Pressure Drop Estimation in Pipelines

(Analytical Modeling and Validation using MATLAB, Python, Excel, Aspen HYSYS & DWSIM)

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Agenda

1. Problem Statement
2. Fluid Mechanics Fundamentals
3. Darcy–Weisbach Equation
4. Flow Regimes & Friction Factor Models
5. Pipeline Roughness & Material Selection
6. Minor Losses
7. Validation with Moody Chart
8. Engineering Methodology & Workflow
9. Demo Outputs (Python, Matlab, Excel, DWSIM, Aspen Hysys)
10. Limitations
11. Summary

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Problem Statement

Objective:
Develop and validate a computational model to estimate pressure drop in pipelines under different flow and material conditions.

Engineering Value:

- Enables quick estimation before simulation
- Useful for pump sizing
- Reduces energy consumption
- Helps avoid undersizing/oversizing during design

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Fluid Transport Fundamentals

Key Quantities:

- Flow rate (Q)
- Cross-sectional area (A)
- Velocity (v)
- Density (ρ)
- Viscosity (μ)
- Pipe diameter (D)
- Length (L)

Formula:

$$A = \frac{\pi D^2}{4}, v = \frac{Q}{A}$$

Concept: Higher velocity increases frictional resistance → higher pressure drop.

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Darcy–Weisbach Equation

$$\Delta p = f \cdot \frac{L}{D} \cdot \frac{\rho v^2}{2}$$

Where:

- f = friction factor
- L = pipe length
- D = pipe diameter
- v = velocity
- ρ = fluid density

Interpretation:

Pressure drop is proportional to:

- Length
- Velocity^2
- Friction factor

Inversely proportional to diameter

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Flow Regimes (Reynolds Number)

$$Re = \frac{\rho v D}{\mu}$$

Regimes:

- **Laminar:** Re < 2300
- **Transitional:** 2300–4000
- **Turbulent:** Re > 4000

Engineering Insight:
Most industrial flows are turbulent → friction factor depends on *roughness* + *Re*.

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Friction Factor Models

Laminar Flow

$$f = \frac{64}{Re}$$

Turbulent Flow (Swamee–Jain)

Explicit formula:

$$f = 0.25\left[\log_{10}\left(\frac{\varepsilon}{3.7D} + \frac{5.74}{Re^{0.9}}\right)\right]^{-2}$$

Turbulent Flow (Colebrook Equation)

Implicit equation (iterative):

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{\varepsilon}{3.7D} + \frac{2.51}{Re\sqrt{f}}\right)$$

Note: Colebrook is more accurate but requires iteration; Swamee–Jain is explicit and fast.

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Pipe Roughness (ε) Values

Material	ε (m)	Notes
PVC	1.5e-6	Smooth
Copper	1.5e-6	Very smooth
Stainless Steel	4.5e-5	Standard engineering value
Commercial Steel	4.5e-5	Used widely in industries
Concrete	3e-3	Very rough

Importance:

- Roughness directly affects turbulent friction → huge impact on pressure drop.
- Roughness has negligible effect in laminar flow but significantly increases pressure drop in turbulent flow.

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Minor Losses (K-values)

$$\Delta p_{minor} = K \cdot \frac{\rho v^2}{2}$$

Component	K-value	Meaning
90° Bend	0.75	Change in direction
Gate Valve (open)	0.15	Small loss
Sudden Expansion	1.0	High loss
Entrance	0.5	Sharp-edged entry

Engineer Tip:
In short pipelines, minor losses can exceed frictional losses → never ignore.

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Total Pressure Drop

$$\Delta p_{total} = \Delta p_{friction} + \Delta p_{minor}$$

Combine both effects for accurate design.

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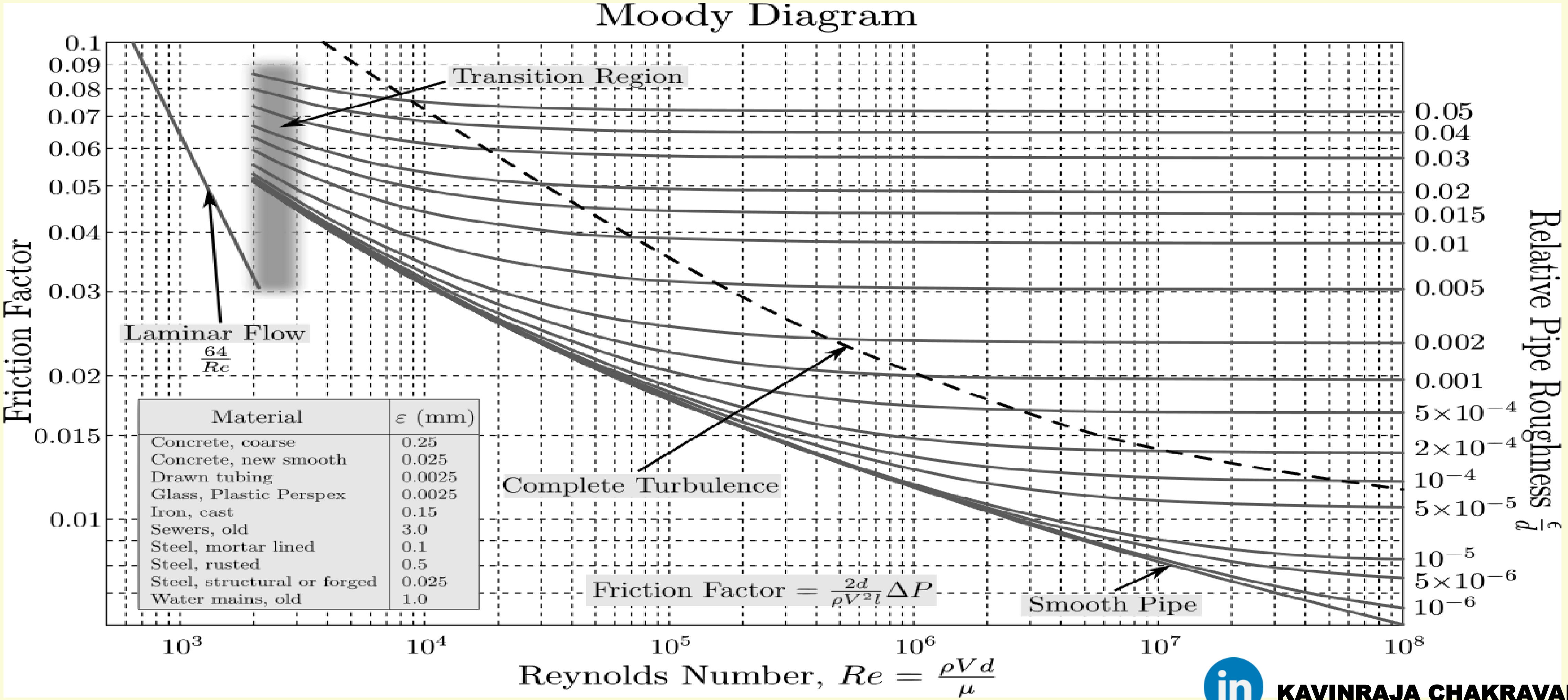
Validation with Moody Chart



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Engineering Algorithm & Computational Workflow(Python,Matlab)

Inputs → **Calculations** → **Outputs**

- Input: Q, D, L, ρ, μ, ε, K-list
- Compute A
- Compute v
- Compute Re
- Determine flow regime
- Compute f (laminar / Swamee–Jain / Colebrook)
- Compute $\Delta p_{friction}$
- Compute Δp_{minor}
- Output results

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Python Demo Outputs

Output

```
==================================================
 PRESSURE DROP IN A STRAIGHT PIPE
 Darcy–Weisbach Method
==================================================
Enter volumetric flow rate Q (m^3/s): 0.002784861111
Enter pipe diameter D (m): 0.1143
Enter pipe length L (m): 500
Enter fluid density rho (kg/m^3): 997.452
Enter fluid viscosity mu (Pa.s): 0.000889873
Enter pipe roughness epsilon (m): 0.000045
Enter number of fittings / minor losses: 1
Enter K-value for fitting 1: 0.5

Select friction factor method:
1 → Swamee–Jain (Explicit)
2 → Colebrook (Iterative)
Enter choice (1 or 2): 1

================ RESULTS ================
Flow regime              : Turbulent Flow
Velocity (m/s)           : 0.2714
Reynolds number          : 3.477e+04
Friction factor (f)      : 0.02382
Δp (friction) (Pa)       : 3828.33
Δp (minor) (Pa)          : 18.37
Δp (total) (Pa)          : 3846.70
==========================================
```

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Matlab Demo Outputs

Command Window

```
Pressure_Drop_Estimation_in_Pipelines
==================================================
 PRESSURE DROP IN A STRAIGHT PIPE
 Darcy-Weisbach Method
==================================================
Enter volumetric flow rate Q (m^3/s): 0.002784861111
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=========================================
fx >>
```

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Excel Demo Outputs

Pressure Drop Estimation in Pipelines

USER INPUT			
Parameter	**Symbols**	**Value**	**Units**
Fluid Density	ρ	997.452	kg/m^3
Dynamic Viscosity	μ	0.00089	Pa.s
Pipe Diameter	D	0.1143	m
Pipe Length	L	500	m
Flow Rate	Q	0.00278	m^3/s
Pipe Roughness	ε	4.5E-05	m
K-values	K	0.5	-

REFERENCE

Pipe Roughness (ε) Values		
Material	**ε (m)**	**Notes**
PVC	1.50E-06	Smooth
Copper	1.50E-06	Very smooth
Stainless Steel	4.50E-05	Standard engineering value
Commercial Steel	4.50E-05	Used widely in industries
Concrete	3.00E-03	Very rough

Minor Losses (K-values)		
Component	**K-value**	**Meaning**
90° Bend	0.75	Change in direction
Gate Valve (open)	0.15	Small loss
Sudden Expansion	1	High loss
Entrance	0.5	Sharp-edged entry

Determine Flow Regime					
Area(A)	0.01026	m^2	Reynolds Number (Re)	34789.8	
Velocity (v	0.27154	m/s			
			Friction Factor(f)	0.02382	

Darcy–Weisbach Equation		
$\Delta p_{friction}$	3831.83	pa
Minor Losses		
Δp_{minor}	18.3872	pa

Total Pressure Drop		
Δp_{total}	3850	pa

Pressure drop is calculated using the Darcy-Weisbach equation, with friction factors derived from f=64/Re for laminar flow and the explicit Swamee-Jain approximation for turbulent flow to enable direct, non-iterative computation.

Created by Kavinraja Chakravarthy

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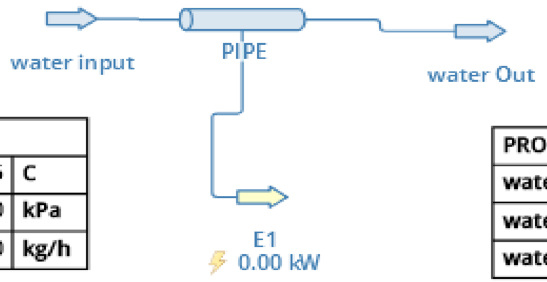
DWSIM Outputs

Pressure Drop Estimation in Pipelines



PROPERTIES TABLE			
water input	Temperature	25	C
water input	Pressure	1000	kPa
water input	Mass Flow	10000	kg/h

PROPERTIES TABLE			
water Out	Temperature	25.0012	C
water Out	Pressure	993.397	kPa
water Out	Mass Flow	10000	kg/h

PROPERTIES TABLE			
PIPE	Total Length (Straight Tubes)	500	m
PIPE	Total Elevation (Straight Tubes)	0	m
PIPE	HydraulicSegment,1,Elevation	0	m
PIPE	HydraulicSegment,1,InternalDiameter	102.3	mm
PIPE	HydraulicSegment,1,ExternalDiameter	114.3	mm

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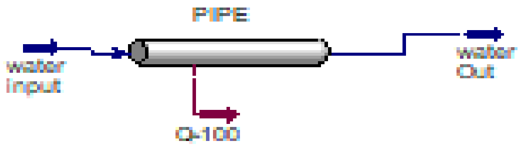
Aspen Hysys Outputs

Pressure Drop Estimation in pipelines

water input		
Temperature	25.00	C
Pressure	1000	kPa
Mass Flow	1.000e+004	kg/h



PIPE		
Inside Diameter(1)	102.3	mm
Outside Diameter(1)	114.3	mm
Pipe length(1)	500.0	m
Elevation(1)	0.0000	m
Fitting Type(1)	Pipe	
Material Type (Material Type_1)	Mild Steel	

water Out		
Temperature	25.00	C
Pressure	993.4	kPa
Mass Flow	1.000e+004	kg/h

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Limitations

- Assumes incompressible flow
- Single pipe only (no network)
- No temperature correction for fluid properties
- Transitional flow not modeled accurately
- Roughness constant (no aging/scaling)
- Assumes steady-state, single-phase flow

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Summary

- Darcy–Weisbach provides reliable pressure drop estimation
- Friction factor selection is critical and regime-dependent
- Analytical results were validated using multiple software tools
- The project demonstrates strong fundamentals in fluid mechanics and process simulation

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GitHub Repository: https://github.com/kavinrajachakravarthy/Pressure-Drop-Estimation-in-Pipelines

linkedin: https://www.linkedin.com/in/kavinraja-chakravarthy

Thank You

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