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Explosion characteristics of micron-size conveyor rubber dust

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A B S T R A C T

Explosion characteristics of micron-size conveyor rubber dust were determined employing a normal 20 L stainless steel orbicular chamber and two types of modified 1.2-L Hartmann tubes. Maximum explosion pressure (P_{max}), maximum rate of pressure rise $(dP/dt)_{max}$, and minimum explosion concentration (MEC) were tested in the spherical chamber. The results indicated that the explosion severity of conveyor rubber powders is weaker than some common dust, such as coal, magnesium, and aluminum dust. However, conveyor rubber dust is a kind of combustible dust. Furthermore, the explosion severity increased as the particle size decreased from 120 to 48 μm. The MEC decreased from 90 to 30 g/m^3 on decreasing particle size from 120 to 48 μm. Moreover, the MEC of conveyor rubber dust was 30, 50 and 90 g/m^3 for the particle size of 48, 75, and 120 μm. The minimum ignition energy (MIE) was measured by two types of modified 1.2–liter Hartmann tubes. The results indicated that particle size and dust concentration had influences on MIE. However, the MIE of conveyor rubber dust was much higher than 10 mJ. Accordingly, conveyor rubber dust cannot be ignited by collision, friction, and attrition. The experimental data presented could be useful for process plants that manufacturing conveyor rubber to evaluate explosibility of their conveyor rubber powders and propose/design adequate safety measures.

1. Introduction

Synthetic rubber is widely used in the production of tires, rubber hoses, and conveyor belts, etc. The European Union, United States, and China are dominant consumers for synthetic rubber, and the demand for synthetic rubber has been growing swiftly. According to statistics, the total production of tyres, which are manufactured in about 90 plants in the EU, was ca. 355 million in 2014, corresponding to 24% of the total world production. Meanwhile, synthetic rubber is a main production material of tyres (Torretta et al., 2015). In addition, there are numerous manufacturing and processing enterprises for other rubber products. Much rubber dust is generated in the process of manufacturing and processing of tyres as well as other rubber products.

Combustible dusts can be found in various industries, and dust explosions present substantial threats to people, assets, and the environment (Yuan et al., 2015), such as the catastrophic aluminum-alloy dust explosion which killed 146 persons in China (Li et al., 2016a). Table 1 lists several serious disasters caused by dust explosion (Yuan et al., 2015). Accordingly, it is necessary to explore the explosion severity and ignition sensitivity parameters for the conveyor rubber dust.

Conveyor rubber is essentially a kind of polymer. There exists some information on explosion characteristics of polymer powders (Marmo and Cavallero, 2008; Amyotte et al., 2012; Gao et al., 2015; Addai et al., 2015, 2016). Amyotte et al. (2012) conducted experiments to determine the explosion severity and ignition sensitivity parameters for fibrous wood and polyethylene. Gao et al. (2015) studied the pressure characteristics of vented 100 and 800 nm polymethyl methacrylate (PMMA) dust explosions with different venting diameters. Addai et al. (2015) tested the explosion behavior of corn starch, and investigated the effects of methane and acetone on the explosion behavior of corn starch. Addai et al. (2016) determined the minimum ignition energy (MIE) of starch, wheat flour, protein, polypropylene, and dextrin. Marmo and Cavallero (2008) tested the MIE of fibrous nylon dust cloud.

For micron-size dust, Soundararajan et al. (1996) experimentally

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Table 1
Accidents caused by dust explosion (Yuan et al., 2015).

Date	Country	Material	Equipment involved	Types of industries	Dead/ injured	Ignition sources
1993	US	PR	Air arc gauge with Plasmarc and Mappgas; mixing tank	Plastic products factory	2d/2i	Electrical sparks
1996	US	PR	Blending tote	Automobile brake pads and lining manufacturer	1d	–
1998	US	PR	Dust collector; air handling ducts	Sports equipment manufacture	16d	–
1999	US	PR	Oven; dust collection system	Grey and duct tile foundries	9d/3i	Flame and direct heat
1999	US	PR	Machine that grinds plastic pellets	Plastic manufacturing	2d	Hot work
2002	US	PR	Tire bin	Tire recycling	13d	–
2003	US	PR	Milling equipment	Mechanical rubber goods	38d/6i	–
2003	US	PR	Oven	–	37d/7i	–
2004	US	W	Dust collection system	Wood products plant	3d	Impact sparks
2007	CHN	W	Conveyor	Wood pelts manufacturer	4d/5i	–
2007	CHN	F	Workshop, pulverizer	Rice process factory	–	Hot surface
2009	CHN	M	Workshop	Aluminum products	11d/20i	Self-heatingand smoldering
2009	CHN	IN	Dust collection system	Chemical preparations	2i	–
2010	CHN	M	Dust setting chamber	Metal polishing	2d/6i	Impact sparks
2011	US	M	Pipes, furnace	Iron powder plant	3d/2i	Impact sparks
2012	CHN	M	Polishing workshop	Metal polishing plant	13d/16i	Electrical sparks
2014	CHN	M	Polishing workshop	Metal polishing	146d/114i	self-ignition

PR: Plastic/rubber; W: Wood; F: Food; M: Metal; IN: Inorganic.

researched the influences of powder diameter on explosion features of micron-pyrite and pyrrhotine. Denkevits and Dorofeev (2005, 2006) investigated the explosibility of micron-graphite and micron-tungsten dusts along with mixtures for different particle size. Pilão et al. (2006) studied the explosion severity and ignition sensitivity of cork and air dust mixtures in an almost spherical apparatus. Azhagurajan et al. (2012) studied the MIEs of micron- and nano-size flash powders in fireworks industry with the change of electrode gap, electrode material, and dust concentration, dust composition, etc. Mittal (2013), Yuan et al. (2014), and Li et al. (2016b) conducted experiments to study the explosion characteristics of micron coal dust. Castellanos et al. (2014) investigated the effects of powder diameter polydispersity on the explosibility features of aluminum dust. Boskovic et al. (2015), Medina et al. (2015a, b), and Saeed et al. (2015) tested the explosibility characteristics of biomasses. All of the above research results have provided useful data to design proper and sufficient safety measures to mitigate or prevent dust explosion. To supply useful information for manufacturing and handling enterprises of conveyor rubber products, it is significant to investigate the explosion severity and ignition sensitivity parameters of conveyor rubber dust.

The conveyor rubber dust samples used for the current works were supplied by Gates Unitta Power Transmission (Suzhou) Co. Ltd., a company manufacturing different kinds of conveyor belts composed mainly by synthetic rubbers. And during the cutting and polishing process, a large number of conveyor rubber powders with different particle sizes would be generated, and suspended by the momentum from processing machines and ventilation system. Therefore, the conveyor rubber dust mainly distributed in the workshops, ducts, and dust collectors. In the present paper, the objective was to test and elucidate the explosion characteristics of micron-size conveyor rubber dust. The influences of dust concentration and powder size of conveyor rubber dust on maximum explosion pressure (P_{max}) and explosibility index (K_{st}) were studied, along with the influences of powder size on minimum explosion concentration (MEC) and the effects of dust concentration and particle diameter on MIE.

2. Methodology

2.1. Apparatuses and methods

2.1.1. Experimental apparatus for MEC and explosion severity parameters

A normal 20 L stainless steel orbicular chamber (Fig. 1), produced by Northeastern University in Liaoning province, China and recommended by International Standard *ISO6184/1* (International Organization for Standardization, 1985), was selected to test P_{max}, maximum rate of pressure rise $(dP/dt)_{max}$, and MEC of conveyor rubber dust. This device mainly consists of a spherical vessel,

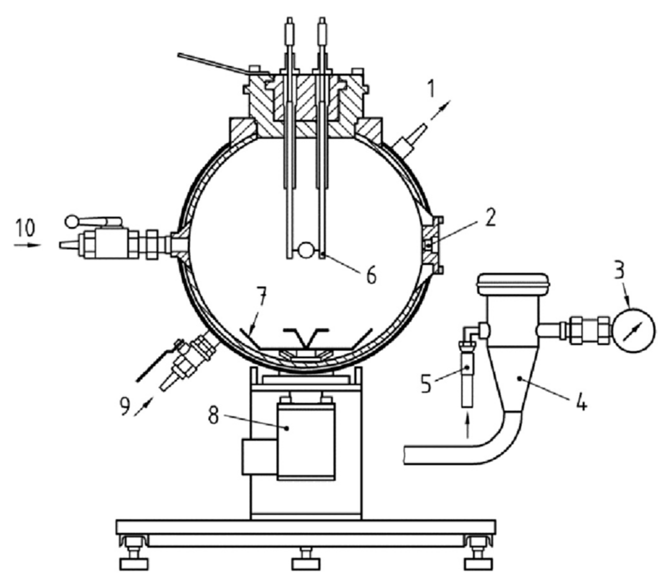

Fig. 1. The 20 L spherical experimental apparatus.
Notes: 1–Water outlet, 2–Pressure sensor, 3–Manometer, 4–Dust container, 5–Air inlet, 6–Ignition source, 7–Rebound nozzle, 8–Fast acting valve, 9–Water inlet, 10–Outlet (air, reaction products).