Dust Lifting up Process From the Layer in Slow Air Flow

R. Klemens, P. Zydak
Warsaw University of Technology, Warsaw, Poland,

Corresponding author, R. Klemens: klemrud@itc.pw.edu.pl

Introduction

The aim of the research was to investigated the dust lifting up process from a layer in a slow air flow. This research are closely related to the flame propagation problem in channels where the dust is not premixed with air but is deposited in form of a layer. Most of investigations done in this field were devoted to the problem of dust dispersion from a layer behind a propagating shock wave. The aim of the conducted research is to extend the experiments to slow gas flows. The measured parameters were: vertical velocity of the dust cloud and dust concentration distribution along the height of the tube. The obtained results will be used in further numerical modeling of the dust lifting up process.

Research stand

The main element of the research stand is a tube. The scheme of the research stand is shown in figure 1. The tube of internal cross section 72x112 mm^2 was 3.5 m long.

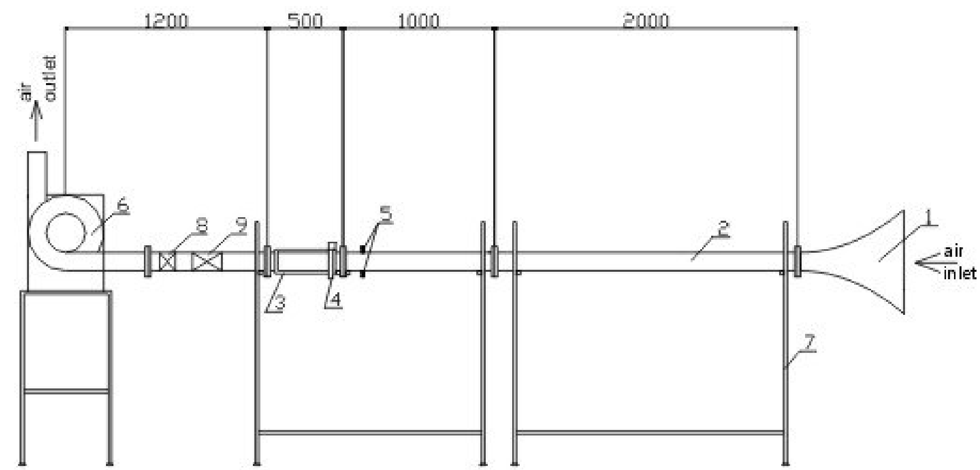

Figure 1. Scheme of the research stand

1- lemniscate inlet, 2 - tube, 3 - visualization chamber, 4 - optical instruments for dust concentration measurement, 5 - velocity and turbulence measurement instruments, 6 - fan, 7 - stand frame, 8 - venting mechanism, 9 - honeycomb straighteners

In the tube, there is a 0.5 m long visualization chamber (3) equipped with optical instruments for dust concentration measurement (4). Before the visualization chamber, the instruments for air velocity and turbulence measurements were located. At one tube end, a lemniscate inlet was mounted to make the air flow smooth. At the other end, a centrifugal fan forcing air flow through the tube and working in a sucking mode was fixed. Between the fan and the tube an additional section of the tube was mounted. The section was equipped with honeycomb straighteners to avoid flow perturbation generated by the fan. A venting mechanism was also mounted to enable fast opening and closing of the air flow through the tube at full fan rotation speed. The dust layer was prepared on a metal insert 1.5 m length by using a special dispersing chamber. The insert was fixed inside the tube along two sections - the visualization chamber and the previous one. In some experiments a 5 mm height and 2 mm thick obstacle was fixed on the insert surface. The general view of the main research stand is shown in figure 2.

Figure 2. The research stand

A stand for dust layer formation on the insert surface was also developed. A special tube with a dispersing system was constructed. At the bottom of the tube, there was a specially fitted and stiffened metal insert of the length equal to 1.5 m. The compressed air impulse dispersed the dust and formed an even, thin dust layer on the surface of the metal insert. The thickness of the obtained dust layer depends on the amount of dispersed dust.

In the first part of the visualization chamber, a special five-channel optical device was fixed, enabling dust concentration measurement at five points located in one vertical plane along the height of the tube. Every channel consists of a laser diode and silicon photodiode. The system was calibrated by using a separate stand containing a vertical tube in which a continuous dust stream of a known concentration was produced. The system also enable us to measure the vertical velocity of the dust dispersed from the layer. The first laser was located 8 mm above the dust layer, the others were mounted 21 mm between each other. The optical instrument for dust concentration measurement is shown in figure 3.

The process was registered by a high speed electronic camera. The film pictures were used to verify and to complete the results collected by use of the laser system.

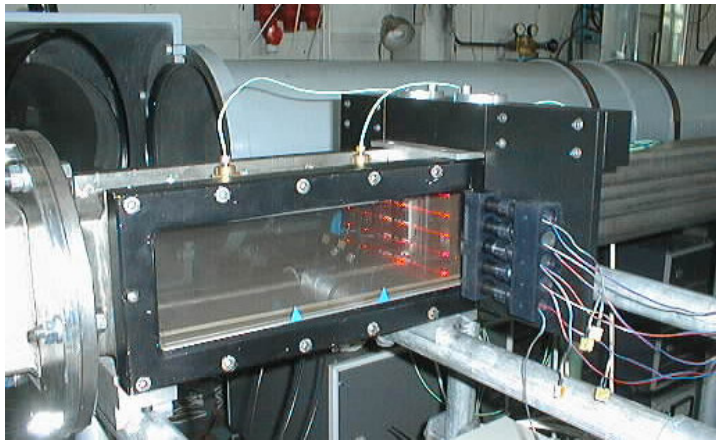

Figure 3. View of the visualization chamber and dust concentration measurement system.

Research

Four different dusts were chosen for the experiments: coal dust (mean particle size 18 μm), silicon dust (mean particle size 20 μm) and two potato starch dusts with different mean particle size 35 μm and 75 μm. Three kinds of dust layer thickness were used in experiments: 0,1 mm, 0,4 mm and 0,8 mm. The air flow velocity generated by the centrifugal fan was about 29 m/s. The dust lifting up process was also tested in a tube with an obstacle located 40 mm before the measurement point. In this case, only two dusts were tested: coal dust and potato starch dust (mean particle size 75 μm). Measurements of air flow velocity and turbulence in a non-dusty flow were also done.

On the basis of the results obtained from the dust concentration measurement system, the vertical velocity of the dust cloud between the laser beams was calculated. The history of dust concentration in lasers position was also calculated and the results are presented in form of graphs.

The film pictures analysis enables us to draw plots showing the particles position over the dust layer surface as the function of time. The vertical velocity of the dust cloud calculated on the basis of those plots is also presented. A good agreement between these results and the ones from the dust concentration measurement system is obtained.

The time delay after which dust lifting up process could be observed was measured from the films and also some information concerning the influence of turbulence on that process was found. In conducted experiments, the time delay of the dust lifting up process was defined as the time period between the air flow initiation in the tube and the beginning of lifting up of the dust from the layer.

An exemplary results are shown in figures 4 and 5.

Conclusions

- the vertical velocity of the dust cloud is of the range of several percent of the air flow velocity and depends on the kind of tested dust

- the influence of the obstacle is not clearly defined. Probably, at a short distance behind the obstacle, the influence is relatively strong
- in case of the flow with the obstacle, the time when the velocity of dust lifting up reaches its maximum value does not depend so distinctly from the dust layer thickness
- the results obtained lead to the conclusion that the beginning of the dust lifting up process is directly linked with formation of a turbulent boundary layer
- graphs elaborated on the basis of the films confirm the results obtained by the use of the dust concentration measurement system
- the film pictures show uniform process of dust lifting up from the layer along the visualization chamber
- obtained results will be very useful for development and validation of numerical models of dust lifting up process in slow air flows

Acknowledgments

The work was supported by E.U. Project DESC – Development of a CFD – Code for Predicting of the Potential Consequences of Dust Explosions in Complex Geometries, Contract No. GRD1-CT-2001-00664.

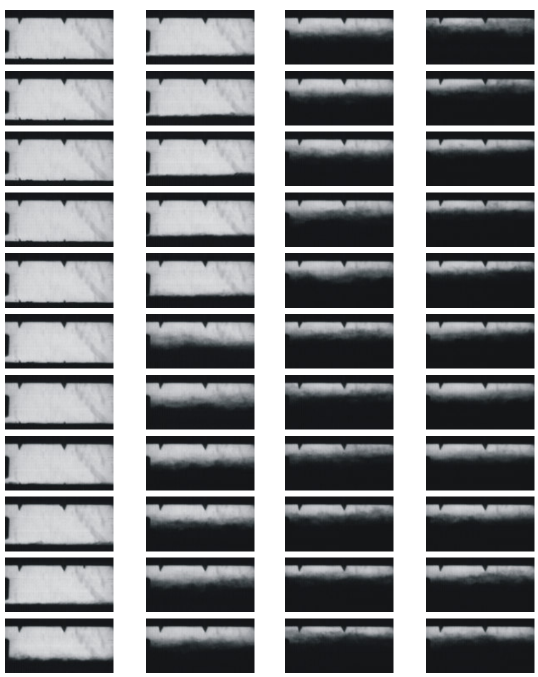

Figure 4. Frame pictures of dust lifting process. Air flow velocity in the channel axis equal to 29 m/s. Flow without obstacle. Coal dust layer thickness 0,4 mm. Time interval between the pictures equal to 7,4 ms.

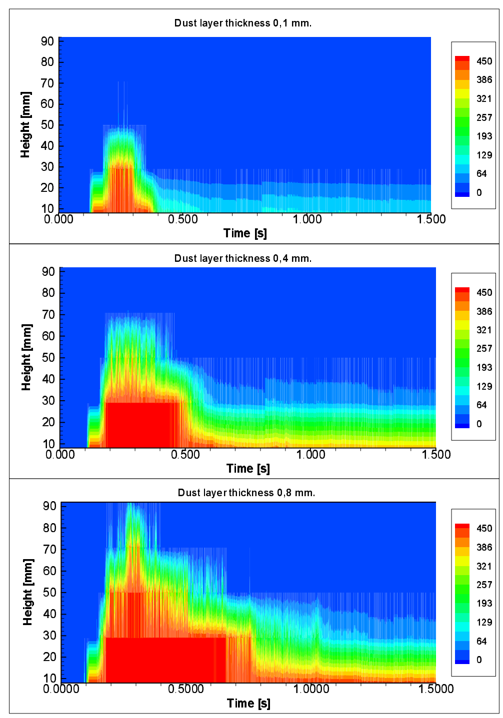

Figure 5. Coal dust concentration [g/m^3]. Air flow velocity 29 m/s. Flow without obstacle. Occurrence of the maximum dust concentration in any area means that dust concentration has reached there its maximum measurable or higher value.