Risk Management of Very Ignition Sensitive Powders

Shengjun ZHONG[1], Zhufang WANG[2], Jinming LIU[3], Siegfried RADANDT[4], Jianye SHI[5]

[1] Northeastern University, E-mail: zhongsj@smm.neu.edu.cn; [2] Shenyang University of Technology, E-mail: wangzhufang@163.com; [3] Tangshan Weihao Magnesium Co. Ltd. [4] Forschungsgesellschaft fuer angewandte Systemsicherheit und Arbeitsmedizin, E-mail: Siegfried.Radandt@t-online.de and Jianye.Shi@bgn.de

Abstract

Some kinds of powders such as magnesium and sulfur are extremely easy to be ignited. Normally, these powders are produced and processed in inert atmosphere. During process maintaining, powder transportation, filling and unloading, powder is out of inert atmosphere protection. Explosion prevention methods include prevention of ignition sources and prevention of explosion atmosphere and inherent safety in designing and operation integrates these two methods. Application of inherent safety design was presented. Some practical experiences on how to prevent ignition sources and dust generation were introduced.

1 Introduction

Ignition energy is a very important characteristic for prevention of explosions. Several kinds of powders have very low minimum ignition energies [1]. Typical ignition sensitive powders include some metal powders such as magnesium, aluminum and some nonmetal powders such as phosphor and sulfur.

NFPA published related standards of fire and explosion prevention for metals and sulfur [2,3]. Some accidents of these ignition sensitive powders and suggestions of prevention were reported [4-6]. Normally, ignition sensitive powders are produced and processed in inert atmosphere. However, during maintenance, transportation, and when powder is filled to or removed from the process, inert atmosphere might fail to protect.

Current investigation tried to lay a frame of risk management of ignition sensitive powders. Magnesium and sulfur are used as examples.

2 Evaluation of ignition sensitivity

Ignition sensitivity can be characterized by minimum ignition energy(MIE), minimum ignition temperature of dust layer(MIT-L), minimum ignition temperature of dust cloud(MIT-C), limiting oxygen concentration(LOC) and lower explosion limit (LEL). Among these characteristics, MIE is the most important.

Minimum ignition energy is related to particle size distribution. Characteristics of two samples of magnesium and sulfur were measured. The particle size distributions and explosion characteristics of the two samples are shown in Fig. 1, and table 1, respectively.

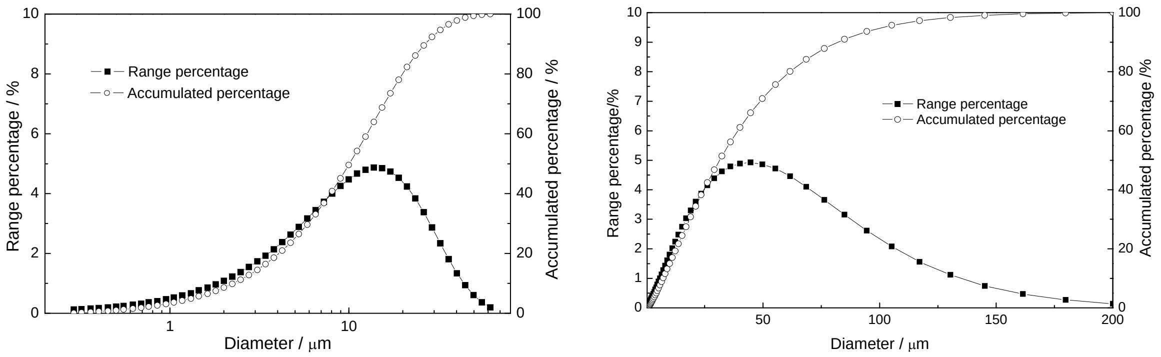

Fig. 1 Size distribution of magnesium and sulfur dust used for standard explosion characteristics test

Table 1 Explosion characteristics of magnesium and sulfur

	MIE/mJ	MIT-C/℃	MIT-L/℃	LOC/%	LEL/g.m^{-3}	$p_{\max}$/MPa	$K_{\max}$/(MPa.m/s)
Magnesium	2	400	530	2	30	0.91	44.5
Sulfur	0.3	210	250	9	30	0.68	25.1

Eckhoff and Randeberg reported that minimum ignition energies of many dusts are less than 1 mJ[1]. Ignition hazard classification method had been given by Zhou et. al. The principle of the classification is to classify the energy level by energy range of different kind of electrostatic discharge (Table 2).

Table 2 Classification of minimum ignition energy

Class	Minimum ignition energy/mJ	Ignited by type of electrostatic discharge
1	<0.025	Corona discharge
2	<3	Brush discharge
3	<10	Bulk discharge
4	<30	Human body discharge
5	<10^3	Spark discharge
6	>10^3	Propagating brush discharge

From experience, if MIE is less than 10mJ, it can be considered as sensitive, and if MIE is less than 3 mJ, it is very sensitive.

Very sensitive powders can be ignited by friction or strike of operation tools, or by brush discharge and other kinds of discharge with higher energies.

3 Ignition sources in typical accidents

Most accidents of ignition sensitive powders occurred when the processes were maintained, or when powder is filled to or removed from the process. The main ignition sources of typical accidents are introduced as follows.

(1) Mechanical sparks

Explosion occurred in a steel netting bag filter. The filter contained 25 steel netting filter ducts, and the ducts are not fixed well. During cleaning of inner wall of a pipe, strike of two ducts ignited the dust generated by cleaning (Fig. 2).

Many explosions occurred when changing bags of magnesium bag filters. The scenarios were similar: Vibration of bags generated dust, and frictions and strikes generated ignition sources.

A sulfur dust explosion occurred when a fan was disassembled.

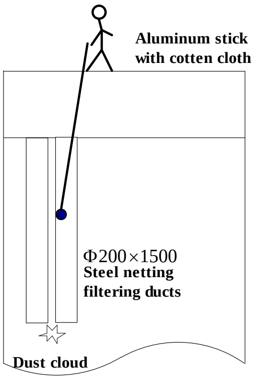

Fig. 2 Magnesium explosion when cleaning steel netting filtering ducts

(2) Electrostatic discharge

Explosion occurred in a magnesium powder silo when a worker was cleaning the silo using compressed air. The rubble pipe has a 150mm length iron duct head. Probably the ignition was caused by friction or strike of the iron head, or by electrostatic discharge.

Two reported accidents indicated that electrostatic discharge ignited magnesium dust when floor and surface of equipment were cleaning by a whisk.

Vacuum cleaner can also be an ignition source if the pipe is not conductive and earthed.

(3) Hot work

During cutting a pipe of a magnesium filter system, the flanges of the pipe connected with the filter was disassembled, but no blind flange was put between. Cutting sparks ignited the powder inside the duct and explosion propagated to the filter and fan.

Causes of several dust explosion accidents were hot work such as cutting and welding.

(4) Auto-ignition

Auto-ignition occurred in fine sulfur powder with water content in a sulfur warehouse. There were several reports of explosions in unloading troughs.

(5) Other sparks and hot surface

An exhausted pipe of a truck engine ignited sulfur dust cloud in a sulfur warehouse.

Sulfur dust entered the heat exchanger of a discharging machine in a ship and caused an explosion.

4 Risk management of ignition sensitive powders

4.1 Inerting

In a running process, powder is continuously processed in the system, so dust concentration is difficult to control. For ignition sensitive powders, the main prevention method is inerting. The European standard committee has drafted a guide for inerting [8].

The maximum explosion pressures and rates of pressure rise of magnesium are shown in Fig. 3 and Fig. 4. It can be seen that when oxygen concentration is below 4%, the maximum explosion pressure is below 0.6 MPa, and explosion index K_{max} is below 9.

For magnesium, the setting point can be 0.25%, and trip point can be 0.5% to 1%. For sulfur, the setting point can be 2%, and trip point can be 5% to 8%.

When process is stopped for repairing, local inerting is necessary in case of hot working.

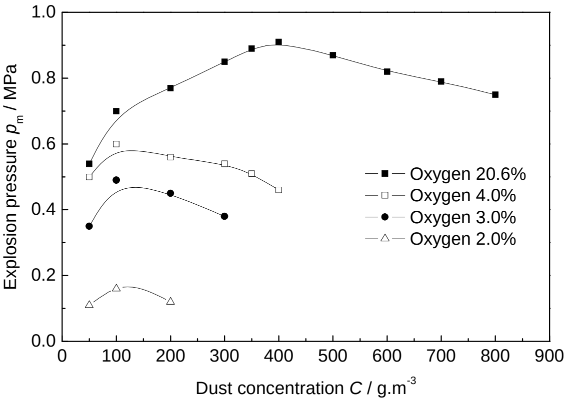

Fig. 3 Explosion pressures of magnesium powder at different oxygen concentrations

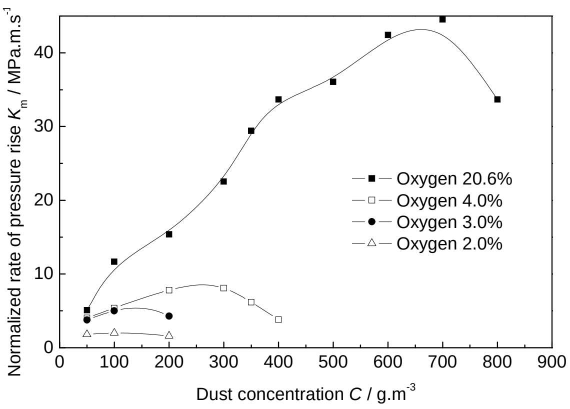

Fig. 4 Normalized rate of pressure rises of magnesium at different oxygen concentrations

4.2 Containment

Venting of magnesium is very dangerous. Air may enter the close system and burning inside the system can’t be extinguished easily because the limiting oxygen concentration is very low.

Through increasing the strength of the equipment and ducts, the system will withstand the overpressure in case of explosion. Considering the inert atmosphere might fail but it can reduce the explosion pressure in a certain degree even it fails partially, the designing pressure of the process system can set to 1 MPa.

4.3 Inherent safety designing and operation

Inherent safe design prevent explosion or reduce the probability of explosion inherently by improving the process design [7,8].

The principle of inherent safety is to prevent ignition sources and explosion atmosphere. The following methods demonstration how the principle is applied in processes handling sensitive powders.

(1) Mechanical friction and spark prevention

- Reserve enough space to prevent friction and strike;
- Operation carefully when powder is handled to prevent friction and strike of tools;
- Use non-spark tools made of bronze or aluminum rather than iron and steel tools.

(2) Electrostatic discharge prevention

- Use conductive equipment and component;
- All equipments should be electrically connected and earthed well, and movable equipment should be electrically connected with fixed equipment during operation (typically, powder filling and unloading);
- The floor should be electrostatic conductive floor, and workers should have electrostatic-proof clothes and gloves;
- The filter bag should be made of electrostatic-proof materials;
- Use natural fiber materials such as cotton, palm fiber in cleaning.

(3) Other ignition sources management

- Use dust ignition proof electrical apparatus;
- Strict hot work management.

(4) Good factory layout

The distribution of equipment shall guarantee that in case of explosion, the harms to human and devices are minimized. So dust filter and silos shall locate outside or on the top of the process buildings.

(5) Isolation

It is necessary to design enough valves to divide the process to be several sections. In case of maintaining, the valves can limit possible explosion in defined zones. The butterfly valves can’t withstand explosion pressure, and rubble sealing can generate electrostatic. Ball valves with graphite sealing can be used instead of butterfly valves.

(6) Fluent flow

The angle of the taper of the silos and the bag filter are 65° to ensure the flow is mass flow rather than funnel flow. When powder is easy to be “bridged” in the silo, pneumatic stirring or mechanical vibration devices can improve fluency of mass flow.

(7) Reduce amount of hazardous materials

To process less materials in the system, and remove final product in the workshop to well managed storage and stored in packaged form rather than bulk powder.

(8) Dust concentration control in maintaining

During maintaining and repairing, equipment such as filter is not protected by inert atmosphere, dust concentration control is very important. Kerosene or silicon oil can be used to prevent generation of dust cloud, when changing filtering bags or cleaning equipment such as silos. Oil is sprayed to the inner walls and bags to stick powder particles together. This method was proven to be effective.

5 Conclusion

Inerting is the basic method in the processes of ignition sensitive powders. Many explosion accidents of sensitive powder occurred when the processes were maintained, or during filling and unloading. When powder is out of protection of inert atmospheres, to prevent ignition sources is the most important.

Most ignition sources including mechanical friction and sparks, electrostatic discharge can be avoid by inherent safety designing and operation.

When ignition sources can’t be avoided, local inerting and isolation can be applied during maintaining with hot work.

Kerosene or silicon oil can be used to prevent generation of dust cloud, when changing filtering bags or cleaning equipment such as silos.

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