Kinetic Theory of Fluids

Rajeev Kumar*

Abstract

In this paper a kinetic theory of fluids has been presented.
Keyword : Kinetic theory of fluids.

1 INTRODUCTION

The internal translational kinetic energy of a stable fluid can be obtained by local dynamic equilibrium hypothesis, i.e.,

$$\langle v_x^2 \rangle = \langle v_y^2 \rangle = \langle v_z^2 \rangle = \frac{\langle v^2 \rangle}{3} = \frac{v_{rms}^2}{3}$$

$$P_x = P_y = P_z = P = \frac{\rho v_{rms}^2}{3} \qquad (i)$$

where

P = pressure of the fluid

ρ = density of the fluid

v_{rms} = root mean square speed of the fluid particles

2 INTERNAL TRANSLATIONAL KINETIC ENERGY

Let's consider a container containing a fluid and is stationary with respect to an inertial frame of reference. Now for a static fluid, the pressure at a depth h from the top of the fluid is given by the Pascal's law as

$$P_x = P_y = P_z = P = P_o + \rho g h \qquad (ii)$$

where

P_o = pressure at the top of the fluid

ρ = uniform mass density of the fluid

g = uniform gravitational acceleration

From equations (i) and (ii), we obtain

$$\frac{\rho v_{rms}^2}{3} = P_o + \rho g h$$

$$\Rightarrow v_{rms}^2 = \frac{3P_o}{\rho} + 3gh$$

*rajeevkumar620692@gmail.com

Now the internal translational kinetic energy

$$KE = \frac{1}{2}\int_V \rho v_{rms}^2\, dV = \frac{1}{2}\int_V 3P_o dV + \frac{1}{2}\int_V 3\rho g h dV$$

$$= \frac{3}{2}P_o \int_V dV + \frac{3}{2}\rho g \int_V h dV$$

$$= \frac{3}{2}P_o V + \frac{3}{2}\rho g V h_c$$

$$\Rightarrow KE = \frac{3}{2}P_o V + \frac{3}{2}Mgh_c$$

where

V = volume of the fluid

M = mass of the fluid

h_c = depth of the centroid of the fluid volume from the top of the fluid

3 CONCLUSION

It should be noted that this theory is not compatible with the concept of temperature from the conventional kinetic theory wherein the temperature is assumed to be proportional to the internal kinetic energy per particle and per degree of freedom. Consequently this theory differentiates between the concept of temperature from the zeroth law of thermodynamics and the concept of temperature from the conventional kinetic theory. Therefore, the concept of temperature needs to be revised in accordance with the zeroth law of thermodynamics.

References

1. Hugh D. Young, Roger A. Freedman, Albert Lewis Ford, *"Sears' and Zemansky's University Physics with Modern Physics 13th edition."*

2. Yunus A. Cengel, John M. Cimbala, *"Fluid Mechanics: Fundamentals and Applications, 3rd Edition."*