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Explosion risk evaluation during production of coating powder

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Abstract

Powder coating is widely used in industry to prevent equipment corrosion. More than 600 companies produce coating powder in China, but most do not understand the explosion hazard of such products. In the present investigation the explosibility parameters of a coating powder were determined. Results showed that the coating powder is explosible, though the ignition energy is higher than those of normal dusts such as coal powder and corn starch. Based on these experimental findings, a systematic explosion protection method is proposed, with explosion isolation and explosion venting being adopted as the main protective methods.

Keywords: Powder coating; Dust explosion; Protection methods

1. Introduction

Powder coating is widely used in industry world wide to provide corrosion and wear resistant coatings on metals and other materials. In Europe, North America, Australia, etc. the dust explosion hazard associated with production, handling and use of many types of coating powder has been known for many years, as indicated by the paper of Eckhoff et al. [1] and the wide selection of ignitability and explosibility properties of coating powders provided by BIA [2]. Furthermore there are European standards for the application of such powders [3,4]. The use of the powder coating technique in China has developed rapidly over the last years, in particular in the southern part of the country. Presently more than 600 companies in China produce various types of coating powder, but so far insufficient attention seems to have been paid to the dust explosion hazard. Composition of powder used in the coating process varies according to the purpose of the coating. Normally, the powder is composed of an organic polymer, such as polyethylene, with some organic additives. Melting temperature of the coating powder is relatively low (<100 °C). When exposed to open flame, such as from a match, the powder initially begins to melt rather than combusting. It is widely held that such coating powder cannot combust, let alone explode. In powder coating production systems, the potential explosion hazard has not been adequately investigated in China.

A series of experiments were conducted on a selected coating powder to determine explosion parameters, including minimum ignition energy (MIE), minimum ignition temperature (MIT) for dust clouds and dust layers, maximum explosion pressure (P_{max}), and the maximum pressure rise rate.

Based on the test results explosion risk will be analyzed for the typical coating powder production process. A kind of practical explosion protection strategy will be illustrated.

2. Powder properties

2.1. Composition of tested coating powder

Composition of the tested coating powder is given in Table 1. Powder particle size distribution was tested with a BT-9300H laser particle size tester and results are shown in Fig. 1.

2.2. Explosion parameters

Explosion parameters of the coating powder were determined according to VDI2263 [5] in the Fire & Explosion Laboratory at Northeastern University.

The explosibility properties of the coating powder of concern was determined using a 20 l closed spherical explosion bomb. The tests confirmed that the coating powder was explosible. Using a 10 kJ chemical igniter, the maximum explosion pressure

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Table 1
Composition of the tested coating powder

Ingredient	%
Colophony	60
Vitriolic	10–15
Calcium carbonate	10–15
Additives	10–15

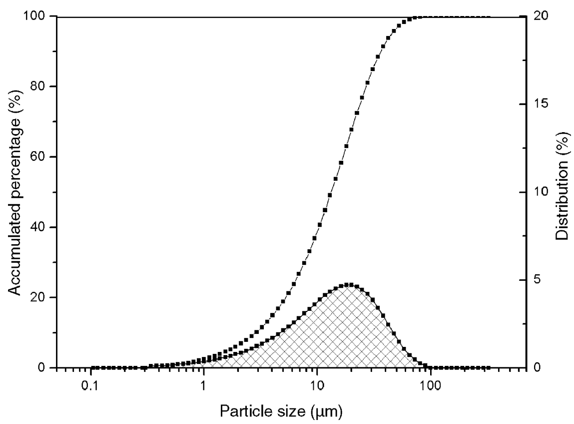

Fig. 1. Coating powder particle size distribution.

was as high as 7.1 bar(g) at a dust concentration of 900 g/m^3, whereas the maximum rate of pressure rise was 406 bar/s. With the 2 kJ igniter, the minimum explosive dust concentration (MIC) was found to be as low as 60 g/m^3, as indicated in Table 2.

In order to better quantify the explosion sensitivity of the coating powder, the minimum ignition temperature was tested for dust layers and dust clouds. The powder began to melt when the plate temperature reached 70 °C, and therefore no powder layer minimum ignition temperature could be identified. A minimum ignition temperature of clouds in air of the powder of 480 °C was determined in the Godbert–Greenwald furnace. The minimum electric spark ignition energy (MIE) of the powder was also tested, using a modified Hartmann apparatus. A special generator (MIE III, made by Chilworth Technology) was used to produce the electric sparks. The MIE of the powder of concern was found to be in the range 50–75 mJ, as shown in Table 2. For comparison, the explosibility properties of wheat starch were given together.

3. Explosion hazard evaluation and explosion protection measures

Based on the test results, it can be concluded that the coating powder is explosible. Comparing MIT and MIE values with those of corn starch, the sensitivity of the coating powder is lower. The P_{max} of the coating powder was equivalent to that of bituminous coal (with 20% content of volatile) dust. With the exception of explosion resistant vessels, nearly all types of equipment and construction would be severely damaged when subjected to such a high pressure. Thus, production processes for coating powder must adopt explosion prevention and protection methods.

3.1. Hazard evaluation for the production process

A typical process for coating powder production is illustrated in Fig. 2. Different kinds of raw material fed into the air classifying mill are crushed and mixed. Powder meeting the specifications is drawn by suction into a cyclone and collected. Finer particles leaving the cyclone are continuously collected by a filter located downstream of the cyclone.

In such a system, explosive dust clouds can be expected during normal operation in the cyclone, filter, and connecting pipes. The primary portion of the product is collected by the cyclone. The calculated average concentration in the conveying system before cyclone is about 90 g/m^3, which is within the limits of explosion. In the filter, the concentration of powder surpasses the lower explosion limits possibly only at the moment of automatic dust removal from the filter bags.

Dust in the filter is especially fine. It is well known that MIE decreases with decreasing particle size. Explosion accident statistics indicate that static electricity sparking can be an effective ignition source in the dust collectors [6]. Sparks from mechanical friction and smoldering nests can be expected to occur inside the mill because of high rotor speed. However, the explosion is hard to be initiated because the space is tight and turbulence is high. Under such conditions, explosion cannot spread easily within the mill, but strong explosion can develop in the downstream pipe. And the initial explosion can enter the cyclone and cause serious secondary explosion phenomena.

3.2. Explosion hazard control

Engineering measures for minimizing dust explosion hazard involve both prevention and protection. Protective measures are the primary concern of this paper. According to American standards explosion venting and isolation technology are chosen for the coating powder production process [7,8].

The location and strategy are shown in Fig. 2.

- ♦ A diverter is used between the miller and the grade cyclone. The diverter not only vents high pressure that may otherwise

Table 2
Explosion parameters of the tested coating powder and corn starch

Parameter						
Dust type	MIT-dust cloud (°C)	MIT-dust layer (°C)	MIE (mJ)	LEL (g/m^3)	P^1_{max} (bar)	$(dp/dt)_{max}$ (bar s^{-1})
Coating powder	480	70–80, melting	50–75	60	7.1	406
Corn starch	520	440		60	9.7	582

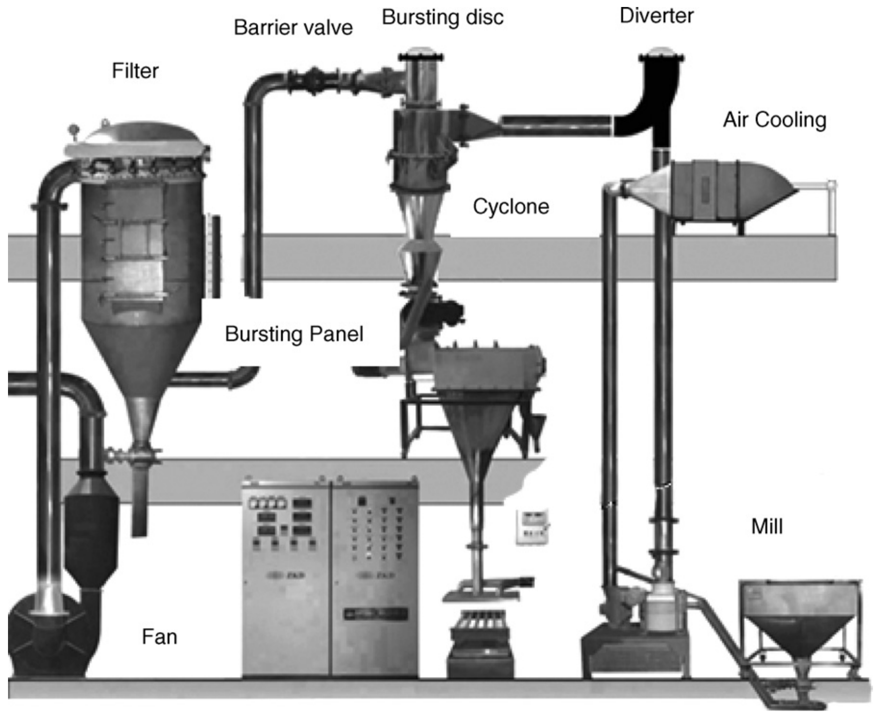

Fig. 2. Coating powder production process.

build up in the mill and pipes, but also isolates the strong pressure shock on the grade cyclone.

- ♦ A barrier valve is installed between the filter and cyclone. Under normal operating conditions, the flow containing coating powder passes through the barrier valve with a small pressure drop. In the event of explosion in the filter or cyclone, the barrier valve popet moves to the other side of the original explosion site and can be locked, thereby preventing the explosion pressure and flames from spreading to other equipment via the barrier valve.
- ♦ Venting panels are used for the filter and the cyclone. These prevent pressure from exceeding the specified strength of the equipment.

4. Conclusion

It has been confirmed experimentally in the present work that coating powders can give rise to dust explosions. Therefore methods for preventing and mitigating dust explosions should be implemented in plants producing coating powders. Some suggestions for explosion mitigation including explosion isolation and explosion venting, are given in the paper. In addition, supplemental measures such as grounding and utilizing electrical explosion-proof equipment should be considered.

Acknowledgements

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