University of Mosul
College of Petroleum & Mining Engineering

Fluid Flow I

Lecture (3)

Compressibility , Elasticity

Petroleum and Refining Engineering Department

Ass.P. Raqeeb Hummadi Rajab
Ass.L. Ghufran Faris Alrahhawi

Email: ghufranalrahhawi @uomosul.edu.iq

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Compressibility , Elasticity

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Compressibility, Elasticity

A fluid can be compressed by application of pressure, elastic energy being stored in the process; assuming perfect energy conversion, such compressed volumes of fluids will expand to their original volumes when the applied pressure is released. In engineering this is summarized by (**bulk modulus of elasticity E**)

$$E = -\frac{dp}{\frac{d\forall}{\forall_1}}$$

$P = \frac{F}{A}$ ……. Stress

$\frac{d\forall}{\forall_1}$ ……….. strain

E = modulus of elasticity

dp = is the change pressure (pa)

$d\forall$ = change in volume (m^3)

$\forall$ = original of volume (m^3)

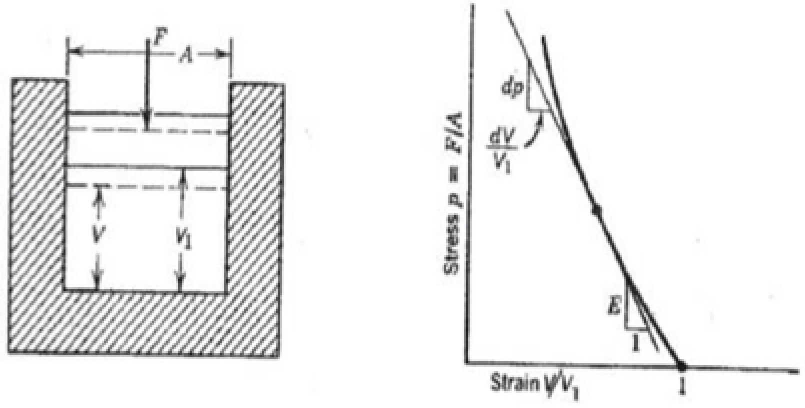
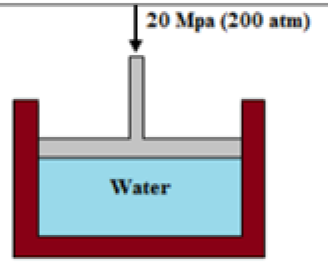
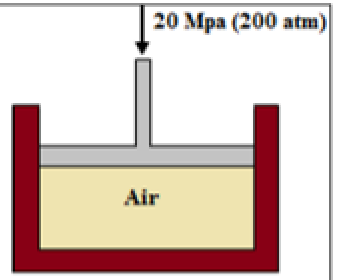
$E = \dfrac{dp}{\frac{-d\forall}{\forall}}$ $= \dfrac{N/m^2}{m^3/m^3}$		 $d\forall \approx 0.1\% \rightarrow d\rho \sim 0$ **Fluid is incompressible.**	 $d\rho \neq 0$ **Fluid is compressible**

Fig (3)

The fractional change in volume can be related to the change in material density using

$m = \rho\forall$ since the mass is constant

$$dm = \rho d\forall + \forall d\rho = 0$$

$$\rho d\forall = -\forall d\rho$$

$$\frac{d\rho}{\rho} = -\frac{d\forall}{\forall}$$

$$E = -\frac{dp}{\frac{d\rho}{\rho}} = \frac{change\ of\ pressure}{Fractional\ change\ of\ density}$$

Or

$$m = \rho\forall$$

$$d\rho = d\left(\frac{m}{\forall}\right) = -m\frac{d\forall}{V^2} = -\rho\frac{d\forall}{\forall}$$

$$\frac{d\rho}{\rho} = -\frac{d\forall}{\forall}$$

$$E = \rho\frac{dp}{d\rho}$$

Elasticity is measure of liquid incompressibility. The **bulk modulus of elasticity** of water is approximately 2.2 GN/m^2 which corresponds to a 0.05% change in volume for a change of 1 MN/m^2 in pressure. Obviously, the term **incompressibility** is justifiably applied to water because it has such a **small** change in volume for a very **large** change in pressure

Example 1

Determine the bulk modulus of elasticity of a liquid, if the pressure of the liquid is increased from 70 N/cm2 to 130 N/cm2. The volume of the liquid decreases by 0.15 per cent.

Solution: Initial pressure = 70 N/cm^2; Final pressure = 130 N/cm2

$\therefore dp = \text{increase of pressure} = 130 - 70 = 60 N/cm^2$

Decrease in volume = 0.15%

$$\therefore -\frac{d\forall}{\forall} = +\frac{15}{1000}$$

$$E = \frac{dp}{-\frac{d\forall}{\forall}} = \frac{60}{\frac{0.15}{100}} = \frac{6000}{0.15} = 4 \times 10^4 \frac{N}{cm^2}$$

Example 2

What is the bulk modulus of elasticity of a liquid which is compressed in a cylinder from a volume of 0.0125 m^3 at 80 N/cm2 pressure to a volume of 0.0124 m3 at 150 N/cm2 pressure?

Solution: Initial volume = 0.0125 m^3; Final pressure = 0.0124 m^3

$\therefore d\forall = \text{decrease in volume} = 0.0125 - 0.0124 = 0.0001 m3$

$$\therefore -\frac{d\forall}{\forall} = +\frac{0.0001}{0.0125}$$

Initial pressure =80 N/cm^2; Final pressure=150 N/cm^2

$\therefore dp = \text{increase of pressure} = 150 - 80 = 70 N/cm^2$

$$E = \frac{dp}{-\frac{d\forall}{\forall}} = \frac{70}{\frac{0.0001}{0.0125}} = 70 \times 125 = 8.75 \times 10^3 \frac{N}{cm^2}$$

Vapor Pressure

It is a common observation that liquids such as water and gasoline will evaporate if they are simply placed in a container open to the atmosphere. Evaporation takes place because some liquid molecules at the surface have sufficient momentum to overcome the intermolecular cohesive forces and escape into the atmosphere. If the container is closed with a small air space left above the surface, and this space evacuated to form a vacuum, a pressure will develop in the space as a result of the vapor that is formed by the escaping molecules. When an equilibrium condition is reached so that the number of molecules leaving the surface is equal to the number entering, the vapor is said to be saturated and the pressure that the vapor exerts on the liquid surface is termed the vapor pressure. Ex., water of 20C has vapor pressure of 2.451Kpa absolute.

- **Cohesion:** Cohesion means intermolecular attraction between molecules of the same liquid. Cohesion is a tendency of the liquid to remain as one assemblage of particles.
- **Adhesion:** Adhesion means attraction between the molecules of a liquid and the molecules of a solid boundary surface in contact with the liquid. This property enables a liquid to stick to another body

- **Surface tension:** At the interface between a liquid and a gas, or between two different liquids, forces develop in the liquid surface which causes the surface to behave as a "skin" stretched over the fluid mass. **it** is caused by the force of cohesion at the free surface. At liquid–air interfaces, surface tension results from the greater attraction of liquid molecules to each other (due to cohesion) than to the molecules in the air (due to adhesion).