Multi-hole cage

The multi-hole cage is designed for flow control. It consists of a hollow cylinder, in the wall of which a system of holes is drilled. The size of the throttling cross-section is controlled by exposing the field of these holes with the upper edge of the seat. A single stream of medium is fragmented into many local streams. The flow area is not one-piece and has no one boundary but is given by adding the cross-sections of the individual holes. Therefore, it is not possible to achieve such a smoothness of the curve and a certain ripple of the flow characteristic is evident here.

The multi-hole cage is ideal for handling high pressure. In addition, the seat can be shielded from the flow direction and does not need to be loaded. The direction of the medium flow towards the inside of the cage is important, where the individual partial currents meet and a considerable part of the kinetic energy is dissipated there, which would otherwise disrupt parts of the control system or body.

A multi-stage cage is required to reduce cavitation. If the pressure at a certain point during the flow through the cage falls below the value of the saturated vapor pressure of the liquid, corresponding to its temperature, cavitation occurs. The cavitation bubbles suddenly disappear when they reach a higher-pressure area with the liquid flow, and cavitation wear of the material is caused. For the formation of cavitation, it is decisive whether the liquid pressure falls below the critical value of cavitation pressure, which favorably corresponds to the saturated vapor pressure P_T lies in the range of minimum pressure and pressure behind the cage, when cavitation occurs, and cavitation wear can be expected after a certain time. If the minimum pressure is greater than the saturated vapor pressure, steam cavitation will not occur.

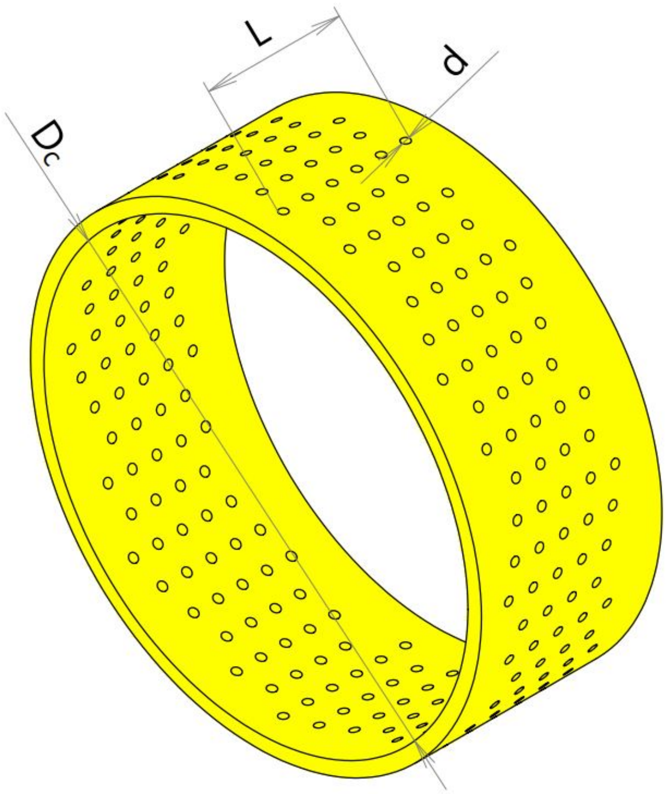


Fig. 1 cage

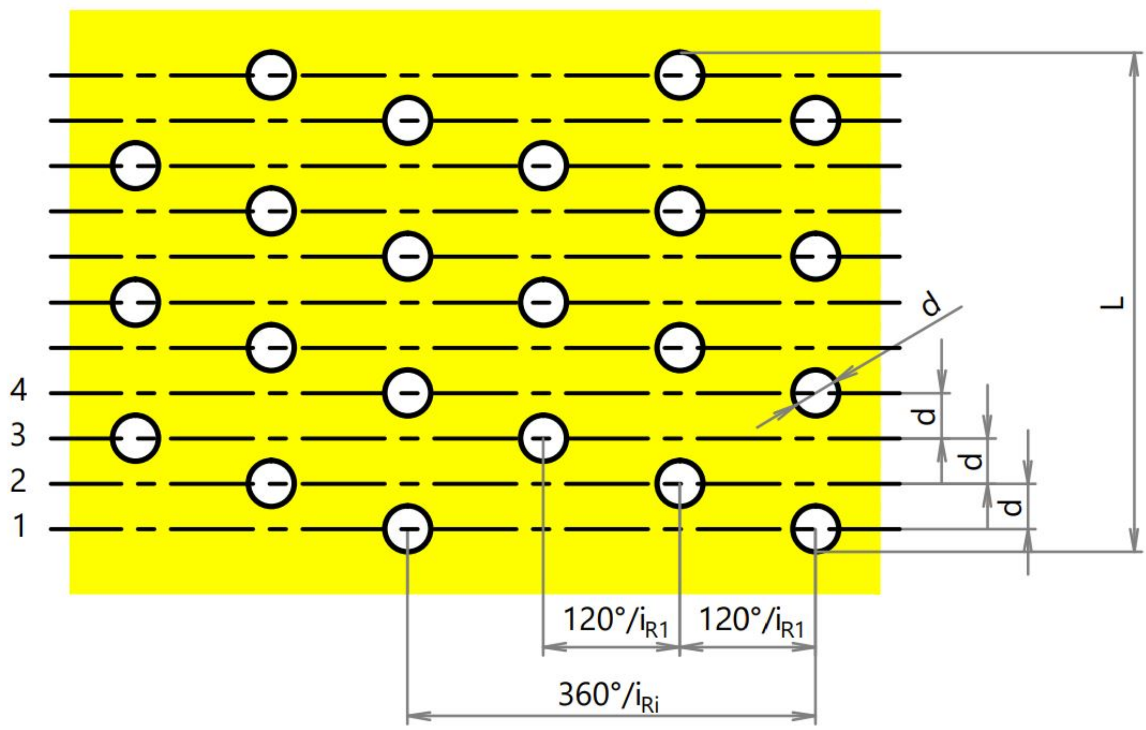


Fig. 2 developed view of the cage

Cage flow characteristic:
It is the dependence of the instantaneous free flow area in the throttle system of the regulating cage on the instantaneous position of the cage exposure. The basic types of flow characteristics are shown in Fig. 3.

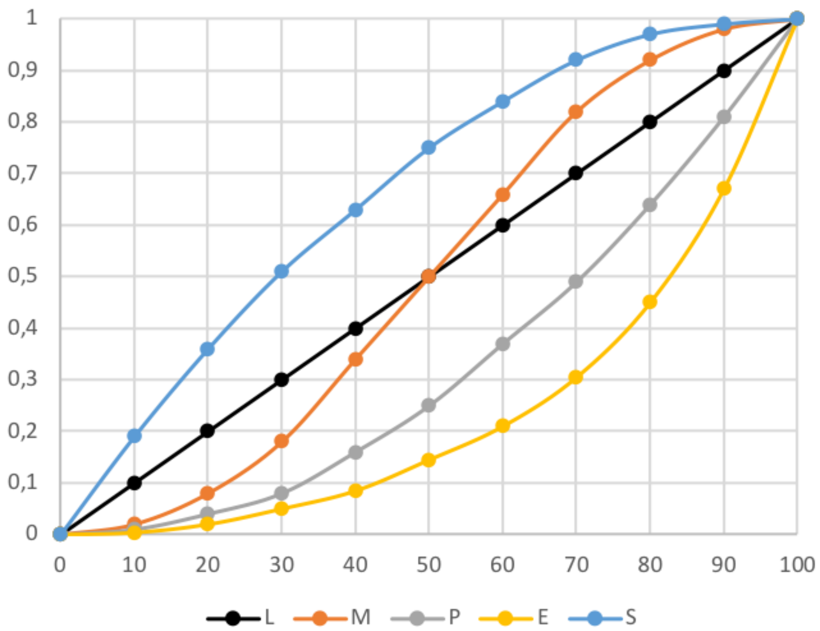


Fig. 3 overview of basic flow characteristics: L – linear, M – modified linear, P – parabolic, E – equal percentage, S – square root

In the case of control valves, cavitation can develop if the condition is met:
$(P_1 - P_2) \geq 0,6 * (P_1 - P_T)$

P_1	inlet absolute static pressure	[Pa]
P_2	output absolute static pressure	[Pa]
P_T	saturated vapor pressure at a specific temperature	[Pa]

Pipeline speed:

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

v	pipeline speed	[m/s]
Q	pipeline flow	[m^3/s]
D	internal pipe diameter	[m]

The flow area of the output hole:

$$F = \frac{Q}{\mu * \sqrt{2\frac{P_1 - P_2}{\rho}}}$$

$$\frac{F}{\frac{\pi * D^2}{4}} \leq 0,5$$

F	the flow area of the output hole	[m^2]
Q	pipeline flow	[m^3/s]
μ	output coefficient	[]
P_1	inlet absolute static pressure	[Pa]
P_2	output absolute static pressure	[Pa]
ρ	density	[Kg/m^3]
D	internal pipe diameter	[m]

Number of holes:

$$i = \frac{4F}{\pi d^2}$$

$$\frac{D}{50} \geq d$$

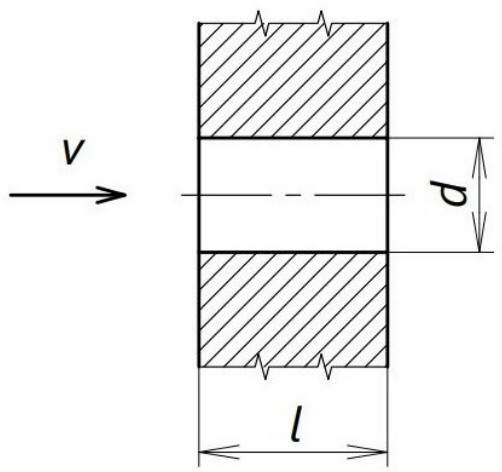
i	number of holes	[]
F	the flow area of the output hole	[m^2]
d	diameter of the output hole	[m]
D	internal pipe diameter	[m]

Output coefficient:

- Sharp-edged hole

  $\mu = 0{,}65$

  $\frac{l}{d} = 1{,}65$

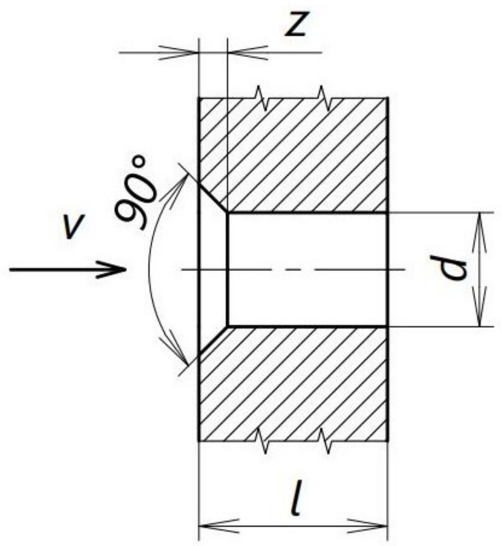


- Beveled hole

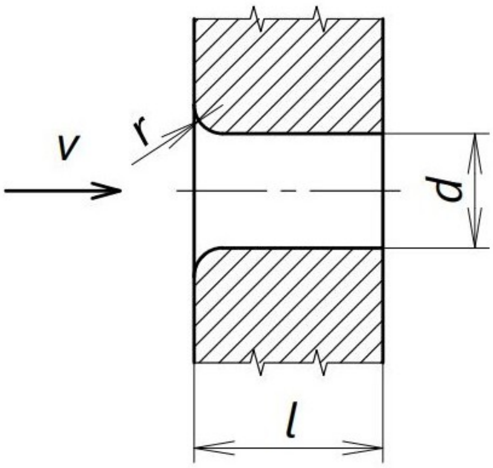
  $\mu = 0{,}78$

  $\frac{l}{d} = 1{,}65$

  $\frac{z}{d} = 0{,}25$



- Rounded hole
  $\mu = 0{,}84$
  $\frac{l}{d} = 1{,}65$
  $\frac{r}{d} = 0{,}25$



Allowable maximum number of holes in one row:

$$n_{max} = \frac{\pi D_c}{\sqrt{(9d)^2 - (3d)^2}}$$

$$n_{max} \geq n_{imax}$$

n_{max}	allowable maximum number of holes in one row	[]
D_c	inner diameter of the cage	[m]
d	diameter of the output hole	[m]
n_{imax}	maximum number of holes in one row	[]

Density:

Density ρ [Kg/m³] water depending on temperature and pressure

Temperature [°C]	Pressure [MPa]					
	0,1	0,25	0,5	1	1,5	2
0°	999,8	999,9	1000	1000,3	1000,6	1000,8
10°	999,7	999,8	999,9	1000,1	1000,4	1000,6
20°	998,2	998,3	998,4	998,6	998,8	999,1
30°	995,6	995,7	995,8	996	996,3	996,5
40°	992,2	992,3	992,4	992,7	992,9	993
50°	988,1	988,1	988,2	988,4	988,6	988,8
60°	983,2	983,3	983,4	983,6	983,9	984,1
70°	977,8	977,8	978	978,2	978,4	978,6
80°	971,8	971,9	972	972,2	972,4	972,7
90°	965,3	965,3	965,5	965,7	966	966,2
100°	-	958,4	958,5	958,8	959	959,2

Density ρ [Kg/m³] water depending on temperature and pressure

Temperature [°C]	Pressure [MPa]					
	2,5	3	3,5	4	4,5	5
0°	1001,1	1001,3	1001,6	1001,8	1002,1	1002,3
10°	1000,8	1001	1001,3	1001,6	1001,8	1002
20°	999,3	999,5	999,8	1000	1000,2	1000,4
30°	996,7	996,9	997,2	997,4	997,6	997,8
40°	993,3	993,4	993,7	993,9	994,1	994,3
50°	989,1	989,2	989,5	989,7	989,9	990,2
60°	984,3	984,5	984,6	984,9	985,1	985,3
70°	978,9	979,1	979,2	979,5	979,7	979,9
80°	972,9	973,1	973,3	973,5	973,8	974
90°	966,4	966,6	966,8	967,1	967,3	967,6
100°	959,5	959,7	960	960,2	960,4	960,6

Density ρ [Kg/m³] water depending on temperature and pressure

Temperature [°C]	Pressure [MPa]					
	6	7	8	9	10	12,5
0°	1002,8	1003,3	1003,8	1004,3	1004,8	1006
10°	1002,5	1003	1003,4	1003,9	1004,4	1005,5
20°	1000,9	1001,3	1001,8	1002,2	1002,7	1003,8
30°	998,3	998,7	999,1	999,6	1000	1001,1
40°	994,8	995,2	995,6	996,1	996,5	997,6
50°	990,6	991	991,5	991,9	992,3	993,3
60°	985,8	989,2	986,6	987,1	987,5	988,5
70°	980,4	980,8	981,3	981,6	982,1	983,2
80°	974,5	974,9	975,3	975,7	976,2	977,2
90°	968	968,4	968,9	969,4	969,7	970,9
100°	961,1	961,5	962	962,5	962,9	964

Density ρ [Kg/m³] water depending on temperature and pressure

Temperature [°C]	Pressure [MPa]					
	15	17,5	20	25	30	35
0°	1007,3	1008,5	1009,7	1012,1	1014,5	1016,9
10°	1006,7	1007,9	1009	1011,3	1013,6	1015,7
20°	1004,9	1006	1007,2	1009,3	1011,4	1013,6
30°	1002,2	1003,2	1004,3	1006,5	1008,6	1010,6
40°	998,6	999,7	1000,8	1002,8	1004,9	1007
50°	994,4	995,5	996,5	998,6	1000,7	1002,7
60°	989,6	990,7	991,7	993,7	995,8	997,9
70°	984,3	985,3	986,4	988,4	990,5	992,6
80°	978,4	979,4	980,5	982,6	984,7	986,8
90°	972	973,1	974,2	976,4	978,5	980,6
100°	965,2	966,3	967,4	969,7	971,8	974

Density ρ [Kg/m³] water depending on temperature and pressure

Temperature [°C]	Pressure [MPa]					
	40	45	50	60	70	80
0°	1019,3	1021,6	1023,9	1028,3	1032,7	1037
10°	1018	1020,2	1022,3	1026,6	1030,7	1034,9
20°	1015,7	1017,8	1019,9	1024,1	1028,1	1032
30°	1012,8	1014,7	1016,8	1020,8	1024,7	1028,5
40°	1009	1011	1013	1017	1020,8	1024,6
50°	1004,7	1006,8	1008,7	1012,6	1016,4	1020,2
60°	999,9	1001,9	1003,8	1007,8	1011,5	1015,3
70°	994,6	996,6	998,6	1002,5	1006,3	1010,1
80°	988,8	990,9	992,9	996,8	1000,7	1004,4
90°	982,7	984,7	986,8	990,8	994,6	998,5
100°	976,1	978,2	980,3	984,3	988,3	992,3

Saturated vapor pressure at a specific temperature:

Temperature [°C]	Saturated vapor pressure [Pa]
0°	611,3
10°	1228,1
20°	2338,8
30°	4245,5
40°	7381,4
50°	12344
60°	19932
70°	31176
80°	47373
90°	70117
100°	101320

Recommendation:

- The individual screens must be apart min. $5d$.
- The individual outlets located on one screen must be spaced apart min. $3d$.
- The individual outlet openings between the screens must not overlap.

d diameter of the output hole [m]

Literature:

Prof. Ing. Jaromír Noskievič, DrSc a kolektiv: Kavitace v hydraulických strojích a zařízení.
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V. Kolář, S. Vinopal: Hydraulika průmyslových armatur. SNTL 1964.