Seoul National University

457.309.02 Hydraulics and Laboratory
.11 Turbulent flow in rough pipe(3)

Prepared by Jin Hwan Hwang
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Today's objectives

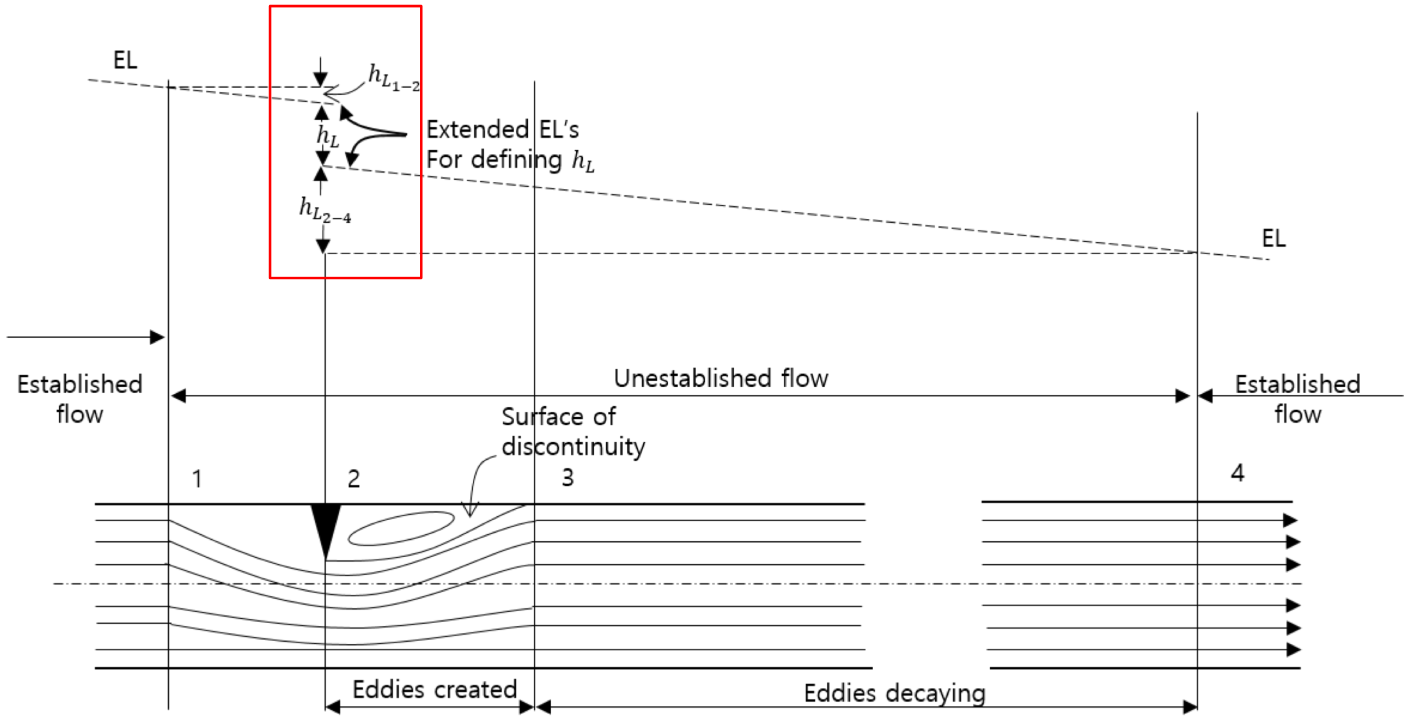
- Can determine the head loss due to the shape change of pipes.
- Apply the knowledge to the more practical problems.

9. Local losses in pipelines

- Bends, elbow, valves, and fittings. Those have the chang e of cross-section and it causes the head loss.
- In the long pipes, such effects can be neglected but in th e short ones, those are significant.
- For example, an abrupt obstruction placed in a pipeline c reates dissipation of energy and causes local loss.
- This is generated by the velocity change mainly, and dec eleration of velocity causes more energy loss (or head lo ss) due to the turbulence than acceleration.

9. Local losses in pipelines

- Head loss



9. Local losses in pipelines

- Earlier experiments with water (at high Reynolds number) indicated that local losses vary approximately with the square of velocity and led to the proposal of the basic equation.

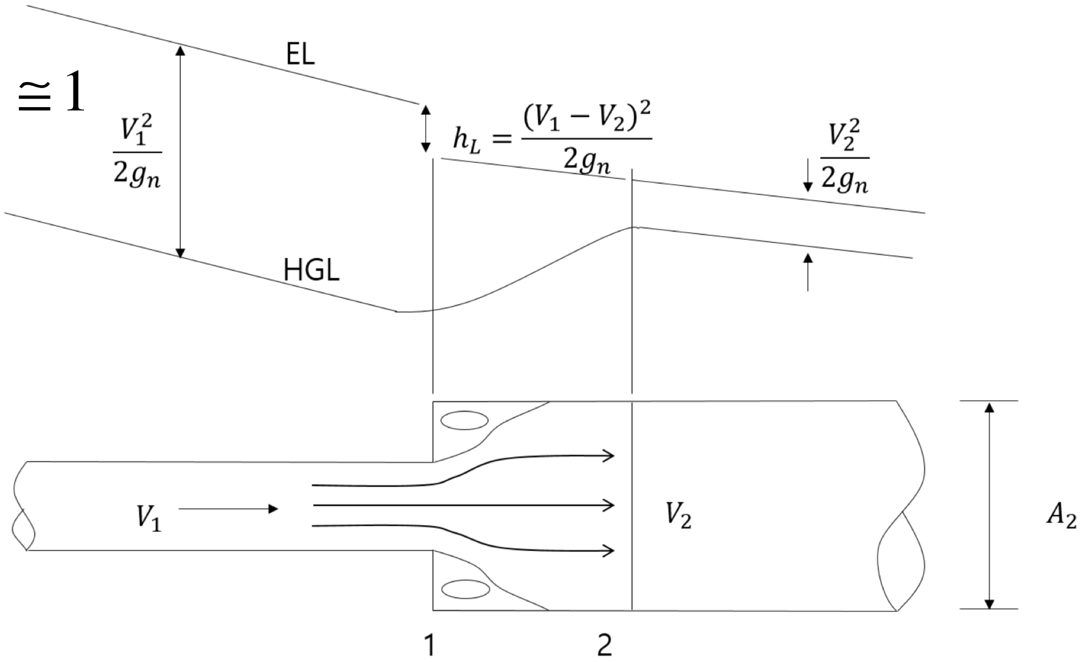
$$h_L = K_L \frac{V^2}{2g_n} \quad K_L \text{ is the loss coefficient}$$

  - Loss coefficient tends to increase with increasing roughness
  - Increases with decreasing Reynolds number
  - Constant at the real high Reynolds number
  - Mainly determined by the geometry and the shape.

9. Local losses in pipelines

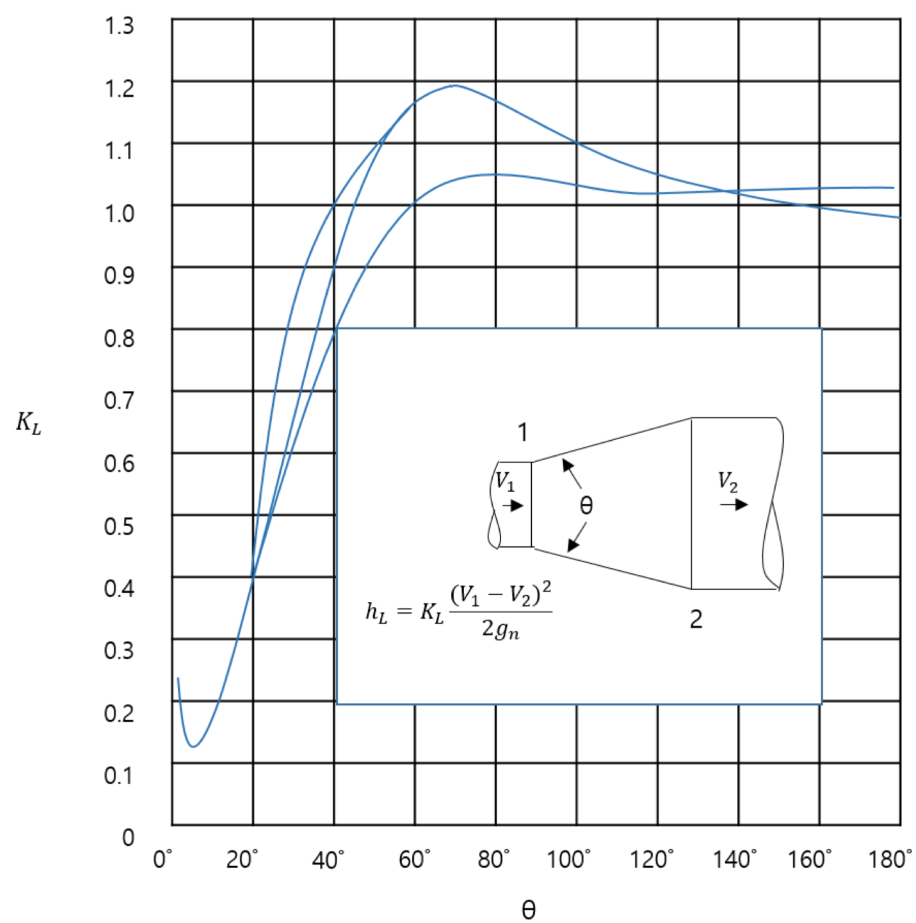
- When an ***abrupt enlargement*** of section occurs in a pipeline, a rapi d deceleration takes place, accompanied by characteristic large-scal e turbulence
- It will persist for a distance of 50 diameter or more down stream.

$$h_L = K_L \frac{(V_1 - V_2)^2}{2g_n} \qquad K_L \cong 1$$



9. Local losses in pipelines

- The loss of head due to ***gradual enlargement*** is, of course, dependent on the shape of the enlargement.
- Effects of wall friction and large-scale turbulence
- As angle becomes larger, big separation occurs (minimizing effects of wall friction and separation at 7)



Example 1.

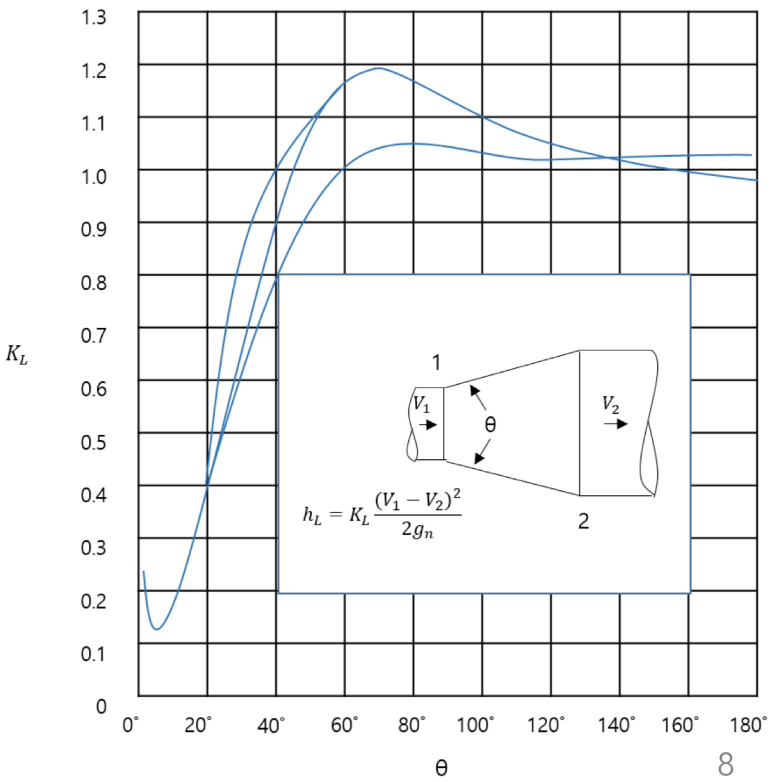
- A 300 mm horizontal water line enlarges to a 600 mm line through 20° conical enlargement. When 0.30 m³/s flow through this line, the pressure in the smaller pipe is 140 kPa. Calculate the pressure in the larger pipe, neglecting pipe friction.

- Velocities in each pipe

$$V_{300} = \frac{Q}{A_{300}} = \frac{0.30 m^3/s}{(\pi/4)(0.300 m)^2} = 4.24 m/s$$

$$V_{600} = \frac{Q}{A_{600}} = \frac{0.30 m^3/s}{(\pi/4)(0.600 m)^2} = 1.06 m/s$$

- K_L = 0.43 (see the figure)



Example 1

- To compute the pressure in the large pipe, , using Bernoulli's

$$z_{300} + \frac{p_{300}}{\gamma} + \frac{V_{300}^2}{2g_n} = z_{600} + \frac{p_{600}}{\gamma} + \frac{V_{600}^2}{2g_n} + h_L$$

$$h_L = K_L \frac{\left(V_{300} - V_{600}\right)^2}{2g_n}$$

- Taking the datum as the pipe centerline eliminates z from the calcula tions leaving

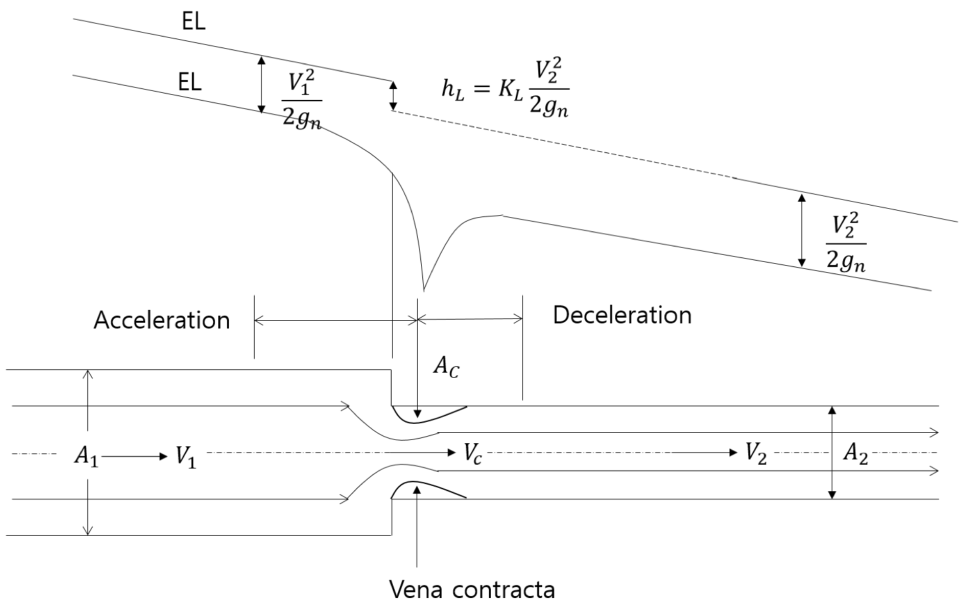
$$\frac{140 \times 10^3 \text{Pa}}{9{,}800 \text{N/m}^3} + \frac{(4.24 \text{m/s})^2}{2 \times 9.81} = \frac{p_{600}}{\gamma} + \frac{(1.06 \text{m/s})^2}{2 \times 9.81} + 0.43 \frac{(4.24 - 1.06)^2}{2 \times 9.81}$$

$$\frac{p_{600}}{\gamma} = 14.6 \text{m}, \qquad p_{600} = 14.6 \times 9{,}800 = 143 \text{kPa}$$

- Pressure rose at 2 comparing 1. (where we can use it?)

Local Losses in pipelines

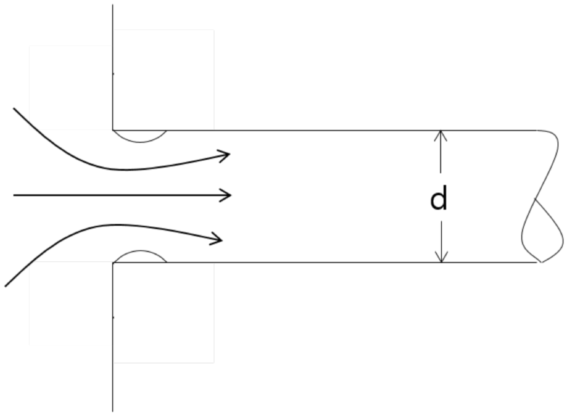
- Flow through an abrupt contraction (figure) and is featured by the for mation of a vena contracta and subsequent deceleration and reexpa nsion.

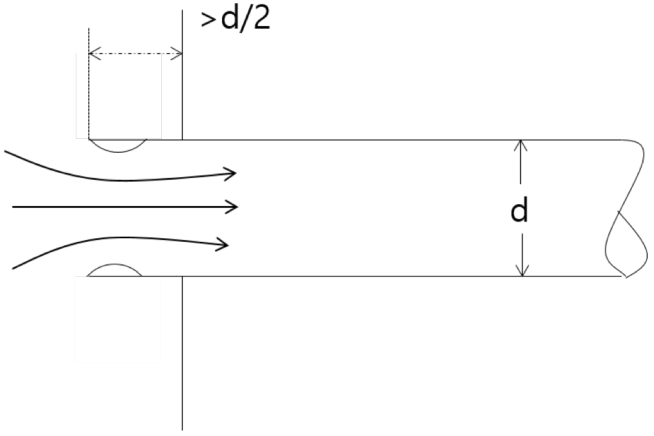


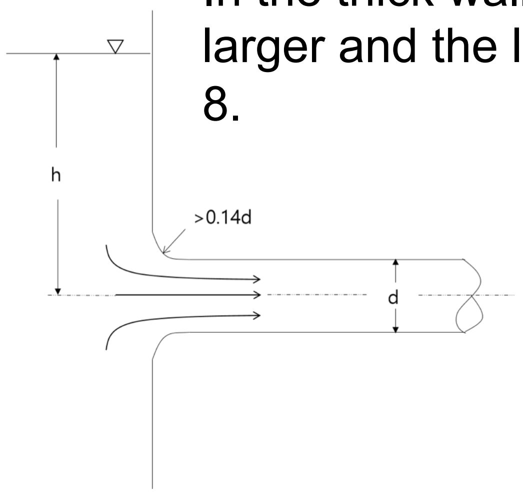
A_2/A_1	0	0.2	0.4	0.6	0.8	1.0
$C_c=A_c/A_2$	0.617	0.632	0.659	0.712	0.813	1.00
K_L	0.50	0.41	0.30	0.18	0.06	0

Local Losses in pipelines

- Square edge
  - Limiting case of the abrupt contraction ($A_2 / A_1 = 0$, since A_1=infinite)
  - K_L is 0.5 in turbulent flow
- Re-entrant
  - In the thin wall of pipe, due to the vena contracta large deceleration loss.
  - In the thick wall, vana contracta becomes larger and the loss coefficient less than 0.8.

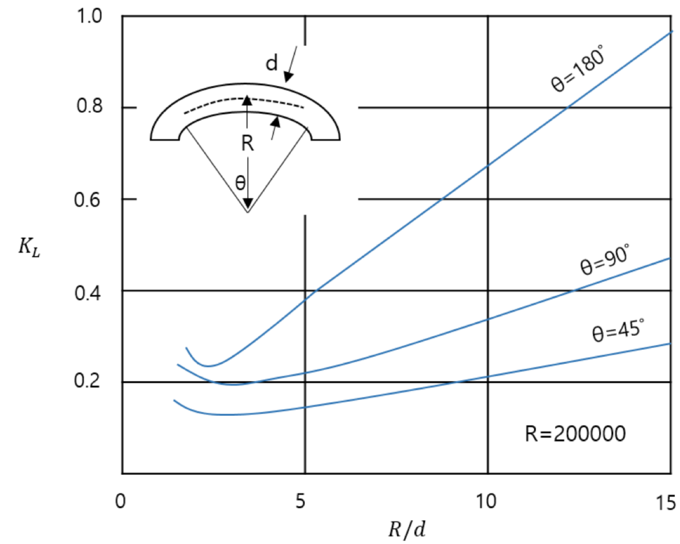




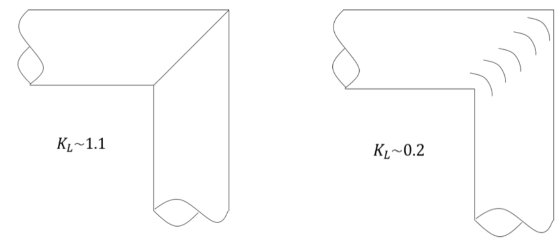


- Bell mouth entrance can prevent vena contracta (R>0.14d)
- Gradual contraction can reduce loss to 0.02~0.04

Local Losses in pipelines



- Losses of head in smooth pipe bends are caused by the combined effects of separ ation, wall friction and the twin-eddy seco ndary flow.
- For bends of large radius of curvature, th e last two effects will predominate,
- Whereas, for small radius of curvature, s eparation and the secondary flow will be the more significant.
- K_L minimum at a certain value of R/d.



Miter fit needs to special design for breaking stream line

- As a conclusion, if we can break up the large scale turbulence afte r separation, then we can reduce the head loss