Bingham Plastic Pipe Flow: Hedström Number and Pressure Drop

Pressure drop of a Bingham plastic in a pipe: Buckingham–Reiner laminar solution, Hedström number and Darby's turbulent and combined friction factor.

Method: Perry's Chemical Engineers' Handbook; 9th ed. (McGraw-Hill, 2019); ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Yield stress	10.000	Pa
Plastic viscosity	50.000	cP
Density	1,300.0	kg/m³
Pipe inside diameter	102.30	mm
Mean velocity	1.5000	m/s
Pipe length	100.00	m

Calculated results

Parameter	Value	Unit
Bingham Reynolds number	3,989.7	
Hedström number	54,420	
Laminar Fanning friction factor	0.012778	
Turbulent Fanning friction factor (Darby)	0.006176	
Combined friction factor	0.012778	
Pressure drop	73.071	kPa

Notes for this case

- The combined factor follows the laminar value at low Re_B and the turbulent value at high Re_B. Rheology from a viscometer at the pipe's shear rates governs the accuracy.

Formula and method

$$\frac{8V}{D}=\frac{\tau_w}{\mu_p}\left(1-\frac{4}{3}\xi+\frac{1}{3}\xi^4\right),\ \xi=\frac{\tau_y}{\tau_w},\quad f_L=\frac{2\tau_w}{\rho V^2},\quad He=\frac{\rho D^2\tau_y}{\mu_p^2}$$

$$f_T=\frac{10^a}{Re_B^{0.193}},\ a=-1.47\left[1+0.146e^{-2.9\times10^{-5}He}\right],\quad f=(f_L^m+f_T^m)^{1/m},\ m=1.7+\frac{40000}{Re_B}$$

Variables

τ_y	Yield stress	Pa
μ_p	Plastic viscosity	Pa·s
ρ	Density	kg/m³
D	Pipe inside diameter	m
V	Mean velocity	m/s
L	Pipe length	m
Re_B	Bingham Reynolds number	-
He	Hedström number	-
f_L	Laminar Fanning friction factor	-

f_T	Turbulent Fanning friction factor (Darby)	-
f	Combined friction factor	-
Δp	Pressure drop	Pa

Method and standards

Buckingham–Reiner laminar solution and Darby's combined correlation.

Assumptions and limits

- Bingham model; smooth pipes only (Darby's turbulent correlation has no roughness term).
- The laminar–turbulent transition Reynolds number, which rises with He, is not reported; the combined factor bridges the two regimes.

References

• Perry's Chemical Engineers' Handbook
• 9th ed. (McGraw-Hill, 2019)
• sec. 6
• Eqs. (6-66) and (6-67) and Table 6-9 (Bingham plastics, Hedström number)
• Buckingham–Reiner laminar solution; Darby
• Mun and Boger (1992)
• Chem. Eng. 99(9): 116 (turbulent and combined friction factor)

Report details

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This calculator online

https://calc.firecad.com/mechanical/fluid-mechanics/bingham-plastic-pipe-flow

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Reopens the calculator with the inputs of this report.