Tut_1:PROBLEM:1

- **1).A large slab of aluminium, 25 cm thick, is poured in a sand mould with no superheat.**

- **a)How long will it take the slab to solidify? (Assume negligible resistance to heat flow at the mould-metal interface and within the solidified metal.)**

- **b)Show schematically cooling curves for a thermocouple 6.25 cm from the surface and one at the centre of the casting. (Remember, the solidified portion of the casting remains very close to T_M until the casing is completely solid.)**

T:1,P:1:SOLUTION

$$S = \frac{2}{\sqrt{\pi}}\left[\frac{T_M - T_o}{\rho_s H}\right]\sqrt{K_m \rho_m c_m}\ \sqrt{t}$$

$$t = \left[S\frac{\sqrt{\pi}}{2}\left(\frac{\rho_s H}{T_M - T_o}\right)\frac{1}{\sqrt{k_m \rho_m c_m}}\right]^2$$

S = thickness /2 = 12.5 mm

$$t = \left[12.5\frac{\sqrt{\pi}}{2}\left(\frac{2.7\times 95}{640}\right)\frac{1}{\sqrt{14.5\times 10^{-4}\times 1.5\times 0.27}}\right]^2$$

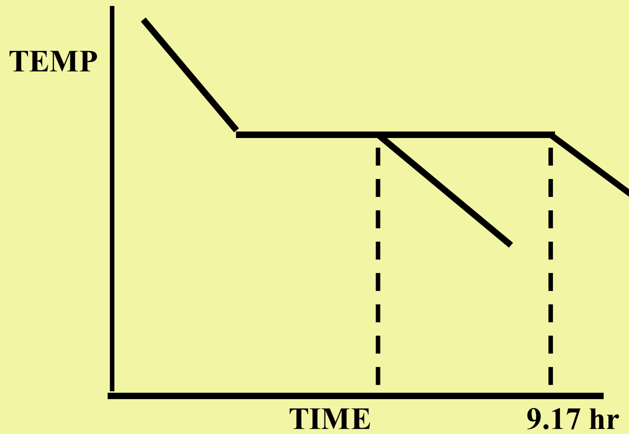
T_M = 660 °C , To = 20 °C,
ρ_s = 2.7 g/cc
H = 95 cal/g

= 33031 seconds
= 9.17 hours

MOULD CONSTANTS FOR SAND:

$K_m = 14.5 \times 10^{-4}$ cal/cm °C s

ρ_m = 1.5 g/cc, c_m = 0.27 cal/g °C



Ts:1,P:2

2.An approximate method of calculation of solidification time of a sand casting poured with superheat is to add the heat content associated with the superheat to the heat of fusion.

How long would it take the slab casting of Problem 1 to solidify if it were poured with 100 C superheat?

TS:1,P:2:SOLUTION

100 ^{o}C SUPERHEAT

H = 95 + (100 x 0.26) = 121

$$t = (12.5)^2 \frac{\pi}{4}\left[\frac{2.7 \times 121}{640}\right]\frac{1}{14.5 \times 10^{-4} \times 0.27 \times 1.5}$$

t = 54453 s → ANSWER

t = 15 hours

TS:1,P:3

3. Aluminium is splat cooled on a copper substrate with a mould-metal interface heat-transfer coefficient of 1 cal/cm^2 C s.

(a) Assuming heat transfer is interface-controlled, how thin must the sample be to achieve a cooling rate (in the liquid at just above the melting point) of 10^6 C/s ?

(b) For the thickness calculated above, is it reasonable to assume interface-controlled heat transfer?

TS:1,P:3:SOLUTION

$Q/A = h\,(T_M - T_o)$

THE RATE AT WHICH THE SPLAT LOSES HEAT IS GIVEN BY:

$Q/A = \rho\, C\, (dT/dt)\, d$

d = THICKNESS OF THE SPLAT

$H = 1\ cal/m^2.C.s$; $T_M = 660$ C ; $T_o = 20$ C

$\rho = 2.7$; $c = 0.26$; $dT/dt = 10^6$ C/s

$$d = \frac{1 \times 640}{2.7 \times 0.26 \times 10^6} = 9.11 \times 10^{-4}\ cm$$

= Answer

TS:1,P:4

4.One of the advantages claimed for magnesium die-casting compared with aluminium is a shorter solidification time.

Show that this is true for processes where heat transfer is controlled at the mould-metal interface.

TS:1,P:4:SOLUTION

IN INTERFACE CONTROLLED SOLIDIFICATION:

$$t_f = \frac{\rho_s H}{h\left[T_M - T_o\right]}\frac{V}{A}$$

COMPARING RELATIVE SOLIDIFICATION TIMES, WE HAVE THE RATIO:

$$\frac{(t_f)_{Mg}}{(t_f)_{Al}} = \frac{\left[\rho_s H\right]_{Mg}}{\left[T_M - T_o\right]_{Mg}} \frac{\left[T_M - T_o\right]_{Al}}{\left[\rho_s H\right]_{Al}} \qquad = \frac{1.7 \times 89}{630} \times \frac{640}{2.7 \times 95}$$

= 0.59

$(t_f)_{Mg} = 0.59 \text{ X } (t_f)_{Al}$

THUS MAGNESIUM DIE CASTINGS SOLIDIFY IN 60 % OF THE TIME FOR ALUMINIUM CASTINGS.

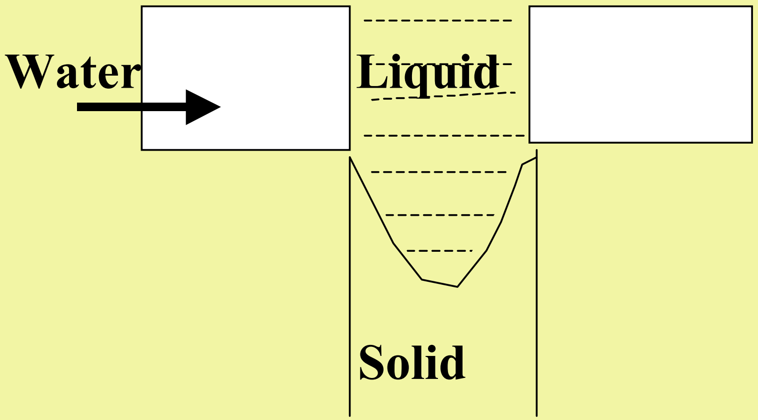
TS:1, P:5

5. You are to help design a vertical continuous-casting machine to make 8-in thick low-carbon steel slabs.

Casting speed to be aimed for is 100 in/min. What is the minimum height casting tower you must plan to build?

Note: Heat flow in the longitudinal direction can be neglected. You may use the data for pure iron.

TS:1,P:5:SOLUTION



THICKNESS REQUIRED TO SOLIDIFY = 4 IN

FOR A WATER COOLED CHILL
$S = 1.6 \times \sqrt{t}$

FOR S = 4 in, t = 6.25 minutes
IN 6.25 MINUTES, THE SLAB WOLD TRAVEL
6.2 x 100 = 625 in = 52 ft

THUS WE NEED TO HAVE A MINIMUM HEIGHT OF THE TOWER EQUAL TO 52 ft.

TS:1, P:6

6. Give possible reasons for the good mould-filling characteristics which are exhibited by pure metals and eutectic alloys during the casting of small sections.

Discuss them with regard to the interface morphology.

TS:1,P:6:SOLUTION

(A) .The superior mould-filling characteristics of pure metals and eutectics during casting, especially of small sections, can be attributed to the fact that both materials exhibit smooth interface morphologies when solidifying in a positive temperature gradient at the wall of a small channel. Consequently, the liquid can flow easily through these channels.

TS:1,P:6:SOLUTION

(B).In the case of alloys, which have a solidification range, dendritic interfaces form and rapidly obstruct the channels. As a result, small sections may not be fed with the liquid metal, leading either to widespread porosity or complete absence of part of the casting.

TS:2, P:1

A plate casting of dimension 200 mm × 15 mm × 25 mm was separately cast in two moulds having the properties as shown in Table.

(i)Determine the solidification times.

(ii)Rank the dendritic arm spacing.

(iii) Rank the mechanical properties variation amongst the two castings.

Property	Sand I	Sand II
Density, ρ_s (kg/m^3)	1100	3400
Specific heat, c_s (Joule kg^{-1} K^{-1})	930	600
Thermal conductivity, k (Watts m^{-1} K^{-1})	0.71	1.7

TS:2, P:1

(i) RATIO OF SOLIDIFICATION TIMES =

= $(\text{solidification time})_{\text{sand II}}/(\text{solidification time})_{\text{sand I}}$
= $(k_m \times \rho_m \times c_m)_{\text{sand I}} / (k_m\ \rho_m\ c_m)_{\text{sand II}}$

$(1100 \times 930 \times 0.71)_{\text{sand I}} / (3400 \times 600 \times 1.7)_{\text{sand II}}$

716100/3468000 = 0.21

(ii) DENDRITE ARM SPACING (DAS) IS PROPORTIONAL TO √t
$(\text{DAS})_{\text{sand II}} / (\text{DAS})_{\text{sand I}}$ =
$[(\text{solidification time})_{\text{sand II}}/(\text{solidification time})_{\text{sand I}}]^{1/2}$

$= (0.21)^{0.5} = 0.447$

TS:2, P:1

(iii) MECHANICAL PROPERTIES (ULTIMATE TENSILE STRENGTH AND % ELONGATION) ARE INVERSELY PROPRTIONAL TO DAS.

(MECHANICAL PROPERTIES OF THE CASTING CAST IN SAND II)/ (MECHANICAL PROPERTIES OF THE CASTING CAST IN SAND I)

$= (1/DAS)_{sand\ II} / (1/DAS)_{sand\ I}$

$= 1/0.447 = \ 2.24$

CASTING POURED IN SAND II SOLDIFIES FASTER, SMALLER DAS AND HIGHER MECHANICAL PROPERTIES THAN CASTING POURED IN SAND I