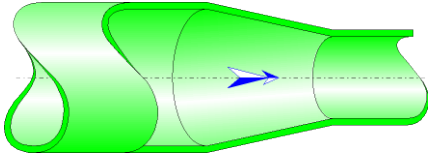




Gradual Contraction Circular Cross-Section (IDELCHIK)



Model description:

This model of component calculates the head loss (pressure drop) generated by the flow in a gradual contraction.

The head loss by friction in the inlet and outlet piping is not taken into account in this component.

Model formulation:

Top angle of cone (°):

$$\alpha = 2 \cdot \tan^{-1} \left(\frac{D_1 - D_0}{2 \cdot l} \right)$$

Minor cross-sectional area (m²):

$$F_0 = \pi \cdot \frac{D_0^2}{4}$$

Major cross-sectional area (m²):

$$F_1 = \pi \cdot \frac{D_1^2}{4}$$

Cross-sections ratio:

$$n_0 = \frac{F_0}{F_1}$$

Mean velocity in minor diameter (m/s):

$$w_0 = \frac{Q}{F_0}$$

Mean velocity in major diameter (m/s):

$$w_1 = \frac{Q}{F_1}$$

Mass flow rate (kg/s):

$$G = Q \cdot \rho$$

Fluid volume in the truncated cone (m³):

$$V = N \cdot \frac{\pi}{3} \cdot \left(\left(\frac{D_0}{2} \right)^2 + \left(\frac{D_1}{2} \right)^2 + \left(\frac{D_0}{2} \right) \cdot \left(\frac{D_1}{2} \right) \right)$$

Fluid mass in the truncated cone (kg):

$$M = V \cdot \rho$$

Reynolds number in minor diameter:

$$Re_0 = \frac{w_0 \cdot D_0}{\nu}$$

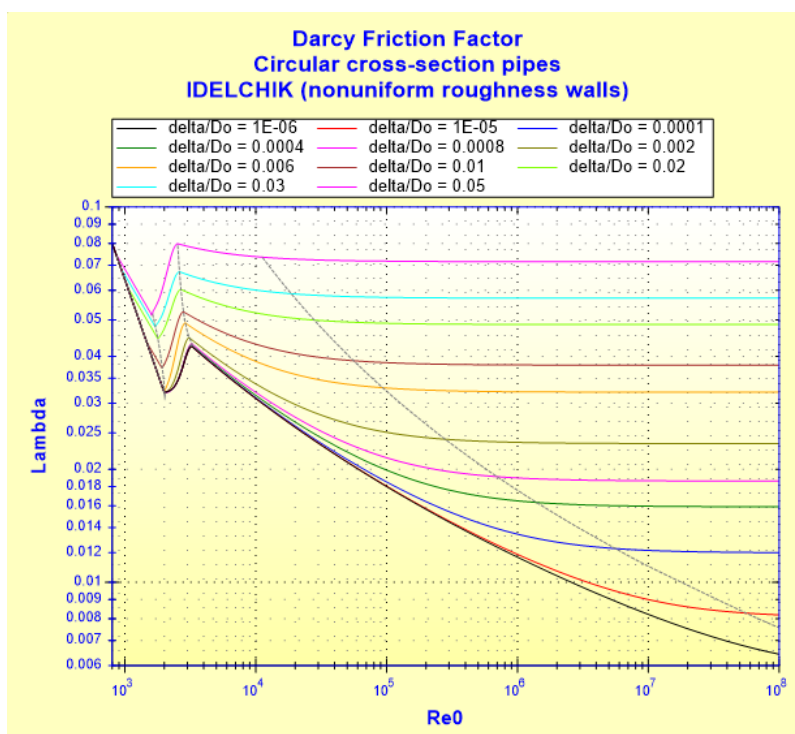
Reynolds number in major diameter:

$$Re_1 = \frac{w_1 \cdot D_1}{\nu}$$

Darcy friction factor:

$$\lambda = f \left(Re_0, \frac{\Delta}{D_0} \right)$$

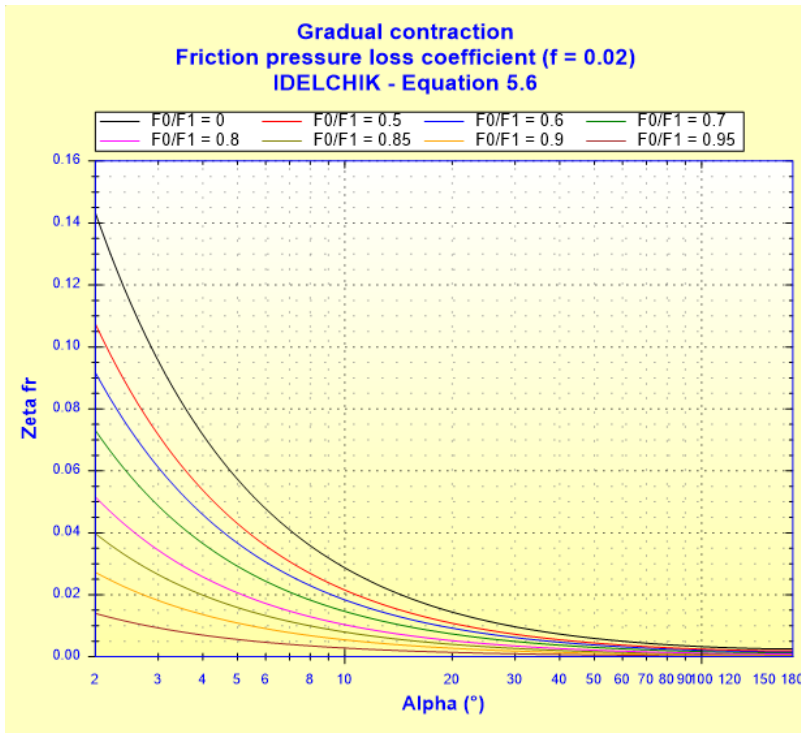
See [Straight Pipe - Circular Cross-Section and Nonuniform Roughness Walls \(IDELCHIK\)](#)



Friction resistance coefficient:

$$\zeta_{fr} = \frac{\lambda}{8 \cdot \sin(\alpha/2)} \cdot \left[1 - \left(\frac{F_0}{F_1} \right)^2 \right]$$

([1] equation 5.6)



([1] equation 5.6 with $\lambda = 0.02$)

Local resistance coefficient:

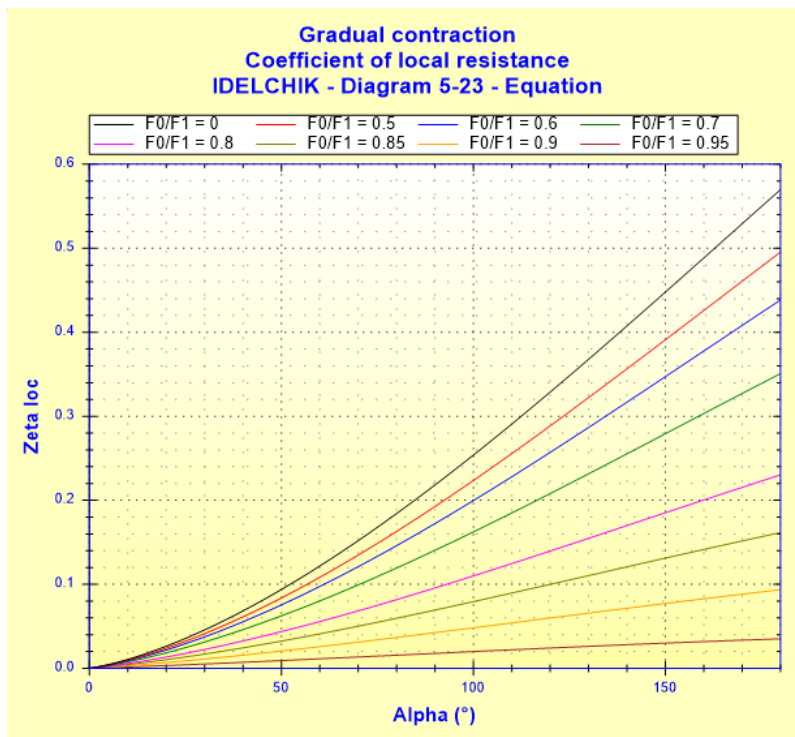
$$\zeta_{loc} = (-0.0125 \cdot n_0^4 + 0.0224 \cdot n_0^3 - 0.00723 \cdot n_0^2 + 0.00444 \cdot n_0 - 0.00745) \cdot (\alpha_r^3 - 2 \cdot \pi \cdot \alpha_r^2 - 10 \cdot \alpha_r)$$

([1] diagram

5.23 (1))

with:

$$\alpha_r = 0.01745 \cdot \alpha$$



Total pressure loss coefficient (based on mean velocity in minor diameter):

$$\zeta = \zeta_{loc} + \zeta_{fr}$$

Total pressure loss (Pa):

$$\Delta P = \zeta \cdot \frac{\rho \cdot w_0^2}{2}$$

Total head loss of fluid (m):

$$\Delta H = \zeta \cdot \frac{w_0^2}{2 \cdot g}$$

Hydraulic power loss (W):

$$Wh = \Delta P \cdot Q$$

Symbols, Definitions, SI Units:

D_0	Minor diameter (m)
D_1	Major diameter (m)
α	Top angle of cone (°)
l	Truncated cone length (m)
F_0	Minor cross-sectional area (m ²)
F_1	Major cross-sectional area (m ²)
n_0	Cross-sections area ratio ()
w_0	Mean velocity in minor diameter (m/s)
w_1	Mean velocity in major diameter (m/s)
Q	Volume flow rate (m ³ /s)
G	Mass flow rate (kg/s)
V	Fluid volume in the truncated cone (m ³)

M	Fluid mass in the truncated cone (kg)
Re ₀	Reynolds number in minor diameter ()
Re ₁	Reynolds number in major diameter ()
Δ	Absolute roughness of walls (m)
$\bar{\Delta}$	Relative roughness of walls ()
λ	Darcy friction factor ()
ζ_{loc}	Local resistance coefficient ()
ζ_{fr}	Friction resistance coefficient ()
ζ	Total pressure loss coefficient (based on mean velocity in minor diameter) ()
ΔP	Total pressure loss (Pa)
ΔH	Total head loss of fluid (m)
Wh	Hydraulic power loss (W)
ρ	Fluid density (kg/m ³)
ν	Fluid kinematic viscosity (m ² /s)
g	Gravitational acceleration (m/s ²)

Validity range:

- turbulent flow regime in minor diameter ($Re_0 \geq 10^5$)

Example of application:

The screenshot displays the HydraulCalc 2018b interface for a 'Gradual contraction - IDELCHIK (3rd Ed.)' problem. The software is set to calculate fluid flow through a truncated cone. The fluid is Water @ 1 atm [HC] with a temperature of 20 °C and a pressure of 1.013 bar. The flow is turbulent in the minor diameter section.

Fluid characteristics:

- Fluid: Water @ 1 atm [HC]
- Temperature: 20 °C
- Pressure: 1.013 bar
- Density: 998.2061 kg/m³
- Dynamic Viscosity: 0.00100159 N.s/m²
- Kinematic Viscosity: 1.00340E-06 m²/s

Geometrical characteristics:

- Mass flow rate (G): 4.9910 kg/s
- Volume flow rate (Q): 0.005 m³/s
- Minor diameter (D1): 0.0703 m
- Major diameter (D0): 0.0431 m
- Top angle of cone (α): 53.7 °
- Length (l): 0.01 m
- Relative roughness (Δ): 1.0E-05
- Velocity in minor diameter (w1): 1.288 m/s (Turbulent)
- Velocity in major diameter (w0): 3.427 m/s (Turbulent)
- Pressure loss (ΔP): 0.01190738 bar
- Head loss (ΔH): 0.1216 m of fluid

Complementary results:

Designation	Symbol	Value	Unit
Diameters ratio	D0/D1	0.6130868	
Minor cross-section area	F0	0.001458963	m ²
Major cross-section area	F1	0.003881508	m ²
Cross-sections area ratio	F0/F1	0.3758754	
Internal truncated cone volume	V	2.573391E-05	m ³
Mass of fluid in the truncated cone	M	0.02568774	kg
Minor diameter Reynolds number	Re0	147207.5	
Major diameter Reynolds number	Re1	90251	
Top angle of cone	α	107.3464	°
Relative roughness	$\bar{\Delta}$	0.0002320186	
Darcy Friction Factor	λ	0.01948662	
Friction pressure loss coefficient	ζ_{fr}	0.002596271	
Coefficient of local resistance (Diagram 5-23)	ζ_{loc}	0.2005342	
Pressure loss coefficient (based on velocity in minor diameter)	ζ	0.2031305	
Hydraulic power loss	Wh	5.953692	W

References:

