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Journal of Loss Prevention in the Process Industries 21 (2008) 481–484
Journal of Loss Prevention in the process industries
www.elsevier.com/locate/jlp

Short Communication

Dust/vapour explosions: Hybrid behaviours?

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Received 29 August 2007; received in revised form 15 November 2007; accepted 15 November 2007

Abstract

This article underlines the peculiar behaviour of hybrid mixtures towards explosions. It should notably be noticed that there are more than additive effects on explosions severity, especially on the maximum rate of pressure rise. Moreover, the evolution of the maximum explosion pressure as a function of combustibles concentrations shows that the impact of hybrid mixtures is perceptible even for vapour amounts or dust concentrations lower than the explosion limits of the pure compounds.

Keywords: Dust explosions; Hydrid mixture; Pharmaceutical products; Vapours; Explosion severity

1. Introduction

The explosivity of a dust, i.e. its ignition sensitivity and its explosion severity, could be greatly affected by slight changes in the atmosphere composition or humidity, by modifications of the particle shapes or size distribution, or by initial temperature and pressure evolutions. Nevertheless, other parameters should also be taken into account, especially when the risk analysis is conducted on workplaces or processes dealing with both dust and solvents. The explosive mixture resulting in the simultaneous presence of dust or gas/vapour and another combustible compound in a different physical state will be called a hybrid mixture whatever the proportions.

These atmospheres are encountered, but not so often considered, in food industries—for instance, wheat dust and fermentation gases or oil cakes and hexane, in painting industries—pigments and diluents, or in pharmaceuticals ones—for example, excipients and solvents (Glor, 2006). Processing the accidentology data demonstrates the occurrence and gravity of the explosion of such mixtures (1994—Groβ-Umstadt, Germany) (1906—Courrières, France). However, if studies have been carried out to underline and characterize the behaviour of gas/dust mixtures (Pellmont, 1979; Pellmont, 1980; Pilão, Ramalho, & Pinho, 2006), in particular in relationship with the mining sector (Cashdollar, 1996; Chatrathi, 2004), only few researches deal with the explosion of vapour/dust mixtures (Nifuku et al., 2006).

The aims of this article are to draw attention to the peculiar effects of such hybrid mixtures and to encourage taking them systematically into account during risk analyses.

2. Experimental set-up and procedure

During this study, many experiments have been carried out on hybrid mixtures and especially on pharmaceutical products having various applications: excipients, active principles, vitamins and their associated solvents (Dufaud, Perrin, Traoré, Chazelet, & Thomas, 2007). In this article, the example of niacin (B3 vitamin also known as nicotinic acid) and diisopropyl ether has been used. A laser diffraction analyzer (Mastersizer, Malvern Instrument) combined with scanning electron microscopy have been used to determine the particle-size distributions and the d_{10}, d_{50} and d_{90} quantiles of the volumetric distribution of the dust, which are, respectively, 12, 26 and 104 μm. The powder was systematically dried at 50 °C under vacuum during 2 h before handling.

The products' explosivity, characterized by the maximum explosion pressure P_{max}, the maximum rate of pressure rise $(dP/dt)_{max}$ and the corresponding $K_{St/G}$

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0950-4230/$ - see front matter
doi:10.1016/j.jlp.2007.11.005

Nomenclature

$(dP/dt)_m$ maximum rate of pressure rise (bar s^{-1})
$(dP/dt)_{max}$ maximum value of the maximum rate of pressure rise for various dust concentrations (bar s^{-1})
d_x quantiles of the volumetric distribution; size at which x% of the particles are smaller (μm)
K_G volume-independent gas explosion constant (m bar s^{-1})
K_{st} volume-independent dust explosion constant (m bar s^{-1})
LEL lower explosive limit (%vol)
MEC minimum explosion concentration (g m^{-3})
P_m maximum explosion pressure (bar g)
P_{max} maximum value of the maximum pressures for various dust concentrations (bar g)
UEL upper explosive limit (%vol)

constants, as well as the minimum explosive concentrations (MEC) of the powder, have been determined by using a 20 L explosion chamber (Kühner AG) according to ISO 6184-3 standard (Callé, Klaba, Thomas, Perrin, & Dufaud, 2005) (Table 1). Dust, gas and hybrid mixtures have been ignited thanks to two pyrotechnic ignitors of 5 kJ each as ignition sources.

Table 1
Explosion characteristics of the dust and the solvent

Products	Niacin	Diisopropyl ether
MEC (g m^{-3})	60	–
LEL (17 °C)	–	0.7%
UEL (17 °C)	–	8.4%
P_{max} (bar)	8.4	8.8
dP/dt_{max} (bar s^{-1})	790	1310
$K_{st/G}$ (m bar s^{-1})	214	356

Moreover, lower (LEL) and upper explosive limits (UEL) of the solvents have been determined thanks to a 5 L apparatus (Chilworth Technology Ltd.) at 17 °C and as a function of the temperature over a 17–150 °C range according to ASTM E681-94 standard.

3. Hybrid mixtures explosions

The effects of vapour addition on the niacin/diisopropyl ether mixtures explosivity and especially on the maximum explosion pressure and on the maximum rate of pressure rise are noticeable but significantly distinct. The increase of the explosion pressure due to the addition of small vapour amounts could be seen in Fig. 1 and on its two-dimensional projection in Fig. 2. The maximum explosion pressure rises from 8.4 and 8.8 bar g, respectively, for niacin and diisopropyl ether to 9 bar g for mixtures containing 250 g m^{-3} of niacin and less than 2% of diisopropyl ether.

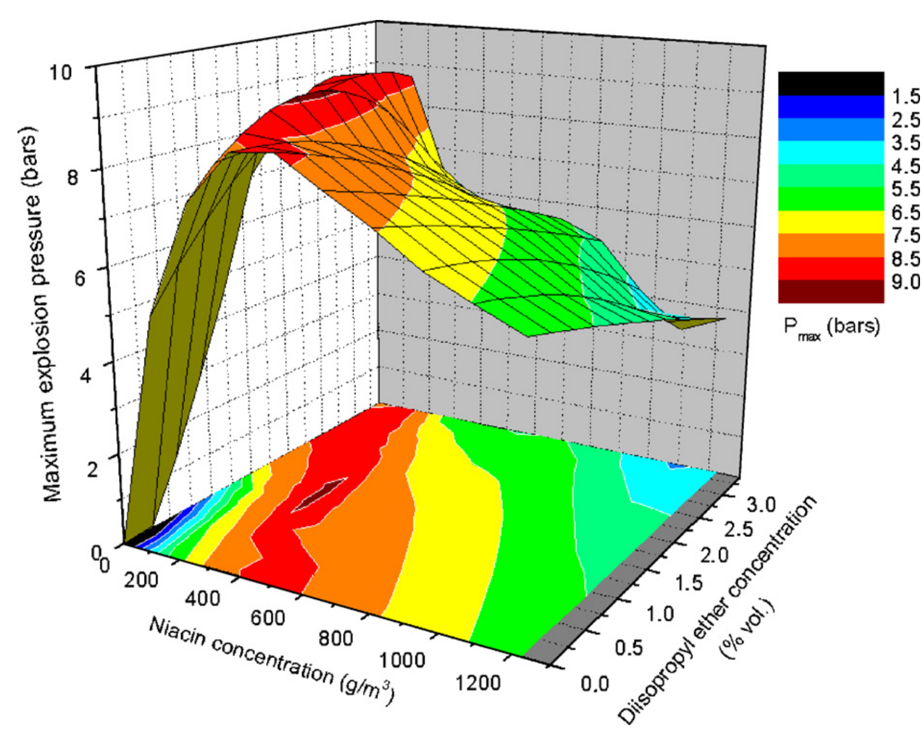

Fig. 1. 3D representation of the maximum explosion pressure P_m of niacin/diisopropyl ether hybrid mixtures.