Assessment of dust explosions in the sugar industry with regard to screening technology

The prevention of dust explosions is a necessary treatment to ensure the safe operation of sugar plants worldwide. Especially in the field of screening technology only few mistakes can lead to hazardous process conditions. This paper discusses the principles of sugar dust explosions with special focus on their formation. An example is given to show possible threats which can occur during production. Advices for choosing suitable process parameters and equipment are given. A professional dust control is key to decrease the risk of dust explosions.

Key words: screening, dust, explosion

1 Introduction

The mixture of sugar dust and oxygen is a potential explosive. The tragical accident of Port Wentworth’s Imperial Sugar plant in 2008 (Fig. 1) is the most known incident of sugar causing an explosion that caused lethal injuries. With 14 fatalities and 36 injured workers the Wentworth explosion is the largest sugar explosion of this millennium. Unfortunately, it is not the only one. In 2007 two sugar explosions occurred in the United States, one in Scottsbluff, Nebraska and one in Baltimore, Maryland. Europe as well has been the scene of a sugar explosion, when an accident happened at the Iscal sugar plant in the Netherlands in 2013 [1]. To avoid such incidents most governments have released health and safety requirements as well as standards and regulations. It is the producer’s responsibility to meet these regulations by using appropriate technology. Dust explosions are not limited to the sugar industry. All organic, carbon rich materials tend to explode when the concentration and particle size is critical. But in the sugar industry practical experience shows that there is still optimization potential especially with regard to screening sugar. Therefore, it is crucial to have a closer look on the production process to determine potential threats during sugar manufacture.

2 Explosion parameters

Sugar explosions are not spontaneous. They occur when three major parameters are given:

- Critical dust concentration;
- Oxygen;
- Source of ignition.

This explosion is a very fast oxidation reaction on the surface of sugar particles. A basic rule is that the smaller the particles are the higher the reaction speed is going to be and therefore the larger the effect of the explosion will be. Beck [3] has determined the characteristic explosion values for sugar particles less than 0.063 mm in diameter. The results are shown in Table 1.

Current literature [3, 4] suggest that the maximum sugar particle size that can cause an explosion is with 0.4 mm at a concentration of 15 kg/m³. In order to trigger an explosion, the concentration of sugar needs to be at least 750 g/m³ at a particle size of 0.4 mm or 60 g/m³ at a particle size of 0.063 mm. Given a sugar bulk density of 0.8 g/cm³ this means that a dust layer of more than 0.075 mm can be critical, if accidentally dispersed.

| Table 1: Characteristic explosion values of sugar [3] |
|---------------------------------|----------|
| Class of dust explosion         | ST1      |
| Maximum explosion pressure in bar | 9        |
| \( K_0 \) in (bar · m)/s*       | 140      |
| Lower explosion limit in g/m³   | 60       |
| Minimum ignition temperature of dispersed dust in °C | 360     |
| Minimum ignition temperature of dust layer in °C  | 420     |
| Minimum ignition energy in MJ   | 10       |
| Degree of flammability          | BZ2      |

* \( K_0 \) is an index used to classify the explosion severity of a combustible dust.
Dispersion alone is not the only factor for creating an explosive atmosphere. An adequate oxygen concentration is also necessary: At least 9% oxygen is required. Ambient air contains 21% oxygen and consequently creates a favorable atmosphere for explosions.

In addition to an explosive atmosphere in the production process, a source of ignition is necessary to lead to an explosion. Due to the fact that sugar is tending to melt instead of building glow nests, an effective ignition needs to be created spontaneously in the production process [4]. Potential ignition sources are hot surfaces and sparks, which arise during production. Therefore all kinds of machines and moving parts can be a potential source.

3 Screening machines

Most customers request sugar in predefined particle sizes, which are attained through screening. Technically spoken this is a division of a polydispers material into two or more fractions. The separation is realized by comparing the particle diameter $d$ as often as possible with the wire spacing $w$ of the screen cloth to see if it fits through (Fig. 2) [5].

Screening machines may increase the likelihood for an explosion in the production process. During the classification of sugar, particles are treated with vibrations to be forced into motion. Especially fine sugar particles are fluidized during the deposition of the fines. Therefore, the dispersion of fine particles inside the screening machine is very likely [6].

Very often fine separations at a screen cut of 0.2 mm are made to separate the dust of crystallized sugar. Even though the amount of dust smaller than 0.2 mm in the feed material is normally relatively low by mass e.g. <5%, the mass flow of this fine fraction can be up to 0.24 t/h and m$^2$ screen surface. On average surface a machine volume of 2 m$^3$ to 4 m$^3$ is necessary for every m$^2$ of screen, comprising of the sieve underhopper and screen outlets for instance. Given that the residence time of sugar in an inclined screen normally is 3 to 4 s the maximum amount of dust in the air inside of the screen can reach up to 0.26 kg/m$^3$. This said it becomes obvious that in the inside of the machine an explosive concentration with highly
reactive fine sugar particles can be formed. Furthermore, the necessary oxygen is also present and the sugar particles are well dispersed in the air. Thus, it is of utmost importance to avoid potential sources of ignition inside of the screening machine and to make sure that the machine itself is as air and dust tight as possible. This prevents ignition sources from the outside getting contact with the atmosphere inside the screen. These aforementioned calculations are based on average values. A detailed analysis of the situation on site is essential to get a precise idea whether the situation is critical or not.

The manufacturer has got an obligation to recommend machinery which prevents the production process from incidents like dust explosions. Unfortunately once installed, the machines are not always utilized as indicated. In Figure 3 an example of an inappropriate screen setting for handling sugar is shown. The operators have removed the screen covers, leading to the screen having open parts where fluidized sugar particles can be emitted. A further reason for the large amount of sugar dust in the surrounding of the screen is that the screen is not a confined space, e.g. the feeder is not directly connected to the screen. Subsequently, particles dispersed in the feeding process can be whirled out of the machine due to flow-mechanical turbulence.

**4 Prevention / avoidance**

There are different approaches to avoid dust explosions while screening. They can roughly be divided into two categories, at first organizational measures and second constructional measures. These measures help to either prevent dust explosions by averting one or more of the necessary components named in chapter 2 or reducing the impact of dust explosions occurring. Prevention should be focused on in first place and therefore will be highlighted in this chapter.

Organizational measures to prevent dust explosions start with a regular cleaning of the production site. Since the necessary dust layer to cause an explosion is relatively small, the better approach is avoiding dust emissions as well as possible sources of ignition close to the machinery.

Starting with the material input, it is much safer to transport the sugar in a sealed transport line. One possibility is the usage of closed chutes and/or feeders to guide the material into the screen (Fig. 4). Chutes or closed feeders are working reliable and will also ensure a consistent loading at the screen width. Furthermore, they shall be earthed in order to reduce significantly the amount of electrostatic charges. Pipes are not optimal for feeding and in case they are made of plastic they are electric insulators and furthermore do not distribute the material on the screen surface well.

Not only the feeding system, but also the screen itself can be optimized to prevent the dust from leaving the process area. Sealable hatches withhold the dust inside the screen. As a basic rule screens that make linear, elliptical or circular movements are more difficult to seal compared to inclined statical screens. One reason is that pipes in the outlet and inlet of this kind of screen have to compensate the movement of the screen against the not moving surrounding e.g. steel work of the sugar plant. As hoses are made of plastic and cannot take unlimited load cycles, the inlet and outlet of these screens have to be surveyed carefully in order to detect leakages right in time. A preferable way to avoid this is to use inclined directly excited screens.
The direct excitation of the screen cloth is preferably achieved by using electromagnetic pulsed generators (Fig. 5). These generators are mounted on the outside of the screen in separate dustproof casings. A gasket is used to seal the knocker shaft from the outside of the screen as well as the electromagnetic pulse generators from the plunger. An advantage of this screen type is that the screen housing only takes a static function. No fan belts or other moving equipment is necessary. All parts like the knocker shafts are earthed to reduce the risk of electrostatic charge formation in the inside of the screen. Moreover due to the avoidance of sliding parts less friction can be found in the process. Friction is the major source of mechanically induced sparks and hot surfaces which could be sources of ignition. Temperatures of surfaces exposed to dust are advised to be less than 235 °C [6]. To reduce the amount of dispersed dust inside the screen an inner dedusting is recommended. It can significantly reduce the level of very fine dust thus decreasing the possibility of an explosion. Another possibility with a static screen is to sieve the material in an inert environment. Therefore the screening machine has to be filled with gases like nitrogen, carbon dioxide or noble gas like argon. Using these gases is rather expensive due to higher investment costs as well as operating costs. Therefore, alternatives are used if possible. In the sugar industry the use of inert gas is without any significance until now [6].

5 Conclusion

This paper is focused on potential risks of explosive atmospheres in screening processes in the sugar industry. The environmental parameters for an explosion are described and compared to realistic screening processes, e.g. de-dusting of crystallized sugar. The analysis of the operating conditions in the screen shows that it is quite possible to generate an explosive atmosphere in a screen. Fortunately, so far no explosions caused by screening processes in the sugar industry are known to the authors. Nevertheless, in reality there is often a discrepancy between requirements formulated during purchase of a screening machine in contrast to the operating conditions of the screening machine later. An example shows at which points these safety issues can occur and how they can be avoided. To minimize the safety risks caused by screening machines in a production process a detailed analysis of screen types, screen cuts, feed rates and other operating conditions has to be made. RHEWUM as a supplier of screening machines to the sugar industry for decades can reliably help to analyze the situation and perform tests in its laboratory and testing facility.

References

7 Meek, R. (1952): Explosive properties of sugar dust. Georgia Institute of Technology, Atlanta

Paper received on March 9, 2017.

Authors’ address: Christoph Büschgens, M.Sc., Dr.-Ing. Oliver Pikhard, RHEWUM GmbH, Rosentalstraße 24, 42899 Remscheid, Germany; e-mail: info@rhewum.de