Dust carried by hot air and the influence of wind fluctuation

Satoshi Ogaki, Tatsuya Iwasaki

\textsuperscript{a}Asahi Glass co.,ltd C-Solution team, higashi-ueno taito-ku tokyo ,Japan
\textsuperscript{b}Asahi Glass co.,ltd C-Solution team, higashi-ueno taito-ku tokyo ,Japan

ABSTRACT: In many production process, there are a lot of heat sources. Undesirable problems caused by hot air flow from heat sources are in there. There are actually a lot of cases which coarse particles are lifted to the ceiling by updraft in a production room. Ventilation property changes greatly by buoyancy to occur in difference of temperature and balance of the wind pressure. This paper describes investigations based on measurements and computer simulations in the production process. The effects of heat sources, ventilation and dust distribution in production rooms will be discussed.

KEYWORDS: heat sources, hot air flow, coarse particles, wind pressure fluctuation, ventilation

1 INTRODUCTION

Over the years, there is an increasing demand for eliminating dust out of production process. Clean rooms are designed to achieve dust-free production, but so far in many industries, their actual state is the production area with improved cleanliness by doing some renovation work to the existing production site. When the dust level of the external environment is significantly higher than the required dust level of production equipment, only one layer of separation wall is difficult to maintain the necessary dust level there. Multi-layers of buffer zones are necessary between the external environment and production equipment.

On the other hand, production process cause heat radiation and generate dust, which must be eliminated efficiently. It is common to have an exhaust opening on the top of the factory building to utilize natural ventilation and to discharge heat and pollutant. Fluctuation of wind pressure can influence inside the factory building and affect clean rooms and even production equipment.

This paper, therefore, will explain factory ventilation plans with the minimum influence of external wind pressure fluctuation and with ensured good working environment by securing sufficient volume of ventilation, based on the examined results of surveys carried out at actual factory buildings and numerical analysis.

1.1 Factory’s natural ventilation and wind pressure fluctuation

Generally, machining shops and other plants have ventilator or ventilation windows (Figure 1) near the roof to facilitate discharge of hot air. For bringing outside air, openings such as windows near the floor or wall gaps are used in many cases. Glass factories with high-temperature and large heat source have internal heat radiation of ten to one hundred times greater than that of general factories, they generate enormous volume of hot air. Therefore, large ventilation equipment with low pressure loss but high hot air emission capability called “monitor roof ventilator” (Figure 2) is installed covering all over the roof.

Enlarging the exhaust opening for better natural ventilation of factory buildings makes the area more vulnerable to external wind pressure fluctuation and allows entry of dust from outside, which is a drawback.
It is commonly known that, inside factory buildings where heat sources are located, the pressure around the floor level (the bottom area) is low, while it is high around the ceiling (the top area), and if there are openings, outside air is brought in from the floor area and hot air is emitted from the ceiling. Taking an example of a factory where the height difference between an opening at the top and the one at the bottom is 15m, with inside-and-outside temperature difference of 20°C, the maximum pressure difference is approximately 10Pa. The hot air releasing pressure around the ceiling is around 5Pa if both of the exhaust openings at the top and at the bottom have same level of ventilation resistance. (Figure 3) On the other hand, wind pressure acting on the outer surface of the factory building is greatly affected by wind direction and velocity. For instance, wind pressure is about 6Pa when wind velocity at eaves height is 4m/s and coefficient of wind pressure is +0.6. (Figure 4) Taking influence by the gust into consideration, a ventilation window on the top part of a building as shown in Figure 1 is virtually defenseless against entry of dust from outside caused by the reverse air flow.

Glass factories have monitor-roof ventilator which can avoid direct influence of wind pressure fluctuation applied at the openings. Under the strong wind, however, many dust-related defects (average 2%) occurred at production sites caused by outside dust entered through monitor-roof ventilation openings. (Figure 5)

In order to avoid such dust, the following controlling measures of temperature and pressure distribution were undertaken. (Figure 6)
The idea that outside dust was mainly entered through an opening near the floor level was wrong. Sufficient air supply, therefore, was secured from the opening near the floor level, the opening area at the monitor roof instead was narrowed accordingly to elevate pressure level around exhaust opening area.

Utilizing temperature zone formation inside the factory building, the temperature at the top area of the building was raised to increase exhaust air discharging temperature and speed, keeping working area temperature unchanged.

When the speed of exhaust air discharge becomes 2m/s or higher, outside dust of 100 μm or smaller particle diameter (and the density of 2000kg/m³) cannot pass through the exhaust opening to enter inside.

As a result of improvement measures, the defective ratio caused by dust was dropped down to around 0.5% on the average. By analyzing the responsible dust, it was found out that the majority of it came from inside the factory, not from external environment. In this way, these improvement measures are proven to be effective.

1.2 Air flow control in glass factories

In spite of this, facilities handling large volume of powdery materials up to a clean room for the final process are all located in the same glass factory building. Controlling pressure and air flow distribution in the building, therefore, is a key technology for dust reduction in glass factories. It is necessary to control and prevent fine powdery materials from being diffused with the hot air flow as they can cause flaws in the following high clean processes.

It is commonly known that in-process air flow distribution has a big sensitivity to dust behavior. Figure 7 shows dust particle diameters and their properties. The most sensitive dust with particle diameters of 20 μm to 50 μm, which can cause flaws and defects to glass products, drops at a certain sedimentation speed in the static air, but can keep ascending when the speed of up draft surpasses its sedimentation speed. Heat sources in glass factories generate plume (with the speed of 3 to 4 m/s). Due to this, even the dust with particle diameter exceeding 100 μm is lifted all the way up close the ceiling level. Along with the upward air flow turns to a horizontal flow near the ceiling, dust starts to fall.

Figure 8 illustrates temperature and air flow distribution (numerical simulation result*1,*2) of a vertical section in the longitudinal direction (right side is high clean process) of a glass factory building and an example of falling dust distribution. The arrows indicate directions of main air flows. The area around the factory floor is in a low-temperature zone, while the ceiling area is in
a high-temperature zone. The plume can be seen ascending from radiation heat sources. At
glass factories, ceiling height is different for different processes such as furnace area, center area,
high clean area, respectively.

The ceiling level holding the highest pressure in a space where center area is located is
connected with the middle level of a space where furnace is in operation, the air flows from the
center area to the direction of furnace. Even if dust generated in furnace area is induced by the
updraft generated by the heat source and reach the ceiling level there, the dust contained in the
hot air flow cannot easily move in to the following process where the building height is lower.

By observing the distribution of dust volume (of 20 μm or larger), it is clear that the number
of dust declines logarithmically as the production proceeds from furnace to high clean area.

Controlling pressure distribution inside the factory by making appropriate height
arrangement and reducing dust in areas where proper cleanliness is required are a part of dust
reduction technique for glass factories.

2 CONCLUSIONS

In this paper, several measures have been presented to prevent reverse air flow from outside
through a monitor roof or other top-area exhaust opening and to avoid entry of outside dust by
controlling temperature and pressure inside factories.

This suggests that, even when strong and hot updraft containing dust is generated in the
factory building, efficient discharge of dust and heat is possible by properly arranging
distribution of its ceiling shape and height.

3 REFERENCES

1) Yoshiichi Ozeki, Tsunehiro Saito, Satoshi Ohgaki and Yoshiyuki Sonda: Simulation on Temperature and Flow Fields
2) Yoshiichi Ozeki, Shinsuke Kato and Shuzo Murakami: CFD Analysis on Flow and Temperature Fields in
Experimental Real Scale Atrium, 5th International Conference on Air Distribution in Rooms, Vol.3, pp.179-186,
1996.