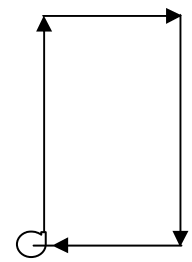
EN-634 Nuclear Reactor Thermal Hydraulics

Assignment -4



1. Solving real life reactor problems are tedious and time consuming. However, to illustrate the principles involved, let us look at a closed loop constructed of a pipe with diameter d = 2.5 cm and a total length of 20 m driven by a centrifugal pump as shown in the figure. The fluid circulated is water of density 1000 kg/m^3 and viscosity 10^{-3} Pa.s at a rate of 1.5 kg/s.

(a) Calculate the frictional pressure drop in the total circuit.

(b) The next task is to choose a pump. Calculate the head required to be developed by the pump

(c) To be conservative, add an additional 30% on the estimated head. If the market offers two pumps of the following given characteristics, which one would you choose? The characteristics are:

Pump-A H (m) = 10 – 700,000 Q^2 where Q is flow rate in m^3/s
Pump-B H (m) = 12 – 700,000 Q^2 where Q is flow rate in m^3/s

(d) Assuming that the actual circuit behaves ideally with no error (30% accounted in part c is not there), estimate the actual mass flow rate the pump will circulate

(e) Assuming that the desired flow rate is 1.5 kg/s, estimate the friction loss coefficient K for the valve that has to be installed in the circuit.

(f) Now imagine that the circuit you engineered is working fine. Suddenly due to pump malfunction, it seized (got jammed) instantly and so the head developed is zero. Now the circulating fluid would slowly come to rest. You are asked to estimate the time required for the flow to reduce to 1% of the design flow rate. During this process, for simplicity, assume that the friction factor is a constant and equal to the design value (though it will change in reality)

2. Consider the flow of water in a channel of 1 cm diameter entering at 12 m/s and 50^{o}C.

(a) Compute the frictional pressure gradient, assuming that the channel is smooth. Use Darcy friction factor is 0.184 $Re^{-0.2}$.

(b) For data given in part (a), assuming that the channel is adiabatic, compute (a) the temperature gradient along the channel due to the shear work at the wall. Proceed systematically from the relevant governing equation. Now comment at what heat flux on the wall (if it is also heated by uniform heat flux), the frictional energy deposition shall be within 1% and hence for heat flux above this value the frictional contribution can be neglected.

(c) You are now asked to develop a model in which the shear work on the wall (assumed to be thin) is split between the ambient and the fluid, unlike in part (b) where, all the work was ploughed back into the fluid as heat. For this you may assume that the channel wall is at a temperature T_w . The wall temperature will be decided in such a way that the heat flux to the fluid in the pipe and the ambient will add up to rate of shear work. Mathematically set up the equations for the same. For the data given in part (a), compute the split at the entrance. You may note that the heat transfer is by forced convection in the inside and free convection on the outside. Use the heat transfer coefficient between the wall and inner fluid to be 1000 W/m^2-K and the same between the wall and ambient is 10 W/m^2-K. Ambient may be assumed to be at 30^{o}C.

3. Consider a loop constructed with pipe of length 4L and diameter d as shown in the figure. In the bottom half of the loop fluid is heated by uniform heat flux q$''$ and the fluid is cooled in the top half of the loop in a similar fashion. Show that under steady natural circulation conditions, the non-dimensional velocity, Re = $\frac{\rho v d}{\mu}$, is equal to $\frac{Gr}{128}$, where

   $Gr = \frac{g\ \beta\ \Delta T_f\ d^3\rho^2}{\mu^2}$ and ΔT_f is the increase in temperature of the fluid in the heating section. You may assume that (a) the length of the horizontal sections are short and therefore are negligible, (b) Flow is single-phase and laminar and (c) Boussinesq approximation is valid.(By solving this problem you will realize that in single-phase, the anchoring temperature (coolant temperature) is not necessary to estimate the flow. The temperature difference is uniquely fixed and the absolute temperature just slides depending on the anchoring temperature.)