MEE1004 – Fluid Mechanics

Revision –losses in pipes

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$$h_L = h_{L\text{-}major} + h_{L\text{-}minor}$$

MAJOR LOSSES

$$h_{L-major} = f\frac{\ell}{D}\frac{V^2}{2g} \qquad f = \frac{64}{\mathrm{Re}}$$

where f is friction factor.

laminar flow

It is because, in turbulent flow, Reynolds number and relative roughness influence the friction.

Reynolds number, $\mathrm{Re} = \dfrac{\rho V D}{\mu}$

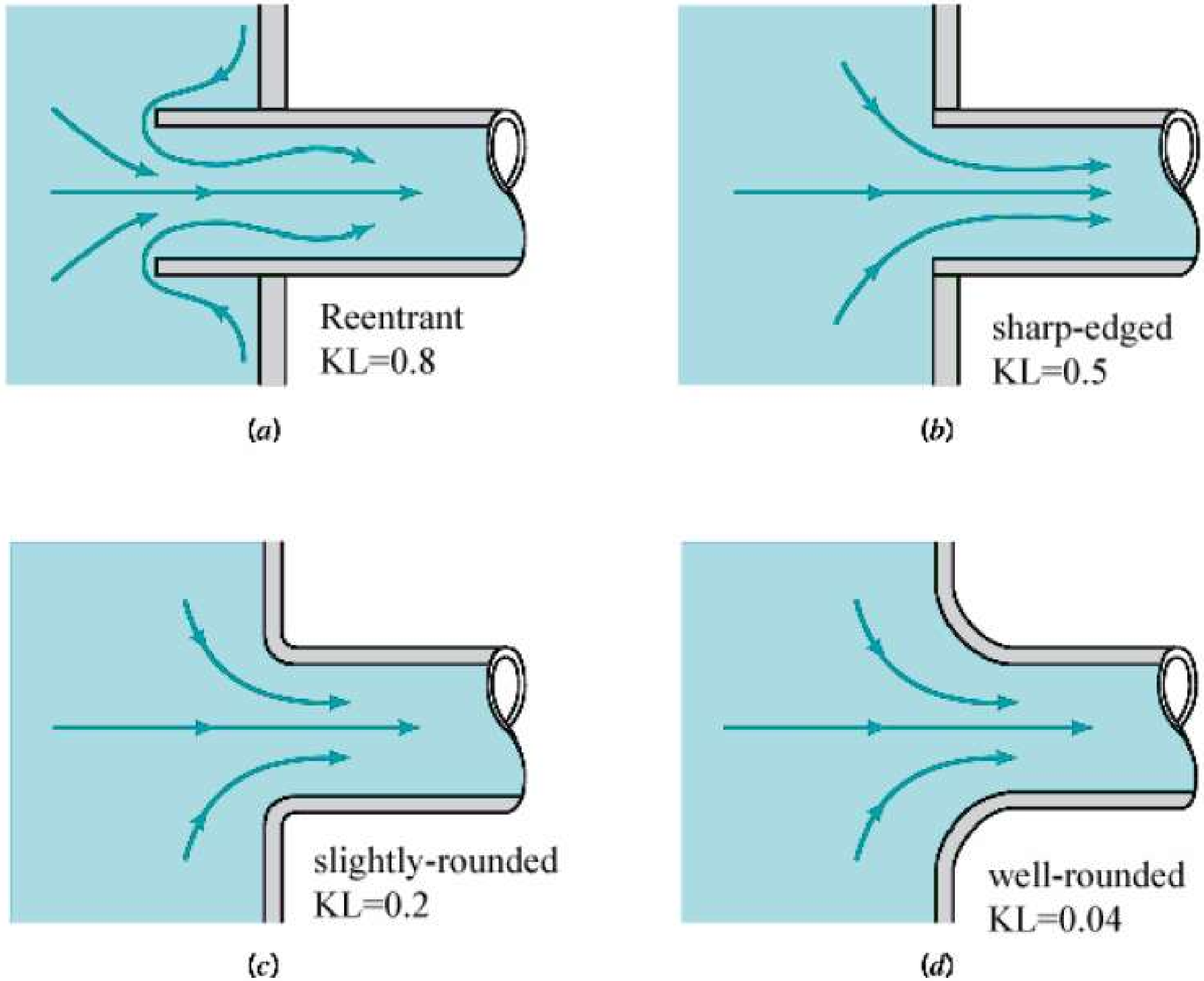
Relative roughness $= \dfrac{\varepsilon}{D}$

(relative roughness is not present in the laminar flow)

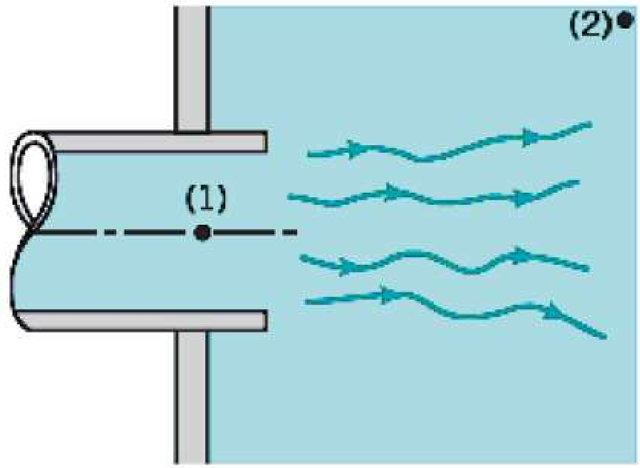
The following equation from *Colebrook* is valid for the entire non-laminar range of the *Moody* chart. It is called *Colebrook formula*.

$$\frac{1}{f} = -2.0\log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\text{Re}\sqrt{f}}\right)$$

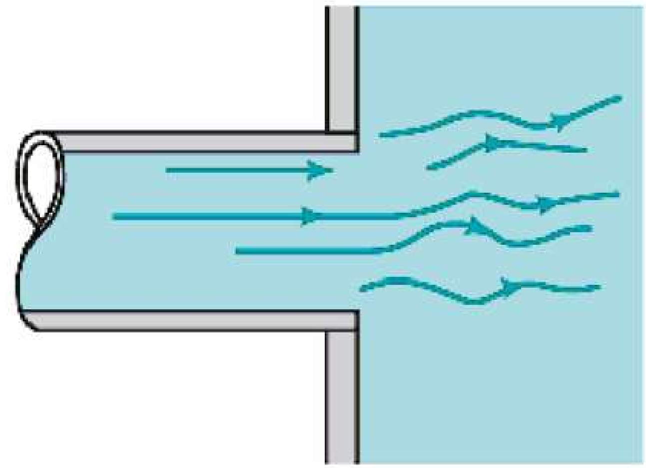
Head Loss at the Entrance of a Pipe (flow leaving a tank)



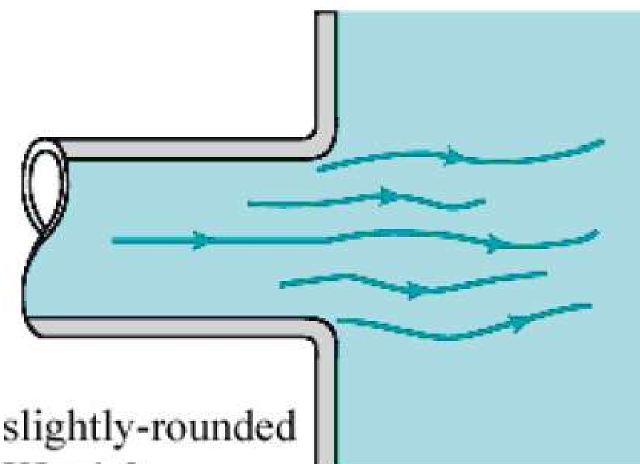
Exit flow conditions and loss coefficient.



(a) Reentrant
KL=1.0

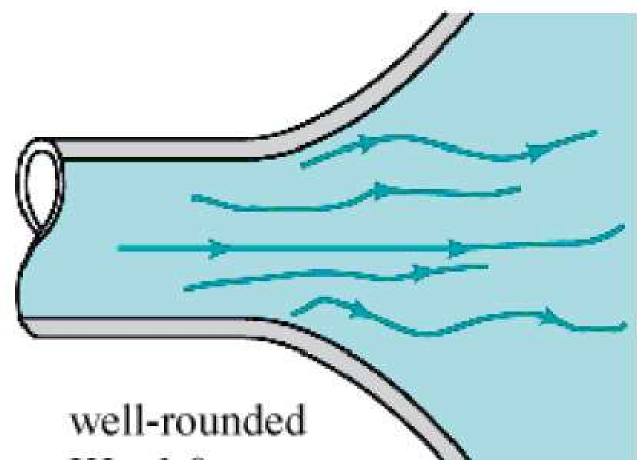


(b) sharp-edged
KL=1.0



slightly-rounded
KL=1.0

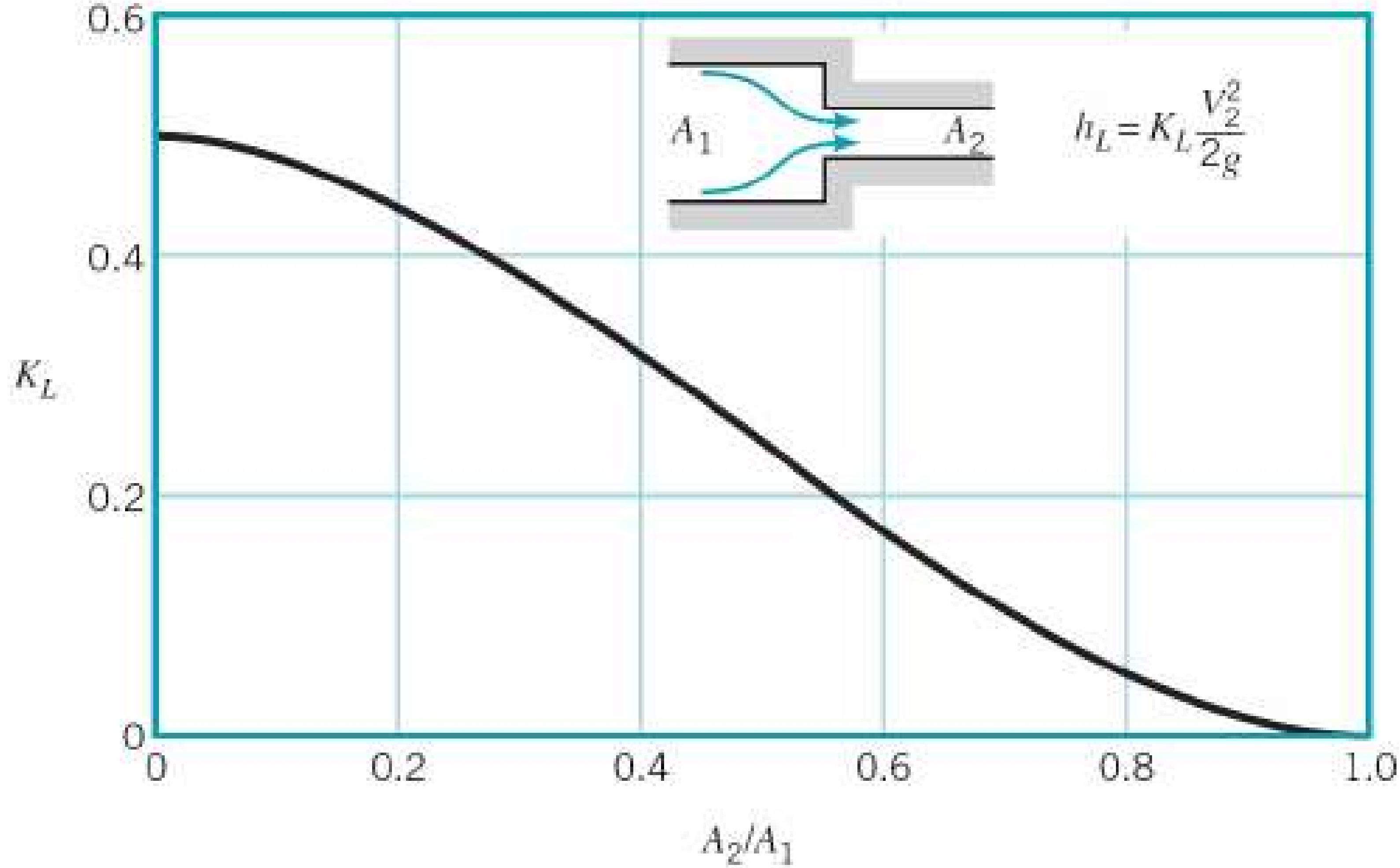
(c)



well-rounded
KL=1.0

(d)

For sudden contraction:



$$K_L = \left(1 - \frac{A_2}{A_1}\right)^2 = \left(1 - \frac{A_2}{A_c}\right)^2 = \left(1 - \frac{1}{C_c}\right)^2$$

Three pipes of 400 *mm*, 200 *mm* and 300 *mm* diameters have lengths of 400 *m*, 200 *m* and 300 *m* respectively. They are connected in series to make a compound pipe. The ends of this compound pipe are connected with tanks whose difference of water levels is 16 *m*. If co-efficient of friction for these pipes is same and equal to 0.005, determine the discharge

Difference of water levels,	$H = 16m$
Length and dia. of pipe 1,	$L_1 = 400m$ and $d_1 = 400$ mm $= 0.4m$
Length and dia. of pipe 2,	$L_2 = 200m$ and $d_2 = 200$ mm $= 0.2m$
Length and dia. of pipe 3,	$L_3 = 400m$ and $d_3 = 300$ mm $= 0.3m$

Also, $f_1 = f_2 = f_3 = 0.005$

(a) At inlet, $h_i = \dfrac{0.5V_1^2}{2g}$

(b) Between 1st pipe and 2nd pipe, due to contraction,

$$h_c = \frac{0.5V_2^2}{2g} = \frac{0.5\left(4V_1^2\right)}{2g} \qquad (\because V_2 = 4V_1)$$

$$= \frac{0.5 \times 16 \times V_1^2}{2g} = 8 \times \frac{V_1^2}{2g}$$

(c) Between 2nd pipe and 3rd pipe, due to sudden enlargement,

$$h_e = \frac{(V_2 - V_3)^2}{2g} = \frac{(4V_1 - 1.77V_1)^2}{2g} \qquad (\because\ V_3 = 1.77\ V_1)$$

$$= (2.23)^2 \times \frac{V_1^2}{2g} = 4.973\frac{V_1^2}{2g}$$

(d) At the outlet of 3rd pipe, $h_o = \frac{V_3^2}{2g} = \frac{(1.77V_1)^2}{2g} = 1.77^2\frac{V_1^2}{2g} = 3.1329\frac{V_1^2}{2g}$

The major losses are

$$= \frac{4f_1 \times L_1 \times V_1^2}{d_1 \times 2g} + \frac{4f_2 \times L_2 \times V_2^2}{d_2 \times 2g} + \frac{4f_3 \times L_3 \times V_3^2}{2g}$$

$$=\frac{4\times 0.005\times 400\times V_1^2}{0.4\times 2\times 9.81}+\frac{4\times 0.005\times 200\times (4V_1)^2}{0.2\times 2\times 9.81}+\frac{4\times 0.005\times 300\times (1.77V_1)^2}{0.3\times 2\times 9.81}$$

$$=403.14\times\frac{V_1^2}{2\times 9.81}$$

$\therefore$ Sum of minor losses and major losses

$$=\left[\frac{0.5V_1^2}{2g}+8\times\frac{V_1^2}{2g}+4.973\frac{V_1^2}{2g}+3.1329\frac{V_1^2}{2g}\right]+403.14\frac{V_1^2}{2g}=419.746\frac{V_1^2}{2g}$$

$$\therefore \qquad 419.746\times\frac{V_1^2}{2g}=16$$

$$\therefore \qquad V_1=\sqrt{\frac{16\times 2\times 9.81}{419.746}}=0.864\,\text{m/s}$$

$$\text{Discharge, } Q=A_1V_1=\frac{\pi}{4}(0.4)^2\times 0.864=0.1085\ \text{m}^3/\text{s}.$$