Basics of Mechanical Engineering-2

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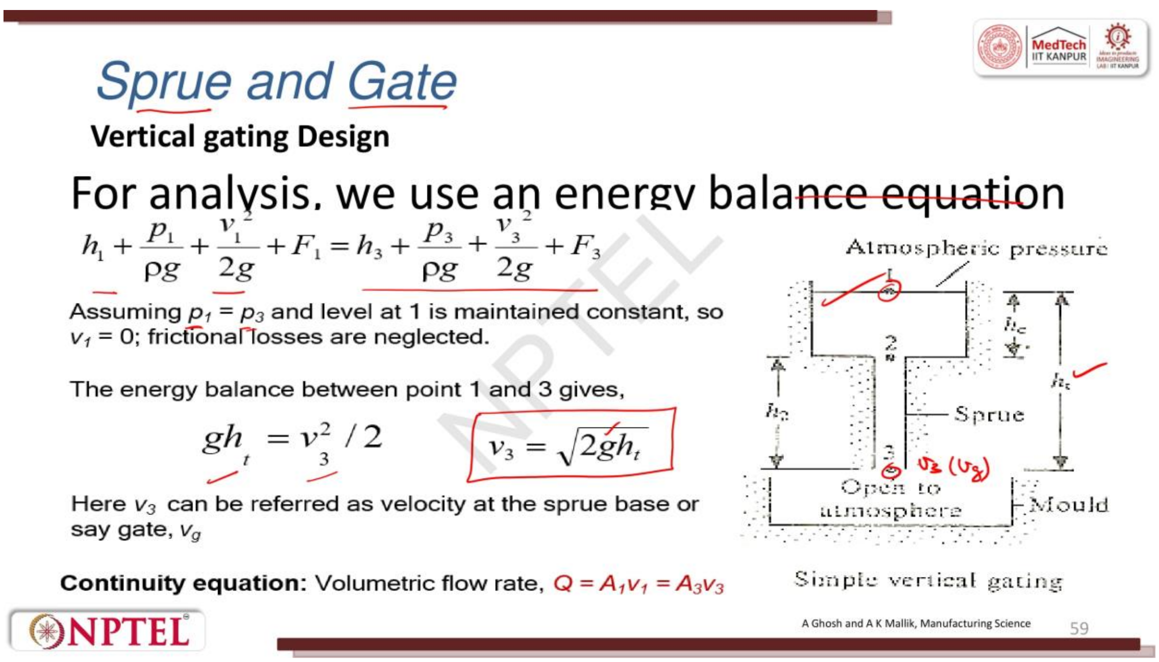
Week 04

Lecture 14

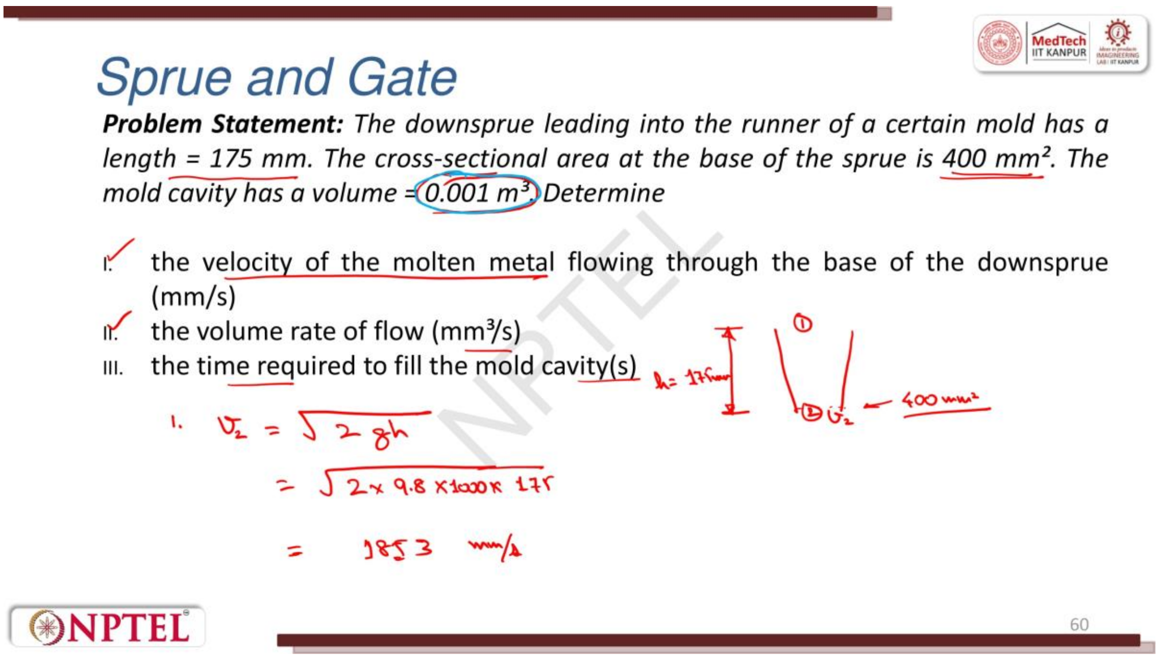
Tutorial-2 (Casting, Part 2 of 2)

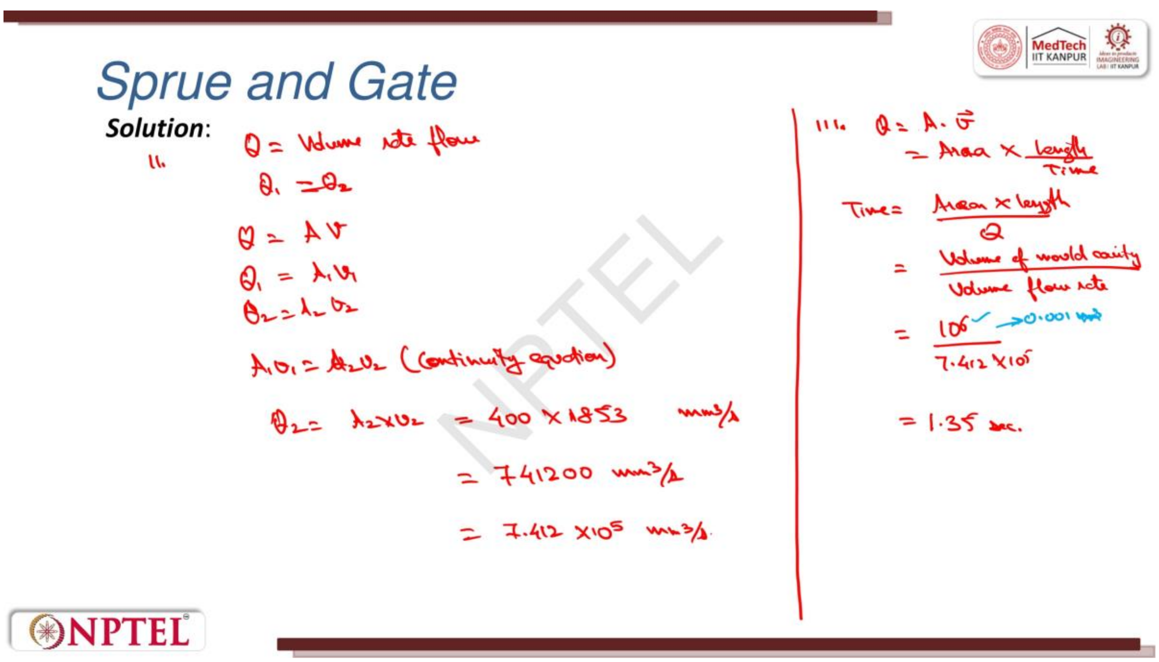
Welcome to the second part of the tutorial on casting that we are discussing this week. We are in the course Basics of Mechanical Engineering II. This is the Manufacturing Processes course. I am Dr. Amandeep Singh. We will discuss casting further in this lecture.



Let us now try to review the sprue and gate design that we discussed in the previous lectures. For analysis, we use the Bernoulli equation, where the pressure head and the velocity head stay constant over time, and the sum of these heads remains unchanged. Now, assuming p1 = p3 and the level at 1 is maintained constant, so v1 = 0. You can see this figure. Energy balance between points 1 and 3 gives $gh_t = v_3^2/2$ which gives $v_3 = \sqrt{2gh_t}$ where v3 is the velocity at the sprue base. This is the velocity at the sprue base here, or we can also call this vg, which is the velocity at the gate. Or, we can also say this as vg, which is the velocity at the gate.

This is the gate entry. 'g' is the gravity coefficient. 'ht' is the height of the sprue. This height ht is given.





Let us start by looking at the problem statement. A down sprue leading into the runner of a certain mold has a length of 175 mm. The cross-sectional area at the base of the sprue is 400 mm^2. The mold cavity has a volume of 0.001 m^3. We need to determine the velocity of molten metal flowing through the base of the down sprue in millimeters per second.

i) V2 = $\sqrt{2gh}$

= $\sqrt{2 \times 9.8 \times 1000 \times 175}$ = 1853 mm/s

ii) Q = Volume rate flow

Q1 = Q2

Q = AV

Q1 = A1V1

Q2 = A2V2

A1V1 = A2V2 (Continuity Equation)

Q2 = A2 x V2 = 400 x 1853 = 741200

= 7.412×10^5 mm^3/s

iii) Q = A . v vector

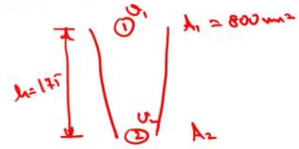
= Area x $\frac{length}{Time}$

Time = $\frac{Area \times length}{Q} = \frac{Volume\ of\ mould\ capacity}{Volume\ flow\ rate} = \frac{10^6}{7.412 \times 10^5}$ = 1.35 sec

Sprue and Gate

Problem Statement: *The flow rate of liquid metal into the downsprue of a mold = 1 liter/sec. The cross-sectional area at the top of the sprue = 800 mm^2 and its length = 175 mm. What area should be used at the base of the sprue to avoid aspiration of the molten metal (mm^2)?*

Solution:



1 liter/sec ; $Q = 10^{-3}\ m^3/sec = 10^6\ mm/sec$

(1000 liter = 1 m^3; 1 liter = $10^{-3}\ m^3$)

$$A_1 v_1 = A_2 v_2 = Q$$

$$A_1 v_1 = 10^6\ mm/s$$

$$800 \times v_1 = 10^6\ mm/sec$$

$$v_1 = 10^6/800 = 1250\ mm/s$$

NPTEL

Sprue and Gate

Using Bernoulli's equation:

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2 \rightarrow \text{At base } z_2 = 0$$

$$\frac{v_1^2}{2g} + z_1 = \frac{v_2^2}{2g}$$

$$\frac{(1250)^2}{2 \times 9.8 \times 1000} + 175 = \frac{v_2^2}{2 \times 9.8 \times 1000}$$

$$v_2 = 2235.173\ mm/sec$$

Velocity at the base of the sprue to avoid aspiration effect

$$A_2 = \frac{Q}{v_2} = \frac{10^6}{2235.173}$$

$$\boxed{A_2 = 447.4\ mm^2}$$

NPTEL

Let me look at another problem where the units are in liters per second. Here, we will apply Bernoulli's equation completely, considering the potential head, pressure head, and velocity head. So, in this problem statement that is given: It says the flow rate of liquid metal into the down sprue of a mold is 1 liter per second. The cross-sectional area at the top of the sprue is 800 millimeter square, and its length is 175 millimeter. What area should be used at the base of the sprue to avoid aspiration of the molten metal?

1 liter/sec; $Q = 10^{-3}\ m^3/sec = 10^6$ mm/sec

(1000 liter = 1 m^3 so 1 liter = $10^{-3}\ m^3$)

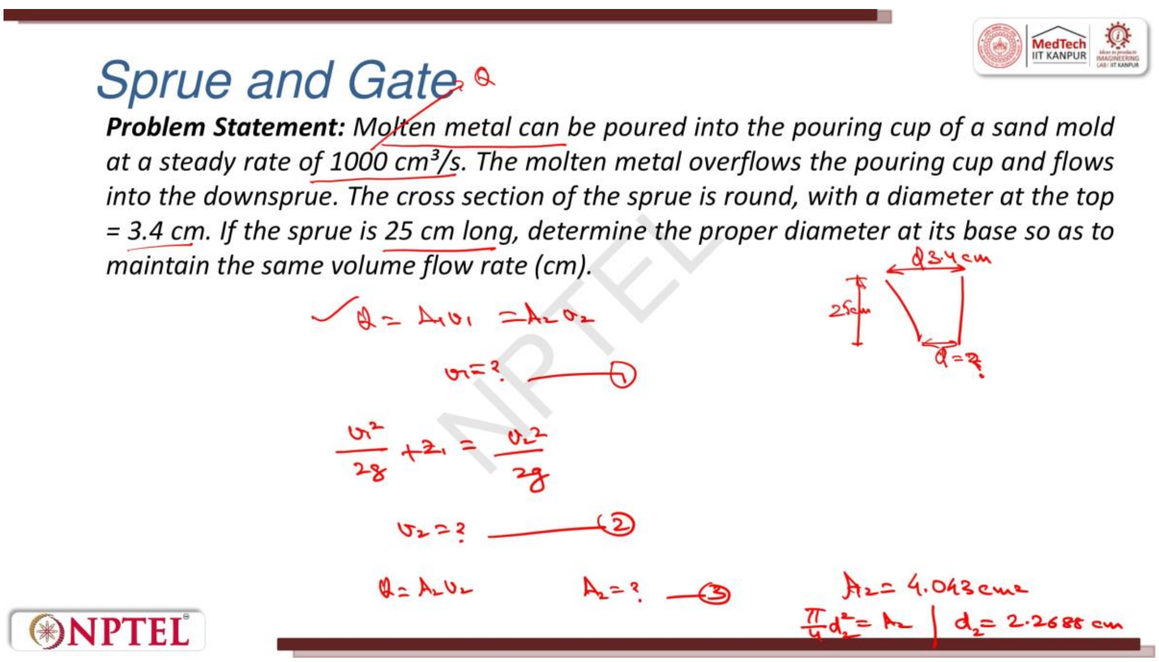
A1V1 = A2V2 = Q

A1V1 = 10^6 mm/s

800 x V1 = 10^6 mm/s

V1 = $10^6/800$ = 1250 mm/s

P1/ρg



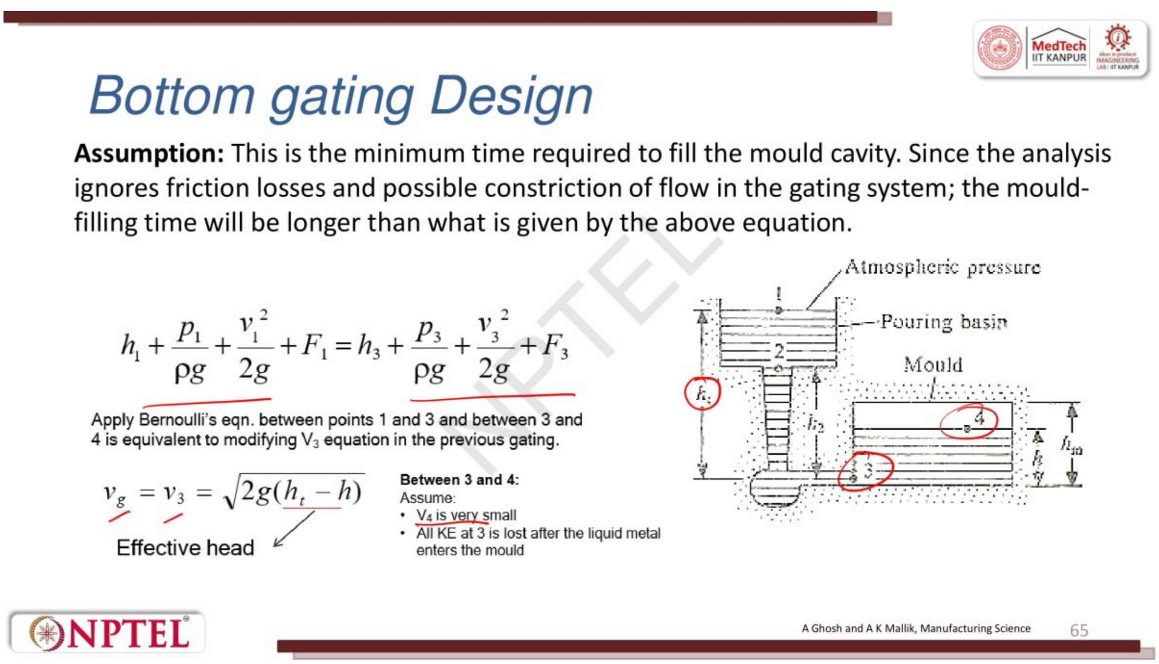
Let me look at another problem statement that will give us more insights into the design of the sprue and the gate. In this problem, it is given that molten metal is poured into the pouring cup of a sand mold at a steady rate of 1000 cm³ per second. We have the value of Q. This is it. The molten metal overflows the pouring cup and flows into the down sprue.

The cross-section of the sprue is round, with the diameter at the top as 3.4 centimeters. The diameter at the top is given. If I design a sprue here, this diameter is 3.4 centimeters. If the sprue is 25 centimeters long, the height of the sprue will be 25 centimeters.

Determine the proper diameter at the base to maintain the same volume flow rate. The required diameter, D, is the unknown. This can be calculated using a similar setup. We will use the continuity equation, Q = A1 V1 = A2 V2. This part will be used to find the value of V1, and then we will use this value to determine the required diameter.

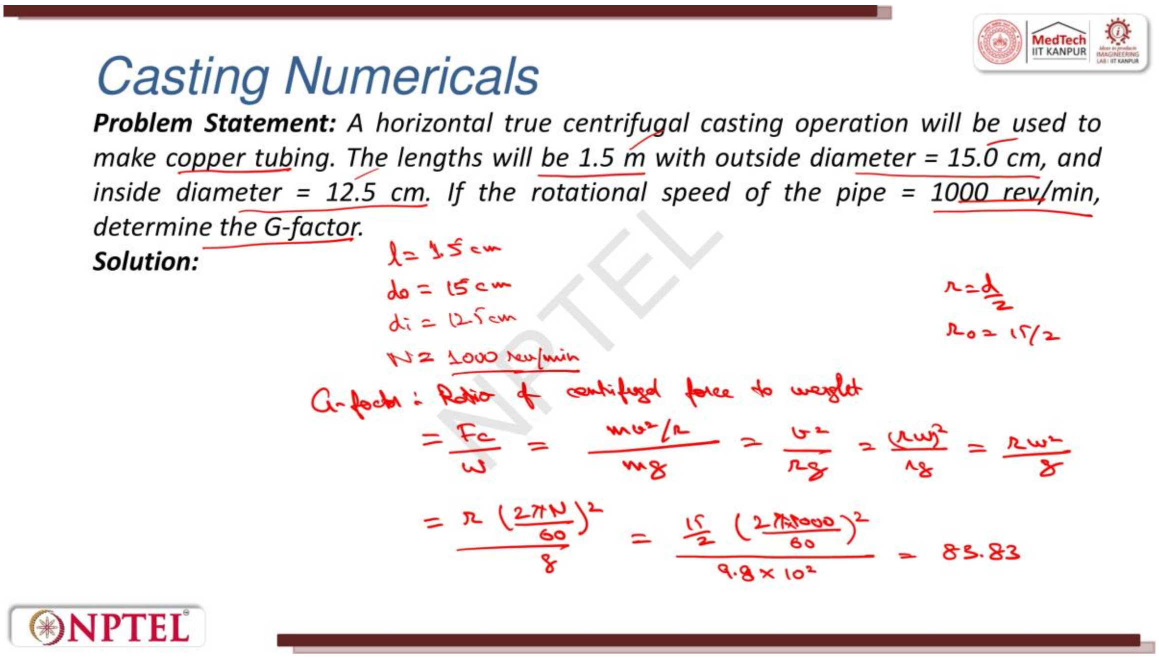
Now, using Bernoulli's equation, we set up the equation as V1 squared by 2g plus Z1 is equal to V2 squared by 2g, similar to what was done in the previous problem. So, you will calculate the value of V2 from here. By substituting this value of V2 into Q = A2 V2, you will find the value of A2. This is step one, step two, and step three. The final value of A2 is 4.043 square centimeters. Since the sprue is circular, we use the formula pi by four into D squared is equal to A2, which gives me the required diameter.

D, that is the diameter at the base, I will call it D2. This is 2.2688 centimeters. You can calculate this and compare your answer with the complete solution provided in the lecture notes. Let me try to solve another interesting problem, where we will calculate the g-factor. These problems are now something that you are getting familiar with.



So, there are certain other problems like this. Before that, let me try to recall one more thing that we discussed in the last lecture.

So, $v_g = v_3 = \sqrt{2g(h_t - h)}$ If the sprue is designed this way, where ht is the total height and h is the height between points 3 and 4, V4 is very small between these two points. All kinetic energy at 3 is lost after the liquid metal enters the mold. So, these are certain assumptions which are taken to calculate or to design the sprue further. Now, here we need to calculate the g-factor.



A horizontal true centrifugal casting operation will be used to make copper tubing. The length will be 1.5 meters with an outside diameter of 15 centimeters and an inside diameter of 12.5 centimeters. If the rotational speed of the pipe is 1000 revolutions per minute, determine the g-factor.

l = 15 cm

d_o = 15 cm

d_i = 12.5 cm

N = 1000 rev/min

r_o = 15/2

G-factor: Ratio of centrifugal force to weight

$Fc/W = \frac{\frac{mv^2}{r}}{mg} = v^2/rg = (rw)^2/rg = rw^2/g$

$$\frac{r\left(\frac{2\pi N}{60}\right)^2}{g} = \frac{\frac{15}{2}\left(\frac{2\pi 1000}{60}\right)^2}{9.8\times10^2} = 85.83$$

Casting Numericals

Problem Statement: *True centrifugal casting is performed horizontally to make large diameter copper tube sections. The tubes have a length = 1.0 m, diameter = 0.25 m, and wall thickness = 15 mm.*

(a) If the rotational speed of the pipe = 700 rev/min, determine the G-factor on the molten metal.

(b) Is the rotational speed sufficient to avoid "rain?"

(c) What volume of molten metal must be poured into the mold to make the casting if solidification shrinkage and contraction after solidification are considered (m^3)?

Solidification shrinkage for copper = 4.5%, and solid thermal contraction = 7.5%

Casting Numericals

Solution:

$l = 1m$

$d_o = 0.25m$

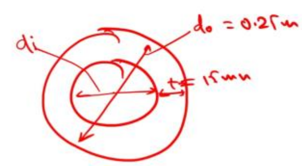
$t = 15mm$

$N = 700$ rev/min

$d_i = d_o - 2t$

$= 0.25 - 2\times(15\times10^{-3})$

$= 0.22m$



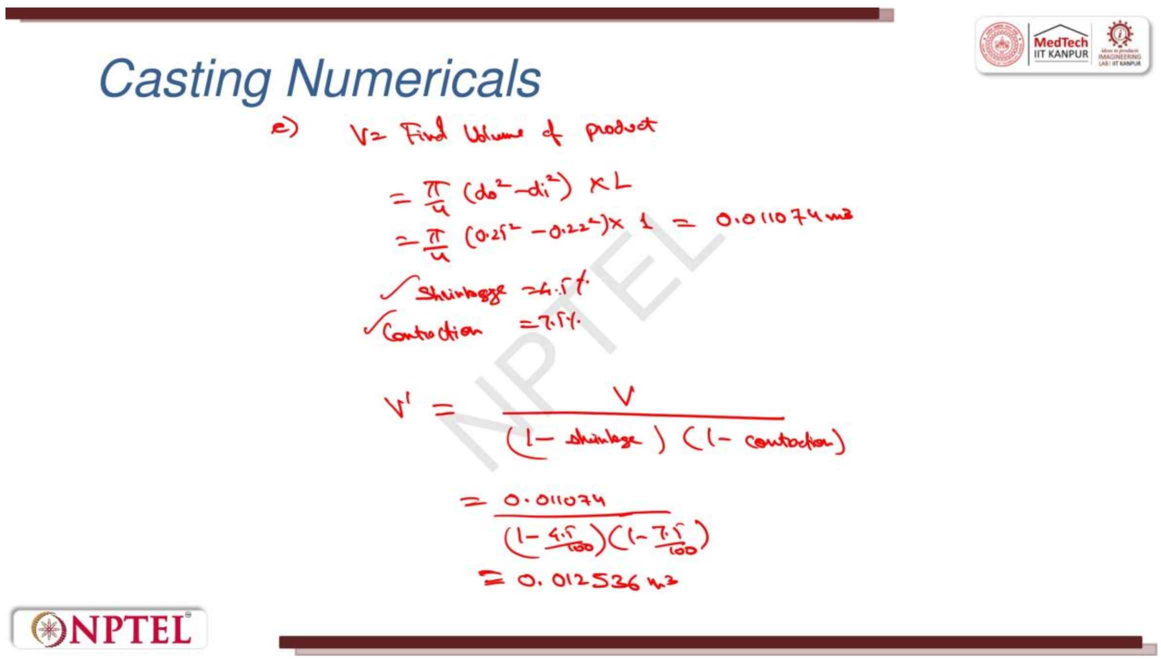
a) G-factor $= \frac{F_c}{W} = \frac{R\omega^2}{g} = \frac{d_o/2 \times \left(\frac{2\pi N}{60}\right)^2}{g}$

$= \frac{\frac{0.25}{2} \times \left(\frac{2\times3.14\times700}{60}\right)^2}{9.8}$

$= 68.46$

b) $60 < 68.46 < 120$; it lies in the optimum range

∴ "Rain" is avoided



A similar problem in calculating the G factor: Tube centrifugal casting is performed horizontally to make large-diameter copper tube sections. The tubes have a length of 1.0 millimeter, a diameter of 0.25 millimeter, and a wall thickness of 15 millimeters. That means I have the length as 1 meter, the diameter as 0.25 meters, and the wall thickness as 15 millimeters. I will call the thickness T as 15 millimeters. Now, it says that if the rotational speed of the pipe is 700 revolutions per minute, That means the rotational speed, denoted as n, is given as 700 revolutions per minute.

Then, it says, determine the G-factor on the molten metal. Part B: Is the rotational speed sufficient to avoid rain? What volume of molten metal must be poured into the mold to make the casting if solidification shrinkage and contraction after solidification are considered? The solidification shrinkage for copper is given as 4.5 percent, and its thermal contraction is 7.5 percent.

l = 1 m

do = 0.25 m

t = 15 mm

N = 700 rev/min

di = do -2t = 0.25 – 2 x (15 x 10^{-3}) = 0.22 m

a) G-factor = Fc/W = rw^2/g = $\frac{\frac{do}{2}\left(\frac{2\pi N}{60}\right)^2}{g} = \frac{\frac{0.25}{2}\left(\frac{2\times 3.14\times 700}{60}\right)^2}{9.8}$ = 68.46

b) 60 < 68.46 < 120; it lies in the optimum range. Therefore, Rain is avoided.

c) V = Volume of Product

$= \pi/4\ (do^2 - di^2) \times L$

$= \pi/4\ (0.25^2 - 0.22^2) \times 1 = 0.011074\ m^3$

Shrinkage = 4.5 %

Contraction = 7.5 %

$$V' = \frac{V}{(1 - Shrinkage)(1 - contraction)}$$

$$= \frac{V}{\left(1 - \frac{4.5}{100}\right)\left(1 - \frac{7.5}{100}\right)} = 0.012536\ m^2$$

With this, I am closing this tutorial session. We will meet in the next lecture, where I will talk about a certain laboratory demonstration, the virtual laboratory demonstration in casting. Thank you.