MODELING AND VISUALIZATION OF COMBUSTION USING FLUID SIMULATOR AND PARTICLE SYSTEMS

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ABSTRACT

Nowadays, modeling and visualization of various physical and nature phenomena using fluid simulators and solvers based on the Navier-Stokes equations has major theoretical and practical importance in simulation and especially computer graphics field.

We have developed fast and simple fluid simulator for real-time simulation and visualization of combustion processes in pulverized coal boilers used in power engineering. We have extended the general concept of fluid simulator with our real-time virtual particle system engine for both simulation and visualization of combustion processes. We use the industry standard OpenGL platform for reliable and fast visualization. Our results are suitable for both the education and preview design of power-plants boilers.

1 INTRODUCTION

Nowadays, simulation and visualization of various physical and nature phenomena using fluid simulators and solvers based on the Navier-Stokes equations has major theoretical and practical importance in simulation and especially computer graphics field. These simulators and solvers are widely used for various research projects and practical applications such as animations of liquids and water [1], fire, gas and smoke, and many others. Some of them are used for special effects such as melting and animations in movies.

We have developed fast and simple fluid simulator for real-time simulation and visualization of combustion processes in pulverized coal boilers used in power engineering. We have extended the general concept of fluid simulator with our real-time particle system engine for both simulation and visualization of combustion processes.

2 FLUID SIMULATOR FOR COMBUSTION SIMULATION

Our fluid simulator is on the top level consists only of application of the two physics laws – Newton's Second Law and The Continuity Equation [2]. The heat and temperature changes generated during the combustion processes are computed using a simplified combustion and heat transfer engine. The fluid simulator also allows distribution of the heat by the moving air mass inside simulated area (e.g. boiler interior).

The simulated area is divided to 2D structured grid cells. In each step we calculate the new characteristics (e.g. velocities, masses) for all grid cells. All calculations are reduced on nearest neighbors of the calculated cells, see Figure 1. We periodically repeat these computations in each time step of the simulation. We use the fluid simulator results as Flow Array, which determines the movement of coal particles inside the simulated area.

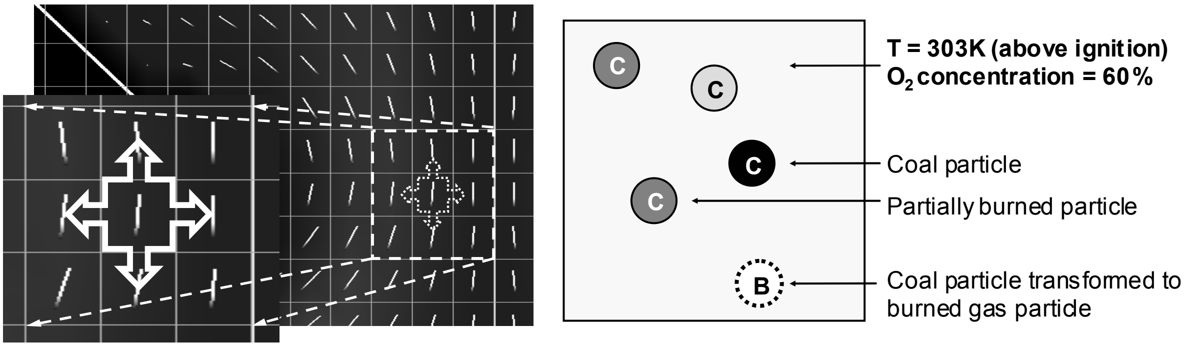

Fig. 1: *Left: Division of the boiler area to 2D grid cells. The cell values in the next time step are computed from nearest neighbors only. Right: Interaction of coal particles with air contained in grid cells*

3 COAL PARTICLE SYSTEM

We use a coal particle system, enabling easy and fast computation of the combustion processes. In our system, the particle system allows us both the computation and visualization of coal mass elements in the boiler. The particles displayed and calculated do not correspond to the real coal particles in the boiler. Instead, they represent corresponding mass of coal in the cell under investigation. The quality and speed of both simulation and visualization can be altered by increasing or decreasing the amount of particles.

Instead of simulation of these processes using classical complex differential equations approach, we use a simple, statistical view of the combustion process [3]. The combustion and heat transfers and fluxes are being computed separately for single grid cells (containing air mass), and corresponding particles inside them, see Figure 1.

4 VISUALIZATION OF THE RESULTS

Our system uses the industry standard OpenGL platform for reliable and fast visualization. This means that our system could be used on a standard low-cost graphics accelerator. We use OpenGL linear interpolated quads with the support of the graphics hardware acceleration for visualization of the cell characteristics, see Figure 2.

There is no lack of speed in particle visualization even when using coal particle streams consisting of ten-thousands of particles, see Figure 3. The selected local characteristics in the voxel, such as the total temperature, mass storage, the wattage, and heat flux state and/or changes can be visualized in real-time. Utilizing the advantage of the particle system concept, we can easily construct the particle traces. We produce this effect by saving the previous particle positions and characteristics. After that we can draw the particles in current time step together with the kept ones. The particle traces can clearly indicate the velocities and direction of move of coal particles, which are visible even on the static state picture, see Figure 4.

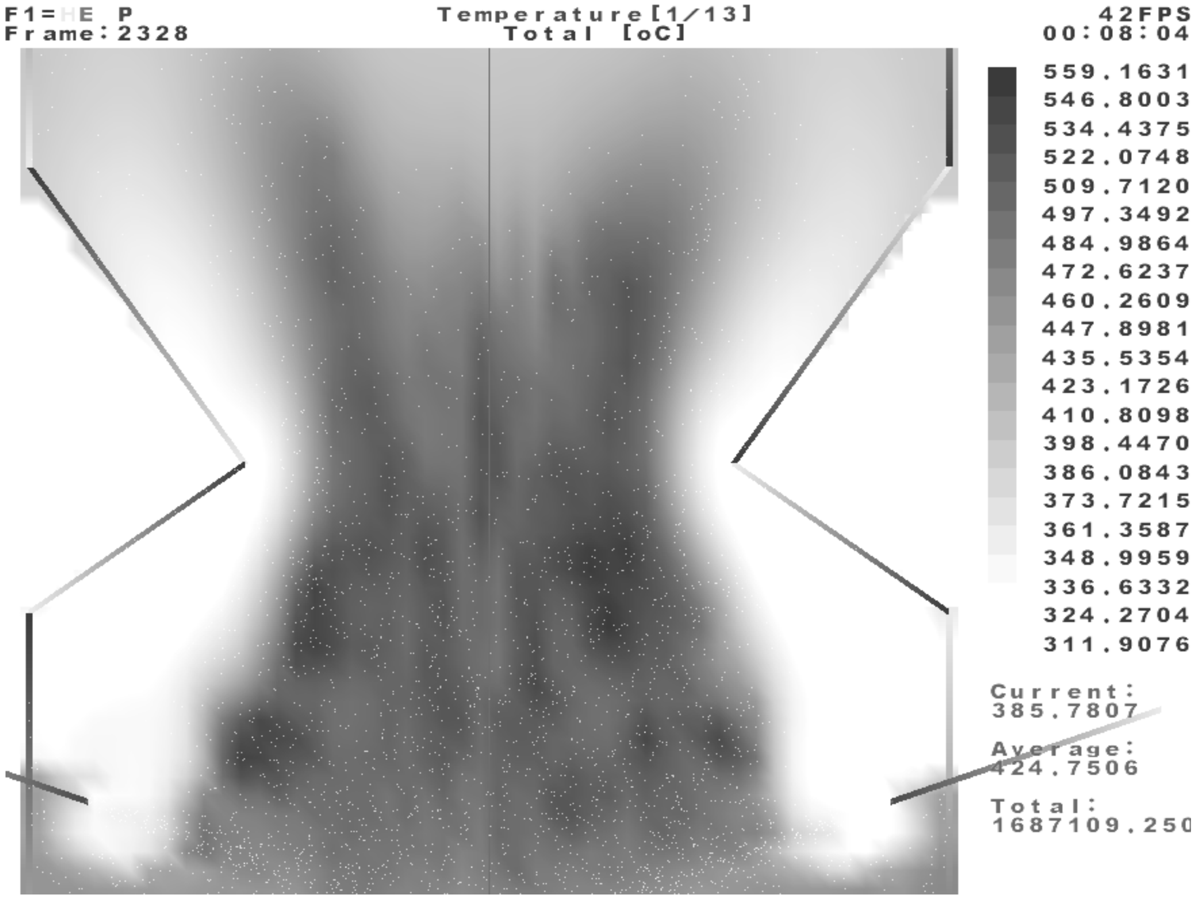

Fig. 2: *Visualization of the combustion temperatures of the power-plant boiler. The greatest temperatures are in the core of the flame tube*

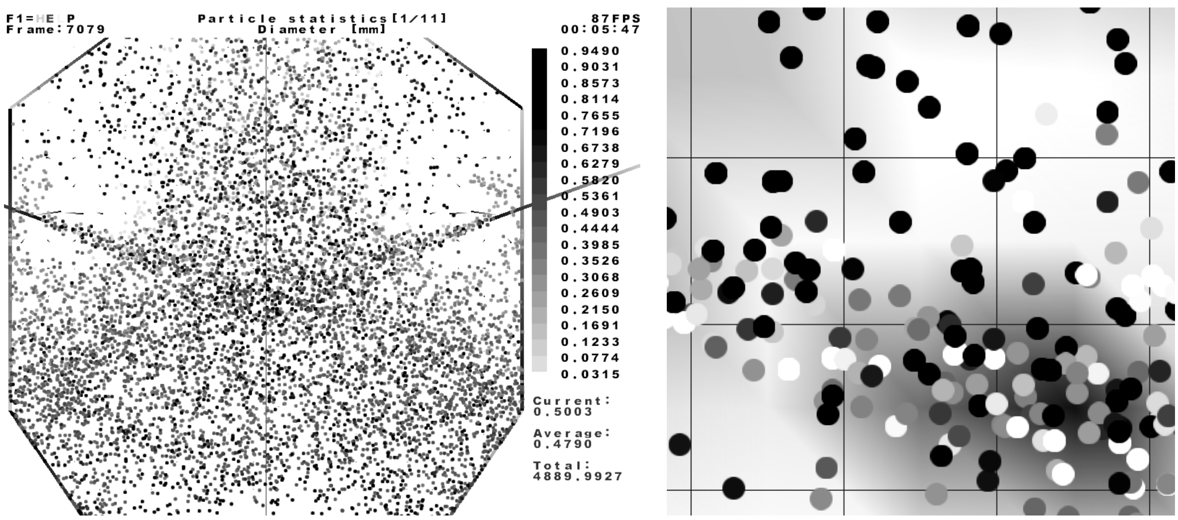

Fig. 3: *Visualization of particles using full hardware accelerated, combined smoothing and blending of drawn pixels gives acceptable visual quality even with a high zoom level.*

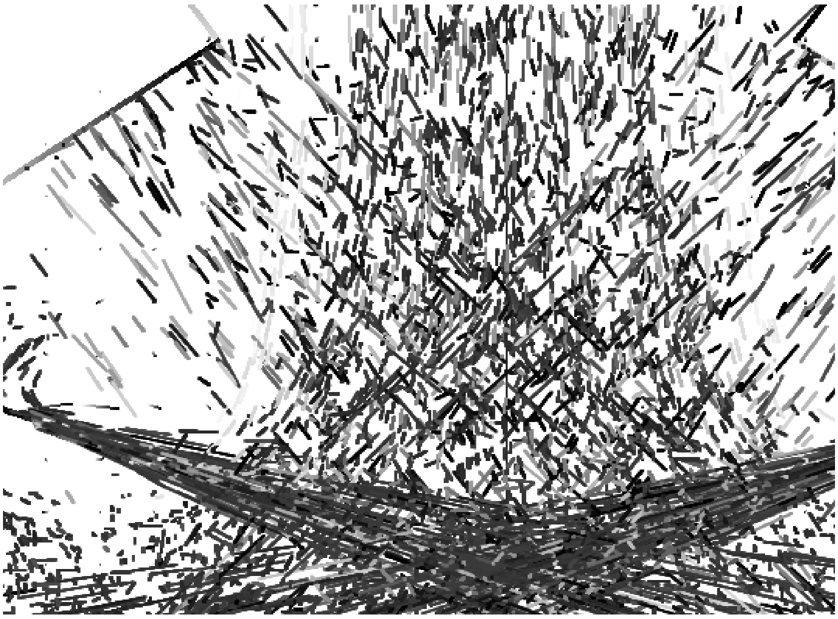

Fig. 4: *Real-time visualization of partial particle traces helps in determining particle speed, direction and dynamics even in static images.*

5 CONCLUSION

Our real-time pulverized coal combustion simulation and visualization system is based on the fast fluid simulator and particle system. The high speed of the fluid simulator and combustion powered by particle system and simplified combustion engine allows real-time visualization of the results (using OpenGL graphics interface).

This results in the possibility to get an interactive preview of the dynamics of combustion processes in a boiler. The students and developers of the combustion boilers could now test many configurations and modifications of pulverized coal boilers interactively with an immediate response.

ACKNOWLEDGEMENTS

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