A Study of the Flow, Heat Transfer, and Mass Transfer Characteristics of Droplet Arrays

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Over the last decades there has been extensive research on droplet arrays, Ref. [1], and this research has been extremely important for understanding combustion physics and chemistry as well as understanding practical flows. At the present time there is a serious gap between completely unsteady models, Ref. [2], and models with a fixed geometry. For example, the stability of droplet arrays has exhibited a wide distribution of both stable and unstable configurations, and it is very difficult to know in advance what conditions will produce a stable array configuration. The present research is an attempt to bridge the gap in our understanding with detailed solutions of the Navier-Stokes equations under realistic IC engine conditions. We will present detailed and time-dependent results for the flow in single and droplet arrays of methanol droplets.

Shown in figure (1) are the results for an array of five methanol droplets, where the mesh, temperature contours, and fuel contours are presented. The thermodynamic conditions are a freestream temperature of 1300 K and a background pressure of thirty atmospheres, and the initial droplet diameter was 12 µm and the Reynolds Numbers was five, which is typical of a modern diesel spray with small droplets. For the time shown in figure (1) the first droplet in the array has lost more than half of its mass, and the differences in droplet diameters can be seen clearly in the temperature contours between the first and last droplet with the first droplet being the smallest. The fuel contours in figure (1) show a high concentration of methanol around the first droplet, and the size of the large concentration region decreases as we move to the rear of the array. The concentration contours have been restricted to a maximum value of ten percent, in order that the gas phase concentrations can be clearly seen, and not be dominated by the liquid fuel values.

For the same flow and thermodynamic conditions we have formed and calculated two arrays of droplets as shown in figure (2). The meshes shown in figure (2) show the ease with which the overset grid technique can treat multiple droplets, and it should be remembered that the droplets can change in size and move. The temperature contours in figure (2) show a strong interaction between the arrays, and the inner region between the arrays is quite cool. The fuel/methanol contours have also been influenced by the array interaction, and there is less vaporization between the arrays. It is straight forward to add droplets and reconfigure the arrays in figures (1) and (2), and we have studied the influence of array geometry on the fluid flow, heat transfer, and mass transfer.

The paper will include time variations in the droplet drag, heat transfer, and mass transfer, as well as variations in droplet spacing and orientation with respect to the parallel alignment of the droplets. Also, calculations with the relative motion of the droplets will be presented to determine the time scale for breakup of the array under various geometric arrangements.

References

1. Sirignano, W.A., **Fluid Dynamics and Transport of Droplets and Sprays**, Cambridge University Press, 1999.
2. Staph, P., Maly, R., and Dwyer, H.A. Dwyer, 1998, “A Group Combustion Model for Treating Reactive Sprays in IC Engines”,27th Inter. Combustion Symposium, 1857-64. The Combustion Institute: Pittsburgh, Pa.

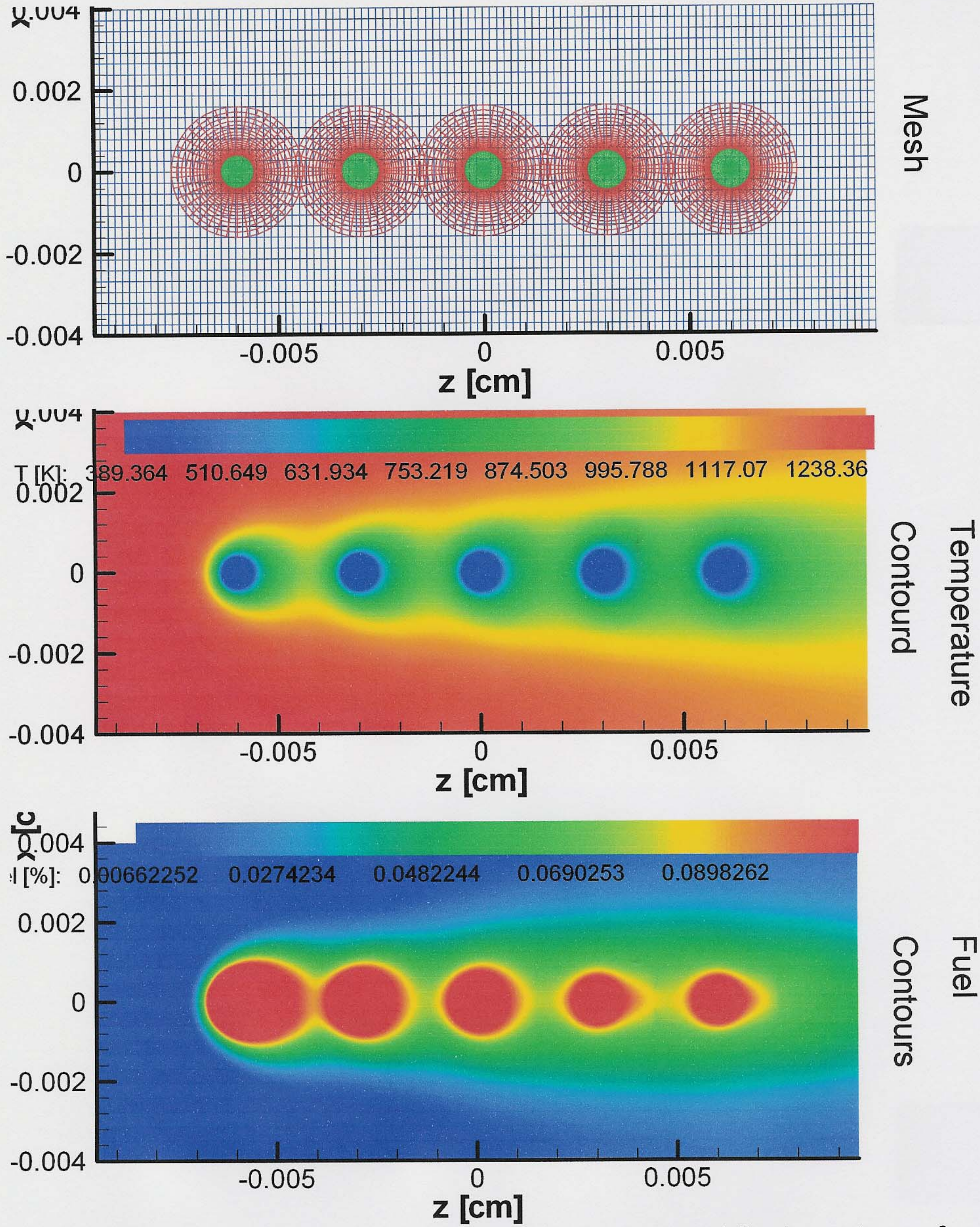

Figure (1) The mesh, temperature contours, and fuel contours for the five droplet array.

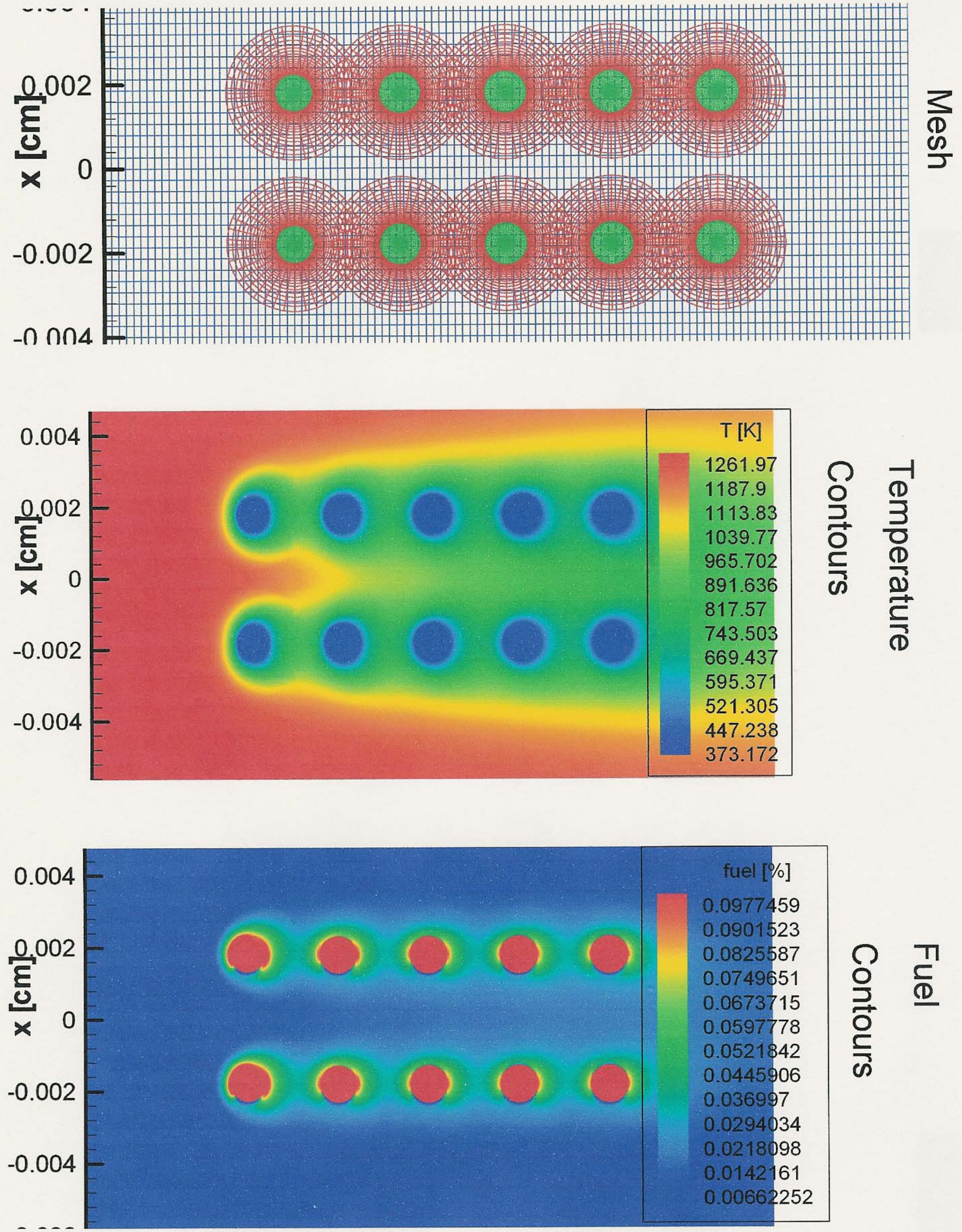

Figure (2) The mesh, temperature contours, and fuel contours for the ten droplet array.