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OBSERVATION OF PARTICULATE MATTER VELOCITIES IN THE FLUE TRACT OF LOCAL HEAT SOURCE

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Abstract: Presence of particulate matter (PM) in the atmosphere is a problem mainly in the winter time. PM are getting into atmosphere from combustion of solid fuels in heat sources. Their impact on people health is harmful, when we breathe them. Therefore, it is necessary for reduction these emissions in the atmosphere. This article investigates downfall velocities of particulate matter based on calculations and then it observes velocity simulation of particulate matter flowing through baffles placed in the flue tract of local heat source by using program Ansys. These baffles are usable for separation of particulate matter in the flue tract. When particles reach downfall velocity, forces which acting on them are in equilibrium and they would not get into atmosphere from the flue tract of heat source. CFD simulation in program Ansys allows us to observe velocity distribution in flue tract and compare it with calculated downfall velocity of these particles.
Keywords: particulate matter, local heat source, reduction emissions

INTRODUCTION

Residential combustion of solid fuels as well as biomass is considered to be a major source of particulate matter and hydrocarbons. Solid fuel contains more amount of inorganic ash forming elements. During combustion of wood, these inorganic elements such as alkali metals, chlorine, sulphur and some heavy metals are partly released to the gas phase, and they may cause deposition, high temperature corrosion, together with emission of harmful gases and particulate matter. Epidemiology studies have shown a clear correlation between the particle concentration in the air and severe health effects on human being [1]. Therefore, it is necessary for reduction these emissions in the atmosphere.

We can distinguish particulate matter into two main groups. PM10 is the coarse fraction, which contains the larger particles with a size ranging from 2.5 to 10 μm. PM2.5 is the fine fraction, which contains the smaller ones with a size up to 2.5 μm. The particles in the fine fraction which are smaller than 0.1 μm are called ultrafine particles. We also know particles with coarser fraction than PM10 [2].

This article as first investigates downfall velocities of particulate matter based on calculations. Downfall velocity is a velocity, when the forces acting on the particle are in equilibrium. These forces are gravitational, lift and resistance [3]. When particles reach downfall velocity, they would not get into atmosphere from the flue tract of heat source.

Then, it observes velocity simulation of particulate matter flowing through baffles placed in the flue tract of local heat source using by program Ansys. These baffles are usable for separation of particulate matter in the flue tract. CFD simulation in program Ansys allows us to observe velocity distribution in flue tract and compare it with calculated downfall velocity of these particles.

MATERIAL AND METHODS

For the calculation of particulate matter downfall velocity was considered shape of these particles as spherical. Equation for calculation of downfall velocity for laminar sedimentation area is:

$$u_P = \frac{d^2(\rho_{\square} - \rho)g}{18\mu} \quad (1)$$

Equation for calculation of downfall velocity for turbulent sedimentation area is:

$$u_P = 1{,}74\sqrt{\frac{d(\rho_{\square} - \rho)g}{\rho}} \quad (2)$$

For selection of sedimentation area, there is used equation:

$$C_D\,Re^2 = \frac{4}{3}\frac{d^3(\rho_{\square} - \rho)\rho g}{\mu^2} \quad (3)$$

≡ for laminar sedimentation area: C_D. $Re^2 < 12 - 48$ with accuracy +/- 0.5 – 5 %

≡ for turbulent sedimentation area: $1.1.10^5 < C_D. Re^2 > 4.10^{10}$

There is possible to use iterative method for calculation of downfall velocity for transition sedimentation area [3, 4]. Based on the measurement of particle density, such as a ratio of their weight and volume, was considered density value of 2000 kg.m^{-3} during downfall velocity calculations.

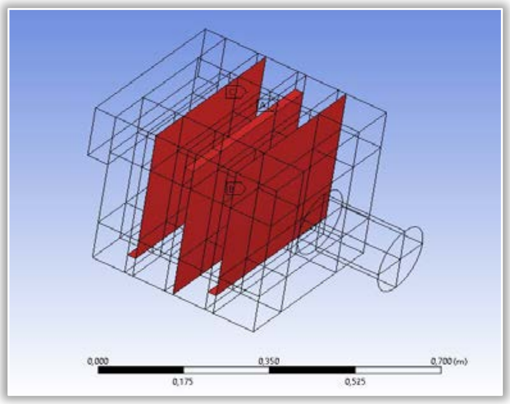

Figure 1: Used 3D model

For the observation of particulate matter velocities was used program Ansys. Particulate matter should be capturing on three baffles placed in the flue tract of local heat source. There was used 3D model with the same length of edge 400 mm, which is shown in the Figure 1. Escaped particles were getting into chimney with diameter 160 mm.

We created mesh with network of 194787 elements, which you can see in the Figure 2. All elements had aspect ratio lower than 10.

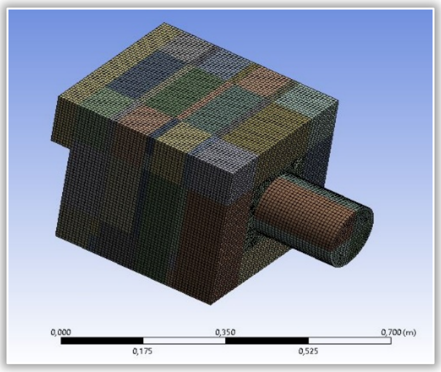

Figure 2: The mesh of 3D model

For the simulation was used k-ε model with standard wall function. The flowing of particles was realized using by a Lagrangian reference frame. Particles were considered spherical and also the influence of turbulence on particle motion. Flowing was time steady and a mass flow was 0.0168 $kg.s^{-1}$ on an inlet place, without combustion with air density of 0.6 $kg.m^3$ and the influence of gravity was considered. There was used hybrid initialization and the calculation has converged.

RESULTS

Results of downfall velocity calculations are shown in the Table 1. It has been found that particles up to 50 μm settle in the laminar area. Particles in range from 50 to 950 μm settle in the transition area and particles over 950 μm settle in turbulent area. Downfall velocities during laminar sedimentation area have very small values, while velocities during turbulent sedimentation are significantly larger.

Table 1: Results of downfall velocity calculations

diameter [μm]	10	20	50	100	150
downfall velocity [$m.s^{-1}$]	0.007	0.029	0.181	0.487	0.939

Result of simulation of PM flowing through baffles is shown in the Figure 3. We can see velocity distribution in the 3D model and compare it with the downfall velocities. Maximum flow velocity in this model was 2.5 $m.s^{-1}$. This velocity is much higher than downfall velocities of particles.

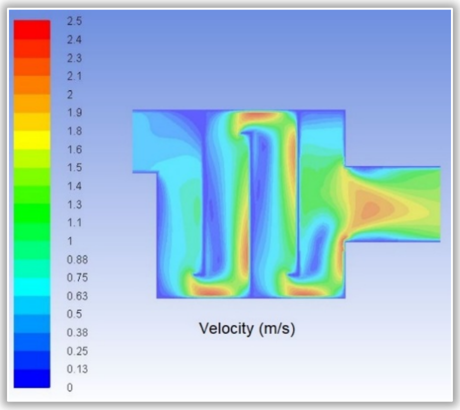

Figure 3: Velocity distribution in the 3D model

Particles achieve bigger velocities in a places of boundary walls after a transition of the baffle and also on the bottom parts of baffles. Smaller velocities are in a surrounding of first baffle place and on the upper parts of other baffles. It means that the smallest particles will escape in the flue gas stream and only larger particles will be capture.

CONCLUSION

Observation of particulate matter is important due their impact on our health. It is also important to try of reduction these emissions. This article investigates downfall velocities of particulate matter based on calculations and then it observes velocity simulation of particulate matter flowing through baffles placed in the flue tract of local heat source by using program Ansys. Calculated downfall velocities have very small values, while velocities in the 3D model are much higher. It means that the smallest particles will escape in the flue gas stream and only larger particles will be capture.

Acknowledgments

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