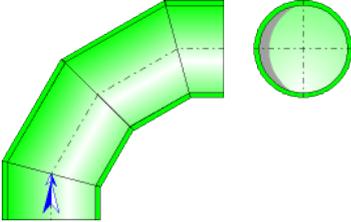




## Composite Bend 90° (3 × 30°) Circular Cross-Section (IDELCHIK)



### Model description:

This model of component calculates the head loss (pressure drop) of a composite bend 90° (3 × 30°) whose cross-section is circular and constant. In addition, the flow is assumed fully developed and stabilized at the entrance bend.

### Model formulation:

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Hydraulic diameter (m):

$$D_h = D_0$$

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Cross-section area (m<sup>2</sup>):

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

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Length measured along the axis (m):

$$l = 6 \cdot R_0 \cdot \operatorname{tg}\left(\frac{90^\circ}{6}\right)$$

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Mean velocity (m/s):

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

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Mass flow rate (kg/s):

$$G = Q \cdot \rho$$

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Fluid volume (m<sup>3</sup>):

$$V = F_0 \cdot l$$

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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

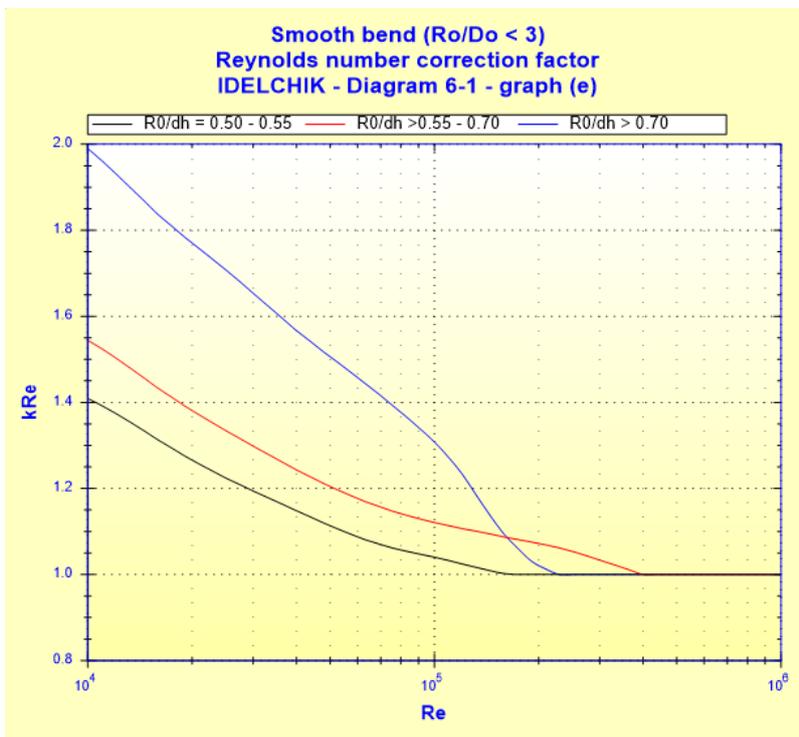
with:

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

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

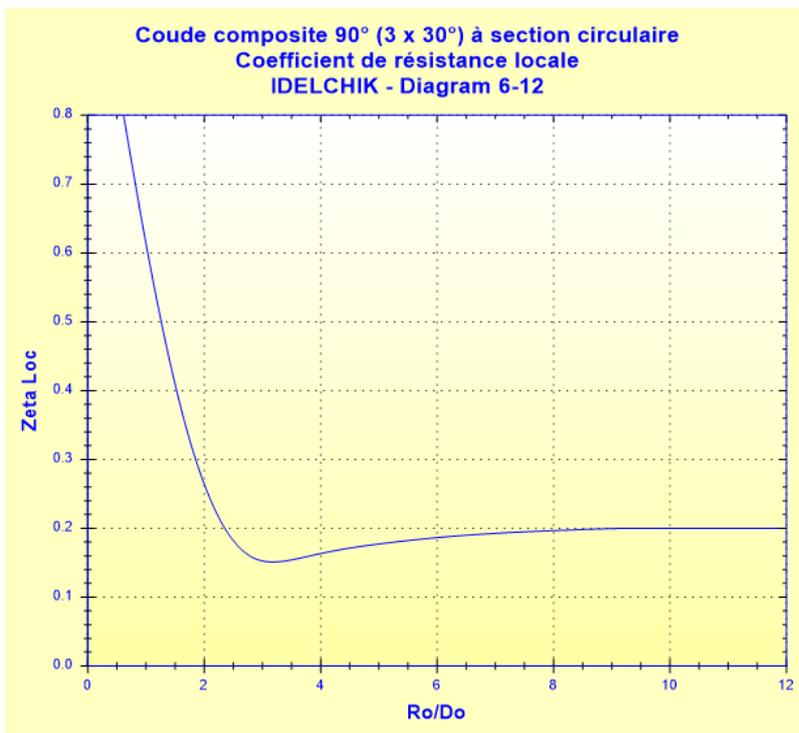
Coefficient of effect of the Reynolds number ( $Re \geq 10^4$ ):

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



Coefficient of local resistance:

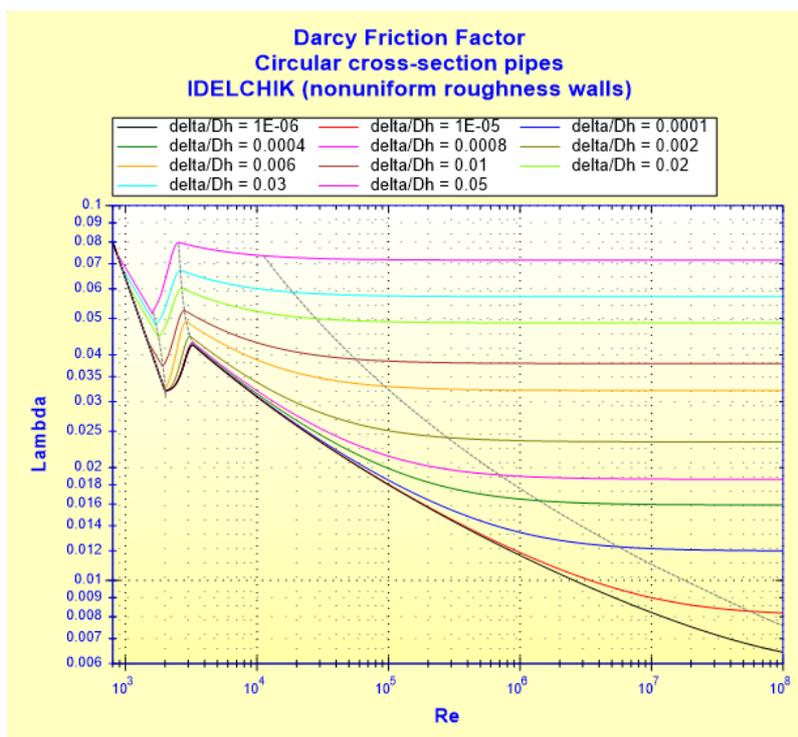
$$\zeta_{loc} = f\left(\frac{R_0}{D_0}\right) \quad ([1] \text{ diagram 6.12})$$



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)

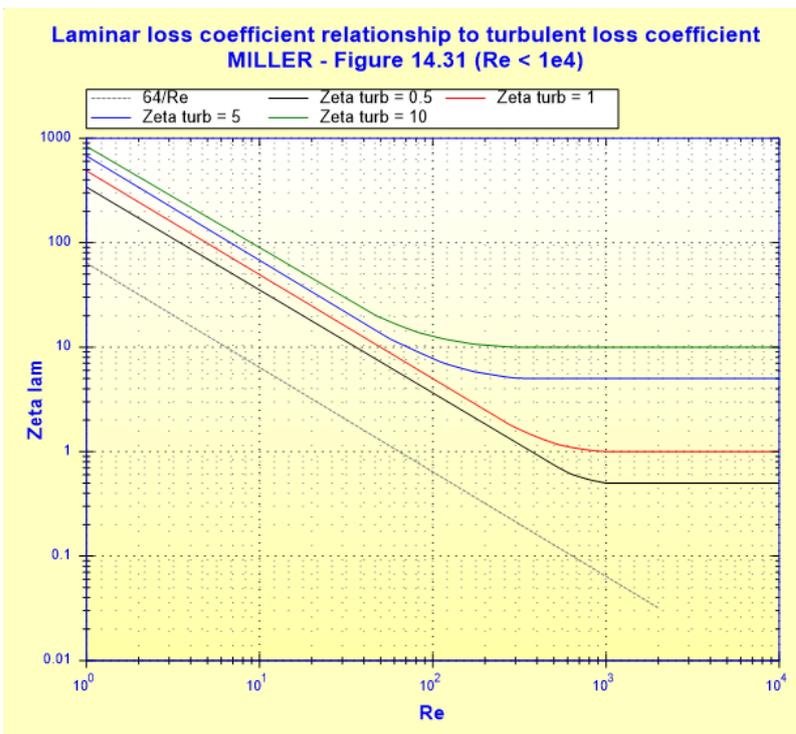
$$\zeta_{turb} = k_{\Delta} \cdot k_{Re} \cdot \zeta_{loc} \quad ([1] \text{ diagram 6.12})$$

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

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

where:

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



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

- Re ≥ 10<sup>4</sup> (turbulent flow)

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

- Re < 10<sup>4</sup> (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 <sub>h</sub>	Bend hydraulic diameter (m)
D <sub>0</sub>	Bend internal diameter (m)
F <sub>0</sub>	Cross-sectional area (m <sup>2</sup> )

$l$	Length measured along the axis (m)
$R_0$	Radius of curvature (m)
$Q$	Volume flow rate ( $\text{m}^3/\text{s}$ )
$w_0$	Mean velocity (m/s)
$G$	Mass flow rate (kg/s)
$V$	Fluid volume ( $\text{m}^3$ )
$M$	Fluid mass (kg)
$Re$	Reynolds number ( )
$\Delta$	Absolute roughness of walls (m)
$\bar{\Delta}$	Relative roughness of walls ( )
$k_{\Delta}$	Coefficient that allows for the effect of the roughness
$k_{Re}$	Coefficient that allows for the effect of the Reynolds number
$\zeta_{loc}$	Coefficient of local resistance ( )
$\lambda$	Darcy friction coefficient ( )
$\zeta_{fr}$	Pressure loss friction factor ( )
$\zeta_{turb}$	Corrected pressure loss coefficient for $Re \geq 10^4$ ( )
$\zeta_{lam}$	Corrected pressure loss coefficient for $Re < 10^4$ ( )
$\zeta$	Total pressure loss coefficient (based on the mean velocity in the bend) ( )
$L_{eq}$	Straight length of equivalent pressure loss (m)
$\Delta P$	Total pressure loss (Pa)
$\Delta H$	Total head loss of fluid (m)
$Wh$	Hydraulic power loss (W)
$\rho$	Fluid density ( $\text{kg}/\text{m}^3$ )
$\nu$	Fluid kinematic viscosity ( $\text{m}^2/\text{s}$ )
$g$	Gravitational acceleration ( $\text{m}/\text{s}^2$ )

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### Validity range:

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

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### Example of application:

HydrauCalc 2021a - [Composite bend 90° (3 x 30°) 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 :  $\rho$  998.2061 kg/m<sup>3</sup>  
Dynamic Viscosity :  $\mu$  0.00100159 N.s/m<sup>2</sup>  
Kinematic Viscosity :  $\nu$  1.00340E-06 m<sup>2</sup>/s

Density  Dyn. Visc.  Kin. Visc.

Geometrical characteristics

Calculate

Pressure loss  
 $\Delta P$  0.0026865 bar  
 $\Delta H$  0.0274 m of fluid

G 4.9910 kg/s  
Q 0.005 m<sup>3</sup>/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 <sup>2</sup>
Relative radius of curvature	Ro/Do	2.489331	
Developed straight length from the axis	l	0.2813466	m
Relative roughness	$\Delta$	0.0001422475	
Reynolds number	Re	90251	
<input checked="" type="checkbox"/> Coefficient of local resistance (Diagram 6-12)	$\zeta_{loc}$	0.1829847	
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	$\lambda$	0.01907611	
Coefficient of friction resistance	$\zeta_r$	0.07634421	
Resistance coefficient in turbulent flow (Diagram 6-12)	$\zeta_{turb}$	0.2480385	
Pressure loss coefficient (based on the mean bend velocity)	$\zeta$	0.3243827	
Hydraulic power loss	Wh	1.34325	W
Straight length of equivalent pressure loss	Leq	1.195428	m

## References:

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