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The Calculation of the Kinematicals Parameters of the Crimped Metal Ribbon

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Abstract

This article deals with the methodologies and the computing relations for the parameters that characterize the functioning of the flame arresters' flange gap made of crimped ribbon. As far as the calculations regarding the sizes of the flame arresters are concerned, the article presents the relations that are essential to determining the diameter and length of the quenching approaches, as well as to determining the velocity of the flame propagation within combustible mixtures.

Key word:*obstruction ratio*, *quenching passageway, velocity, effective section.*

The determination of the obstruction ratio

Besides their purpose to stop the flames, the arresters must achieve a certain value for the pressure drop, depending on the location of their placement.

The value of the hydraulic residentship depends on the number of quenching tracts out of which the stopping grid is made. At the same size of the grid case, a grid with a bigger number of tracts will insert a higher pressure drop, with an increased efficiency in arresting the flame.

The value of the hydraulic residentship inserted in the system by the flame arrester plays a decisive part in installations in which there are more safety systems, and in which the pressure drop inserted by each element (safety relief valves, flame arresters, corner brackets and valve elbows of the installation, etc). This value must be lower than the maximum value allowed by that type of arrester.

In order to determine the degree of obstruction inserted by the grid's ribbon, we used a coefficient k_{opt} called an obstruction coefficient. This coefficient is determined as a ratio between the nominal area of the grid case and the area occupied by the two ribbons.

$$k_{opt} = \frac{\frac{\pi \cdot D^2}{4}}{S_{band}} = \frac{\pi}{4} \cdot \frac{D^2}{2.131 \cdot L \cdot g} \tag{1}$$

where: D_i - the exterior diameter of the grid equal to the interior diameter of the case;

S_{band} - the area occupied by the two ribbons calculated with:

$$S_{band} = L_t \cdot g = (L + 1.131 \cdot L) \cdot g = 2.131 \cdot L \cdot g \tag{2}$$

L - the length of the flat ribbon given by the relation:

$$L = \pi \cdot \frac{D - d}{4 \cdot (h_0 + g)} \cdot [D + d + 2 \cdot (h_0 + g)] \tag{3}$$

g - the thickness of the flat and crimped ribbons.

The density of quenching passageway

For the thermodynamic determinations, one needs to know the number of quenching tracts per the area unit of the stopping grid. For this reason, we marked with δ_{canal} the density of quenching passageway on the surface of the stopping grid made of crimped ribbon. This density is calculated as a ratio between the number of quenching passageway and the transversal area of the grid. The number of quenching passageway contained by the stopping grid n_{canal} can be determined as a ratio between the effective section of the flow S_{ef} and the transversal area of a drain S

$$n_{canal} = \frac{S_{ef}}{S} \tag{4}$$

In accordance with what has been stated above, the density of quenching passageway is determined by the relation:

$$\delta_{canal} = \frac{n_{canal}}{\frac{\pi \cdot \left(D_i^2 - d^2\right)}{4}} \left[mm^2\right] \tag{5}$$

Table 1 presents the result of the determination after the methodology of determining the geometric parameters that characterize the crimped ribbon used in making the dray flame arresters was implemented in a program of table computing.

where: d_o - the exterior diameter of the winding bush;

d_i - the maximum winding diameter;

g - the thickness of the ribbon used in manufacturing the stopping grid;

l - the width of the stopping grid;

h_0 - the height of the crimped ribbon

Table 1. The determination of the geometric parameters of the crimped ribbon grid

d_o(mm)	12						
d_i(mm)	146						
g(mm)	0.15						
l(mm)	10						
h_0	L_{flat}	$L_{crimped}$	L_{total}	Area (mm^2)	Volume (mm^3)	Weight (g)	Obstruction coefficient (k_{opt})
0.69	19996.12	22615.61	42611.73	6391.76	63917.59	501.75	0.3820
0.75	18677.07	21123.76	39800.83	5970.13	59701.25	468.65	0.3568
0.8	17705.14	20024.51	37729.65	5659.45	56594.47	444.27	0.3382
0.85	16830.4	19035.18	35865.58	5379.84	53798.37	422.32	0.3215
0.88	16346.32	18487.69	34834.01	5225.10	52251.02	410.17	0.3123
1.13	13194.77	14923.29	28118.06	4217.71	42177.08	331.09	0.2521
1.25	12081.82	13664.54	25746.36	3861.95	38619.55	303.16	0.2308
1.41	10864.24	12287.45	23151.69	3472.75	34727.54	272.61	0.2075

The maximum velocity of the gases through the stopping grid

When designing the safety relief valves of the respiratory equipment, the gas velocity allowed is $w_g = 35 \, {}^{m}\!/_{s}$ which ensures a maximum flow through the installation with the diameter D_n of:

$$Q_{\max} = \frac{\pi \cdot D_n^2}{4} \cdot w_g \left[\frac{Nm^3}{s} \right] \tag{6}$$

where: D_n - the nominal diameter of the installation and of the arrester $[m]$;

w_g - the maximum velocity allowed through the safety relief valves $\left[\frac{m}{s} \right]$

This flow will pass through the stopping grid, through a section equal to the gas flow section S_{ef}. By writing the law of mass conservation through the two sections D_n and S_{ef}, we obtain:

$$\frac{\pi \cdot D_n^2}{4} \cdot w_g = S_{ef} \cdot w_{\max} \tag{7}$$

where: $w_{\max}$ - the maximum velocity of the gases through the stopping grid $\left[\frac{m}{s} \right]$.

From (7) we obtain the relation for the determination of the value of the maximum velocity of the gases through the stopping grid, a value which cannot be higher than $w_g = 35 \left[\frac{m}{s} \right]$.

$$w_{\max} = \frac{\pi \cdot D_n^2}{4 \cdot S_{ef}} \cdot w_g \leq 35 \tag{8}$$

From the relation (8) we determine the maximum value of the effective section of the stopping grid:

$$S_{ef} \geq \frac{\pi \cdot D_n^2}{4 \cdot 35} \cdot w_g \tag{9}$$

The determination of the length of the quenching passageway

The quenching diameter and the quenching length represent two very important parameters in designing the dry deflagration and detonation flame arresters. This chapter briefly presents some aspects regarding the quenching of the flames and the equations for the assessment of the quenching diameter and the quenching length.

The penetration of a flame through a flame arrester depends on the length and size of the passageway (openings) of the stopping grid, on the velocity of the flame propagation, on the pressure increase, and on the temperature of the arrester (Wilson and Flessner 1978). Wilson and Flessner established by tests that low velocity flames can be quenched while passing through small section tracts installed in the pipes, if the effective diameter of the tract respects the following criterion:

$$d_{cr} < 30 \cdot \frac{\alpha}{w_u} \tag{10}$$

where: d_{cr} = the critical (quenching) diameter (m);

α = the thermal diffusion in the air $\left(\frac{m^2}{s}\right)$;

w_f = the burning velocity under standard conditions $\left(\frac{m}{s}\right)$.

For the flames with high velocity propagation, which are usually accompanied by pressure increases, the tracts need to have a section which must ensure a pressure drop to brake the flame, and an adequate length to ensure, through a heat transfer, a low temperature necessary to stop the flame. Thus, the diameter criterion is not enough to stop the flame; the effective length of the passageway has to respect the following criterion as well:

$$L > 2 \cdot w_t \cdot d_{cr}^2 \tag{11}$$

where: L = the effective length of the passageway (cm);

w_t = the velocity of the turbulent flame through the pipe $\left(\frac{m}{s}\right)$;

d_{cr} = the critical quenching diameter of the passageway (cm).

For methane, methylic alcohol, butane, gasoline vapors and other ordinary gases, these two criteria imply that the flame arrester (the active element) must have the effective length of the passageway bigger than 25.4mm and the effective diameter of the tracts smaller than 0.762mm in order to prevent the penetration of both low velocity and high velocity flames through the arrester's tracts.

As far as the determination of the length of the quenching passageway is concerned, Piotrowski recommends the following relation meant to calculate the length of the quenching passageway at the flame arresters which have the stopping grid made of crimped ribbon, based on the researches made by Wilson and Antallah:

$$L = \frac{w_f \cdot d_{ech}^2}{100 \cdot \nu} \tag{12}$$

where: $L =$ the length of the quenching passageway (cm);

$w_f =$ the velocity of the turbulent flame;

$d_{ech} =$ the equivalent hydraulic diameter (cm);

$\nu =$ the kinematic viscosity of the burnt gas $\left[\frac{cm}{s}\right]$.

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Calculul parametrilor cinematici ai grilei opritoare

Rezumat

În acest articol sunt stabilite metodologiile şi relațiile de calcul pentru parametrii ce catacterizează modul de funcționare a grilei pentru oprirea flăcării, fabricată din bandă metalică ondulată. Pentru calulele de dimensionare a opritorilor de flăcări, se prezinta relatiile ce stau la baza determinării diametrului şi lungimii canalelor de stingere(quenching), precum si pentru determinarea vitezelor de propagare a flăcării în amestecurile combustibile.