WEEK 5: FIRST and SECOND LAWS OF THERMODYNAMICS

FUNDAMENTAL RELATIONS FOR THE FLOW THROUGH AN ARBITRARY TURBOMACHINE

c) The First Law of Thermodynamics [1]

When the first law of thermodynamics for 1-D and steady flow of an incompressible fluid is combined with the definition of enthalpy, one can obtain:

$$\dot{Q_{1-2}} + \dot{W_{1-2}} + \dot{m}.\left(u_1 + \frac{p_1}{\rho} + \frac{V_1^2}{2} + g.z_1\right) = \dot{m}.\left(u_2 + \frac{p_2}{\rho} + \frac{V_2^2}{2} + g.z_2\right)$$

When there is no heat transfer, the internal energy of incompressible fluid is constant and the above equation becomes:

$$\dot{W_{1-2}} + \dot{m}.g.\left(\frac{p_1}{\rho}.g + \frac{V_1^2}{2g} + z_1\right) = \dot{m}.g.\left(\frac{p_2}{\rho} + \frac{V_2^2}{2g} + z_2\right)$$

Noting that:

$$\dot{m} = \rho.Q$$

$$h_{t1} = \frac{p_1}{\rho}.g + \frac{V_1^2}{2g} + z_1$$

$$h_{t2} = \frac{p_2}{\rho}.g + \frac{V_2^2}{2g} + z_2$$

Regarding the above equation:

$$\dot{W_{12}} + \rho . g . Q . h_{t1} = \rho . g . Q . h_{t2}$$

$$\dot{W_{12}} = \rho . g . Q . (h_{t2} - h_{t1})$$

c) The Second Law of Thermodynamics [1]

For incompressible flows without heat transfer, there is no need to explicit consideration of the second law of thermodynamics.

However, when compressibility and heat transfer are present, one should be careful so that the second law of thermodynamics is not violated.

For incompressible flows, the angular momentum equation and the first law of thermodynamics can be combined to yield a very useful relation.

To obtain this relation, first note that the power is the product of the torque and angular velocity, so that

$$P = T . \omega$$

Other additional equations which are not violated:

$$\partial s = 0 (reversible)$$

$$\partial s > \frac{\partial Q}{T} (irreversible)$$

$$\partial s \geq 0$$

However, when compressibility and heat transfer are present, one should be careful so that the second law of thermodynamics is not violated.

REFERENCES

1. Aksel, M.H., 2016, “Notes on Fluids Mechanics”, Vol. 1, METU Publications

2. DOUGLAS, J. F., GASIOREK, J. M. and SWAFFIELD, J. A., *Fluid Mechanics,* 3rd ed., Prentice Hall, Inc., New Jersey, 2003.

3. FOX, R. W. and MCDONALD, A. T., *Introduction to Fluid Mechanics,* 6th ed., John Wiley and Sons, Inc., New York, 2005.

4. ÜÇER, A. Ş., *Turbomachinery,* Middle East Technical University, Ankara,Turkey, 1982.