The risk analysis of dust electrostatic based on on-site survey of polypropylene plant

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Abstract. The dust electrostatic explosion accidents in polypropylene plant are mainly caused by the interaction of combustible gas, dust and static electricity. This paper analyses the key parts easy to produce dust and the risks of dust electrostatic by on-site survey of polypropylene plant, and proposes corresponding safety protection measures. The analysis results indicate that any careless mistakes and deviation in every step of process control may lead to electrostatic explosion in the silo. And if the equipment has some inherent defects and there are some careless mistakes in the process control, it will be easier to cause dust electrostatic explosion accidents.

1. Introduction
The production of polyolefin powders in China has developed rapidly in recent two decades. However, the electrostatic explosion accidents have also increased. According to the statistics, there were more than 70 electrostatic explosion accidents in powder silo of China from 1986 to 2000. There were also more than 10 electrostatic explosion accidents after 2000. At the same time the ratio of electrostatic explosion accidents was also very high abroad. This paper analyzes the causes of the dust electrostatic explosion accidents in polypropylene production plant, and discusses the rules of dust electrostatic ignition and explosion, which is essential to propose related preventive countermeasures.

2. On-site survey of risk factors of dust in polypropylene plant

2.1. Process of polypropylene plant
The refined propylene is put into the loop reactor through measuring tank. The main catalyst, activator, molecular weight regulator and electron donor are also added to the loop reactor in a certain proportion in order to perform the bulk polymerization of liquid phase. There are mainly polypropylene solid particles and unreacted high pressure propylene gases in the reactor. Gas-phase propylene is cooled and then recycled by circulating gas compressor. After they are dried by the dryer, fed by the pneumatic handling system, polypropylene powder materials are treated by extruding granulation, homogenization in particle silo and packaging in the packing department.

2.2. Main causes of producing dust easily in polypropylene production plant
(1) Quality problem of granulation
When the melting index is high, it tends to produce the materials with tails and fiber drawing; when the melting index is low, it tends to produce broken particles caused by collision. As a result, the dust

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is increased. After the reaction, if the oligomers are not treated properly, the increasing oligomers will make the melting point lower, and the particles tend to be soft and broken easily so that the dust quantity is increased.

2) Malfunctioning of granulating process
It tends to produce materials with tails or irregular shapes in the following situation: tool breaking, template wearing, gap or rotational speed regulation.

3) Mixing operation
In the process of internal or external mixing operation, the upper part of the mixing silo is easy to accumulate dust.

4) Internal structure of the pipelines
When the surfaces of the pipelines are rubbed down, it tends to produce the materials with fiber drawing and broken particles so that the dust quantity is increased.

5) Fast wind speed
If the wind speed is too fast, it tends to produce broken particles.

6) Other causes
Emptying, filtration, and so on.

3. Analysis of electrostatic risk in the key parts of polypropylene production plant and suggestions

3.1. Mixing silo
The test of powder electrostatic mass-to-charge ratio is carried out at the entrance of the silo by faraday cup and the charge meter. The data is shown in table 1.

The data indicates, the average of powder electrostatic mass-to-charge ratio is $-1.7 \ \mu C \ \text{kg}^{-1}$ (variation range: $-0.4$ to $3.24 \ \mu C \ \text{kg}^{-1}$), which is far beyond the recommended safety values ($<0.1$ to $0.3 \ \mu C \ \text{kg}^{-1}$).

The powder static electricity may cause the following discharging and ignition risks:

1) It can produce conical discharging frequently at the surface of the material heap. The discharging energy $\geq 10 \ \text{mJ}$, and the discharging period is about 26 to 71 seconds. When the concentration of combustible gas $\geq 0.5\% \ \text{wt}$, this conical discharging may cause flash burning or explosive accidents.

2) When the materials approach the position of material level alarm, it is easy to produce long spark discharging [1], the discharging energy is large, and the ignition rate is high.

Suggestion: The material high level alarm should be changed into anti-electrostatic type [4]; the entrance of the silo should be equipped with electrostatic eliminator.

| No. | Electric charge ($\mu C$) | Sample Mass (kg) | mass-to-charge ratio ($\mu C \ \text{kg}^{-1}$) |
|-----|--------------------------|-----------------|-----------------------------------------------|
| 1   | -0.10                    | 0.25            | -0.40                                         |
| 2   | -0.20                    | 0.25            | -0.80                                         |
| 3   | -0.36                    | 0.25            | -1.44                                         |
| 4   | -0.43                    | 0.25            | -1.72                                         |
| 5   | -0.67                    | 0.25            | -2.68                                         |
| 6   | -0.81                    | 0.25            | -3.24                                         |
3.2. Finished products silo
It also tends to produce electrostatic discharging in the finished products silo. The recent adopted protection measures include: clean wall-sticking materials regularly and so on.

3.3. Intermediate silo
The diameter of powder material silo is large, and the load of the pneumatic handling system is high. In the powder material simulation experiment, the charge of the material is up to 10-18 µC kg⁻¹ which can produce conical discharge frequently. If there is a tuning fork material level meter on the top of the material, it can cause long spark discharge. The discharging energy can be dozens of mJ. In the experiment, when the material charge ≥ 1.65 µC kg⁻¹, the potential of the material 200 mm away from the tank wall is up to 50 kV, which is far beyond the critical potential of igniting the dust (40 kV). The electrostatic safety in the silo mainly depends on the nitrogen protection system. Suggestions: monitor the oxygen content in the silo to prevent powder electrostatic explosion; increase the system safety by replacing tuning fork material level meter with the anti-electrostatic one.

3.4. Additive feeding platform
In the continuous feeding operation, the static electricity accumulated in the worker’s body is 2-8 kV, and the discharging energy can be 0.4-6.4 mJ, which can cause the ignition of additive dust and electric shock. On the platform, intrinsically safe type of body electrostatic eliminator should be installed to eliminate or slow down the accumulation of static electricity in the worker’s body. Suggestion: intrinsically safe type of body electrostatic eliminator should be installed on the platform to eliminate the accumulation of static electricity in the worker’s body.

3.5. Vibrating screen
By multiple vibrating screen, the selected qualified materials will be sent to the downstream storage and transportation system and the unqualified materials will be sent to waste material tank to be retreated. When the vibrating screen is selecting the materials, it tends to produce dust as well as static electricity easily.

(1) When the powder material is treated, the nonmetallic material is not only the “electrostatic source” producing static electricity, but also the “hidden dangerous source” accumulating static electricity easily and producing surface discharging. For example, several flash burning happened to the DMT powder material suction machine in a company. Investigation showed that the accidental fire source is related with the electrostatic accumulation of soft connection rubber board. The similar accidents never happened after installment of an anti-electrostatic soft pipeline.

(2) The material potential in the bottom material tank >80 kV, which is far beyond the critical potential of dust ignition (40 kV) and controlling index (<10 kV). Suggestion: take some reliable measures to solve the problem of electrostatic grounding and eliminate static electricity in this place.

3.6. Buffer hopper
The materials in the hopper may have high electrostatic charge, and produce a lot of dust. It tends to produce electrostatic discharging and flash explosion when the material is accumulated in the hopper. So it is necessary to limit strictly the height of material heap in the hopper.

3.7. Discharge and pack
In the process of discharge and packaging, it tends to produce dust and a lot of static electricity. Measures: make sure the function of the process of reaction and granulation; strengthen ventilation to reduce the dust; install electrostatic eliminator.

3.8. Bag filter
Bag filter tends to produce dust and a lot of static electricity. Measures: use anti-electrostatic bag filter; check the ventilation of the filter.
3.9. Temporary manual material receiving opening
Temporary manual material receiving opening tends to produce dust and static electricity. Measures: install powder electrostatic eliminator and body electrostatic releasing device for the temporary manual material receiving opening.

4. Risk analysis and suggestions of combustible gas in polypropylene production plant
The combustible gas may be out of control in the following situations: (1) When the reaction is not steady, there are unqualified materials or transitional material; (2) When devolatilization equipment is out of work or is out of control; (3) When something is wrong with the dryer, the concentration of the combustible gas increases. Suggestion: monitor the concentration of the combustible gas in the dryer. (4) When start or shut down the low pressure discharge tank, powder, gas and steam are discharged mixed, which tends to produce electrostatic discharge and explosive accidents. Suggestions: when we make sure the grounding of the equipment is safe, we should check and confirm CH<0.2% before the discharge. Install the electrostatic eliminator at the discharge port. (5) When receiving and discharging material are improperly operated, there will be a certain amount of combustible gas in the silo. At this moment, we should monitor the amount of combustible gas in the air conveying silo.

5. Typical case analysis of electrostatic flash explosion accident in the silo of polypropylene production plant

5.1. Brief introduction of the plant
The plant had three production lines which have a capacity of 100 thousand t/a respectively. The first two production lines, which were imported from Italy, used tubular process. The third production line used domestic tubular loop technology. All these three production lines could produce homopolymerization, random copolymerization and anti-impact copolymer products.

5.2. History of the accidents
(1) A flash explosion happened in 2D903B silo On February 12th, 2000,
(2) A flash explosion happened in 2D903E silo On September 16th, 2000.

5.3. Analysis of the accidents
(1) In both of the two flash explosion accidents, the plant was producing high melting index material with higher volatilization content.
(2) In accident of 9.16, the material level position was out of control in 2D501 steaming machine. The material level position was too low, and the devolatilization of the material was not enough. When steaming machine works properly, the volatile component of the feed is about 2~2.5% wt, and that of the discharging material <500 ppm. The concentration of the gas is about 20~50% LEL in 2D803. When tested after the accident, the concentration of the gas was up to 100% LEL in 2D803. When the production is normal, the concentration of the gas in the same products is only 57% LEL.
(3) The air-conveying PP particles tend to produce a lot of static electricity. The charge mass ratio in the feed pipes is about 0.43~2.72 μC kg⁻¹ (The measurement data of the charge mass ratio in the silo are seen in table 2), which is far beyond the critical value of conical discharging (0.1 μC kg⁻¹). When the concentration of the gas on the top of the material heap in the silo is beyond 0.5%wt, the dust may be ignited by the conical discharging on the surface of the material heap.

| Table 2. Measurement data of electrification amount in the silo |
|-----------------|--------|--------|--------|--------|--------|
| 2D903           | Silo A | Silo B | Silo C | Silo D | Silo E |
| charge mass ratio, μC kg⁻¹ | 0.71   | -1.12  | -0.43  | -2.72  | -1.33  |
6. Conclusion
The dust electrostatic explosion accidents in polypropylene production plant are caused by the interaction of combustible gas, dust and static electricity. It is a common phenomenon in the silo that the air-conveying materials tend to produce a lot of static electricity and discharge, which is the inherent hidden danger; but whether the accident will happen mainly depends on the control of the combustible gas and the dust in the silo, which is the fuse or the inducement. A lot of factors influence the gases and the dust in the silo. Any careless mistakes and deviation appeared in any step of the process control can be the inducement of electrostatic explosion in the silo. If the plant has more inherent defects and there are more careless mistakes of the process control, it is much more likely to cause electrostatic explosion accidents in the silo. Therefore, it is our urgent task to find out the hidden dangers and defects in the production plant and define reasonable countermeasures.

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