DETAILS EXPLANATIONS

Material Science + Fluid Mechanics

[PART : A]

1. If the density of a fluid varies significantly due to moderate changes in pressure or temperature, then the fluid is called compressible fluid If the change in density of a fluid is small due to changes in temperature and or pressure, then the fluid is called incompressible fluid.

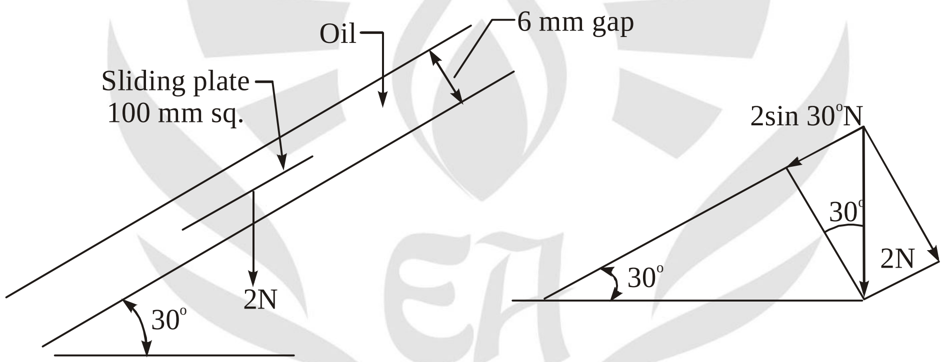
2. The vertical force of 2 N due to the weight of the plate can be resolved along and perpendicular to the inclined plane. The force along the inclined plane is equal to the drag force on both sides of the plane due to the viscosity of the oil. Force due to the weight of the sliding plane along the direction of motion

$$= 2 \sin 30^o = 1\text{N}$$

Viscous force, $F = (A \times 2) \times \mu \times \left(\frac{du}{dy}\right)$ (both sides of plate)

Substituting the values, $1 = \mu \times [(0.1 \times 0.1 \times 2)] \times \left[\frac{\frac{(3-0)}{6}}{2 \times (1000)}\right]$

Solving for viscosity, $\mu = 0.05$ Ns/m^2 or 0.5 Poise.



3. Force, F opposing the movement of the shaft = shear stress × area

$$F = \mu\left(\frac{du}{dy}\right)(\pi \times D \times L)$$

$$\mu = 2.4 \times 10^{-4} \times 900 \text{ Ns/m}^2$$

$$du = 0.1 \text{ m/s},\ L = 0.1 \text{ m},\ D = 0.4 \text{ m}$$

$$dy = \frac{402-400}{2 \times 1000} \text{m}$$

Substituting $F = 2.4 \times 10^{-4} \times 900 \times \{(0.1 - 0) / [(402 - 400)/(2 \times 1000)]\}$
$(\pi \times 0.4 \times 0.1)$
$= 2714$ N

4. Fluid under static conditions pressure is found to be independent of the orientation of the area. This concept is explained by pascal's law which states that the pressure at a point in a fluid at rest is equal in magnitude in all directions.

5. Buoyant force = Weight of water displaced

$$= \left(\pi \times \frac{0.3^2}{4}\right) 0.6 \times 1000 \times 9.81 = 416.06 \text{ N}$$

This acts upward at the centre of gravity G

Check: Bottom is at 1.6 m depth Top is at 0.6 m depth

Buoyant force = Force on the bottom face – force on top face

$$= \left(\pi \times \frac{0.3^2}{4}\right)(1000 \times 9.81 \times 1.6 - 1000 \times 9.81 \times 1.0)$$

$$= 416.16 \text{ N}$$

6. In a flow field if a continuous line can be drawn such that the tangent at every point on the line gives the direction of the velocity of flow at that point, such a line is defined as a stream line.

7. The total energy plotted along the flow to some specified scale gives the energy line. When losses (frictional) are negligible, the energy line will be horizontal or parallel to the flow direction. For calculating the total energy kinetic, potential and flow (pressure) energy are considered.

Energy line is the plot of $\frac{P}{\rho g} + \frac{V^2}{2g} + Z$ along the flow. It is constant along the flow when losses are negligible. The plot of $\frac{P}{\rho g} + Z$ along the flow is called the hydraulic gradient line.

8. Separation of flow is said to occur when the direction of the flow velocity near the surface is opposed to the direction of the free stream velocity, which means (du/dy) ≤ 0. Such a situation does not arise when there is no pressure gradient opposed to the flow direction, ie., the pressure downstream of flow is higher compared to the pressure upstream.

If (dp/dx) increases to the extent that it can overcome the shear near the surface, then separation will occur. Such a pressure gradient is called adverse pressure gradient.

9. Elbow meter is used to measure the flow through a pipe. When the fluid flows through the elbow fitted in a pipe line, higher pressure results at the outer wall surface than at the inner wall surface. The difference in pressure at the outer and inner wall is a function of the flow rate. The elbow meter is inexpensive and accurate if it is calibrated carefully.

10. Flow velocity,

$$V = C_v \sqrt{2gh_m[(\rho_m / \rho) - 1]}$$

$$= 0.98 \sqrt{2 \times 9.81 \times \left(\frac{1000}{113} - 1\right) \frac{5}{100}}$$

$$= 28.86 \text{ m/s}$$

11. When applied to a single body Newtons second law can be started as “The sum of forces on the body equals the rate of change of momentum of the body in the direction of the force. In equation from (F and V are in the same direction)

$$\Sigma F = \frac{d(mV)}{dt}$$

This can also be written as $\Sigma F \, dt = d(mV)$

where m is the mass of the body and V is the velocity of the body and t is the time. This also means the impulse Fdt equals the change in momentum of the body during the time dt.

12. The dimensionless constants can also be used to predict the performance of a given machine under different operating conditions. As the linear dimension will be the same, the same will not be taken into account in the calculation. Thus Head coefficient will now be

$$\frac{H_1}{N_1^2 D^2} = \frac{H_2}{N_2^2 D^2} \text{ or } \frac{H_2}{H_1} = \frac{N_2^2}{N_1^2}$$

The head will vary as the square of the speed. The flow coefficient will lead to

$$\frac{Q_1}{N_1 D^3} = \frac{Q_2}{N_2 D^3} \text{ or } \frac{Q_2}{Q_1} = \frac{N_2}{N_1}$$

Flow will be proportional to N and using the previous relation

$$\frac{Q_2}{Q_1} = \sqrt{\frac{H_2}{H_1}} \quad \text{or} \quad \frac{\mathbf{Q}}{\sqrt{\mathbf{H}}} = \text{constant for a machine.}$$

The constant is called unit discharge.

Similarly $$\frac{N_2}{N_1} = \sqrt{\frac{H_2}{H_1}} \quad \text{or} \quad \frac{\mathbf{N}}{\sqrt{\mathbf{H}}} = \text{constant.}$$

This constant is called unit speed.

Using the power coefficient :

$$\frac{P_1}{N^3 D^5} = \frac{P_2}{N^3 D^5} \text{ or } \frac{P_2}{P_1} = \frac{N_2^3}{N_1^3} = \left(\frac{H_2}{H_1}\right)^{3/2}$$

or $$\frac{\mathbf{P}}{\mathbf{H}^{3/2}} = \text{constant.}$$ This constant is **called unit power.**

Hence when H is varied in a machine the other quantities can be predicted by the use of unit quantities.

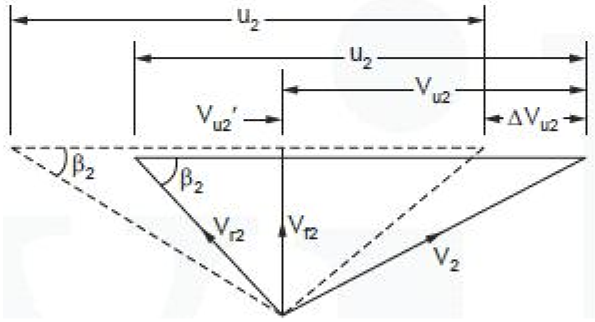
13. Net Positive Suction Head (NPSH) is defined as the available total suction head at the pump inlet above the head corresponding to the vapour pressure at that temperature.

$$\text{NPSH} = \frac{P_s}{\gamma} + \frac{V_s^2}{2g} - \frac{P_v}{\gamma}$$

Where, P_v is the vapour pressure.

14. In the analysis it is assumed that all the fluid between two blade passages have the same velocity (both magnitude of direction). Actually at the leading edge the pressure is higher and velocity is lower. On the trailing edge the pressure is lower and the velocity is higher. This leads to a circulation over the blades. Causing a non uniform velocity distribution. The average angle at which the fluid leaves the blade is less than the blades angle. The result is a reduction in the exit whirl velocity V_{u2}.

This is illustrated in the following figure. The solid lines represent the velocity diagram without slip. The angle β_2 is the blade angle. The dotted lines represent the velocity diagram after slip. The angle $\beta'_2 < \beta_2$. It may be seen that $V'_{u2} < V_{u2}$. The ratio V'_{u2} / V_{u2} is known as slip factor. The result of the slip is that the energy transfer to the fluid is less than the theoretical value



$$H_{th} = \sigma_s . \frac{u_2 V_{u2}}{g}$$

where, σ_s is the slip coefficient or slip factor.

15. Martempering is the process of tempering of martensite. The steel is heated to the austenite range, followed by rapid quenching in water bath to a temperature aboveMs. Thereafter, the material is maintained at constant temperature in an oil bath so that entire section is brought to uniform temperature, but not long enough to cause austenite decomposition.

Martempering produces martensite and retains austenite in the hardened steel. Over conventional hardening, the process has advantages of reduced possibility of warping, distortion, quenching cracks and volume change.

16. Spherodizing is used especially for improving machinability of high carbon steels, for making ball bearings, and ball races.

17. Babbitt, also called Babbitt metal or bearing metal, is any of several alloys used to provide the bearing surface in a plain bearing. Some common compositions are: (90% Sn, 10% Cu), (89% Sn, 7% Sb, 4% Cu), (80% Pb, 15% Sb, 5% Sn).

18. Resilience is defined as the ability of a material to absorb energy when deformed elastically. This property is important when the material is subjected to shock loading.

19. Toughness is measured as energy absorbed before fracture in the tension test. Endurance strength is the strength against fatigue loading. Resistance to abrasion is called hardness. Deflection in beams is determined using moment area method.

20. If the hydrogen content of the molten steel exceeds the solubility limit of hydrogen in solid iron, the hydrogen will be rejected during solidification, and this leads to pinhole formation and porosity in steel. It is called hydrogen embrittlement.

[PART : B]

21. Power = $\frac{2\pi NT}{60W}$, Substituting the given values,

$$50 = 2\pi \times 700 \times \frac{T}{60},$$

Solveing torque, $T = 0.682$ Nm

This is a situation where an annular surface rotates over a flat surface.

Torque, $$T = \frac{\mu\pi^2 N\left(R_o^4 - R_i^4\right)}{60h}$$

$$\mu = 30 \text{ cP} = 30 \times 0.0001 \text{ Ns/m}^2$$

Substituting the values, $0.682 = (30 \times 0.0001) \times \pi^2 \times 700 \times (0.15^4 - 0.1^4)/\ 60 \times h$

$\therefore$ $h = 0.000206 \text{ m} = 0.206 \text{ mm}$

22. This has to be calculated in two steps, first for oil and then for water.

Density of the oil = 1000 × 0.82 = 820 kg/m^3

Gauge pressure at interface = (ρ × g × h) × oil

= 820 × 9.81 × 0.4 = 3217.68 N/m^2

Absolute pressure at interface = 3217.68 + 1 × 105 N/m^2

= 103217.68 N/m^2 = 1.0322 bar

Pressure due to water column = ρ × g × h = 1000 × 9.81 × 0.3 = 2943 N/m^2

Gauge pressure at the bottom = gauge pressure at the interface + (ρ × g × h)water

= 3217.68 + 1000 × 9.81 × 0.3 = 6160.68 N/m^2

Absolute pressure at bottom = 6160.68 + 1 × 105

= 106160.68 N/m^2 or 1.0616 bar

This value also equals the sum of absolute pressure at interface and the pressure due to water column.

23. ***Stability of a body :***

A ship or a boat should not overturn due to small disturbances but should be stable and return, to its original position. Equilibrium of a body exists when there is no resultant force or moment on the body.

A body can stay in three states of equilibrium :

(i) Stable equilibrium: Small disturbances will create a correcting couple and the body will go back to its original position prior to the disturbance.

(ii) Neutral equilibrium Small disturbances do not create any additional force and so the body remains in the disturbed position. No further change in position occurs in this case.

(iii) Unstable equilibrium: A small disturbance creates a couple which acts to increase the disturbance and the body may tilt over completely.

24. To check for steady flow use continuity equation :

(i) $\frac{\partial u}{\partial x} = 1, \frac{\partial v}{\partial y} = -1$ $\therefore \frac{\partial u}{\partial x}+\frac{\partial v}{\partial y} = 0$, So the flow is steady

(ii) $\frac{\partial u}{\partial x} = t^2, \frac{\partial v}{\partial y} = -t^2$ ∴ Satisfies the continuity equation and flow is steady.

(iii) $\frac{\partial u}{\partial x} = t^2, \frac{\partial v}{\partial y} = xt + 2y$

This does not satisfy the requirements for steady flow

To Check for irrotational flow :

$$\frac{\partial u}{\partial y}-\frac{\partial v}{\partial x} = 0$$

(i) $\frac{\partial u}{\partial y} = 1, \frac{\partial v}{\partial x} = 1$ ∴ flow is irrotational

(ii) $\frac{\partial u}{\partial y} = 2, \frac{\partial v}{\partial x} = 2x$ ∴ flow is not irrotational

(iii) $\frac{\partial u}{\partial y} = 0, \frac{\partial v}{\partial x} = yt$ ∴ flow is not irrotational

25. Displacement thickness äd is the distance by which the solid boundary would have to be displaced in a frictionless flow to give the same mass flow rate as with the boundary layer.

$$\delta_d = \int_0^{\delta} \frac{(u_\infty - u)}{u_\infty} dy = \int_0^{\delta} \left(1 - \frac{u}{u_\infty}\right) dy$$

The thickness which at free stream velocity will have the same momentum flow as the dificit flow is called momentum thickness.

$$\delta_m = \int_0^{\delta} \left[\frac{u}{u_\infty} - \left(\frac{u}{u_\infty}\right)^2\right] dy = \int_0^{\delta} \frac{u}{u_\infty}\left(1 - \frac{u}{u_\infty}\right) dy$$

26. Re = 5 × 140/1.4 × 10^{-6} = 0.5 × 10^9

$$C_D = \frac{0.455}{(\log 0.5\times10^9)^{2.58}} - \frac{1610}{0.5\times10^9} = 1.719 \times 10^{-3}$$

$$F_D = C_D A\left(\frac{1}{2}\right)\rho u^2$$

$$= (1.7179 \times 10^{-3})\left(\frac{1}{2}\right) \times 140 \times 50 \times 1025 \times 5^2 \text{ N}$$

$$= 0.154 \times 10^6 \text{ N}$$

$$\text{Power} = F_D u = 0.154 \times 10^6 \times 5 = 0.77 \times 10^6 \text{ W}$$

$$= 0.77 \text{ MW}$$

27. ***Cofficient of velocity (C_v) :***

There is alsways some loss of energy due to viscous effects in real fluid flows. Due to these effects, the actual flow velocity through the orifice will always be less than the theoretical possible velocity. The velocity coefficients C_v is defined as follows.

$$C_v = \frac{\text{Actual velocity of jet at venacontracta}}{\text{Theoritical velocity}} = \frac{V}{\sqrt{2gh}}$$

C_v varies from 0.95 to 0.99 for different orifices depending on their shapes and size.

Coefficient of contraction C_c :

As water leaves an open tank through an orifice, the stream lines converge and the area just outside the orifice is lower compared to the area of the orifice. This section is called as vena contracta. Area of jet at the vena contract is less than the area of the orifice itself due to convergence of stream lines. The coefficient of contraction C_c is defined as follows

C_c = Area of the jet at vena contract/Area of orifice

The value of coefficient of contraction varies from 0.61 to 0.69 depending on the shape and size of the orifice.

Coefficient of discharge (C_d) Coefficient of discharge is defined as

C_d = Actual discharge/Theoretical discharge

Average value of Cd for orifices is 0.62.

28. The main classification depends upon the type of action of the water on the turbine. These are

(i) Impulse turbine

In the case of impulse turbine all the potential energy is converted to kinetic energy in the nozzles. The imulse provided by the jets is used to turn the turbine wheel. The pressure inside the turbine is atmospheric. This type is found suitable when the available potential energy is high and the flow available is comparatively low. Some people call this type as tangential flow units. Later discussion will show under what conditions this type is chosen for operation.

(ii) ***Reaction Turbine***

In reaction turbines the available potential energy is progressively converted in the turbines rotors and the reaction of the accelerating water causes the turning of the wheel. These are again divided into radial flow, mixed flow and axial flow machines. Radial flow machines are found suitable for moderate levels of potential energy and medium quantities of flow. The axial machines are suitable for low levels of potential energy and large flow rates. The potential energy available is generally denoted as "head available". With this terminology plants are designated as "high head", "medium head" and "low head" plants.

29. If at any point in the flow the pressure in the liquid is reduced to its vapour pressure, the liquid will then will boil at that point and bubbles of vapour will form. As the fluid flows into a region of higher pressure the bubbles of vapour will suddenly condense or collapse. This action produces very high dynamic pressure upon the adjacent solid walls and since the action is continuous and has a high frequency the material in that zone will be damaged. Turbine runners and pump impellers are often severely damaged by such action. The process is called cavitation and the damage is called cavitation damage. In order to avoid cavitation, the absolute pressure at all points should be above the vapour pressure.

Cavitation can occur in the case of reaction turbines at the turbine exit or draft tube inlet where the pressure may be below atmospheric level. In the case of pumps such damage may occur at the suction side of the pump, where the absolute pressure is generally below atmospheric level.

To compare cavitation characteristics a cavitation parameter known as Thoma cavitation coefficient, ó, is used. It is defined as

$$\sigma = \frac{h_a - h_v - z}{h}$$

Where, h_a = The atmospheric head

h_v = The vapour pressure head

z = The height of the runner outlet above tail race

and h = The total operating head

The minimum value of s at which cavitation occurs is defined as critical cavitation factor σ_e. Knowing σ_c the maximum value of z can be obtained as.

30. Annealing (or full annealing) is the process of heating to 60ºC above A3 line to fully convert the structure into austenite, and subsequently cooling it very slowly in the heating furnace itself. This results in a grain structure of fine pearlite with excess of ferrite or cementite. The process eliminates internal stresses, reduces hardness, increases ductility, enhances machinability, and refines the grain structure. Different degrees of softening can be achieved by slight variation in the annealing temperature, cooling rate, and atmosphere. For example, oxidation of the alloy can be minimized by annealing in a sealed container under controlled conditions. This process is called box annealing. Annealing in a protective atmosphere of inert gas (e.g. argon, nitrogen) to prevent surface discoloration is known as bright annealing. In process or intermediate annealing, the workpiece (e.g. sheet, wire) is annealed in order to restore the ductility, which would have been exhausted by work hardening during cold working. This enables further cold working of the workpiece.

31. Given that the number of grains per square inch N = 65, therefore, the ASTM grain size number n is given by

$$N = 2^{n-1}$$

$$\ln N = (n - 1) \ln 2$$

$$n = \frac{\ln N}{\ln 2} + 1 = 7.02$$

32. Fatigue strength depends upon many factors, such as surface area, size. Work hardening depends upon the work done or strain in the material. Similarly, work hardening and fracture strength also depends on the basic crystal structure of the material. Elastic constants are determined by the basic crystal structure.

[PART : C]

33. Force on the gate from oil side = γAh = (0.9 × 1000 × 9.81) (1 × 1.5) (6 + 0.75) = 89394 N

$$h_{cp} = \left(\frac{I_G}{\bar{y}A}\right) + \bar{y}$$

$$I_G = \frac{bd^3}{12}$$

$$\bar{y} = 6.75 \text{ m}$$

$$= ((1 \times 1.5^3/\ 12)/6.75 \times 1 \times 1.5) + 6.75 = 6.78 \text{ m}$$

The resultant force will act at a distance of 6.78 m from the surface of oil at the centre line of the gate.

34. The pressure at C and B are atmospheric. Considering locations C and B and taking the datum at B, applying

Bernoulli equation, noting that the velocity at water surface at C = 0.

$$0 + 0 + \frac{V_B^2}{2g} = 3 + 0 + 0$$

$$V_B = 7.672 \text{ m/s}$$

$$\text{Flow rate} = \left(\frac{\pi D^2}{4}\right) \times V$$

$$= \left(\pi \times \frac{0.1^2}{4}\right) \times 7.672$$

$$= 0.06 \text{ m}^3/\text{s}$$

The velocity at A is the same as velocity at B. Now considering locations C and A,

$$3 + 0 + 0 = 4 + \left(\frac{P_A}{\gamma}\right) + \frac{7.672^2}{(2 \times 9.81)}$$

$$\therefore \quad \frac{P_A}{\gamma} = -4 \text{ m or } -4 \text{ m of water head}$$

or 4 m water head below atmospheric pressure.

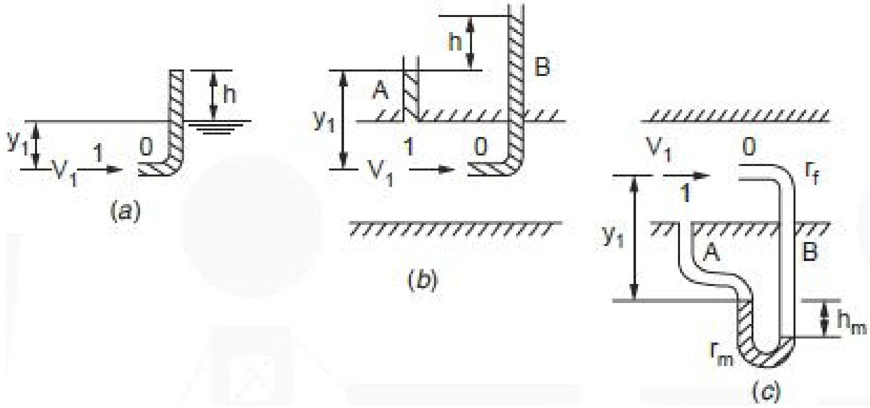
Consider points A and B

$$4 + \frac{P_A}{\gamma} + \frac{V_A^2}{2g} = \frac{V_B^2}{2g} + 0 + 0$$

as $V_A = V_B$

$$\frac{P_A}{\gamma} = -4\text{m}$$

35. If a small bore hollow tube bent at 90° is placed in a flow stream with its end facing upstream, fluid will rise in the vertical side of the tube as shown in figure. This method is used as pick-up in velocity measurement.



If Bernoulli equation is applied between a point. 1 upstream at the submerged end of the tube and a point, 0 at the other end of the tube, then leaving out P_{atm} on both sides

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} = \frac{P}{\rho g}$$

Since stagnation condition exists within the tube

$$P_0 = \rho g(y + h)$$

at point 1, the static pressure is $P_1 = \rho g y_1$

Substituting $\frac{V_1^2}{2g} = \frac{(P_0 - P_1)}{\rho g} = \frac{\rho g(y_1 + h) - y_1}{\rho g} = h$

$\therefore$ $V_1 = \sqrt{2gh}$

Note that h is the head expressed as the column of flowing fluid.

For velocity measurement in ducts a different arrangement of pick ups is necessary. A typical method is illustrated in figure. A tapping perpendicular to the flow gives the static pressure. The tube connection at this point is called static tube/probe. The pitot probe held facing upstream measures the tatal pressure. The static tube A and pilot tube B are connected to a U tube manometer as shown, in figure for measurement of velocity in a pipe. Equating the pressure at the left and right side limbs of the manometer.

36.

Velocity $V_2 = \frac{C_d A_1}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gh_m\left(\frac{\rho_m}{\rho} - 1\right)}$ and $Q = V_2 \times A_2$

Flow rate $Q = \frac{C_d A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gh_m\left(\frac{\rho_m}{\rho} - 1\right)}$

Inlet area $A_1 = \frac{\pi}{4} \times 0.15^2 = 0.0177 \text{ m}^2$,

Throat area $A_2 = \frac{\pi}{4} \times 0.075^2 = 0.00442 \text{ m}^2$

Flow rate $= (1.7/60) = 0.0283 \text{ m}^3/\text{s}$, Substituting

$$0.0283 = \frac{C_d \times 0.0177 \times 0.00442}{\sqrt{0.0177^2 - 0.00442^2}} \sqrt{2 \times 9.81 \times 0.15\left(\frac{13.6}{0.9} - 1\right)}$$

$\therefore$ $C_d = 0.963$

37. The turbines have to be installed a few meters above the flood water level to avoidinnundation. In the case of impulse turbines this does not lead to significant loss of head. In the case of reaction turbines, the loss due to the installation at a higher level from the tailrace will be significant. This loss is reduced by connecting a fully flowing diverging tube from the turbine outlet to be immersed in the tailrace at the tube outlet. This reduces the pressure loss as the pressure at the turbine outlet will be below atmospheric due to the arrangement. The loss in effective head is reduced by this arrangement. Also because of the diverging section of the tube the kinetic energy is converted to pressure energy which adds to the effective head. The draft tube thus helps (1) to regain the lost static head due to higher level installation of the turbine and (2) helps to recover part of the kinetic energy that otherwise may be lost at the turbine outlet. A draft tube arrangement is shown in Figure 1 (as also in figure 2). Different shapes of draft tubes is shown in figure 3.

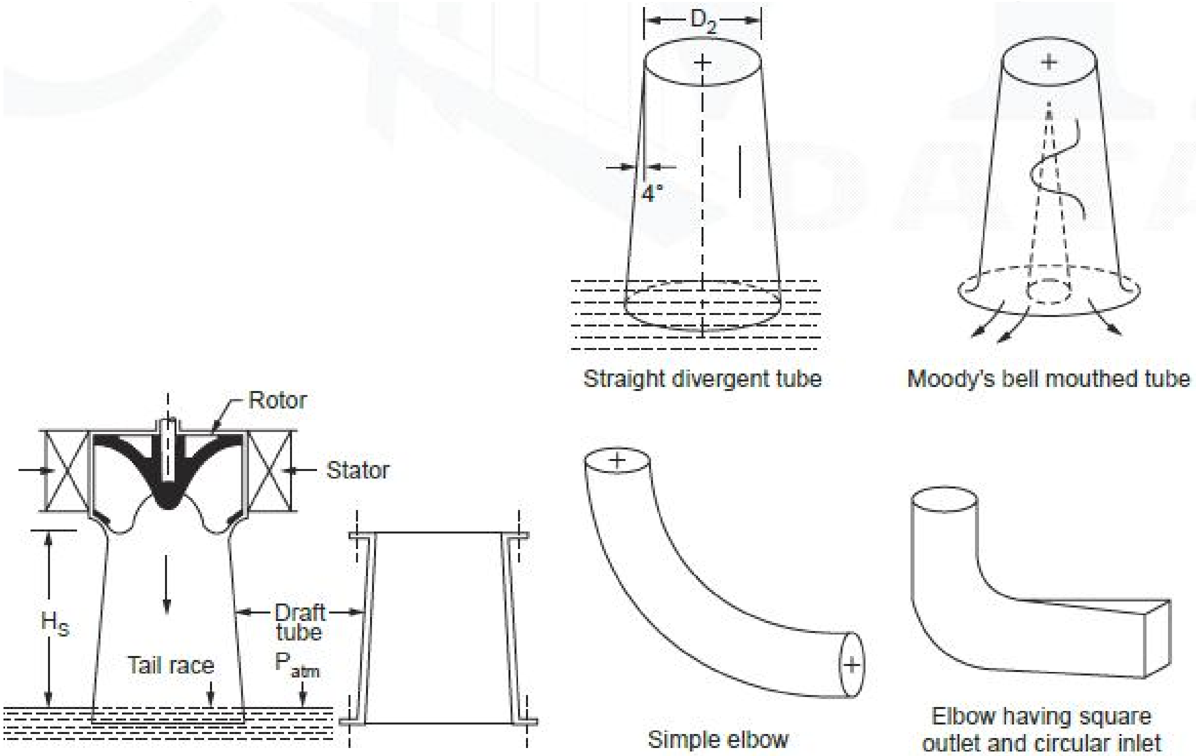


Figure : Draft Tube & Various shapes of draft tubes

The head recovered by the draft tube will equal the sum of the height of the turbine exit above the tail water level and the difference between the kinetic head at the inlet and outlet of the tube less frictional loss in head.

$$H_d = H + \frac{\left(V_1^2 - V_2^2\right)}{2g} - h_f$$

Where, H_d = The gain in head

H = The height of turbine outlet above tail water level

and h_f = The frictional loss of head

Different types of draft tubes are used as the location demands. These are (i) Straight diverging tube (ii) Bell mouthed tube and (iii) Elbow shaped tubes of circular exit or rectangular exit.

Elbow types are used when the height of the turbine outlet from tailrace is small. Bell mouthed type gives better recovery. The divergence angle in the tubes should be less than 10° to reduce separation loss.

The height of the draft tube will be decided on the basis of cavitation. This is discussed in a later section. The efficiency of the draft tube in terms of recovery of the kinetic energy is defined us

$$\eta = \frac{V_1^2 - V_2^2}{V_1^2}$$

Where, V_1 = The velocity at tube inlet

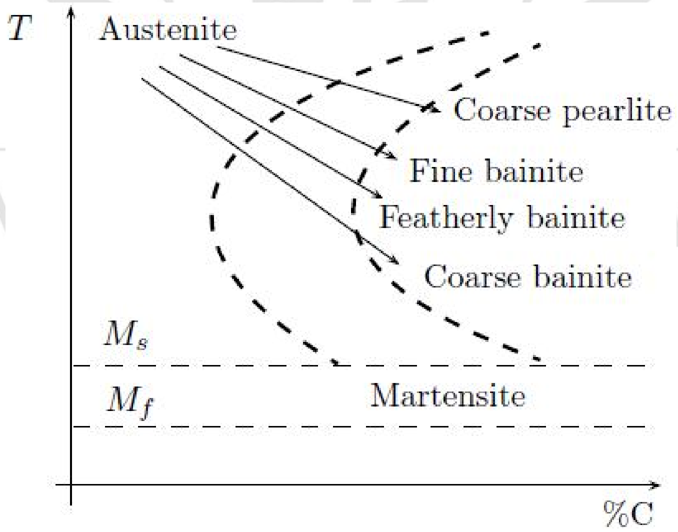
and V_2 = The velocity at tube outlet.

38. The resistance of a material to fracture under dynamic load is characterized by impact strength. It is defined as the specific work required to fracture a test specimen with a stress concentrator (notch) in the middle when broken by a single blow of striker in pendulum type impact testing.

This can be measured by the following standardized tests:

- Charpy Test In this test, the specimen is in the shape of a bar of square cross-section (10 mm×10 mm) into which a V-notch (2 mm depth) is machined at midspan. The load is applied as an impact blow from a weighted pendulum hammer that is released from a height h. After the impact, the pendulum continues to swing rising upto maximum height h2 . The energy absorbed, computed from the difference between h and h2 , is a measure of impact energy. Charpy V-notch technique is most commonly used.
- Izod Test Izod test is performed by the same procedure except in the manner of specimen support. In Izod, it is kept vertical; whereas in Charpy, it is kept horizontal. The impact energy so measured is called notch toughness. Impact strength is affected by the rate of loading, temperature, and the presence of stress raisers in the material. It also depends upon the dimension of specimen and sharpness of notch.

39. Rate of phase transformation also depends upon the temperature. Temperature-time transformation diagram (TTT), also known as isothermal transformation curves, are useful in planning heat treatments. Figure depicts TTT diagram of steel at eutectoid composition. In the diagram, Ms and Mf stand for martensite start temperature and martensite finish temperature, respectively. The transformation rate at some particular temperature is inversely proportional to the time required for reaction to proceed to 50% completion. At temperature just below the eutectoid, very long time is required for 50% transformation, and therefore, the reaction is very slow. The transformation rate increases with decreasing temperature.



TTT Diagram (0.8% C steel)

The resulting micro-structures depend upon the rate of phase transfomration or cooling. These are described under following sections.

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