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INFLUENCE OF THE DISK FLANGE DIAMETER ON THE QUENCHING DISTANCE OF *n*-BUTANE-AIR MIXTURES

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abstract The ability of the flanged electrode technique to provide reliable quenching distance data, irrespective of the flange diameter, has been investigated for *n*-butane-air flame. Following a previous study, ones have chosen three different diameters of the flanged disks and observed variation of the quenching distance for five *n*-butane-air compositions and 21.3÷101.3 kPa initial pressure range. The present results show significant discrepancy from the "expected" behaviour, and the cause is not completely revealed. Back-up redundancy tests are in progress and results will be published shortly after.

Introduction

Quenching distance remains one of the most important characteristics in terms of safety against accidental explosions [1]. It is therefore necessary to get as reliable experimental data as they can be acquired, regardless of the specific method used to measure it.

According to previously reported data [2,3] variation of flange diameter affects the values of the quenching distance, a direct proportionality between quenching distance and flange diameter being observed, for diameters up to 25.4 mm. Moreover, three different mechanisms of quenching have been assumed to explain the discrepancies between values obtained with flange diameter variation.

The objective of the present study is to confirm the reported behaviour for *n*-butane-air mixture.

Experimental Section

The testing equipment is described elsewhere [4,5] but shortly, it consists of three main parts (Fig. 1): the mixing system, the spark control system, and the explosion cell.

The last one has been adjusted to accommodate electrode insulating flanges of 10 mm, 20 mm, and 40 mm diameter, respectively. Several *n*-butane-air mixtures of composition within 2.6% to 5.0%, have been prepared by partial pressure method. The experimental quenching distance has been measured with respect of the initial pressure that ranged from 21.3 to 101.3 kPa), for all three disk diameters taken into consideration.

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The results have been grouped with respect to mixture composition and each dataset has been analyzed through linear regression $y = a + b \cdot x$. The statistic data are shown in terms of: parameter and error of estimation, correlation coefficient, *r*, and standard deviation, SD.

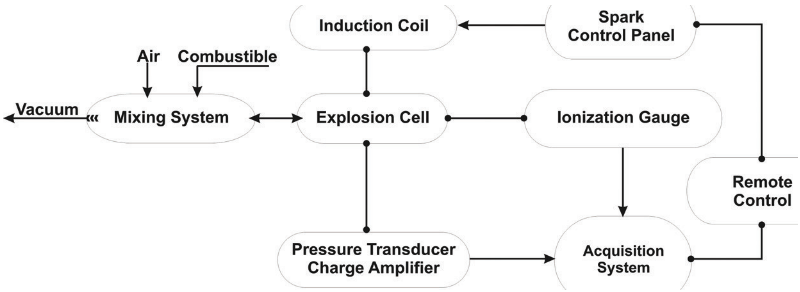

Fig. 1 *Scheme of the experimental setup.*

Results and Discussion

Figs. 2÷6 exhibits the datasets in bilogarithmic scale, shown as comparison for each of the chosen flanged disk diameter value, together with the linear regression results.

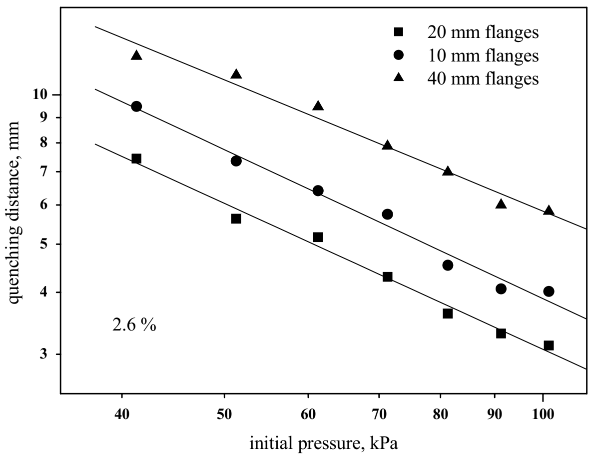

Fig. *Variation of the quenching distance with initial pressure for three diameters of the flanged disks; 2.60 % n-butane-air mixture;* statistical data:

10 mm flanges			20 mm flanges			40 mm flanges		
parameter		error	parameter		error	parameter		error
a	2.58426	0.10837	*a*	2.44131	0.08654	*a*	2.5226	0.11032
b	–0.99756	0.05892	*b*	–0.97708	0.04705	*b*	–0.87846	0.05998
	r	–0.99139		*r*	–0.99425		*r*	–0.98854
	SD	0.02012		SD	0.01607		SD	0.02049

In our experiment, the increase of the flange diameter from 20 mm to 40 mm is significantly increasing the quenching distance, for lean n-butane-air mixture. As approaching stoichiometric to rich mixtures, the effect is not evident anymore; it can be said that, within the limits of experimental errors, similar values of the quenching distance are obtained for the two diameters.

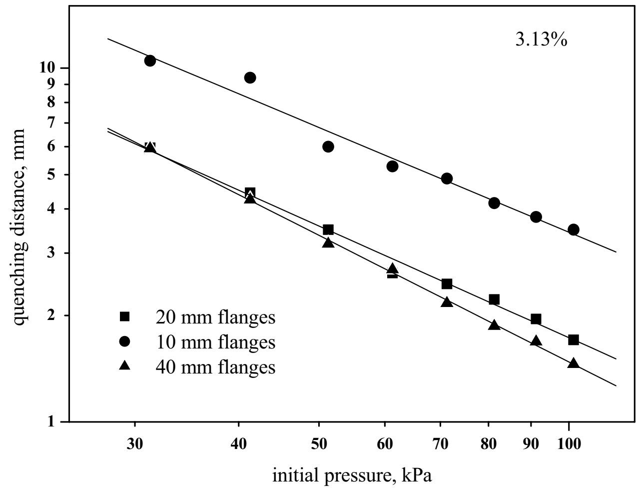

Fig. 3 *Variation of the quenching distance with initial pressure for three diameters of the flanged disks; 3.13 % n-butane-air mixture (stoichiometric);* statistical data:

10 mm flanges			20 mm flanges			40 mm flanges		
parameter		error	parameter		error	parameter		error
a	2.50474	0.12512	*a*	2.33615	0.07158	*a*	2.5468	0.03219
b	–0.98441	0.06951	*b*	–1.04914	0.03977	*b*	–1.18874	0.01788
	r	–0.98537		*r*	–0.99572		*r*	–0.99932
	SD	0.0324		SD	0.01854		SD	0.00834

The observation is valid for the entire pressure range taken into consideration. Accordingly, we expected that the decrease of the flange diameter from 20 mm to 10 mm would decrease the values of the quenching distance.

But the results tell different: for mixture compositions of 2.6÷5.0% *n*-butane in air, the values of the quenching distance are higher for 10 mm diameter than for 20 mm diameter. The “expected” behaviour is encountered only for the mixture containing 6.0% *n*-butane, where for a 10 mm flange diameter gives lower quenching distance than for 20 mm diameter.

The possible explanation rises from gas dynamics: the high energy ignition spark may induce turbulence in the incipient phase of ignition that results in concentration gradients and significant fuel consumption; also as results of such turbulence, perturbation of the front of the flame nucleus, prior propagation, may be encountered. From the overall analysis of current results, for the *n*-butane-air mixture of concentration ranging from stoichiometric to 5.0%, one may say that the only evidence in favour of using a certain diameter of the insulating flanges to measure reliable quenching distance is for 20 mm, especially knowing that this parameter is further used to design *antiex* facilities [5]. It is also true that several discrepancies in quenching behaviour have been observed, especially for leaner and richer mixtures.

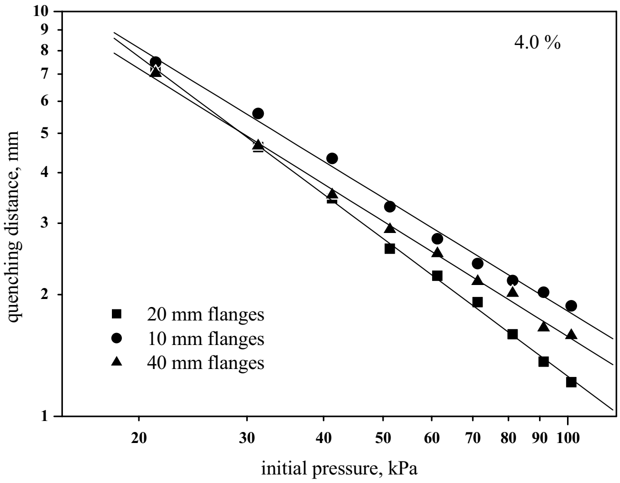

Fig. 4 *Variation of the quenching distance with initial pressure for three diameters of the flanged disks; 4.00 % n-butane-air mixture;* statistical data:

10 mm flanges			20 mm flanges			40 mm flanges		
parameter		error	parameter		error	parameter		error
a	2.12029	0.04863	*a*	2.35796	0.02759	*a*	2.09019	0.03819
b	-0.93027	0.02773	*b*	-1.12954	0.01573	*b*	-0.94653	0.02178
	r	-0.99691		*r*	-0.99932		*r*	-0.99815
	SD	0.01772		SD	0.01005		SD	0.01392

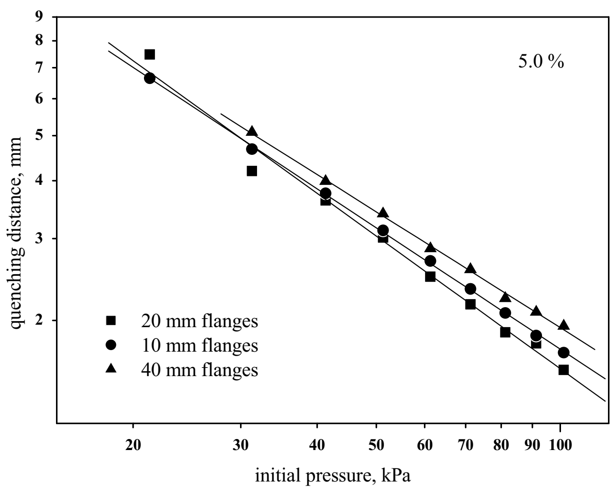

Fig. 5 *Variation of the quenching distance with initial pressure for three diameters of the flanged disks; 5.00 % n-butane-air mixture;* statistical data:

10 mm flanges			20 mm flanges			40 mm flanges		
parameter		error	parameter		error	parameter		error
a	1.97543	0.01227	*a*	2.09532	0.0716	*a*	1.94214	0.02713
b	-0.86821	0.007	*b*	-0.94919	0.04083	*b*	-0.82833	0.01507
	r	-0.99977		*r*	-0.99359		*r*	-0.99901
	SD	0.00447		SD	0.0261		SD	0.00703

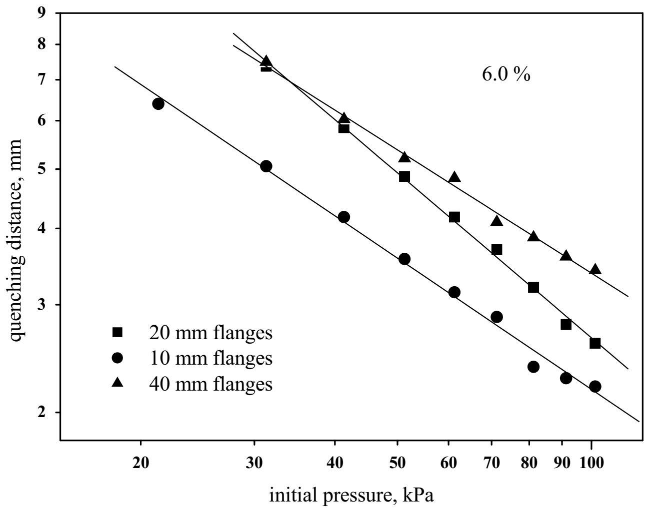

Fig. 6 *Variation of the quenching distance with initial pressure for three diameters of the flanged disks; 6.00 % n-butane-air mixture;* statistical data:

10 mm flanges			20 mm flanges			40 mm flanges		
parameter		error	parameter		error	parameter		error
a	1.76601	0.03919	*a*	2.21567	0.03543	*a*	1.86921	0.0386
b	-0.71368	0.02235	*b*	-0.89629	0.01969	*b*	-0.6702	0.02145
	r	-0.99659		*r*	-0.99856		*r*	-0.99694
	SD	0.01428		SD	0.00918		SD	0.01

Conclusions

Effect of the variation of flange disk diameter has been investigated for the experimentally measured quenching distance of *n*-butane-air mixtures of compositions around the stoichiometric one, and initial pressure ranging between 21.3 and 101.3 kPa.

It has been observed that the increase of the flange diameter from 20 mm to 40 mm is significantly increasing the quenching distance, for lean n-butane-air mixture, but the effect is not that obvious for stoichiometric to rich mixtures.

The decrease of the flange diameter from 20 mm to 10 mm, however, is not having the predicted behaviour; the possible explanation is assumed from gas dynamics.

Considering the discrepancies in the quenching behaviour that have been observed it is concluded as the need to conduct a more in-depth analysis of the process of flame ignition, from the energetic as well as ignition system geometry point of view, in order to gather new evidence to sustain or contradict such behaviour.

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