NUMERICAL SIMULATION OF DUST LIFTING PROCESS BEHIND PROPAGATING SHOCK WAVE

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The two-phase flow modelling still remains a great challenge for scientists and various problems are yet to be resolved. One of them is dust lifting from the layer. In many industrial facilities, the dust is lying on the floor or on machines and is not preliminarily premixed with air. If a small explosion occurs, the generated air flow may disperse the dust and mixed it with air. The explosion mixture is then obtained and, if an ignition follows, a devastating explosion may be initiated.

The experimental study in the field of explosion safety in industrial facilities are limited to small scale tests due to high cost of large ones. That is why it is necessary to develop reliable numerical tools for dust explosion simulation in large geometries. Computational limitations imply the use of sparse meshes and modelling of the dust phase in Eulerian manner. An empirical approach has very often to be used to avoid the current computational limitations. In the same way, the dust lifting has to be simulated using some empirical models based on experimental study.

The presented work is devoted to the study an empirical model developed on the basis of the experimental study of the dust lifting process in a shock tube at Warsaw University of Technology [1]. The process was studied in a 6 m long shock tube for different: shock wave velocities, dust layer thickness and kinds of dusts. Large amount of data was collected, especially vertical velocity of the dust cloud and values of dust concentration, which have been very useful in validation of the model. The model presented in figures 1 and 2 consists of an injection of dust in the vertical upward direction. A mass equation can be written for the first bottom line of the computational cells.

$$\frac{dm_2}{dt} = \rho_p V_p A .$$

After some operation, the equation of conservation for solid phase concentration in the bottom grid cell is obtained.

$$\frac{d\rho_2}{dt} = \frac{\rho_p V_p}{\Delta} .$$

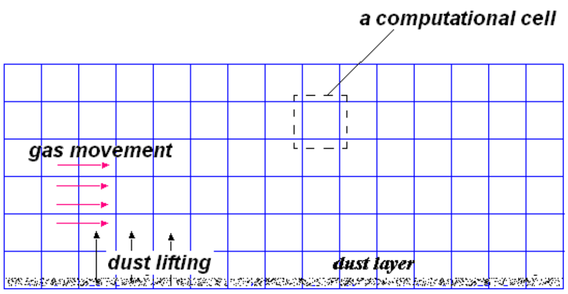

Fig. 1. Scheme of the empirical model

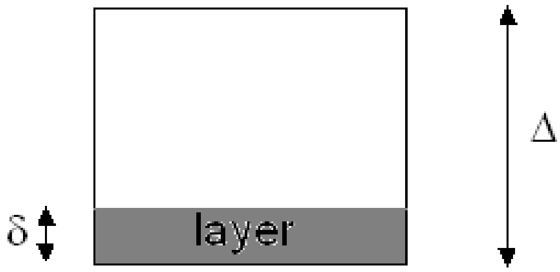

Fig. 2. Bottom grid cell

In the equation two parameters are needed: the velocity of the dust and the dust concentration which were obtained from the measurements. An empirical relation has been obtained and used in numerical simulations.

In order to make the calculation, a two-dimensional, two-phase model was elaborated. The gas flow is described by Navier-Stokes equations solved using the Godunov method [2]. The dust flow is treated in Eulerian manner and the equation describing the dust flow is also solved by using a modified Godunov method. The gas phase and the dust phase are coupled by heat and momentum exchange.

In the calculations, the same 6 m shock tube was used. The results for different dust layer thickness, shock wave velocities and different kind of dusts are presented and compared to the experimental ones. In Fig. 3, exemplary results are presented for coal dust. The pictures represent the dust concentration history in a vertical plane of about 1.15 m after the beginning of the dust layer where, in the experiments, a set of laser probes was located and the concentration of dust was measured.

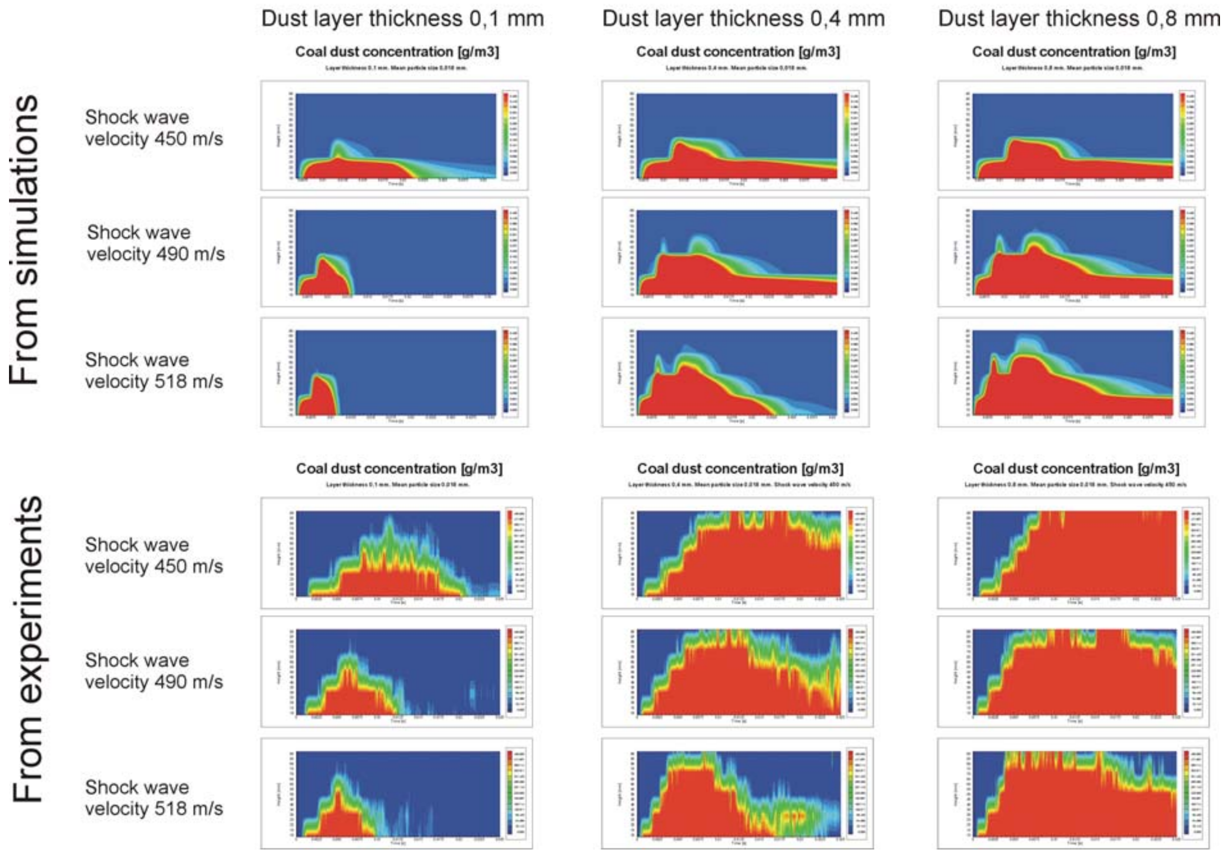

Fig. 3. Comparison of the dust concentration measurements from experiments with the results obtained from the numerical modelling. The pictures represent the dust concentration history in a vertical plane of about 1.15 m after the beginning of the dust layer. Time $t=0$ s is the moment when the shock wave was observed in the vertical plane, where the measurements of dust concentration were carried out. The horizontal axis represents the time range of 0-25 ms. The vertical axis represent the height of the channel in the range of 0-90 mm. The scale of dust concentration is the same for all the pictures from 0 to 450 g/m^3.

As we can observe in Fig. 3, the results of calculations are qualitatively correct. The shape of the dust cloud is similar. The increase of the dust layer thickness leads to an increase of height at which the dust is lifted. Also, like in experiments, the increase of shock wave velocity causes the dust to lift faster and to reach the highest height faster. A delay in dust lifting is observed in the simulation but it is shorter than in the experiments. The results still remain not fully quantitatively correct. The dust is lifted higher in the experiments and the high dust concentration lasts longer. The latest results confirm a weak dependence of the model on the grid cell size.

Acknowledgements

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