

Catastrophic aluminium-alloy dust explosion in China in 2014

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Rolf K. Eckhoff, Dept. Physics and Technology, University of Bergen, Norway

- 7.4.9.1 Overview
- The following account is based on the extensive paper by Li et al. (2016).
- On August 2, 2014 a catastrophic dust explosion occurred in a large industrial plant for polishing various metal parts, in Kunshan, China. When the explosion occurred the plant was polishing aluminium-alloy wheel hubs for the car industry.



- 97 people lost their lives immediately and another 163 were injured. Subsequently, 39 of the seriously injured also died, which increased the total loss of lives to 136.
- The direct economic loss of was 351 million yuan.
- This is probably one of the most serious dust explosion catastrophes in human history apart from some very major coal dust explosion disasters in coal mines.



- 7.4.9.2 The plant that was struck by the explosion
- 7.4.9.2.1 The building
- The explosion occurred in a two-storey reinforced concrete-frame-structure process building of length 44 m (from north to south) and width 24 m (from east to west). The two floors comprised a basement with concrete floor and a second floor above it. The height between floor and ceiling was 4.5 m in both floors. The total floor area (both floors) was 2112 m².



- The roof of the building (and hence also of the second floor) was a light steel beam structure covered by steel panels. The external and internal walls of the building were of brick. The two floors were connected by open stair cases at each end (north and south) of the building. On both sides of the eastern wall there was a 4 m • 4 m steel-panel sliding door leading to the outside.



- **7.4.9.2.2 Process equipment layout**
- The 32 polishing production lines (16 lines on the basement and 16 lines on the first floor) were arranged in parallel in the south-north direction, as shown in *Figure 7-57*. Along each line there were 12 working stations, as also indicated in *Figure 7-57*.



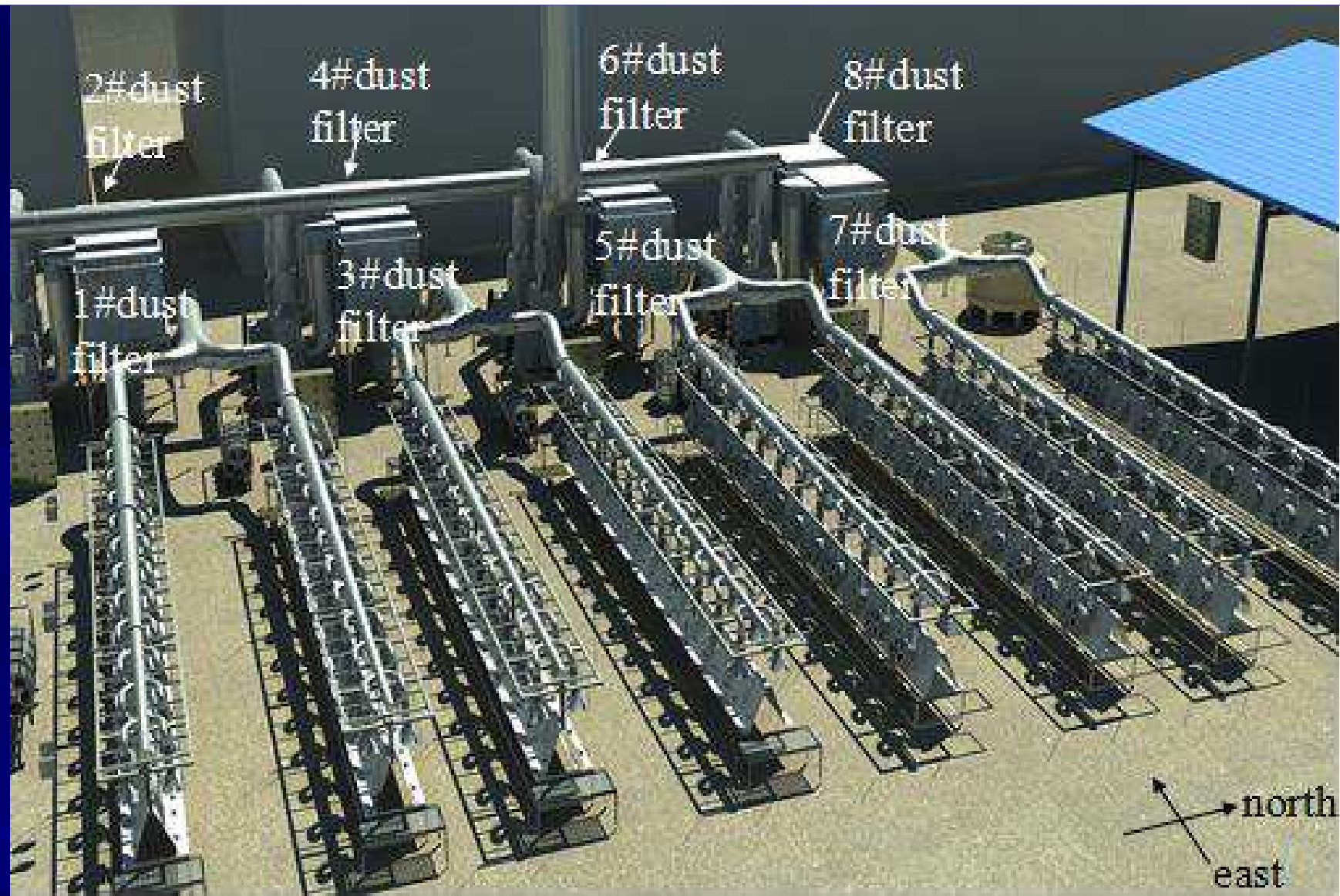


Figure 7-57. Production lines with work stations. From Li et al. (2016)



- On the day before the accident, a total of 29 production lines were in operation, 13 on the first floor and 16 on the second floor. 348 workers were on duty. Polishing operations were conducted manually as shown in *Figure 7-58*. Electric grinding guns were the main tools. According to the finish smoothness required different grades of grinding heads and/or emery papers were used.





Figure 7-58. Workers on duty at the work stations. From Li et al. (2016)



Rolf K. Eckhoff, Dept. Physics and Technology, University of Bergen, Norway

- 7.4.9.2.3 Dust collection system and processing equipment
- 8 sets of similar dust collection systems were installed in March 2006 outside the main factory building to serve the polishing processes on the two floors. Therefore, every two production lines shared a set of de-dusting system. Every two pieces of dust extraction ducts were merged by a T-joint into one main 450 mm Φ main duct leading to the bag filter. At each work location along a production line there was a 500 mm • 200 mm, which meant that each dust extraction system collected the dust from the 48 work locations.



- According to the design of the bag filters in the dust collectors the bags were supposed to be cleaned by mechanical shaking at intervals. However, after the explosion accident survivors told that, due to breakdown of the driving electric motor, of the shaking systems had been in operation for a long time. Instead workers had to clean the bags manually every morning before commencing work by vibrating the carriage of the bags. This process was called "shaking ash".



- The air flow for each of the 8 main dust extraction lines was produced by a suction fan mounted on the clean side of the bag filter unit, and all the 8 air flows were joined in a main discharge duct to the atmosphere.
- No special requirements addressing a possible dust explosion hazard had been had been enforced on selection and installation of all the electrical equipment used in the plant. Neither the dust collectors or the dust extraction ducting, nor all electrical sockets and power distribution cabinets had been adequately earthed.



■ 7.4.9.3 Explosion development

- The series of strong explosions occurred in the morning when normal hub polishing activity has been going on for half an hour. A survivor stated that he was polishing his second hub at the moment of the first explosion. A video camera located outside another factory building about 500 m away from the building that was struck by the explosion revealed a sequence of several explosions lasting for about 5-7 s, including a distinct series of 8 successive explosions.



- These 8 explosions could be identified on the video recording as violent “mushroom-shaped” dust/smoke clouds being expelled abruptly from each of the 8 dust collectors. All the windows in the first floor of the building that exploded were shattered and blown to the outside, and the window frames were completely deformed. Two thirds of the southern wall of the building collapsed.





Figure 7-59. Collapsed and destroyed eastern wall and air conditioner. From Li et al. (2016)



Rolf K. Eckhoff, Dept. Physics and Technology, University of Bergen, Norway

- Almost all process equipment in the workshop was destroyed. **Figure 7-60** shows the total damage of the process lines on the second floor.





**Figure 7-60. Destroyed process lines on the second floor.
From Li et al. (2016)**



Rolf K. Eckhoff, Dept. Physics and Technology, University of Bergen, Norway

- The dust extraction ducts inside the building were basically intact, but the duct connected to the 1# filter suffered serious damage and got detached from the T-joint. A duct branch within the workshop was broke into three parts with the middle part of it having been torn apart. The dust filters (1#, 3#, 5# and 7#) collecting dust from the first floor were more severely damaged than those (2#, 4#, 6# and 8#) collecting dust from the second floor. In particular dust filter 1# was blown entirely apart.



- The dust extraction ducts inside the building were basically intact, but the duct connected to the 1# filter suffered serious damage and got detached from the T-joint. As *Figure 7-61* illustrates, the system of dust extraction ducts in the production halls was torn apart by the explosion.





**Figure 7-61. Detailed view of damage of dust extraction ducting.
From Li et al. (2016)**



- Then these explosions and associated dust flames propagated the entire length from north to south along the first floor and got sucked into the dust extraction ducts leading to the 3#, 5#, and 7# dust filters, triggering 3 further major filter explosions. The explosion also propagated up to the second floor via a stair case and swept through that floor as well.



■ **7.4.9.4 Probable path of explosion development**

- According to the evidence found on site the explosion started in filter #1 connected to the first floor in the factory building. The blast wave followed by burning dust cloud then propagated upstream inside the dust extraction duct and entered the first floor working lines, from where it exited into the main process hall via all the dust extraction hoods above all the working tables, and eventually ignited the dispersed deposited dust on the floor near both the #1 and #2 production lines, causing major escalating secondary explosions.



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■ 7.4.9.5 Probable ignition source of the initial primary explosion

- Two significant details were noted. Firstly, the dust collecting barrel of this filter had its bottom completely blown out. Secondly, another smaller hole was found in the barrel wall that was probably not caused by the explosion but rather by corrosion over a long period prior to the explosion. The filters and the barrels underneath were located outdoors. It had been raining heavily for 2 days before the explosion accident, and it still rained lightly at the time of the accident. Water may have entered the barrel through the corroded hole and moistened the aluminium-alloy dust in the barrel.



- This water probably was a decisive factor in the process leading to self-ignition of the contaminated aluminium-alloy dust in the barrel according to the reaction equation:



- Laboratory experiments conducted after the explosion accident, which support this hypothesis, are described by Li et al. (2016). An important detail must be emphasized. The aluminium-alloy dust in the barrel was contaminated by some organic material from the wheel hub grinding/polishing process (polishing waxes etc.). This made the dust “fluffy” with a much lower bulk density than in deposits of pure dry aluminium alloy dust. Therefore the deposit had also a much lower thermal conductivity than would be expected for pure aluminium-alloy dust of the same particle size distribution.



- Another significant detail was observed during these laboratory experiments: After the self-ignition process had developed fully inside the wet contaminated metal dust deposit, open flames lasting for about 10 s were observed on top of the deposit surface. It seems reasonable to assume that these flames were due to burning of the hydrogen released according to **equation 7-1**, possibly mixed with pyrolysis gases from the organic matter in the deposit. Such flames may have played a central role in igniting the cloud of aluminium alloy dust falling down from the filters in the dust collector during the shaking of the filters.



- **7.4.9.6 Recommended actions for preventing and mitigation similar explosion disasters**
- General ignorance of the potential risk of dust explosions in industries producing fine metal dusts as a small-quantity waste product only, was identified as an important root cause of this catastrophic accident. Even in such plants excessive deposits of waste dust can build up over a long time on floors, shelves, beams and process equipment.



- Therefore, good regular housekeeping to remove layers of accumulated waste dust is a most effective and practical way of preventing and mitigating serious secondary metal dust explosions in such plants. In addition, ignition source prevention, and explosion isolation between dust collecting systems and workrooms are important means for minimizing the risks of such explosions.

