

HUMAN ERRORS AND DUST EXPLOSION PREVENTION AND PROTECTION

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ABSTRACT

With the development of process industry, dust explosion has become a serious potential hazard for the safety in production in China recently. Based on typical accident examples, this paper analyzed the features of human behavior in dust explosions generating and developing and thought human error is a key reason for this kind of frequent accidents at present. Furthermore, the human errors of different people, mainly for top management, plant designers and workers, were analyzed for their contributions to and influences on dust explosions respectively. Finally, the main reasons for human errors were concluded and countermeasures were suggested.

1. INTRODUCTION

According to the viewpoint of system engineering one factory can be regarded as a combination of human, machine and environment, what is called "human-machine"(HM) system. Being a key element in this system, the person needs to finish collecting, processing and dealing with the related information, and finally making decision and manipulating the equipment to complete the expected functions. During the series of human behavior, whatever it is in the information-processing step or decision-making step, it is normally unavoidable for people to make misplay, this is called HE in term.

As for the definition of HE, different subjects like ergonomics, psychology gave different results from their own research angle. Zhang [1] described it for the complex HM system as follows: a failure of a planned action for completing task of human being, on the condition of no surpassing the designing function of the HM system. It includes failures of individual, colony and organization. The main formations of human error may be one or more of the following items: did not complete necessary function, performed an action which should not be done, did not respond on crisis in time, did not know dangerous circumstance, made a wrong decision for the complex perceiving reaction.

It is very popular for accidents caused by human error, for example, putting on the switch of a being repaired line caused electricity-shock accident, opening the valve by mistake inducing the leakage of toxic gas caused poisoning accident, overload suspending inducing rupture of wire rope caused object falling accident and so on. From statistics, more than 85% accidents in industry are from

human error directly or indirectly in the world [2].

In recent decades, with development of processing industry (i.e. powder industry), dust explosion accidents took place more frequently than before in China. Wang [3] reported that the accidents happened from the beginning of 60's to the end of 70's (10 years) are 7 times of that from the end of 80's to the beginning of 90's (10 years). Some serious dust explosion, such as flax explosion accident of Harbin Linen Textile Plant, corn dust explosion of Huangpu Harbor in Guangzhou both happened after the time of 80's. Dust explosions are typical industrial accident. Conducting research on human error for dust explosion has realistic meaning for the prevention and protection of dust explosion accidents.

2. HUMAN ERROR AND DUST EXPLOSIONS

2.1 Typical Dust Explosion Cases Caused by Human Error

Case 1: The first dust explosion recorded in history was a typical accident caused by human error. The procedure of the accident is mostly like this: on the 14th of December, 1785, about six o'clock in the evening, in a small bread workshop in Turin, Italy, a young worker was collecting flour from the upper chamber to supply the bolter below. As he was digging, rather deeply, a sudden fall of quantity took place, followed by a thick cloud, which immediately caught fire, from the lamp hanging to the wall, and caused violent explosion [4]. In this accident, the key human error is that the worker used a fire without protection and made the flour dust suspended. This accident took place more than 200 years ago. At that time, no people

knew what is dust explosion and, say nothing of that wheat flour could cause explosion. Either the administrator or the operator is in unconsciousness on dust explosion. So at that age, it was impossible for people to adopt any measures to prevent this kind of accident.

Case 2: In the middle of the night (2.39 am) on March 15, 1987, the spinning section of the large linen textile plant in Harbin was destroyed with a catastrophic dust explosion. Among 327 women and men working night shift, 58 lost their lives and 177 were injured, 13000 m² of factory area was demolished. However, the ignition sources were not identified, but an electrostatic spark was considered as one possibility, a local fire or glow as another. When this accident happened, a lot of experimental research on dust explosions had been carried out in America and Europe, and some standards or rules have been issued. But such knowledge and techniques were very rare in China, even for the more modern plant, such as Harbin Linen Textile Plant, basically there were no rules to prevent such accident and no explosion-proof equipment to use. Maybe people knew the linen dust has explosion hazard, however, what they could do was to operate carefully according to their own experiences. The designer and the management should be responsible for the accident.

Case 3: In 1994, there was a coal dust explosion happened in Fushun Fire Power Plant. The coal powder generating system was going to start after two days shutdown. However, the monitoring system manifested that the CO concentration in coal silo (with volume of 150 m³) is a little higher than normal value. But it did not surpass the upper limitation. The monitor on duty dare not start the product system. The vice-manager responsible for production thought there was no problem according to his experience and asked the monitor to start the producing line. Unfortunately, the coal dust silo exploded within 5 minutes. It was the spontaneous combustion of deposited coal dust ignited the falling dust cloud. In other words, the manager's wrong commanding caused the accident indirectly.

Case 4: Following the wood dust explosion happened in Dragon Floor Plant in 2002, another similar accident took place in Fuxing Floor Plant in July of 2003 in Shenyang. When the product line was stopped to get repair, three dustmen went down to the tunnel, which is under the table planer, to collect the wood dust. At the same time, one worker was beginning to weld the cracked presser just above the tunnel. Suddenly, the dropped welding clinker ignited the raised wood dust. The explosion and subsequent fire killed the three dustmen and damaged the welding worker

seriously. Later investigation found that the welder did not have welding license. In addition, there was not any operating rules for welding. The welder's wrong action is the direct reason and weak management is the indirect reason.

The above four cases are just a reduction of all dust explosions. In fact, dust explosion accidents have happened in many industries, such as chemical industry, metallurgical industry, cement industry, medicament industry, metal product industry and so on. The contributions of human error to the explosions are obvious almost in every accident. It can be concluded that human error plays an important role in dust explosion producing and developing. Avoiding human errors can largely reduce the occurrence and the loss of dust explosion accidents.

2.2 Human Error's Influence on Dust Explosions from Different Persons

Dust explosion prevention and protection involves almost all the people in the enterprise, from the top manager to administrator, plant designer, safety specialist, purchasing officers and workers on the product line, and even involves casual labors and all foreigners for business. Human error from different persons will influence the safety of dust explosions. In this paper, the influence of human error from three kinds of persons will be given in the following: administrator, plant designer and workers.

1) Administrator

The administrators are responsible for establishing the policy and the object of dust explosion prevention and protection, and make sure the object can be fulfilled by means of providing human resources, financial supporting, techniques and all requirements if necessary. Any human error from administrators, whatever it is because of impercipience or short of knowledge, will give a fatal effect on the safety work of the enterprise.

As said before, China began dust explosion study very late. Almost all the related national dust explosion-proof standards were published after 90's. Many factories, which has the danger of dust explosion, faced the problem of explosion-proof reconstruction. If the administrators could not settle a suitable safety object and policy, such reconstruction project can possibly be postponed for the lack of support from the top manager. Under this condition, the risk from dust explosion in this enterprise is very high. The occasionality of dust explosion accident can change to be an inevitable state. So it has been stipulated that the highest administrator should bear the final responsibilities for the safety in production and

occupational health in any enterprise [5]. This is the most effective method for preventing human error of the top administrators at present.

2) Plant designer

For dust explosion prevention and protection, the plant designers bear more responsibility than other people. From the beginning of design, the designer should adequately consider how to prevent the dust explosion and how to reduce the risk from a contingent accident. It is well-known that dust explosion can happen only when the following four conditions occur at the same time: a) concentration of the dust cloud (not layer) is up to the lower explosion limit; b) supplying ignition source with enough energy; c) with enough oxygen (normally air); d) relatively closed space. If the designer can choose a craft and make the four conditions cannot happen simultaneously when designing, we can get so called intrinsic safety. That is to say there will be no explosion at all hours, this is the best method for dust explosion prevention. For example, crashing under water, constraining velocity/flux, adopting open structure, utilizing explosion-proof equipment are all useful methods for dust explosion prevention and protection designing.

Sometimes, the human error from a designer can cause a blank wall for dust explosion prevention and protection. There is a popular problem for concrete silo's explosion proof. According to the new safety standard, the top of this kind of silo should be equipped with explosion venting devices. However, the top of the silo is very strong and it is very difficult to cut a new hole on it. On the contrary, if the designer obligated a hole when designing, it will not bring any economical problem and difficulty in construction.

A reasonable design can solve the safety problem radically, however a design with human error can imbed a curse for the safety in production.

3) Workers on product line (including repair workers)

In the areas with dust explosion hazard, human error from workers on product line can sometimes cause dust explosion directly, so it is one of the most important parts. The human error from workers has three formations for dust explosion accident:

(1) Inducing dust flying and/or deposited

- Adopted an unsuitable operation way (such as high speed, without starting ventilating system before main production line);
- Cleaning without using vacuum as prescribed;
- Repairing not in time or repairing improperly

inducing the equipment sealed not tightly and the leakage of dust;

- Cleaning not in time or cleaning improperly inducing dust deposited seriously;
- Using unsuitable fire extinguishers.

(2) Carrying and/or causing fire

- Carrying fireworks;
- Not wearing electrostatic-proof shoes and dresses;
- Using non-explosion-proof tools;
- Using fire without obeying rules or dealing with the fire unsuitably;
- Repairing without obeying rules or repairing unsuitably;

(3) Debasing the efficiency of explosion-proof system

- Wrongly installed the explosion-proof equipment (for example, install the bursting disc reversely);
- Disconnecting or wrecking the safety equipment; (for example, welding the frequently venting doors);
- Occupying the safety venting hole or the evacuating channels;
- Exposed to the dust explosion hazardous areas overfull.

2.3 Analysis on the Reasons for Human Error in Dust Explosion Accident

Having many features of physiology, psychology, spirit and society, human beings are so flexible and uncontrollable that the reasons for human error are extremely complicated. Petersen [6] and Verhaegen et al. [7] conducted a quantity of investigations on this subject and put forward several kinds of theories and models. Taking one with another, the reasons for human error can be attributed to the following aspects [8,9]:

- Occupational adaptability factors (whether the operator meet the requirements for this post in physiology, psychology, perceiving capability, characteristics and so on);
- Knowledge and technology factors (the worker's special knowledge and practical skills);
- Working load factors (including physical capability, psychological responsibility, information input/output quantity and velocity and so on);
- Organization and administration factors (whether there is a rule for the safety in production? Whether the labor organization is reasonable?)

- Ergonomic factors.

The above conclusions are based on the human error accidents from all walks of life. It has universal practicability and suitability.

Though dust explosion accident took place many years ago, systematic research on this subject just began in the late 60's. Similar work was not started until the beginning of 80's in China, and mostly is about experimental study. The published documents of human error in dust explosion prevention and protection are very rare. Combining the status quo and the characteristics of many dust explosion accidents happened in metallurgy, light industry, mechanical industry, foodstuff industry and so on, it is thought that there are main three reasons for human error in dust explosion accident:

- Impercipient - It can be classified into three arrangements: Short of sensibility is first. Because of never contacting and even hearing about dust explosion, there is not any precautions in the worker's thought and no countermeasures can be adopted; Short of logos is the second arrangement. Though knowing something about dust explosion from a book or a report, no standards or rules can be followed at that time. He can just do as careful as possible; The third case is that the person always thinks he is lucky. According to his experience or knowledge, he thinks it is safe under this condition or this time, and operates not obeying the rules thoroughly or partly;
- Short in special knowledge - Because the knowledge of dust explosion belongs to a very special majority, it is very difficult to learn in the formal education. Also, books on this subject are not popular. Some related technical national standards began to be executed till late 90's. It can be deduced that short of knowledge is an important reason for human error in dust explosion accident. It is also the resource of impercipient;
- Administration oversight - Activities, like organizing employees to learn knowledge on safety, drafting explosion prevention and protection rules, testing and checking regularly are important contents of safety administration. However, because of impercipient or knowledge limitation, it is unpractical for the administrator to manage in terms of rules strictly. Ignoring or even disobeying the operation rules is still prevalent in China.

3. COUNTERMEASURES ON HUMAN ERRORS IN DUST EXPLOSION PREVENTION AND PROTECTION

Integrating the reasons for human error in dust explosion accidents and human error's influence on dust explosions from different persons, the authors thought that the most effective countermeasures for human error in dust explosion accident include two aspects:

1) Enforcing safety education

First of all, safety education should include education on the national safety law and policy. This part is necessary for administrators. Secondly, safety knowledge and special technology are the main task for safety education. Knowledge about dust explosion can be acquired by reading, listening to lectures, talking to experts, watching simulation experiment on dust explosion, and the like. This is important not only for employer but also for manager. Thirdly, the enterprise should improve the safety culture atmosphere and the workers' safety consciousness roundly. It can help people obey the safety law and rules for the safety in production voluntarily, and finally change their safety concept from "asked to be safe" to "ask for safety". The above educational measures will reduce human error significantly.

2) Consolidate safety administration

Good administration can ensure the countermeasures for preventing human error to be executed and continued effectively. For example, "Three Simultaneity", which is widely used by the Bureau of Labor Surveillance and Administration, can effectively prevent human error from the plant designer, establishing the safety council can supervise and check the administrator's human error, and can find the weak part of human error and the sources of human error through analyzing the human error accident. Suitably organizing production, insisting on working with permission certificate, and examining and approving system are all good administration measures for preventing human error from workers on the product line.

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