FLUID MECHANICS I

QUIZ #2

State the Conservation Laws for Fluid Flow. Identify on the formula sheet the equation for each law. Discuss the various terms in the equations.

A coil in a certain heat exchanger is 20m long and forms a closed loop. It has forty 180° bends each with K=0.5. The coil is made of copper pipe with ID equal to 1cm and roughness 0.0015mm. Derive the system demand equation for the exchanger. Let the water flow rate in the coil be 5gpm. What would be the pump power required to run the exchanger?

A snow plow picks up a horizontal layer of snow which is 2.5m wide and 0.25m high and turns it so that it is vertical and perpendicular to the direction of motion of the plow. Calculate the snow load on plow when it is moving at 50km/hr. Assume that the density of snow is 900 kg/m^3.

CONSERVATION LAWS QUESTION

Conservation of Mass states that the time rate of change of the mass of a specific group of fluid particles in a flow must be zero. Mathematically this can be written as

$$\frac{D}{Dt}\int_V \rho \, dV = \int_V \partial\rho/\partial t \, dV + \int_S \rho \, \mathbf{v}.\mathbf{n} \, dS = 0$$

Conservation of Momentum states that the time rate of change of the momentum of a group of particles in a flow must balance with the net load acting on it. Mathematically this can be written as

$$\frac{D}{Dt}\int_V \rho\mathbf{v} \, dV = \int_V \partial\rho\mathbf{v}/\partial t \, dV + \int_S \rho\mathbf{v} \, \mathbf{v}.\mathbf{n} \, dS$$

$$= \int_S \boldsymbol{\sigma} \, dS + \int_V \rho\mathbf{b} \, dV$$

Conservation of Energy states that the time rate of change of the energy of a group of particles in a flow must balance with heat and work interactions of the group with its surroundings. Mathematically this can be written as:

$$\frac{D}{Dt}\int_V \rho e \, dV = \int_V \partial\rho e/\partial t \, dV + \int_S \rho e \, \mathbf{v}.\mathbf{n} \, dS$$

$$= -\int_S \mathbf{q}.\mathbf{n} \, dS + \int_S \mathbf{v}.\boldsymbol{\sigma} \, dS$$

HEAT EXCHANGER QUESTION

Imagine that the coil is broken at some point: in this case the heat exchanger becomes like a regular pipe system with an inlet and an outlet. Because the inlet and outlet are at the same point, h_{OUT} equals h_{IN}. This implies that h_P is equal to h_L. The system demand equation is just

$$h_S = h_L = (fL/D + \Sigma K)\ C^2/2g \qquad C=Q/A$$

The flow speed C is 4m/s. The Reynolds Number Re is 40000. The pipe roughness is 0.00015. Knowing the Reynolds Number and the pipe roughness we can get the friction factor from the Moody Chart: it is 0.022. The ΣK is 20. Substitution into the system demand equation gives an h_S of 52m.

At the operating point the system demand head h_S is equal to the pump head h_P. Knowing h_P we can get the pump power from the flow power equation

$$\mathbf{P} = PQ = \rho g\ h_P\ Q$$

Substitution into this gives the power 161W.

SNOW PLOW QUESTION

The snow has two force components acting on it: both in the horizontal plane. These are

$$\sum \dot{M}\,(U_{OUT}-U_{IN}) = F_x \qquad \sum \dot{M}\,(V_{OUT}-V_{IN}) = F_y$$

Let the speed of the plow be C. In this case, U_{OUT} is equal to zero and U_{IN} is equal to -C, while V_{OUT} is equal to -C and V_{IN} is equal to zero.

The mass flow rate is

$$\dot{M} = \rho C A \qquad A = wd$$

Substitution gives

$$\dot{M} = 8.68 m^3/s \qquad F_x = +108 kN \qquad F_y = -108 kN$$

The snow forces acting on the plow are the negative of the plow forces acting on the snow.