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PIV Observation of the Baffle Position in the Flue Gas Tract for Particle Flowing

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Abstract. Solid fuel combustion accompanies particulate matter production. These particles negatively affect human health, so ways of capturing them are being sought. Local heat sources are a major producer, with this article focusing on the flue gas tract of this heat source. A baffle has been placed in the flue gas tract, the position of which is changing. It is observed the impact of particulate matter flowing through this baffle with a focus on the settling areas. Particles are trapped in the settling areas and do not flow further through the flue gas tract. Particulate matter flowing was investigated by the visualization method called Particle image velocimetry (PIV). Visualizing the flow allows to get a figure of the flow and a dynamic record of the state of the object. The result of the visualization is the assessment of the monitored flow, the determination of its trajectory and streamlines.

1 Introduction

Particle image velocimetry (PIV) is a method of measuring speeds throughout a two-dimensional field (possibly even a three-dimensional one). The area is illuminated by powerful pulses of light, the most common source of which is the laser, the bundle of laser beams being stretched flat. The liquid must be saturated with particles. These particles are monitored for movement. When measured in a two-dimensional space, a high-speed camera is used to scan the area at certain set time intervals. From these images, the drift of individual particles is then assessed using software. The known time between laser pulses makes it easy to calculate the speed of the particles, which is considered the speed of the fluid [1].

The basic principle of PIV is to derive velocity vectors from smaller sections of the measured area. The calculation is therefore based on the equation:

$$\vec{w} = \frac{\overrightarrow{\Delta x}}{\Delta t} \tag{1}$$

Where $\vec{\boldsymbol{w}}$ is velocity vector, $\overrightarrow{\boldsymbol{\Delta x}}$ is particle shift in a given direction and Δt is time between laser flash.

The continuous profile is illuminated using a laser (two flashes), where each flash takes the surface to be scanned by the camera to produce two timed images. The first step is to

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divide the entire recorded area into sub-plots of the so-called interrogation areas. Correlation methods are subsequently applied to these interrogation areas [2, 3, 4].

2 Measurement method

This article deals with the observation of the baffle position located in the flue gas tract of a local heat source. The baffle has a function of capturing particulate matter from the solid fuel combustion process. The particulate matter in this work represent oil droplets with a size of 1 μm to 5 μm that were produced by the droplet generator. The particles were illuminated by the Nd: YAG laser. The individual images were recorded using a CCD camera rotation 90° from the plane of the laser cut. The camera was fitted with a filter that only released green particles. The experimental set-up included a flue-gas tract with a baffle, a fan, a differential pressure and temperature sensor, an anemometer, a droplet generator, and a measurement switchboard. The flue gas tract is made up of transparent PMMA material connected by metal attachments (Figure 1).

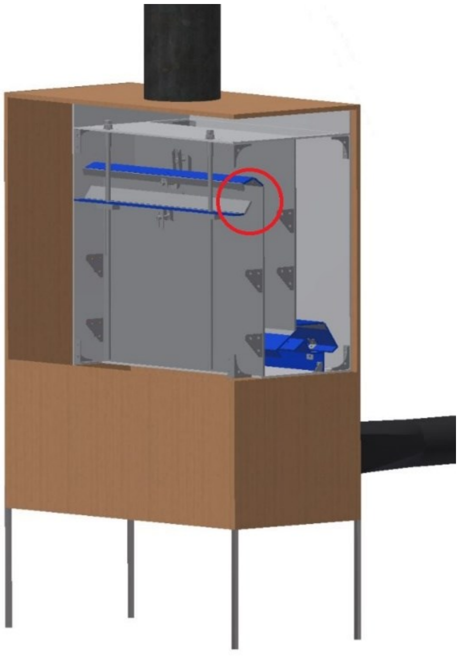

Fig. 1. The overall model of the flue gas tract.

The model of flue gas tract was realized as 330 x 500 x 500 mm block. The particles entered the model through an entry area measuring 80 x 500 mm and exited the model through an exit area measuring 85 x 500 mm. The baffle was 80 mm from the model's wall, 400 mm high. At the end of the flat section of the baffle was a curvature that channelled the flow of flues. This model has been modified twice more to vary sizes X, Y, α, β, γ. In the first variant (1), X = 80 mm, Y = 360 mm, α = 120°, β = 110°, γ = 130°. In the second variant (2), the following dimensions were changed to: X = 90 mm, Y = 355 mm, α = 140°, β = 120°, γ = 120°. Finally, in the third variant (3), the dimensions were as follows: X = 95 mm, Y = 345 mm, α = 155°, β = 135°, γ = 115°. The detail of the baffle is Figure 2.

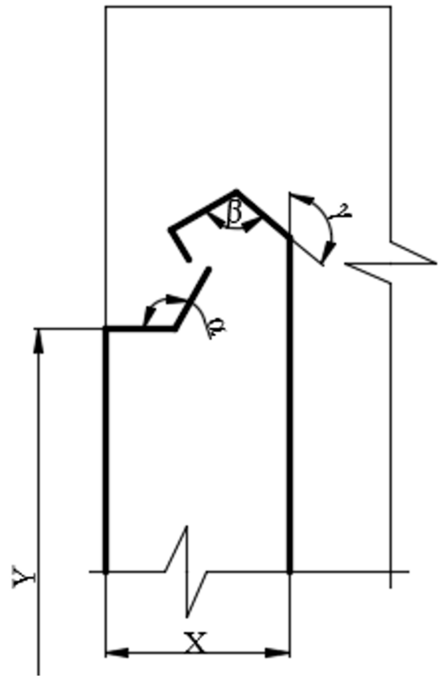

Fig. 2. The detail of the baffle.

The measurement was made without the influence of other light. The measurement was realized in the area of baffle curling at a distance of 60 mm from the front wall. The particles were flowing through the air tunnel at 2.5 $m.s^{-1}$. The camera exposure time was 300 μs and the time between shots was 450-900 μs depending on the speed of flow. Between frames 1 and 2, the optimal displacement was 6 pixels during a given measurement. The intensity of the first laser was 5.7 - 6.2, the second laser 6.0 - 6.3 depending on the visibility of the particles, the amount of shielding and obstacle elements. The assessment area started at 16x16 pixels and in some cases, when no particle was found, increased to 64x64 pixels.

The results were made by using DynamicStudio software. Two images that were taken in the measurement were used, along with correlations, mask use, erroneous vectors removal, and average from the entire set of measurements.

There may have been possible deviations from the PIV measurement due to lost pairs. In these cases, correlation noise is increased, with higher probability of loss pair being at higher velocity particles.

3 Results

In the Figure 3 an be seen scalar maps at the speed of all three variants. The scalar maps have a similar flow pattern, with the speed beginning to increase beyond the narrowed cross-section and reaching a maximum value of 1.1 $m.s^{-1}$.

In the Figure 4 are shown vector flow maps for all three variants and in the Figure 5 are shown each stream. At the end of the baffle, the particles curl up with a certain radius and then follow the vertical wall of the flue gas tract, creating a vortex at the point below the drifting stream to create a settling area for the particles.

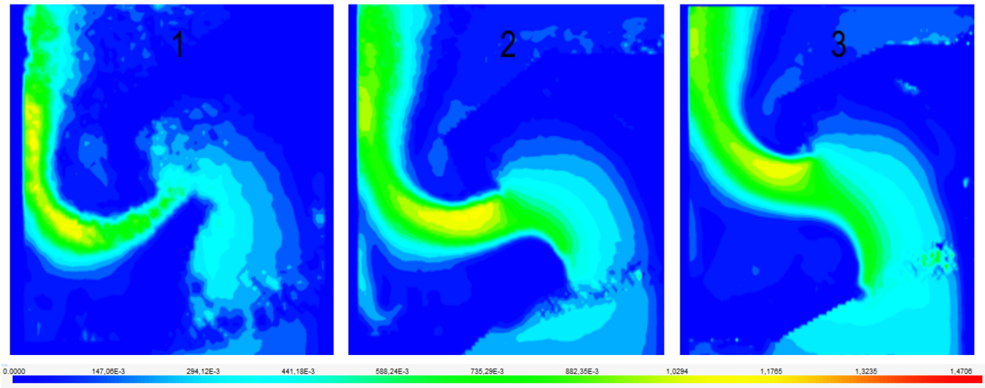

Fig. 3. Scalar velocity maps in the area of the curling up of the first baffle.

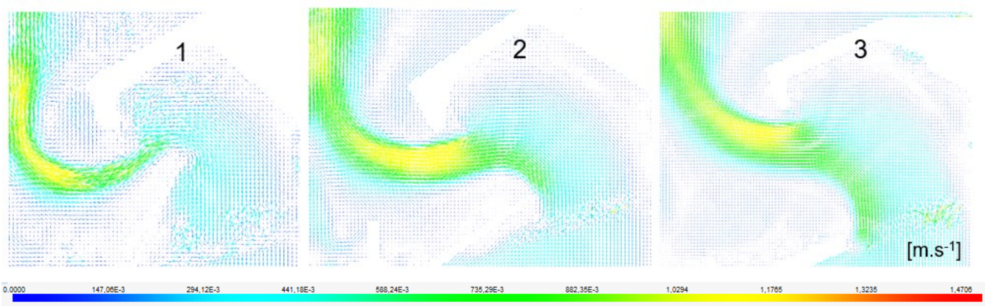

Fig. 4. Vector flow maps in the area of the curling up of the first baffle.

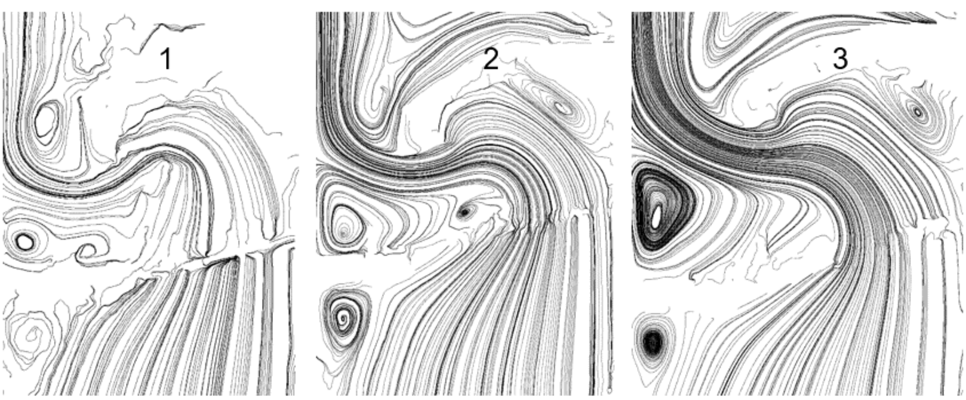

Fig. 5. The trajectory of particle in the area of the curling up of the first baffle.

These figures show that the narrowest and most decreasing stream occurs at the setting marked as Option 1. Broader stream is at options 2 and 3, with the stream rising more at option 3. Option 3 also has the largest cornering radius.

The smallest emerging vortexes can be seen in the first variant, which represents the smallest particle capture potential of the three variants studied. The largest emerging vortexes can be seen in the last third variant, which means that at such baffle settings, the most particles of the three variants studied are caught.

4 Conclusion

In order to decrease the amount of particulate matter in the air, much work is being done on how to reduce it. This article deals with the observation of the baffle position located in the flue gas tract of a local heat source. The baffle has a function of capturing particulate matter from the solid fuel combustion process. The model of flue gas tract has been modified with three setting options. Particulate matter flowing was investigated by the visualization method called PIV. It allows to get a figure of the flow and a dynamic record of the state of the object. The results show a similar flow pattern. At the end of the baffle, the particles curl up with a certain radius and then follow the vertical wall of the flue gas tract, creating a vortex at the point below the drifting stream to create a settling area for the particles. The smallest emerging vortexes can be seen in the first variant, which represents the smallest particle capture potential of the three variants studied. The largest emerging vortexes can be seen in the last third variant, which means that at such baffle settings, the most particles of the three variants studied are caught.

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