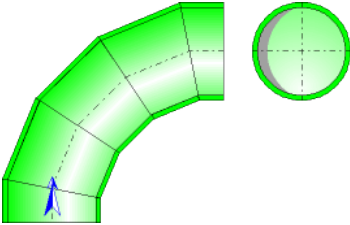




Composite Bend 90° (4 × 22.5°) Circular Cross-Section (IDELCHIK)



Model description:

This model of component calculates the head loss (pressure drop) of a composite bend 90° (4 × 22.5°) whose cross-section is circular and constant. In addition, the flow is assumed fully developed and stabilized at the entrance bend.

Model formulation:

Hydraulic diameter (m):

$$D_h = D_0$$

Cross-section area (m²):

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

Length measured along the axis (m):

$$l = 8 \cdot R_0 \cdot \operatorname{tg}\left(\frac{90^\circ}{8}\right)$$

Mean velocity (m/s):

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

Mass flow rate (kg/s):

$$G = Q \cdot \rho$$

Fluid volume (m³):

$$V = F_0 \cdot l$$

Fluid mass (kg):

$$M = V \cdot \rho$$

Reynolds number:

$$Re = \frac{w_0 \cdot D_h}{\nu}$$

Relative roughness:

$$\bar{\Delta} = \frac{\Delta}{D_0}$$

Coefficient of effect of the roughness:

$$k_{\Delta} = f\left(\frac{R_0}{D_0}, Re, \bar{\Delta}\right) \quad ([1] \text{ diagram 6.1})$$

- $0.50 \leq R_0/D_0 \leq 0.55$

$\bar{\Delta}$	Re	
	$3 \cdot 10^3 - 4 \cdot 10^4$	$> 4 \cdot 10^4$
0	1.0	1.0
0 - 0.001	1.0	$1 + 0.5 \cdot 10^{-3} \cdot \bar{\Delta}$
> 0.001	1.0	1.5

- $R_0/D_0 > 0.55$

$\bar{\Delta}$	Re		
	$3 \cdot 10^3 - 4 \cdot 10^4$	$> 4 \cdot 10^4 - 2 \cdot 10^5$	$> 2 \cdot 10^5$
0	1.0	1.0	1.0
0 - 0.001	1.0	$\lambda_{\Delta} / \lambda_{sm}$	$1 + 10^{-3} \cdot \bar{\Delta}$
> 0.001	1.0	2.0	2.0

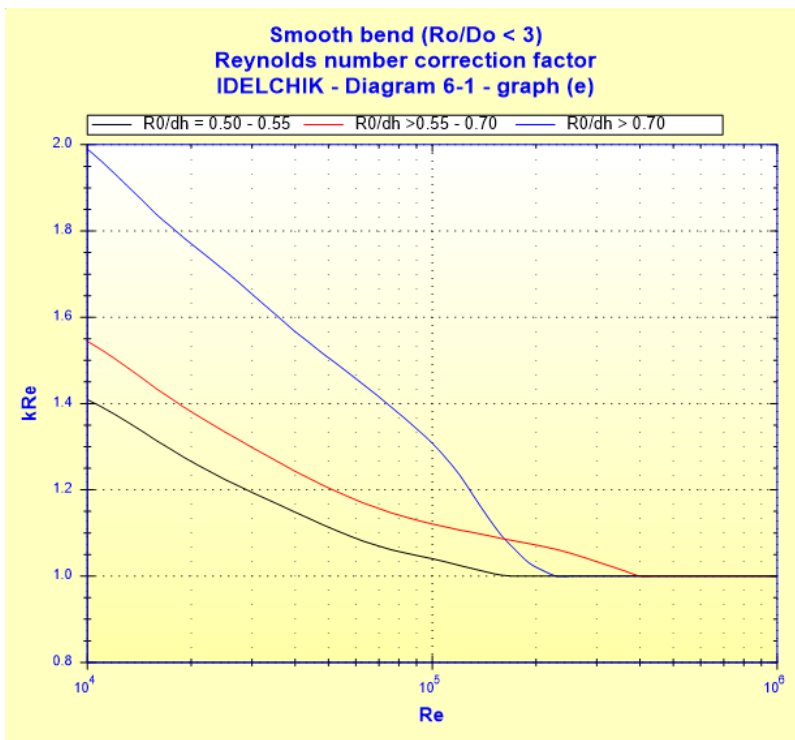
with:

λ_{sm} : Darcy friction factor for hydraulically smooth pipe ($\bar{\Delta} = 0$) at Re

λ_{Δ} : Darcy friction factor for rough pipe ($\bar{\Delta} = \Delta/D_h$) at Re

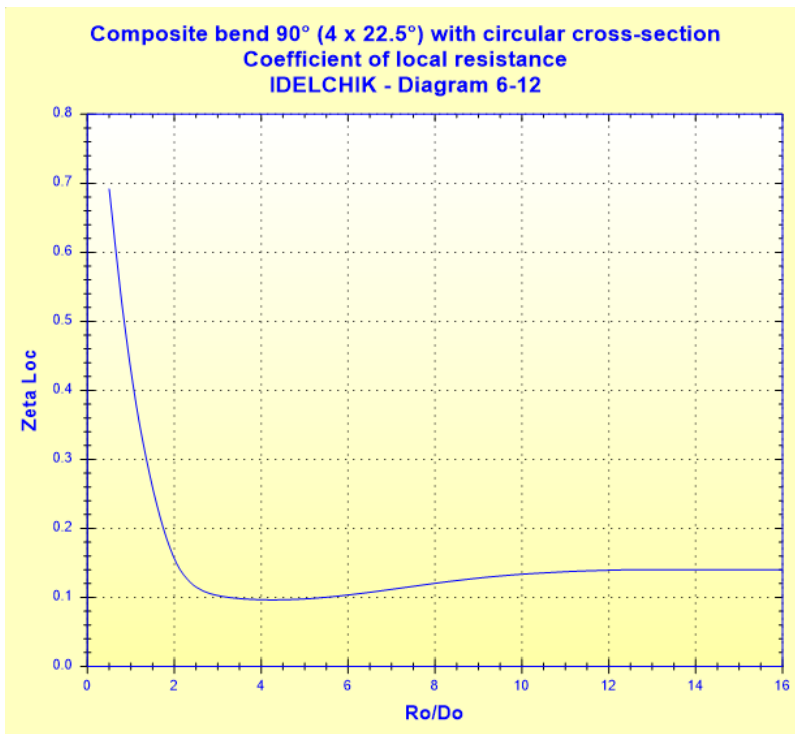
Coefficient of effect of the Reynolds number ($Re \geq 10^4$):

$$k_{Re} = f\left(Re, \frac{R_0}{D_h}\right) \quad ([1] \text{ diagram 6.1})$$



Coefficient of local resistance:

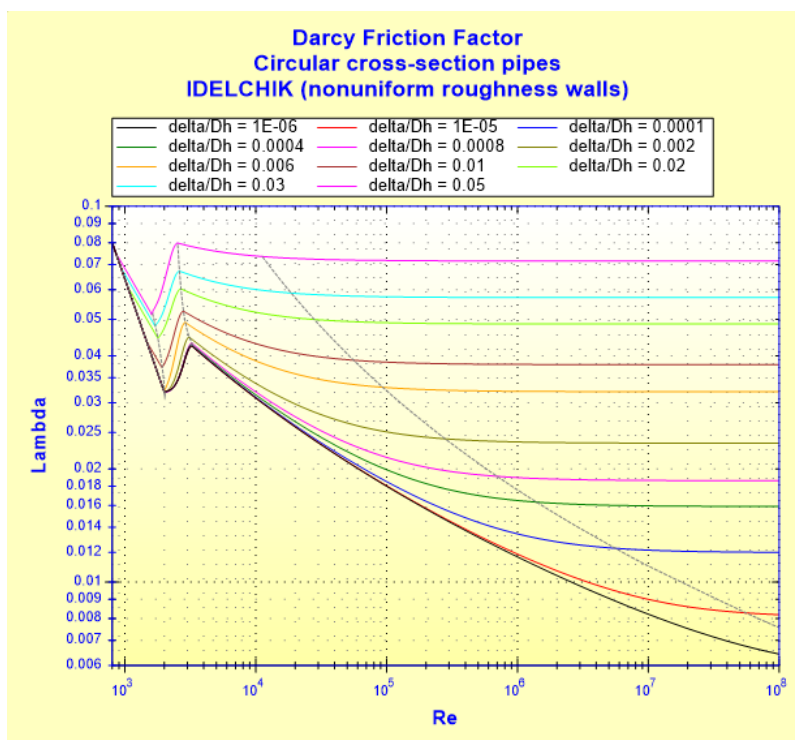
$$\zeta_{loc} = f\left(\frac{R_0}{D_0}\right) \quad ([1] \text{ diagram 6.12})$$



Darcy friction factor:

$$\lambda = f\left(\text{Re}, \frac{\Delta}{D_h}\right)$$

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



Pressure loss friction factor:

$$\zeta_{fr} = \lambda \cdot \frac{l}{D_0} \quad ([1] \text{ diagram 6.12})$$

Corrected pressure loss coefficient:

- $Re \geq 10^4$ (turbulent flow)

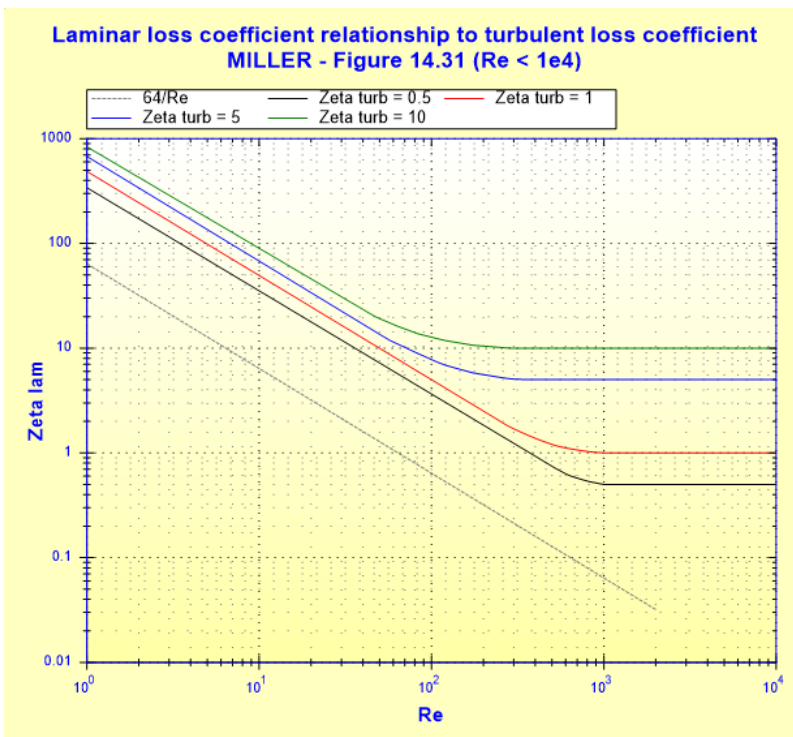
$$\zeta_{turb} = k_{\Delta} \cdot k_{Re} \cdot \zeta_{loc} \quad ([1] \text{ diagram 6.12})$$

- $Re < 10^4$ (laminar flow)

$$\zeta_{lam} = f(\zeta_{turb}, Re) \quad ([2] \text{ figure 14.31})$$

where:

ζ_{turb} is the resistance coefficient in turbulent regime for $Re = 10^4$



Total pressure loss coefficient (based on the mean velocity in the bend):

- Re ≥ 10⁴ (turbulent flow)

$$\zeta = \zeta_{turb} + \zeta_{fr} \quad ([1] \text{ diagram 6.12})$$

- Re < 10⁴ (laminar flow)

$$\zeta = \zeta_{lam} + \zeta_{fr} \quad ([1] \text{ diagram 6.12})$$

Straight length of equivalent pressure loss (m):

$$L_{eq} = \zeta \cdot \frac{D_0}{\lambda}$$

Total pressure loss (Pa):

$$\Delta P = \zeta \cdot \frac{\rho \cdot W_0^2}{2} \quad ([1] \text{ diagram 6.1 - 6.2})$$

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 _h	Bend hydraulic diameter (m)
D ₀	Bend internal diameter (m)
F ₀	Cross-sectional area (m ²)

l	Length measured along the axis (m)
R_0	Radius of curvature (m)
Q	Volume flow rate (m^3/s)
w_0	Mean velocity (m/s)
G	Mass flow rate (kg/s)
V	Fluid volume (m^3)
M	Fluid mass (kg)
Re	Reynolds number ()
Δ	Absolute roughness of walls (m)
$\bar{\Delta}$	Relative roughness of walls ()
k_Δ	Coefficient that allows for the effect of the roughness
k_{Re}	Coefficient that allows for the effect of the Reynolds number
ζ_{loc}	Coefficient of local resistance ()
λ	Darcy friction coefficient ()
ζ_{fr}	Pressure loss friction factor ()
ζ_{turb}	Corrected pressure loss coefficient for $Re \geq 10^4$ ()
ζ_{lam}	Corrected pressure loss coefficient for $Re < 10^4$ ()
ζ	Total pressure loss coefficient (based on the mean velocity in the bend) ()
L_{eq}	Straight length of equivalent pressure loss (m)
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:

- any flow regime: laminar and turbulent
note: for laminar flow regime ($Re < 10^4$), the pressure loss coefficient " ζ_{lam} " is estimated
- stabilized flow upstream bend
- length of the straight section downstream: $\geq 10 D_0$

Example of application:

HydrauCalc 2021a - [Composite bend 90° (4 x 22.5°) with circular cross-section - IDELCHIK (3rd Ed.)]

File Edit Preferences Calculation method Database Tools Help

Fluid characteristics

Fluid : Water @ 1 atm [HC]
Ref.: IAPWS IF97

Temperature : T 20 °C
Pressure : P 1.013 bar

Density : ρ 998.2061 kg/m³
Dynamic Viscosity : μ 0.00100159 N.s/m²
Kinematic Viscosity : ν 1.00340E-06 m²/s

Density Dyn. Visc. Kin. Visc.

Geometrical characteristics

Help Info

Calculate

Pressure loss
 ΔP 0.001923094 bar
 ΔH 0.0196 m of fluid

G 4.9910 kg/s
Q 0.005 m³/s
wo 1.288 m/s (Turbulent)

Complementary results

Designation	Symbol	Value	Unit
Hydraulic diameter	Dh	0.0703	m
Passage cross-section area	F0	0.003881508	m ²
Relative radius of curvature	Ro/Do	2.489331	
Developed straight length from the axis	l	0.2784773	m
Relative roughness	Δ	0.0001422475	
Reynolds number	Re	90251	
<input checked="" type="checkbox"/> Coefficient of local resistance (Diagram 6-12)	ζ_{loc}	0.115557	
Roughness correction (Diagram 6-1)	k_s	1.010951	
<input checked="" type="checkbox"/> Reynolds number correction factor (Diagram 6-1)	k_{Re}	1.340831	
<input checked="" type="checkbox"/> Darcy Friction Factor	λ	0.01907611	
Coefficient of friction resistance	ζ_r	0.07556561	
Resistance coefficient in turbulent flow (Diagram 6-12)	ζ_{turb}	0.1566393	
Pressure loss coefficient (based on the mean bend velocity)	ζ	0.2322049	
Hydraulic power loss	Wh	0.961547	W
Straight length of equivalent pressure loss	Leq	0.8557304	m

References:

- [1] Handbook of Hydraulic Resistance, 3rd Edition, I.E. Idelchik
- [2] Internal Flow System, Second Edition, D.S. Miller