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Minimum ignition energy of medicinal powder – Florfenicol and Tilmicosin

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A B S T R A C T

This work aims to help improve the electrostatic safety design and explosion prevention of medical facilities. In this study, the minimum ignition energies (MIEs) of Florfenicol, Tilmicosin and mixtures of Florfenicol and Tilmicosin at ratios of 1:1, 1:2, 2:1 and 1:4 were measured in a Hartmann apparatus. The results demonstrated that the MIEs for Florfenicol, Tilmicosin and mixtures of Florfenicol and Tilmicosin at ratios of 1:1, 1:2, 2:1 and 1:4 are 200, 70, 180, 150, 200 and 110 mJ, respectively. Tilmicosin is more sensitive to static electricity, which is more dangerous than the other two powders examined in this paper. Furthermore, the MIEs of the mixtures are proportional to the Florfenicol content. For all powders, the MIE first decreased with the powder mass and later reached its minimum value. In addition, scanning electron microscopy (SEM), differential scanning calorimetry (DSC) were used to investigate the morphological specificity and thermal decomposition of the powders to elucidate the parameters governing the powder explosions further.

1. Introduction

Given the current advancements in powder technology, nearly all industrial sectors are subject to explosion risks (Zhi Yuan et al., 2013). Dust explosions invariably occur in the metallurgy, military industry, textile, fiber, food and pharmaceutical industries. We typically use the lower explosive limit (LEL), minimum ignition energy (MIE), minimum ignition temperature (MIT), maximum explosion pressure (P_{max}) and maximum increase in the pressure ($(dP/dt)_{max}$) to characterize the sensitivity and severity of the dust explosion (Li Chang et al., 2013; Li et al., 2004).

The ignition sensitivity is one of the most important criterions to determine the risk of dust explosion (Eckhoff, 1991; VDI, 1990) and is typically described by the MIE to ignite and explode the dust cloud. Experimentally, the MIE is assumed to be the minimum amount of electric energy discharged by a capacitive circuit that can trigger a propagating flame inside the dust cloud in air at specific test conditions.

Many factors affect the MIE, including the material and composition (Kai-Tai Lu et al., 2010; Kaitai Lu et al., 2009). Sun Yawei (2012) found that the MIE is positively correlated with the organic matter content of the material. For example, the MIE of wheat starch dust is less than that of cornstarch, because the organic matter content of wheat starch dust is higher than that of cornstarch. Eckhoff (2009) described the key factors that influence the MIE of dust explosions, including the particle size distribution of the powder, the concentration distribution of the dust cloud and the velocity of the dust cloud. Marmo and Cavallero (2008) found that the MIE of fiber is a function of the diameter multiplied by its length, and its ignition energy can range from 4 to 4000 mJ. In addition, they noted that the turbulence of a cloud can increase the MIE significantly. Nifuku et al. (2005) demonstrated that the ignition probability of industrial waste powders is positively correlated with the powder concentration in an atmosphere of air/pentane. Wu et al. (2009) measured the MIE of Ti powders with diameters of 3 mm, 8 mm, 20 mm, 45 mm, 35 nm, 75 nm and 100 nm, and Fe

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powders with diameters of 150 mm, 15 nm, 35 nm and 65 nm using a modified 1.2-L Hartmann apparatus. The experimental results showed that the MIE is negatively correlated with the titanium powder particle size. Junaid Hassan et al. (2014) drew similar conclusions and supported the notion that the MIE was related to the powder diameter.

The incidence of dust explosion accidents in the pharmaceutical industry has increased in recent years. Medical dust explosions result in serious environmental damage and significant property losses. An explosion causing five fatalities occurred in a pharmaceutical factory in 2010 (Li and Cai, 2010). The anti-inflammation drug Cefotaxime was stirred and discharged when the accident occurred. The accident was determined to occur as follows: first, the dust clouds formed during the stirring; second, O_2 entered the tank during the discharging; then, static electricity was generated due to friction by powder and powder, powder and facilities, and facilities and facilities during the stirring and discharging, which formed the ignition source. Importantly, Cefotaxime and its primary material active esters (AEs) can explode by testing, and the workers were not aware of this fact beforehand. An explosion occurred at another pharmaceutical factory that produced Clavulanate potassium during the mixing process, resulting in two fatalities and one injury (Zhang et al., 2010). Both of the accidents were caused by static electricity created in the mixing or stirring process. The production processes of drugs involve crushing, grinding, screening, mixing and stirring, which have a high risk of creating static electricity. Therefore, the explosion characteristics of medicinal powders must be urgently studied for industrial applications.

Zhang et al. (2009) studied the mixed dust explosion characteristics of medicinal potassium Clavulanate and micro-crystal cellulose powder. The results showed that pure potassium Clavulanate dust was more dangerous than the mixed dust. Agreda et al. (2011) examined the explosion features of a methane/nicotinic acid dust/air mixture of different concentrations using a 20 L Siwek bomb. The non-linear explosion severity and synergistic effects for the hybrid mixture explosion were discussed. Zhang Jinfeng et al. (2014a, b) obtained a lower explosive limit of 18.5 g/m^3 and maximum explosion pressure of 0.82 MPa for the 7-aminocephalosporanic acid (7-ACA). Zhang Jinfeng et al. (2014a, b) then also tested the minimum ignition temperature of 7-ACA dust cloud and its mixture with acetone. The minimum ignition temperature of 7-ACA dust was found to decrease after the addition of acetone.

Dust explosions have garnered increasing public interest (Piccinini, 2008; John and Vorderbrueggen. 2011). Although the statistical data are incomplete, dust explosion accidents in China have become a common occurrence due to the recent rapid development of Chinese industry. Drug powders pose combustion and explosion hazards to the pharmaceutical industry. Florfenicol and Tilmicosin are both antimicrobial and anti-inflammation drugs, such as Cefotaxime and Clavulanate potassium. Inflammable and explosive primary materials were used in the production of Florfenicol and Tilmicosin, which may increase the risk of dust explosion. The production and transport of Florfenicol and Tilmicosin involve crushing, grinding, screening, mixing and stirring, which can create the high-risk ignition source of static electricity. Otherwise, these two drug powders can be used together, and their mixing processes pose combustion and explosion risks. The MIEs of Florfenicol and Tilmicosin may be used to determine the lowest energy needed to ignite Florfenicol and Tilmicosin and establish a safeguard against accidents.

In general, although dust explosions have been widely described in previous studies (Blair, 2007; Zheng et al., 2009; Giby and Luca. 2010; Marmo2004), the explosion data for medicinal powders remain insufficient. Therefore, in this study, the Hartman apparatus was used to test the MIEs of Florfenicol and Tilmicosin powders and their mixtures. The data and conclusions can provide guidance for electrostatic safety design in the pharmaceutical industry.

2. Experimental methods

2.1. Materials

Florfenicol, Tilmicosin and their mixtures were studied herein, and both drugs were manufactured by a pharmaceuticals company in Shanghai. Specifically, the MIEs of these two drug powders and their mixtures were determined in this study. The properties of the powders and mixtures are listed in Table 1.

Florfenicol, a veterinary drug, is a veterinary chloramphenicol antibiotic. It is a white crystalline powder with a melting point of 153 °C, a boiling point of 617.5 °C at 760 mmHg, and a flash point of 327.3 °C. Tilmicosin is a veterinary macrolide antibiotic that is often used to treat pigs, whose physico-chemical properties are unclear. The structural formulas of both drugs are shown in Fig. 1(a and b), which indicates the structural differences between the drugs. Specifically, the structure of Florfenicol is less complex than that of Tilmicosin. Although both drugs contain hydroxyl and oxygen-containing groups, Tilmicosin is much more saturated than Florfenicol.

2.2. Apparatus and test procedures

In the Hartmann apparatus, whose main body contains a transparent organic glass tube with an ignition device, compressed air carrying the powders is blown from the bottom to the top of the cylinder to form a dust cloud. The flames then disperse throughout the cylinder. The Hartmann apparatus used in this study is shown in Fig. 2.

The experimental apparatus used to measure the MIE in this study is a modified 1.2-L Hartmann apparatus. The transparent organic glass tube is vertical and cylindrical, and it has an inner diameter, height and volume of 68 mm, 300 mm and 1.2 L, respectively. The design of the Hartmann apparatus is based on the standards of IEC (1994), ASTM (2003) and BS EN 13821 (British Standards Institution, 2002). This apparatus induces dust cloud explosions via high-voltage ignition sparks. If a flame expands and propagates over 10 cm, it would be recognized as a successful explosion. The ignition energy can be adjusted from 10 to 1000 mJ in this system.

The MIEs of the following sets of drug powders were investigated in this study: Florfenicol (<75 μm), Tilmicosin (<75 μm), and mixtures of Florfenicol and Tilmicosin (at ratios of 1:1, 1:2, 2:1 and 1:4). The MIEs of these five samples were measured at seven mass values (200, 300, 400, 500, 600, 800, and 1000 mg) with low electrical spark ignition energies (from 10 to 1000 mJ).

All experimental procedures in this study conformed to the Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air published by the American Society for Testing and Materials (2003). For one test, we consecutively attempted to ignite a given sample by decreasing spark energies. According to the standards, the MIE lies between the lowest energy value (IE) at which ignition occurs and the highest energy (NIE) at which no ignition occurs for at least 10 successive experiments.

In this study, a scanning electron microscope (SEM) and differential scanning calorimeter (DSC) were used to determine the morphological specificity and thermal decomposition of the powders, respectively. These parameters may influence the MIE of the powders.