Experimental Investigation of Dust Lifting Delay

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1 Introduction

Dust layers are present in many industrial facilities and factory buildings in a form of dust deposited on walls, machines, ceilings and other various installations. The dispersion of such layer can be easily performed by a pressure wave generated by a weak explosion or as a result of compressed gas system damage. If the generated dust-air mixture is ignited, an explosion of the mixture can be initiated.

A typical example of such situation is a coal mine with high risk of methane explosion. An initial weak methane explosion can disperse the dust accumulated in a form of layer on different installations present in the mine gallery. If the obtained air-dust mixture is ignited, then a devastating dust explosion can occur. Also a strong shock wave generated by the dust explosion can disperse the rest of the dust and the explosion can spread on whole area where the deposited dust is present.

It is also important to highlight that the thickness of the layer necessary to obtain an explosive mixture in a large volume is relatively very small. In a duct of rectangular cross-section 1 mm thick coal dust layer deposited only on the floor can produce a soichiometric mixture in the volume of height of about 3.6 m. But the explosive mixture can be obtained on the height of about 13 m.

In the literature, several papers can be found devoted to the problem of dust lifting. Some of the papers concentrate mainly on the mechanism of the dust lifting process (Fletcher [1], Boiko and Papyrin [2]). In some others, the delay of the dust lifting process is also investigated. One of them is the work of Gerrard [3], who investigated the mechanism of dust lifting and obtained empirical relations for the dust lifting delay and the height of the created mixture. Also Suzuki Tateuki and Adachi Takashi [4] studied the dust lifting delay and concluded that the parameter is decreasing along with decreasing of particle size and increasing of Mach number.

The Authors of the current paper worked also on the dust lifting problem. In [5] experimental results obtained for the coal dust layer are presented and further numerical investigation are shown in [6]. In the current paper, additional information are provided concerning the dust lifting process.

2 Research stand

The main element of the research stand is a shock tube. The scheme of the shock tube is shown in Fig. 1. The total length of the shock tube is 6.2 meters. Diameters of the internal cross-section are 72 mm by 112 mm. The driving section (1) is 1.5 m long and is closed by a plastic membrane (3). The visualization chamber (4) 0.5 m long is located on the other end of the tube. At the first part of the chamber, optical instruments (5) are connected to the tube. At the upper wall of the chamber, two high frequency pressure gauges are mounted to measure the shock wave velocity and the pressure distribution behind the shock wave. The shock tube is ended by an expander (7), which protects the visualization chamber against the reflected shock wave penetration. It is important, from the safety point of view, because the temperature behind the reflected shock wave could be in

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some cases high enough to ignite the dust-air mixture. The scheme of the research stand is shown in Fig. 1. The visualization of the dust dispersing process can be obtained by using the Schlieren system with the mirrors 300 mm in diameter. For the dust lifting delay investigation a drum camera and streak pictures technique were used. The scheme of the stand is presented in Fig. 2. The photography of the research stand is presented in Fig. 3.

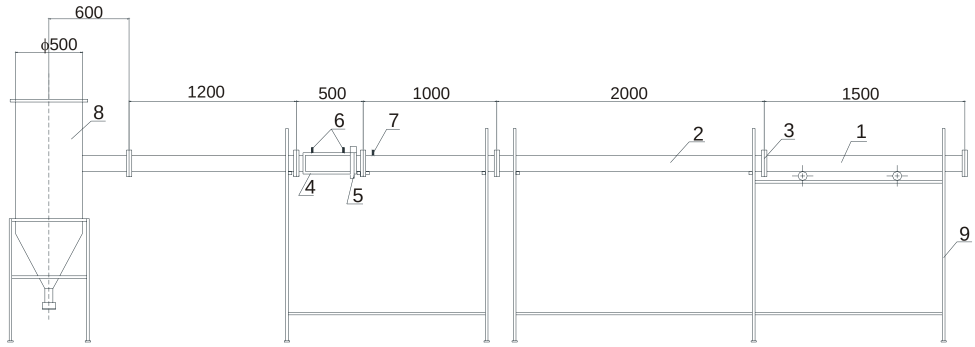

Fig. 1. Scheme of the research stand

1 – driving section, 2 – driven section, 3 – membrane, 4 – visualization chamber, 5 – optical instruments for dust concentration measurements, 6 – pressure gauge, 7 – pressure gauges for triggering the data acquisition system, 8 – expander.

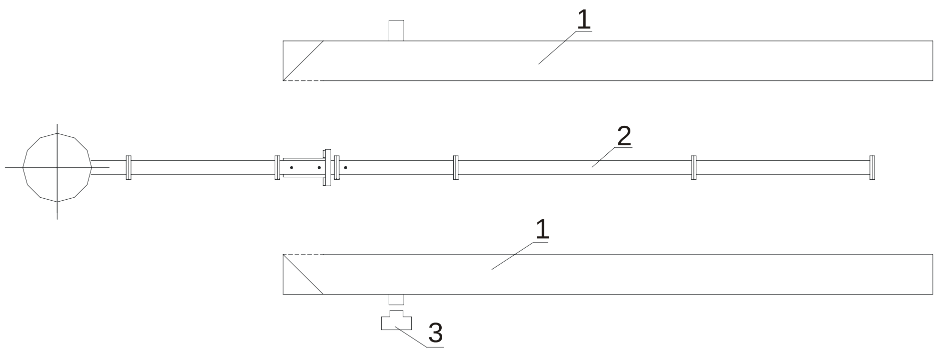

Fig. 2. Scheme of the research stand with Schlieren system

1 – Schlieren system, 2 – shock tube, 3 – drum camera

Fig. 3. General view of the main research stand

The technique of the streak pictures is presented in Fig. 4. The process is filmed through a slot (2). The light passes through the slot and a lens (3). The image is obtained on a film (4) which is fixed to the cylinder surface rotating with the velocity v_t. The shock wave (1) moving with velocity v_x is shown on the film by a strait line. An exemplary picture is presented in Fig. 5. The distance and time axes are shown in the picture. Elementary calculations give the possibility to define the time and distance scales. The process was filmed by using the Schlieren system to observe the propagating shock wave.

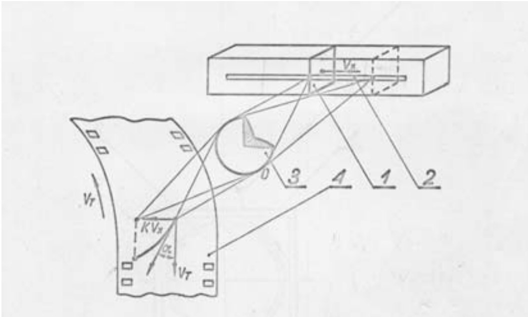

Fig. 4. Streak pictures technique.

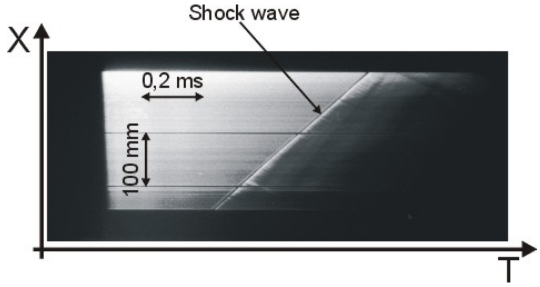

Fig. 5. Exemplary streak picture of the dust lifting up process: T – time, X – length of the slot

3 Experimental results

The experiments have been carried out up to now for two different kinds of dust: coal dust and silicon dust. Experiments with potato starch dust and other dusts are planned. The dust layer thickness was 0,1 mm and 0,8 mm for both dusts and additional experiments were carried out for coal dust layer thickness 0,4 mm. The velocity of the shock wave used to disperse the dusts was 450 m/s. The aim of the experiments was to determine the dust lifting delay in the very initial phase, and it is the reason why the slot was located just above the dust layer. In this manner, one was able to observe the shock wave (as the straight line) and the lifted dust as a dark cloud behind the shock wave. The distance between the shock wave and the dust cloud is the dust lifting delay.

In Figs. 6 and 7, exemplary results obtained for coal dust and silicon dust are presented. The delay time observed in the figures is small. The delay for coal dust is about 0,1 ms (45 mm behind the shock wave). The dust lifting delay for silicon dust is a little longer up to 0,2 ms (90 mm behind the shock wave). A weak influence of dust layer thickness on the delay time can be observed but further investigations are required. As the thickness of the dust layer increases, it is more and more difficult to obtained flat layer. This can lead to imprecision in dust lifting delay determination. The shape of the dust layer has a large impact on the results. The hillocks are lifted faster that the hollows and that complicates the dust lifting delay determination.

4 Conclusions

- The up-to-now results of dust lifting delay investigation show that the delay in dust lifting is very short.
- The dust lifting delay depends slightly on the kind of dust and dust layer thickness. This dependence has to be confirmed by further investigations.
- The shape of the dust layer has a great impact on the dust lifting delay. The hillocks are lifted much faster as they are pushed by the shock wave. The hollows are lifted slower. There appears also some pressure pulsation and it results in certain disturbances in the lifting process.
- Further investigations are planned. The influence of the kind of dust, shock wave velocity and dust layer thickness on dust lifting delay will be investigated.

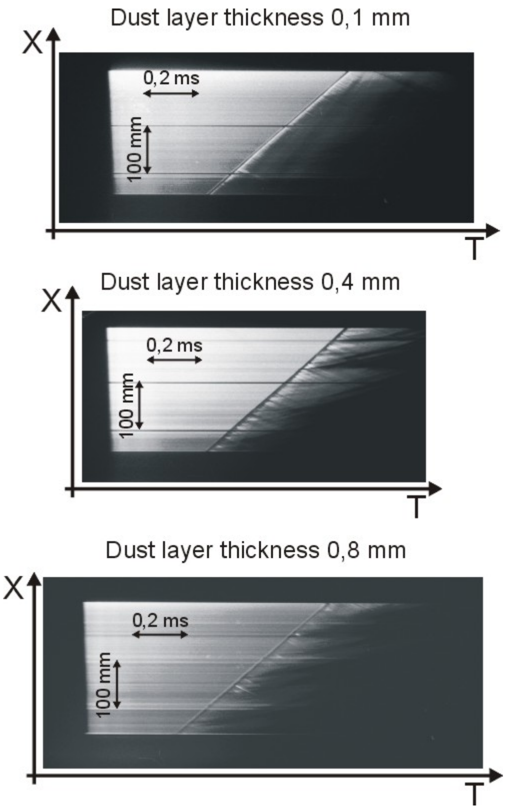

Fig. 6. Streak pictures of coal dust lifting.

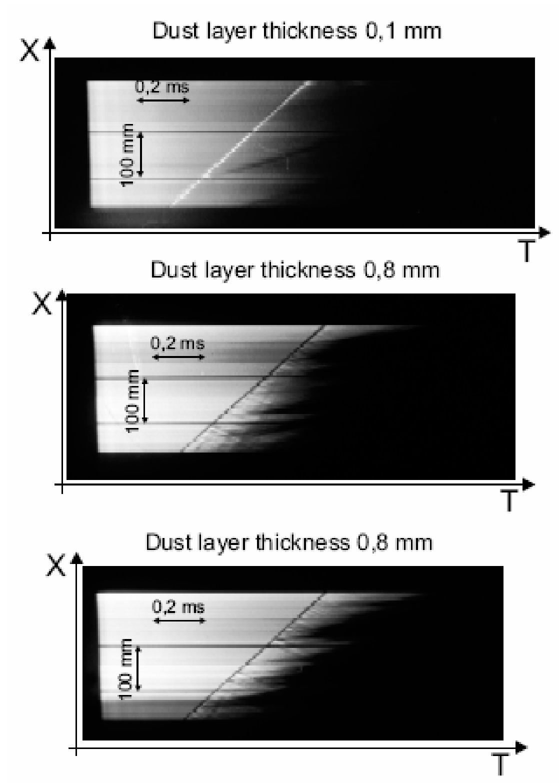

Fig. 7. Streak pictures of silicon dust lifting.

References

[1] Fletcher, B. (1976). The interaction of a shock with a dust deposit. Journal Phys. D: Appl. Phys., 9, No. 2, 197-202.

[2] Boiko, V. M., & Papyrin, A. N. (1987). Dynamics of the formation of a gas suspension behind a shock wave sliding over the surface of a loose material. Combustion Explosion Shock Waves, 23, No. 2, 231-235

[3] Gerrard, J. H. (1963). An experimental investigation of the initial stages of the dispersion of dust by shock waves. In British Journal of Applied Physique, 14, No. 4, 186-192.

[4] Suzuki Tateuki & Adachi Takashi. (1984). The effects of particle size on shock wave dust deposit interaction. In Proceedings of the 14th International Symposium on Space Technology and Science, Tokyo (p. 483-490)

[5] Klemens, R., Zydak, P., Kaluzny, M., Litwin, D. & Wolanski, P. (2006). Dynamics of dust dispersion from the layer behind the propagating shock wave. Journal of Loss Prevention in the Process Industries, 19 (2006) 200-209.

[6] Zydak, P., Klemens, R. (2006). Modelling of Dust Lifting Process behind Propagating Shock Wave, Journal of Loss Prevention in the Process Industries, (in revsion).