Fluid Friction

- The H408 Fluid Friction Apparatus

UTD Mechanical Engineering

Fluids Lab (MECH 3115)

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Outline

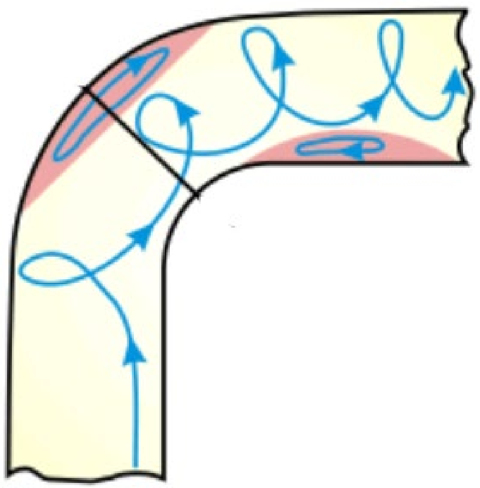
- Fluid friction
- Experimental instruments/apparatus
- Experimental procedure
- Data collection
- Data analysis
- Results and discussion

Introduction to fluid friction

- When the fluid is viscid, 'sticky', if there is velocity difference within water 'particles' or between water particle and other surface (wall), friction will occur (shear force).
- Friction will cause energy dissipated into the environment instead of keeping the energy within the fluid.
- The energy 'lost' to the environment is quantified by friction loss.
- Friction factor, *f* and loss coefficient ,*k* can give us a general ideal of the friction loss in current internal pipe system.
- Further, by understanding friction loss, optimized pipe system can be designed to meet human needs.
- There is *always* frictional loss (head loss) in internal flow of a **viscous fluid.**

Introduction to fluid friction

- This loss can be intensified by roughening the pipe, changing direction in the flow sharply, or introducing different geometries into the path.
- Friction factor, *f* - Lewis Moody created an empirical chart that allowed us to calculate the expected loss as a function of roughness/diameter and Reynolds number for **straight pipe** only (major loss).
  - Loss coefficients must be handled as localized losses (minor loss).



Experiment apparatus

Cautions:

- At least one exit valve needs to be open before opening the inlet valve.
- Only the channel for the current interest needs to be open, every other exit valve remain closed.
- When switch to a different channel, open the designated exit valve first, then close the previous one.
- Watch out for water spill from the piezometer.

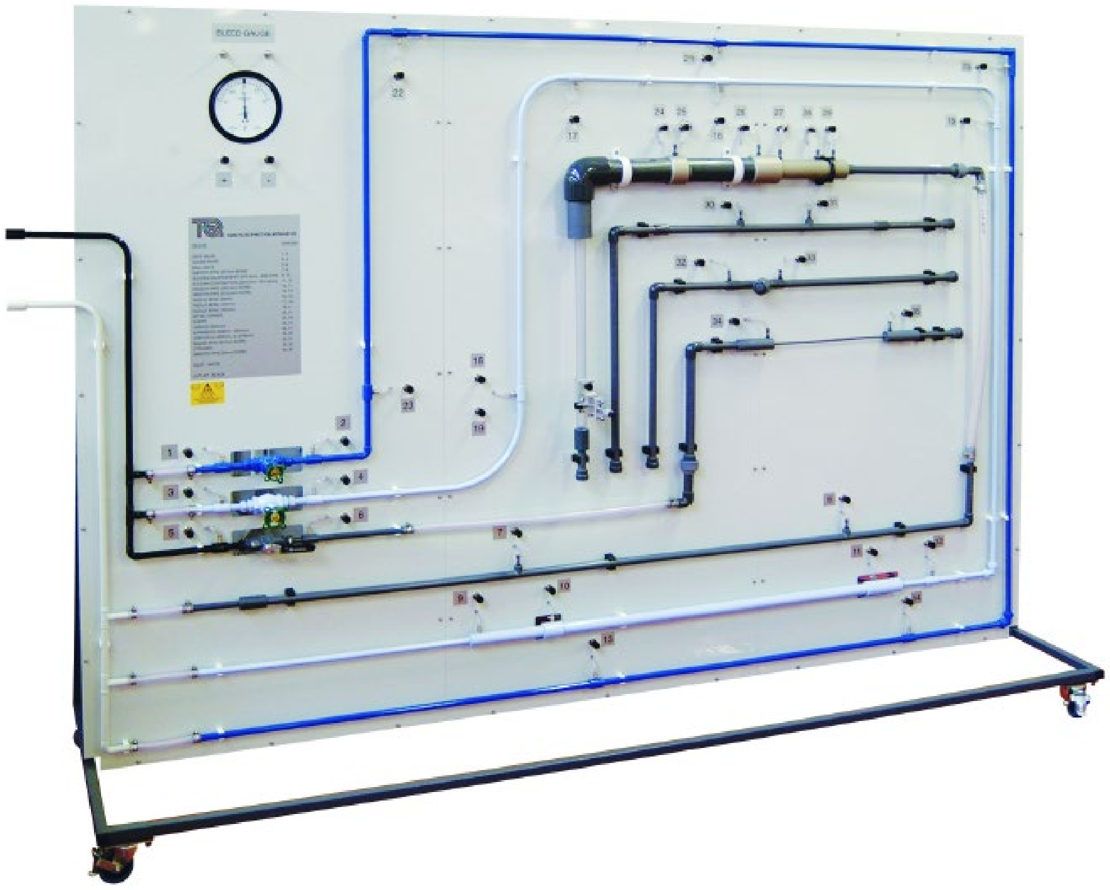


Figure 1 The H408 Fluid Friction Apparatus

Experimental Procedure

1. Start the flow bench.
2. Adjust the valve on the flow bench to your desired flowrate, and make sure at least one outlet valve is open.
3. Open the flow through the section of pipe you wish to measure head loss through (ensure all other pipes are closed)
4. Record the readings in piezometer, Δh.
5. Repeat 2-4 for different sections.
6. Repeat 2-5 for different flow rates.

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Data Collection

- Data you record
  - Difference in pressure heads, Δh for:
    - Smooth pipe (Dark Blue Pipe Tapping #13-#14)
    - Rough pipe (Gray Pipe Tapping #30-#31)
    - Radial Bend (Sky Blue Pipe Tapping #15 - #16)
  - Volume flow rate from the flowmeter, Q

Description of Parts:

Item	Details	Tapping Numbers	Distances Between Tappings
Smooth Pipe	17 mm Diameter Bore	7,8	912 mm
Smooth Pipe	26.2 mm Diameter Bore	10,11	912 mm
Smooth Pipe	13.6 mm Diameter Bore	13,14	912 mm
Radius Bend	50 mm	15,16	920 mm
Radius Bend	100 mm	17,18	864 mm
Radius Bend	150 mm	19,4	652 mm
Rough Pipe	17 mm Diameter Bore 14 mm Effective Diameter	30,31	200 mm
Smooth Pipe	4 mm Diameter Bore	34,35	350 mm

Data Collection

	Section (Tapping Numbers)	Q (Flow rate)	d [m] (pipe inner diameter)	l [m] (Section length)	$H1$ [mm] (from the piezometer)	$H2$[mm] (from the piezometer)	Δh [mm]
Flow rate 1	#13 - #14 Smooth Tube						
	#30-#31 Rough Tube						
	#15 - #16 Radial Bend						
Flow rate 2	#13 - #14 Smooth Tube						
	#30-#31 Rough Tube						
	#15 - #16 Radial Bend						
Flow rate 3	#13 - #14 Smooth Tube						
	#30-#31 Rough Tube						
	#15 - #16 Radial Bend						

Data Analysis

Flow rate#	Section (Tapping Numbers)	*Q* [L/min]	*d* [m]	*l* [m]	Δh [mm]	***u*** [m/s]	***Re***	$f_{Emp.}$	$f_{Exp.}$
1	13,14 Smooth Tube						Hint: *v* is the fluid viscosity	Hint: Empirical friction factor from Moody Chart	Hint: Experimental friction factor from measured Δh
	30, 31 Rough Tube					$u = \frac{Q}{\pi d^2/4}$	$Re = \frac{ud}{v}$		$f_{Exp.} = \frac{gd(\Delta h)}{2lu^2}$
2	13,14 Smooth Tube								
	30, 31 Rough Tube								
3	13,14 Smooth Tube								
	30, 31 Rough Tube								

- Notice unit conversions

Data Analysis

Flow rate#	Section (Tapping Numbers)	Q [L/min]	d [m]	l [m]	Δh [mm]	u [m/s]	Re	$f_{Emp.}$	Δh_{pipe} [mm]	Δh_{bend} [mm]	$k_{b\,Emp.}$	$k_{b\,Exp.}$
1	15, 16 Radial Bend				From the piezometer		Hint: v is the fluid viscosity	Hint: Empirical friction factor for smooth pipe from Moody Chart	Hint: Head loss for due to pipe length from $f_{\mathrm{Emp.}}$		Hint: Babcock & Wilcox Figure	Hint: Experimental bend loss coefficient from Δh_{bend}
2	15, 16 Radial Bend					$u = \frac{Q}{\pi d^2/4}$	$Re = \frac{ud}{v}$		$\Delta h_{pipe} = \frac{2lu^2 f_{Emp.}}{gd}$	$\Delta h_{bend} = \Delta h - \Delta h_{pipe}$		$k_{b\,Exp.} = \frac{2g(\Delta h_{bend})}{u^2}$
3	15, 16 Radial Bend											

- Notice unit conversions

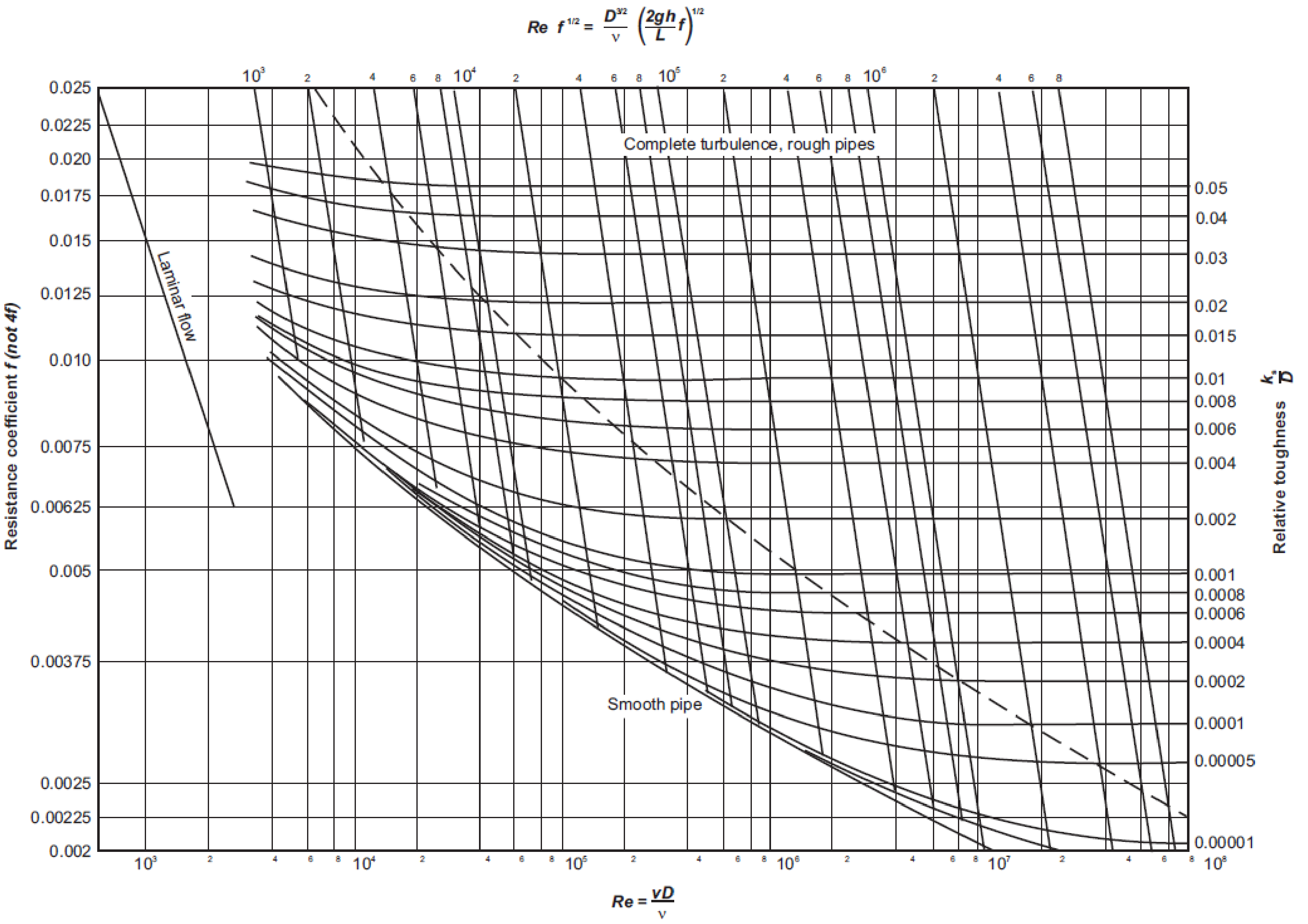
Moody chart for straight pipe

- Transition region
  - 2300 ~ 4000

- Friction factor for smooth pipe:
  - Laminar: $f = \frac{16}{Re}$
  - Turbulent (Blasius correlation):

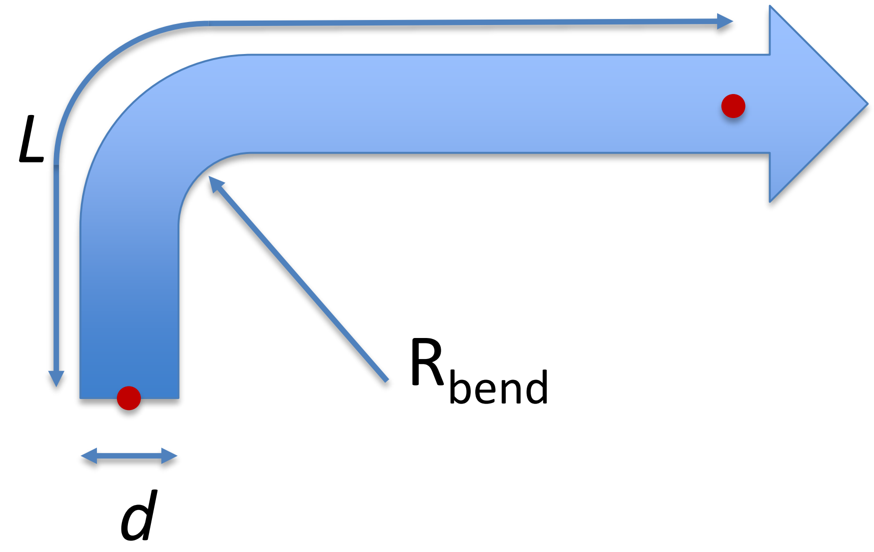
$$f = 0.079/(Re^{0.25})$$

Figure 13 Moody Chart



Please check lab manual <Fluid Friction Apparatus – Long> page 16 and 17 for Ks/d and a detailed Moody chart

Babcock & Wilcox Figure for Radial Bends



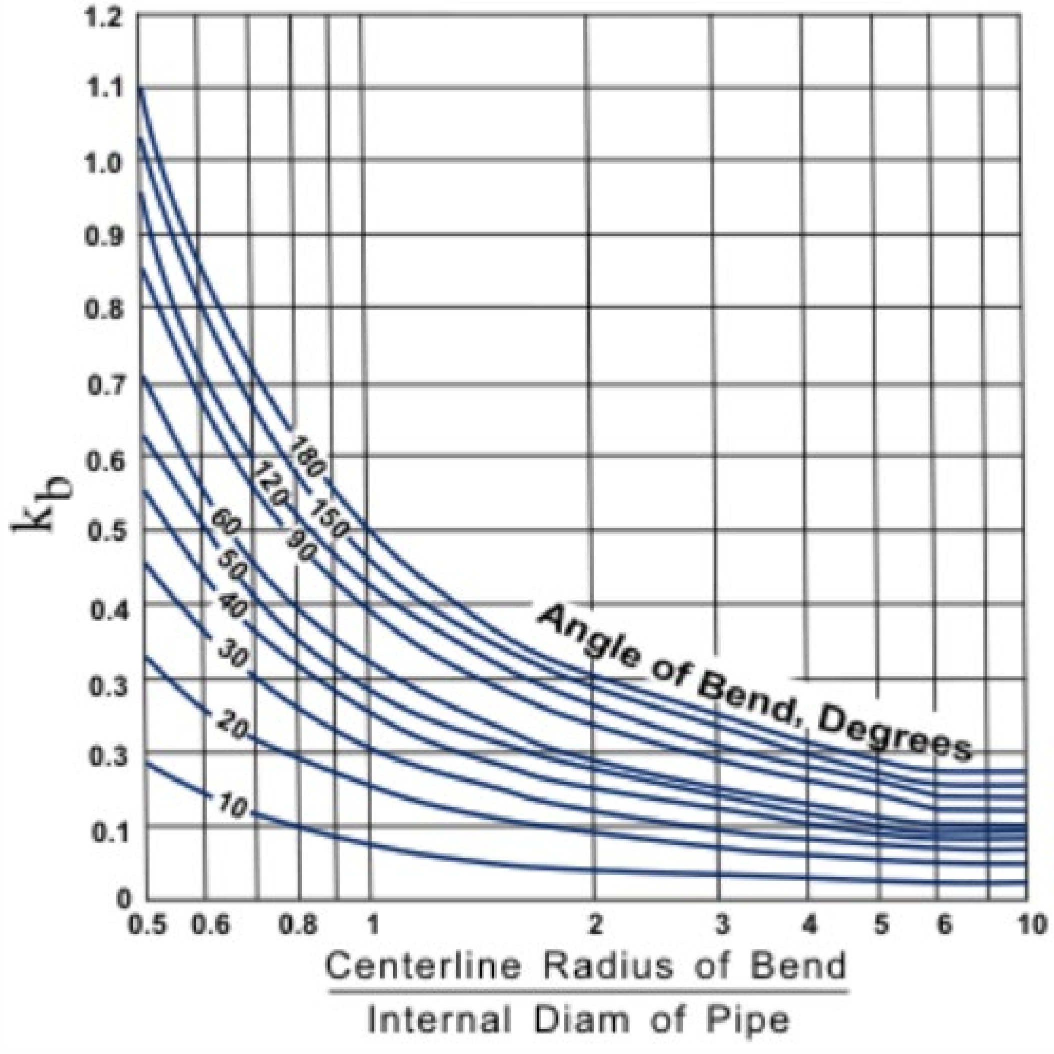


Figure 3. Bend loss coefficients for a pipe (Babcock & Wilcox Co., 1978).

Results and discussion

- The table of data
- Discussion of the data
- For the straight pipe, plot calculated friction factor ($f_{Exp.}$) vs Re for all flowrates; in the same plot, also plot function $f = 0.079/(Re^{0.25})$
- Discuss the plot you created.
- On the second data analysis table, there is a huge difference between the Experimental and Empirical values of Loss Coefficient (k_b). What is the main reason for this error?
- Do instrumental error analysis for one data point of your choice.

The end.