Numerical Study Of Fiber Influences On Droplet Flow and Vaporization

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Introduction :

Many droplet combustion experiments have to be carried out by supporting droplets on a fiber to restrict their movement. The literature which describes these experiments report the presence of a fiber causes certain discrepancies in the results obtained. A few authors in the past have addressed this problem experimentally[2] as well as numerically[1]. In general, the reported results show an increase in vaporization rates for supported droplets. This increase has been attributed to the heat transferred to the droplet from the fiber. The present research studies the supported droplet and accounts for the influences of the fiber on the droplet. The research also compares the supported droplet to free droplets under similar conditions.

Problem Statement :

In the study undertaken by Megaridis [1], comparisons were made for suspended droplets with free droplets to highlight some of the differences in their observed behaviors. These results were for axi-symmetric calculations, and they were carried out for configurations that had a droplet suspended on a bead with the flow parallel to the fiber. The present research addresses this problem by carrying out numerical calculations for flows across droplets supported on the fiber. Our comparisons between cases of supported and unsupported droplets show the influence of the fiber on the flow and droplet history. With our three dimensional calculations a greater understanding of the flow phenomena can be obtained by analyzing the results. Calculations are carried out for two different fuels, methanol and octane, and for a large range of pressures and temperatures as well as flow Reynolds numbers. Various fiber and droplet diameters are also considered in this parametric study. The full effects of thermal surface tension gradients have been considered in the calculations. This is a unique feature of our results, since surface tension effects on supported droplets have not been studied numerically in the past.

Summary of results obtained:

The fiber was chosen as pyrex glass. Fiber heating times vary considerably depending on flow conditions and fiber diameters relative to drop diameter, and these influences have an effect on the initial time histories of the droplets. Our 1000 K calculations showed that the effect of heat transfer from the fiber to the droplet is more than compensated for by its effect on slowing down the circulation inside the liquid and reducing the heat transfer from the gas phase. For these conditions, a reduction in vaporization rates is observed with increasing fiber diameters relative to droplet, as can be seen in fig (1) for fibers and droplets under different conditions. It is also observed that average surface temperatures decrease with increasing fiber diameters, although the total heat transfer from the fiber increases. The effect of large temperature gradients generated on the droplet surface near the fiber causes a pull of liquid towards this region, however in most cases this effect has a small influence on the internal liquid circulation. It has also been shown that supported droplets experience reduced friction drag and heat transfer from the gas phase due to thickening of boundary layers over the droplets near the fiber.

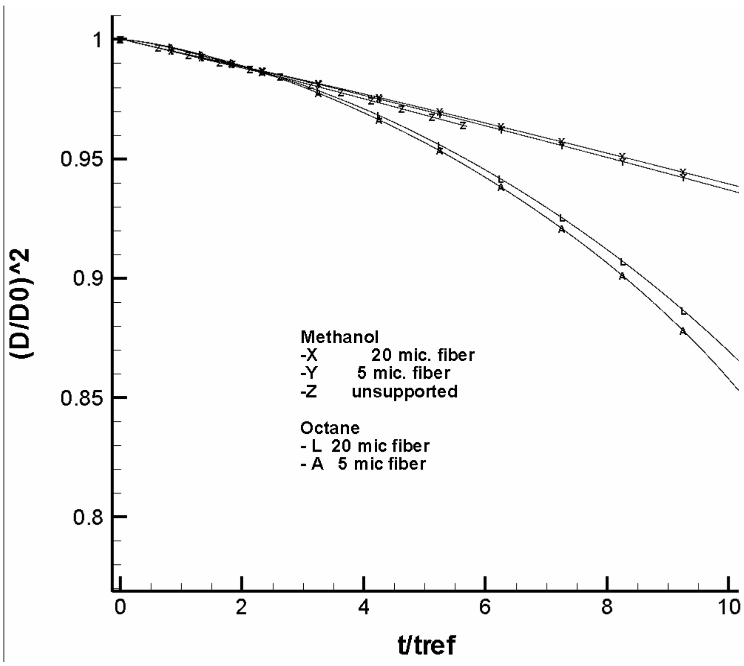

Fig 1:Early droplet size histories of supported and unsupported methanol and octane droplets for 1000 K ,10 atm air, and Reynolds number =50.

Since methanol has a lower boiling point than octane, the influences of surface tension and fiber relative diameter on droplet internal heating differ from those seen for octane droplets at similar temperatures and pressures. For conditions of 1000 K, 10 atm pressure, and initial Re=50, most of the heat transferred from the gas phase goes into droplet vaporization with the result that the droplet front stays a lot warmer than its rear at all times .This surface temperature causes high surface velocities and the droplet core near the fiber remains the coolest region inside the liquid. Octane on the other hand shows significant droplet heating for most of its lifetime. Liquid circulation into the front of the droplet causes transient cooling followed by heating. This heating causes temporal oscillations in its surface velocities that were previously shown by Niazmand [3] and Megaridis[4]. The frequency of these oscillations change with fiber diameters .Weaker mass transfer from the surface of methanol droplets results in an accumulation of vaporized fuel in the gas phase close to the liquid surface in the region of the fiber and droplet interface.

Conclusions :

1) The presence of a fiber affects droplet heating and vaporization rates with a reduction in vaporization rates for methanol as well as octane. This is attributed

largely to lower circulation velocities as compared to unsupported droplets and reduced heat transfer from the gas phase.

2) Both octane and methanol show similar trends as regards fiber heating, surface temperatures and vaporization rates for the cases considered, even though internal heating characteristics are different for these droplets.

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