17/01/2016

LECTURE – 4

Fluid Properties (Contd……)

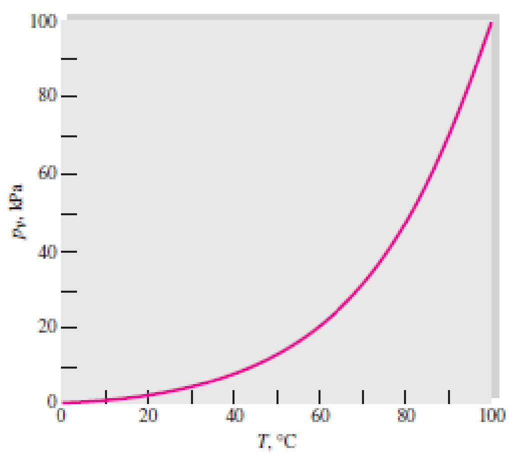
If you recall, in the last lecture we gave introduction to the subject on fluid properties.

We were discussing about fluid properties like,

- Density
- Viscosity
- Vapor Pressure, etc.

Vapor Pressure:

- ✓ Vapor pressure is the pressure at which a liquid boils & is in equilibrium with its own vapor.
- ✓ The curve of equilibrium vapor pressure at which the water boils is given as below:



Vapour Pressure of water
(Image Source: Fluid Mechanics by F.M. White)

- ✓ This vapor pressure curve is also called saturated vapor pressure curve.
- ✓ If the liquid pressure is greater than the saturated vapor pressure, the only exchange between the liquid & vapor is the evaporation at the interface.
- ✓ If the liquid pressure (or ambient pressure) falls below the saturated vapor pressure value, then vapor bubbles begin to appear in the fluid.
- ✓ Due to the phenomenon, if the ambient or liquid pressure falls below the saturated vapor pressure value, bubbles form & the pressure is called cavitation.

Note: If water is accelerated from rest to approximately 15 m/sec, the pressure of water drops nearly by 1 atm.

1 atm = 1.01325×10^5 N/m^2 = 101.325 kPa

So, for the curve, it is obvious that when water is heated to 100°C, the saturated vapor pressure will be same as the ambient atmospheric pressure & water will begin to boil.

- ✓ The flow induced reduction in ambient pressure is described by a dimensionless number:

Cavitation number, $C_a = \dfrac{p_a - p_v}{\frac{1}{2}\rho V^2}$

where,

p_a = ambient liquid temperature

p_v = vapor pressure (saturated) for liquid

V = characteristic flow velocity

ρ = density of the fluid

Example: (adopted from FM White's text Book)

A certain torpedo, moving in fresh water at 15°C, has a minimum-pressure point given by the formula $P_{min} = P_0 - 0.35\rho V^2$, where P_0 = 120 kPa, ρ is density of water, V is torpedo velocity. Estimate the velocity of torpedo at which cavitation bubbles will form on the torpedo. The constant 0.35 is dimensionless.

The following data are given:

T°C	ρ(kg/m^3)
0	1000
10	1000
20	998
30	996

T°C	P_v (kPa)
0	0.611
10	1.227
20	2.337
30	4.242
40	7.375

(Source: Data given in Appendix of FM White's Book)

Solution:

Torpedo is accelerating from zero velocity to a velocity V.

Due to this, there will be reduction of pressure in the liquid surrounding.

The maximum pressure, $P_{min} = P_0 - 0.35\rho V^2 = (120\times10^3) - (0.35\times999\times V^2)$

P_v at 15°C = 1.80 kPa = 1800 Pa

So, for the formation of cavitation bubbles around torpedo, vapor pressure should be equal to the liquid pressure.

Liquid pressure $P_l = P_{min} = (120*10^3) - (0.35*999*V^2)$

Or, $1800 = (120*10^3) - (0.35*999*V^2)$

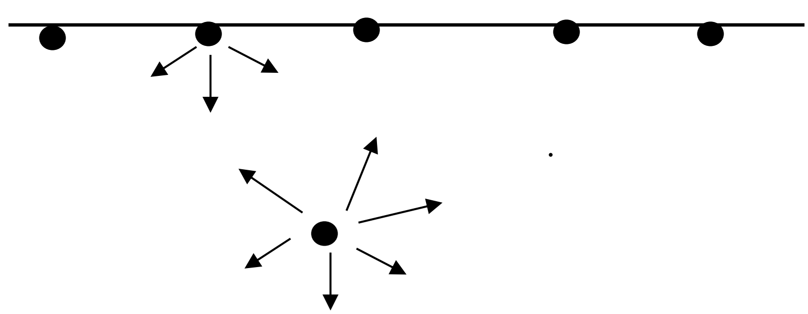
Or, $V^2 = 338$

Or, V = 18.4 m/sec

So, if the velocity accelerates from 0 to 18.4m/sec, cavitation bubbles start forming.

Surface Tension:

- ✓ You know water & other liquids form free surface when subjected to gravity.
- ✓ This free surface can in a way be looked as interface between liquid & gas.
- ✓ Surface tension is the maximum energy level, a fluid can store without breaking apart.
- ✓ Interfacial tension acts between two fluids.



Balanced cohesive forces

You can see, on surface, water molecule have imbalanced cohesive forces.

- ✓ These imbalanced forces create tension in the interface. We represent surface tension as Ơ (N/m).
- ✓ At static equilibrium, the interface forces & other forces should balance.

Surface tension for air-water interface = 0.073 N/m.

Surface tension for air-mercury interface = 0.48 N/m.

Flow Pattern:

Fluid mechanics is a subject that has to be interpreted visually. That is, you need to observe the change in fluid & flow pattern to interpret the flow phenomenon.

Four basic types of line patterns are used to visualize flow.

1. Stream line: It is the line, which is tangent everywhere to the velocity vector.
2. Path line: Line, which shows the actual path traversed by a fluid particle.
3. Streak line: It is the locus of particle that have earlier passed through a prescribed point.
4. Time line: It is a set of fluid particles that form a line at a given instant.