

Explosion Risk Management of ABS Powder Processes

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Abstract: ABS (Acrylonitrile-Butadiene-Styrene terpolymer) is a kind of widely used engineering resin. Several ABS powder explosions occurred in China. The reasons of historical explosions were analyzed. The process of a typical ABS plant was introduced. Historical accidents show that, spontaneous ignition is the main reason of fire and explosion in ABS fluid bed dryer. By means of regular cleaning of ABS dryer, explosion in the dryer can be avoided. The explosion characteristics of ABS powder were measured. The effect of particle size on minimum ignition energy (MIE) was investigated. It is suggested that to handle fine powder collected by dust collectors separately to minimize the possibility of ignition. Different risk management solutions of ABS processes in China were discussed and further research objectives were proposed.

Introduction

ABS (Acrylonitrile-Butadiene-Styrene terpolymer) is a widely used engineering resin. The consumption of ABS in China is 3 million t/a, and the production of ABS in China is 1.8 million t/a. Synthetic Resin Plant of Jilin Petrochemical Company is the biggest ABS plant in China. A new ABS producing process is planned to be build to meet the increasing need. Risk assessment of the current ABS process can give some guides to the construction of the coming new process.

The most serious ABS explosion occurred in July 27, 1997^[1]. Six ABS silos with ABS powder exploded, the top plates of the silos and the bag filters on the top plates flied to different places. Fires occurred in 4 silos after explosions. The direct loss of the accident was 3 million US dollars. There were two opinions on the reason of explosion. Bulk brush discharge was the ignition source^[1]; Rotary valve between the cyclone and the silo top was the ignition source. There was a build up in the rotary valve. The jammed "powder cake" and the moving components of the rotary valve kept rubbing and generated heat or electrostatics^[2].

The main measures to prevent and mitigate ABS explosions suggested by Kau and Duh were;

- (1) using nitrogen for conveying instead of air and nitrogen sealing in silos;
- (2) particle size well controlled;
- (3) moisture control in pipes and silos;
- (4) using lower mass flow rate;
- (5) online monitoring of the electrostatic field of the powders in silo and conducting the electric field if needed;
- (6) explosion venting and decoupling.

Other accidents mostly occurred in ABS fluid bed filters^[3-5]. From Jan. 1999 to Sept. 2000, 4 explosions occurred in ABS dryers in Daqing Chemical Plant, and the direct losses were account to 300 thousand US dollars. To avoid the explosion risk, Daqing Petro-chemical Plant changed the drying process and using nitrogen as drying media instead of air. After that, there was no explosion in the ABS dryer anymore.

There are still some questions to put the suggestions of the former solutions into practice. In some cases, the silo is very big, using inert gas conveying and silo sealing is rather expensive, and there is not much data on what mass flow rate is safe to convey ABS powder. Online monitoring and control of electrostatics is also difficult.

The effect of particle size on ignition energy was investigated in present work, and the possibility to control the particle size is discussed.

1. Risk analysis

1.1 The ABS producing process

The raw material of ABS powder is ABS slurry. The ABS process includes agglomeration, dehydration, drying and mixing processes. In the present paper, only drying and mixing process are considered having hazard of explosion (Fig.1).

After dehydration, the water content of the raw material is 22 %. Wet ABS enters fluid bed dryer by a screw conveyor and a distributor. The distributor can distribute wet ABS uniformly on the fluid bed. Hot air at 90°C enters the fluid bed dryer from the bottom, and served as both drying media and conveying media. ABS particles move from one

end of the dryer to the other and lose water content during movement, and go out of the dryer through a rotary valve. The air, steam as well as some fine particles go out of the fluid bed through a pipe on the top of the dryer at about 65

$\sim 70^{\circ}\text{C}$. Fine particles are collected by the primary and secondary cyclones and return to the dryer in different pipes, respectively.

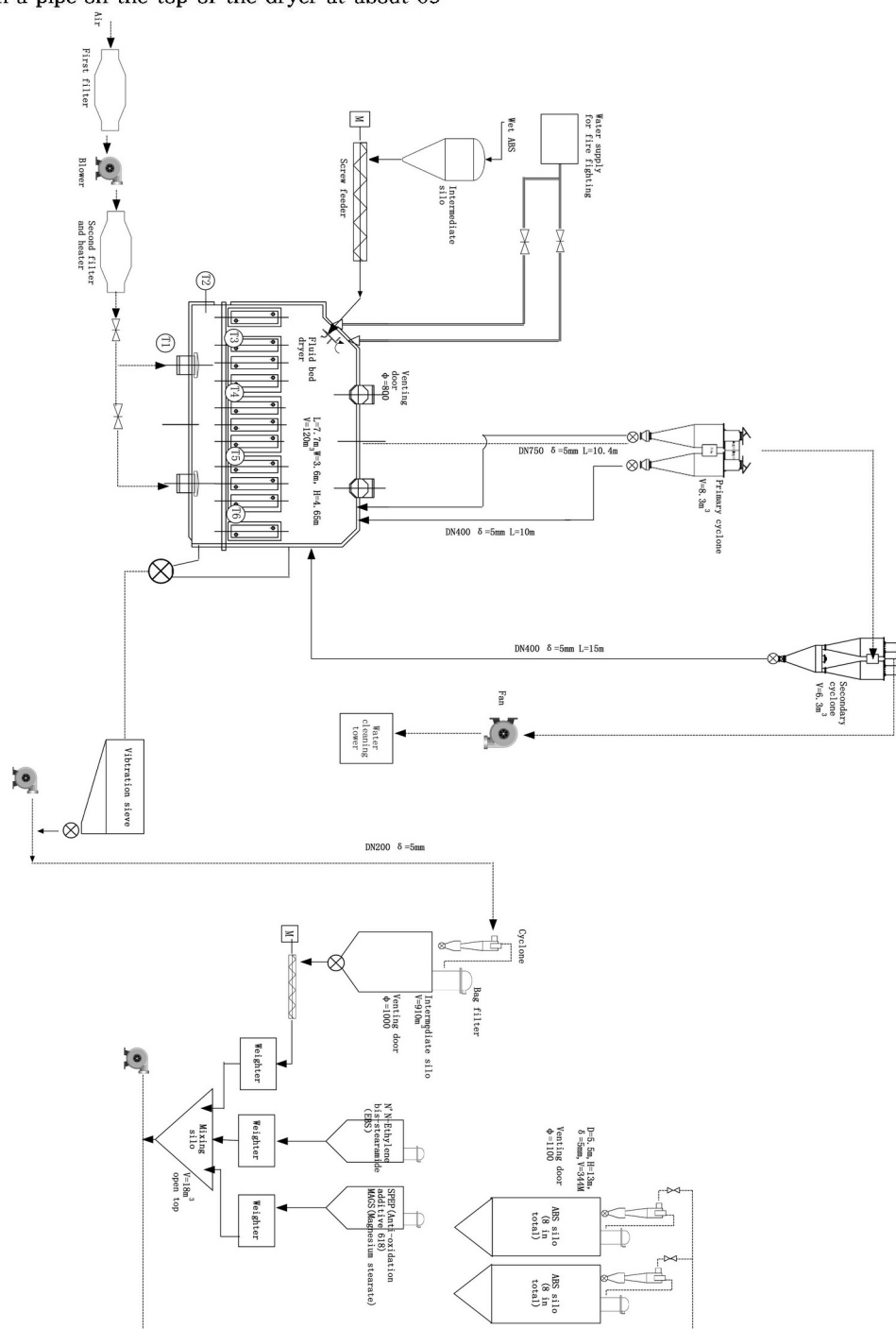


Fig.1 Process of ABS drying and mixing

The dried ABS powder is transported to an intermediate silo by pneumatic conveying, and then it is mixed with N'N-Ethylene bis-stearamide, magnesium phosphate and anti-oxidation additive (type 618) in a mixing bin. The mixed powder (main content is ABS) is conveyed to storage silos by pneumatic transportation.

1.2 The explosion characteristics of ABS powder

The explosion characteristics are listed in Tab.1. The samples for explosion characteristics measurement were original powder taken from the fluid dryer. The size distribution of the ABS powder is listed in Tab.2. The experimental data of explosion characteristics have differences with the data reported in references. The differences may be because of the

size distribution, composition of the ABS powder used.

Tab.1 Explosion characteristics of ABS powder

Parameter	Powder			
	ABS in dryer	ABS in silo	ABS ^[1]	ABS ^[6]
p_{max}/MPa	0.77	0.76	0.73	0.92
$K_{max}/(\text{MPa}\cdot\text{m}\cdot\text{s}^{-1})$	5.72	8.07	8.58	14.7
LEL/(g/m ³)	100	100	10	60
MIE/mJ	25	20	10	
MIT-(C/°C)	415	415		480
Specific resistance/ $\Omega\cdot\text{cm}$	1.14×10^{12}			

Tab.2 Size distribution of the original ABS powder

Mesh	Size/ μm	Ratio/%
Under 200 mesh	<75	4
Under 100 mesh, and above 200 mesh	75~150	32
Under 60 mesh, and above 100 mesh	150~280	10
Under 24 mesh, and above 50 mesh	280~800	37
Above 24 mesh	>800	17

The minimum ignition energy is measured using Hartmann tube, and the spark discharge triggering method is moving electrode method, which is described in IEC 61241-2-3^[7]. The MIE test apparatus (Fig.2) has been calibrated using the 3 kinds of powders given in IEC 61241-2-3, and the accuracy of the apparatus is very good.

To investigate the effect of particle size on minimum ignition energy, the original powder in silo was sieved by sieves with different meshes. The results of minimum ignition test are shown in Tab.3.

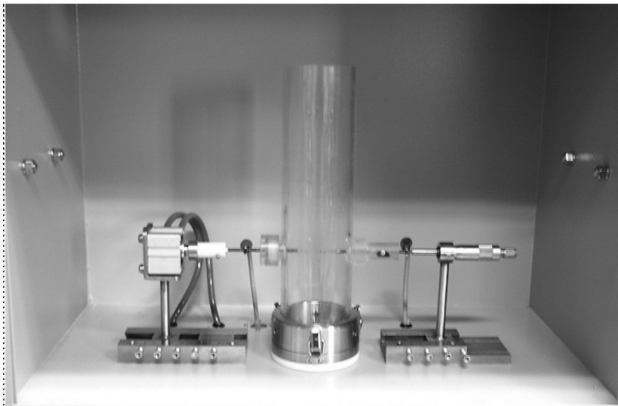


Fig.2 The MIE test apparatus with a moving electrode

Tab.3 MIE of ABS powder of different particle sizes

Mesh	Size/ μm	MIE/mJ
Under 200 mesh	<75	10
Under 100 mesh	<150	30
Under 100 mesh, and above 200 mesh	75~150	40
Above 100 mesh	>150	100

It can be seen from Tab.2 that, the minimum ignition

energy is very dependent on the particle size. For very fine ABS powder, the MIE may be as low as 10mJ, which is easy to be ignited. However, the MIE of course particles are not ignition sensitive.

The specific volume resistance of ABS powder is very high, that specific electrostatic charge will be a problem during ABS powder processing.

1.3 Hazard identification

Historical accident records show that the main places that have explosion hazards are: fluid bed dryer and silos (Tab.4). Spontaneous combustion is the main reason of fire and explosion in fluid bed dryer. The only reported explosion accident in silos didn't provide enough evidence of the fact that bulk discharge is the ignition sources. However, due to the high specific resistance of ABS powder, electrostatic discharges are still considered as ignition sources. When ABS powder is fine, the MIE can be as low as 10mJ, which can be ignited by most of kinds of electrostatic discharges except corona discharge and brush discharge.

Tab.4 Historical accidents of ABS processes

Accident	Reason	Ref.
Jilin Synthetic Resin Plant, Petro-China. 2000, fire and explosion in fluid bed dryer.	Over heating caused spontaneous combustion	
Daqing Petro-Chemical Plant, Petro-China. 1999-2000, 4 fires in fluid bed dryer.	Over heating caused spontaneous combustion	[3-5]
A plastic group in Taiwan province. 1997, explosions in silos.	Unknown, might be over heating because of mechanical failure, or bulk discharge	[1, 2]

2. Risk management of drying process

2.1 Inerting

Daqing Petro-chemical Plant reconstruct the original drying process by apply inerting (Fig.3). Originally, a bag filter was used to collect the dust, and the exhausted air was released to atmosphere. In the reconstructed process, nitrogen is used as drying media. A water washing tower is used to trap the water vapor exhausted from the bag filter, and recycle the nitrogen in the process. A pressure equilibrium system including pressure release and nitrogen supply is adopted to maintain the operation pressure (1kPa). The oxygen concentration is maintained to be below 3%.

Since the drying media is nitrogen, oxidation of ABS powder is slow. The temperature in the fluid bed dryer can be more than 70°C. This can guarantee that the water content of the dry ABS is less than 1%, so there will be no bridge phenomena (funnel flow). In inert atmosphere, the dry ABS powder has better quality than that dried in air.

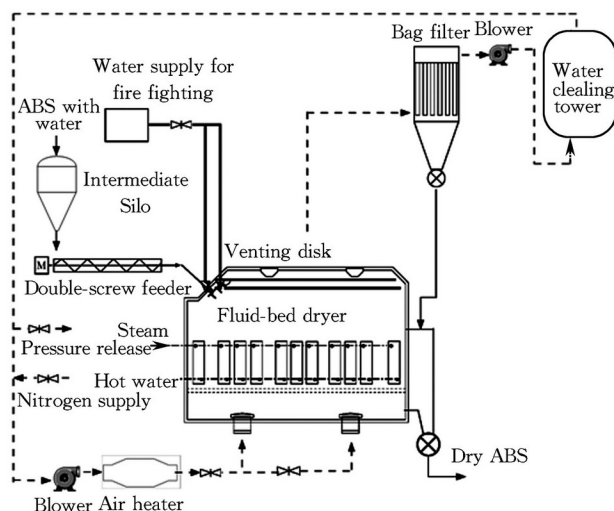


Fig.3 Application of inerting in an ABS drying process

2.2 Regular cleaning of dryer

The wet ABS material is easy to be accumulated in some parts of the dryer. The tendency of lump accumulation increases when the holes on bed bottom are partially jammed by ABS powder. The accumulated lumps are heated continuously without much movement, and they will become yellow and probably become a smoldering nest.

To avoid lump accumulation and possible smoldering, a practical method is to clean the dryer bed and heat exchangers thoroughly regularly. Practice proved that to clean the dryer each month can avoid spontaneous combustion.

2.3 Process operation parameters monitoring and control

Process operation parameters have close relation with the likelihood of lump accumulation:

(1) The water content of wet ABS material shall not exceed 30%, otherwise it is easy to form buildup on the bed. It is necessary to clean the water extraction machine regularly to improve its water extraction efficiency.

(2) When air is used as drying media, operation temperature shall not exceed 70°C. When temperature is above 90°C, process shall be stopped and safety measure shall be adopted. For instance, the dryer shall be opened and checked.

(3) Water content of the dry ABS powder is related to mass rate of raw material filling, air flow rate through the dryer bed, and drying temperature. If water content of dry ABS powder is greater than 1%, in subsequent processes, the powder in silos will not drop down smoothly, and will form "bridge" or buildup.

2.4 Fire and explosion mitigation of drying system

The following mitigation methods can be used:

(1) Explosion venting installed at the dryer, cyclones,

bag filters;

(2) CO₂ or nitrogen emergency filling system to extinguish smoldering and fire;

(3) Water spraying system to extinguish fire;

(4) Slide valves to decouple the dryer and other equipment such as cyclones and bag filters.

3. Risk management of mixing and pneumatic transportation process

3.1 Electrostatic prevention

Former investigations suggested use inert gas to transport ABS powder^[1]. However, using inert gas will increase the cost. Some silos are very big (up to 340m³). Other methods mainly aim to prevent electrostatic charge and discharge:

(1) Earth all pipes and equipment;

(2) Control air flow rate so that velocity in pipe is just enough to transport the particles to minimum electrostatic charge;

(3) Avoid any sharp metal object inside equipment.

To avoid big electrostatic field, a practical method is to divide a big silo into small chambers. In Synthetic Resin Plant of Jilin Petrochemical Company, two inner cylinders divide the silo into 3 homocentric zones. The diameters of 3 walls are 2m, 4m and 5.5m respectively.

3.2 Particle size control

Fine particles play an important role in the minimum ignition energy. The fine particles brought by air flow from the dryer are collected by the cyclones and send back to the dryer. If the fine powder is directed to another silo which is protected by inerting, the fine particles in the silo will decrease. Finally, the minimum ignition energy will increase and the possibility of ignition will decrease.

3.3 Venting and decoupling

(1) Venting shall be applied for all silos;

(2) Fast-closing valves should be installed on pipes between silos to avoid explosion propagation.

4. Conclusion

Historical accidents indicated that spontaneous combustion is the main ignition source in ABS drying process. Regular cleaning of ABS dryer and operating parameters control can avoid spontaneous combustion. Inerting can improve safety lever and there are other benefits: higher drying efficiency, better quality of product, less shutting down for cleaning. However, operation cost will increase.

The electrostatic hazard of big ABS silo is still not clear. Currently some methods are put into practice: Using

lower conveying flow rate and to divide the big silos with homocentric inner cylindrical walls. It is suggested fine particles collected by cyclones and bag filters are not returned to the main ABS powder flow to increase the minimum ignition energy.

Online monitoring of the electric field, charge to mass ratio of the powder may provide useful information for prevent electrostatic charge and discharge. However, related safe criteria and control policies are still unknown. Investigations in this field are necessary.

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