area and volume of right prisms (ACMMG218) (solving practical problems involving surface area and volume of right prisms)

(The majority of the following technical material is sourced from *Foseco Ferrous Foundryman's Handbook, Brown, John R, Butterworth-Heinemann, Oxford, 2000.*)

Introduction

During the cooling and solidification of most metals and alloys, there is a reduction in the metal volume known as shrinkage. Unless measures are taken which recognise this phenomenon, the solidified casting will exhibit gross shrinkage porosity which can make it unsuitable for the purpose for which it was designed.
To avoid shrinkage porosity, it is necessary to ensure that there is a sufficient supply of additional molten metal, available as the casting is solidifying, to fill the cavities that would otherwise form. This is known as 'feeding the casting' and the reservoir that supplies the feed metal is known as a 'feeder', 'feeder head' or a 'riser'. The feeder must be designed so that the feed metal is liquid at the time that it is needed, which means that the feeder must freeze later than the casting itself. The feeder must also contain sufficient volume of metal, liquid at the time it is required, to satisfy the shrinkage demands of the casting.
The application of the theory of heat transfer and solidification allows the calculation of minimum feeder dimensions for castings which ensures sound castings and maximum metal utilisation.



Simple castings with feeders attached

Complex engine casting with feeders removed

Natural feeders

Feeders moulded in the same material that forms the mould for the casting, usually sand, are known as natural feeders. As soon as the mould and feeder have been filled with molten metal, heat is lost through the feeder top and side surfaces and solidification of the feeder commences. A correctly dimensioned feeder in a sand mould has a characteristic solidification pattern: that for steel is shown in Fig. 19.1. The shrinkage cavity is in the form of a cone, the volume of which represents only about 14% of the original volume of the feeder, and some of this volume has been used to feed the feeder itself, so that in practice only about 10% of the original feeder volume is available to feed the casting. The remainder has to be removed from the casting as residual feeder metal and can only be used for re-melting.

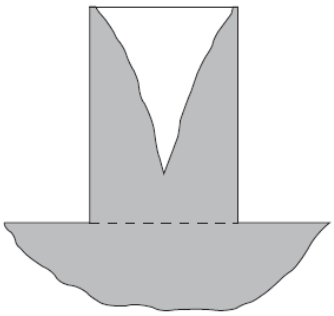


Figure 19.1 Solidification pattern of a feeder for a steel casting (schematic).

The modulus concept

Although this concept has some shortcomings it is, with the exception of computer programs, the most widely used acceptable and accurate method for calculating feeder dimensions. $M\text{c}$ is the ratio of the volume of the casting section to its cooling surface area and is known as the casting's Geometric Modulus. It is expressed in units of length:

$$M\text{c} = V\text{c}/A\text{c}$$

where

$V\text{c}$ is the volume of the casting section;

$A\text{c}$ is the surface area of the casting section actually in direct contact with the material of the mould.

Foundrymen, for the purpose of feeder size determination, are only interested that the feeder solidifies over a longer time than the casting. Having calculated the modulus of the casting section therefore, the modulus of the feeder is calculated as:

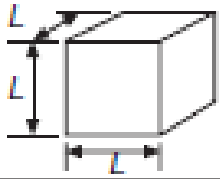
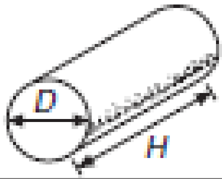
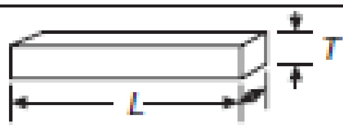
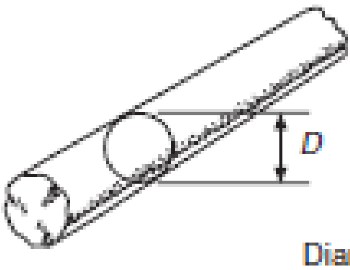
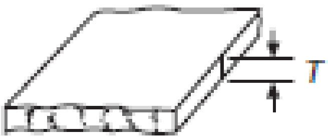
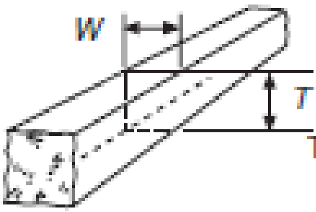
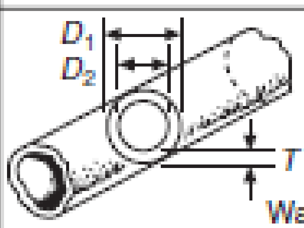
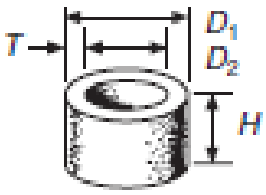
$$M_F = 1.2 \times M_c$$

where

M_F is the modulus of the feeder required to feed a casting section having a modulus of M_c.

This equation applies to natural feeders for most alloys.

The simplified modulus formulae for some common casting shapes are shown in the figure over the page.

Shape	Dimensions	Modulus
(a) Cube	 Side = L	$\frac{L}{6}$
(b) Cylinder	 Diameter = D Height = H	$\frac{DH}{2D+4H}$ *Note*: If $H = D$ the modulus is $\frac{D}{6}$
(c) Disc	 Diameter = D Thickness = T	$\frac{DT}{2D+4T}$
(d) Bar or plate	 Length = L Width = W Thickness = T	$\frac{TWL}{2(TW+WL+LT)}$
(e) Endless cylinder (ends terminated by another part of casting)	 Diameter = D	$\frac{D}{4}$ *Note:* Because radial heat flow is faster than that from a flat surface, calculated moduli for endless cylinders may be reduced by multiplying by 0.85
(f) Endless plate (terminated on all sides by another part of casting)	 Thickness = T	$\frac{T}{2}$
(g) Endless bar (ends terminated by another part of casting)	 Thickness = T Width = W	$\frac{TW}{2(W+T)}$
(h) Endless hollow cylinder	 $OD = D_1$ Dia. core = D_2 Wall thickness = T	$\frac{D_1 - D_2}{4} = \frac{T}{2}$
(i) Annulus	 $OD = D_1$ Dia. core = D_2	$\frac{(D_1 - D_2)}{2(D_1 - D_2) + H}$ $= \frac{TH}{2(T+H)}$

Rectangular Prism:

1. Draw a sketch with dimensions for a rectangular prism 22cm x 8cm x 6cm (2 marks)

2. Draw and dimension a net for the above prism. (2 marks)

3. Calculate the volume in cm^3 of the above prism (showing all working). (2 marks)

4. Calculate the surface area of the prism above in cm^2 (showing all working). (2 marks)

5. Remembering that $Casting\ Modulus = \frac{Casting\ Volume}{Casting\ Surface\ Area}$ or $M_c = \frac{V_c}{A_c}$

   calculate the Casting Modulus of the prism above. (2 marks)

6. Show that the same result is obtained using the formula for the Bar or Plate, item (d) in the table on the previous page (showing all working). (3 marks)

Cylinder:

7. Draw a sketch with dimensions for a cylinder 10cm diameter x 20 cm long. (2 marks)

8. Draw and dimension a net for the above cylinder. (2 marks)

9. Calculate the volume in cm^3 of the above cylinder (showing all working). (2 marks)

10. Calculate the surface area of the cylinder above in cm^2 (showing all working). (2 marks)

11. Remembering that $Casting\ Modulus = \frac{Casting\ Volume}{Casting\ Surface\ Area}$ or $M_c = \frac{V_c}{A_c}$

    calculate the Casting Modulus of the prism above. (2 marks)

12. Show that the same result is obtained using the formula for the cylinder, item (b) in the table on the previous page (showing all working). (3 marks)

Feeder dimensions

13. For your original rectangular prism of 22cm x 8cm x 6cm, design a cylindrical feeder such that the modulus of the feeder is 1.2 x the modulus of the prism.
    For the purposes of this investigation, use the total area of the cylinder in your calculation.
    You can do this by guess-and check (trial and error), working backwards, or using algebra. Whichever method(s) you use, you **MUST** show all your working and give a clear sketch showing the final cylinder giving its dimensions.
    (Marks: Correct modulus (2), working (4), correct dimensions (4), sketch (2) 12 marks)