CHEMICAL REACTIONS in TURBULENT MIXING FLOWS

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This is a continuing effort in both gas phase and liquid phase mixing, chemical reactions and combustion, in moderate to high Reynolds number turbulent free shear flows. This is primarily an experimental investi closely supported by theoretical and modeling efforts, as well as specific diagnostics developments, as dictated by specific needs of the experimental program.

1.0 Gas Phase Shear Layer Combustion

The work described below was conducted in the hydrogen-fluorine shear layer combustion facility.

Heat Release Effects in a Turbulent Reacting Shear Layer — By increasing the concentration of the hydrogen and fluorine reactants in equal density free streams, the amount of heat release was increased, corresponding to an adiabatic flame temperature rise of 900 K (1,200 K absolute). We were surprised to find that the thickness of the layer decreased with increasing heat release, corresponding to a 15% decrease in thickness for a 40% mean density reduction in the layer. This can be seen in figure 1, which depicts the normalized mean temperature (product) profile 1% thickness versus the relative mean density decrease as a result of the heat release. The normalized density-weighted product thickness is plotted in figure 2 and can be seen to depart from its low heat release values (see Mungal & Dimotakis 1984) as the mean density in the layer decreases as a result of the heat released. These results were obtained in a zero pressure gradient flow.

In a separate study, a favorable pressure gradient was applied to the flow, corresponding to a decrease of up to 1/3 of the total dynamic head of the low speed stream (accelerating flow), to study pressure gradient effects on the combusting layer. Except for the easily accounted for thinning of the layer, no other effects of the pressure gradient were observed. This part of the work was recently documented in the form of a Caltech Ph. D. thesis (Hermanson 1985). See also Hermanson, Mungal & Dimotakis (1985).

Work in this area is being extended to include free streams of unequal density, in both the low and high heat release limits.

Finite Rate Kinetic Effects — A brief discussion of the finite kinetic rate data was included in last year's abstract. Figure 3 shows a plot of the normalized product thickness versus the local Dahmkohler number (defined here as the local large eddy turn-over time divided by the chemical reaction time), as the overall chemical kinetic rate is varied. These data are obtained at our nominal flow conditions of $U_1 = 22$ m/s, $x = 45.7$ cm, $U_1/U_2 = 0.4$ under low heat release conditions. A theoretical analysis of the data, based on the Broadwell-Breidenthal model, for finite rate chemistry is presently underway.

Understanding the interaction of chemical kinetics with the turbulent mixing process in shear layer combustion is one of the most important issues in the general problem of supersonic combustion. This effort is pursued, in part, with this consideration in mind.

2.0 Mixing and Chemical Reactions in Turbulent Jets

These studies are undertaken to investigate turbulent jet mixing and chemical reactions in the limit of low heat release. Aspects of this part of the work are co-sponsored by the Gas Research Institute.

Entrainment, Mixing and Chemical Reactions in Turbulent Jets at High Schmidt Numbers — Experiments were conducted in liquid phase (high Schmidt number) turbulent jets. Laser induced fluorescence techniques were used, in both chemically reacting and non-reacting experiments, in combination with real time digital image analysis data acquisition methods. These experiments permitted direct measurements of the Probability Density Function (PDF) of the jet fluid mixture fraction. Several important results were established. The role of large scale structures in the entrainment and mixing processes was established in the far field of the jet. The resulting PDF (and the mixing process) reaches self-similarity in approximately 20 momentum diameters. A similarity form for the conserved scalar and the resulting PDF was discovered. Proper scaling of the flow in terms of the jet momentum diameter d^* (see Dahm & Dimotakis 1985) allows the "flame length" observed in liquid phase acid-base reactions to be correlated with gas phase combusting jets with high heat release and also two-phase jets (condensing vapor, halogen/liquid metal reactors etc.). The correlation of the normalized flame length L is shown in figure 4 plotted versus the stoichiometric mixture ratio ϕ for various reacting jets. A detailed account of this work has been documented in the form of a Caltech Ph. D. thesis (Dahm 1985).

Gas phase turbulent jet mixing — A first phase, set of pilot experiments to verify performance calculations using laser Rayleigh scattering to measure binary gas phase mixture composition has been completed. We are now proceeding with the completion of the full scale facility in which a jet discharges from a 0.75" diameter nozzle into a 4'x4'x8' reservoir, with sufficient co-flow in the reservoir to satisfy the entrainment requirements of the jet to the measuring station. Single point measurements of the composition PDF are planned, which we expect to compare to our completed liquid phase data to investigate Schmidt number effects on turbulent mixing.

3.0 REFERENCES

DAHM, W. J. A. [1985] Experiments on Entrainment, Mixing and Chemical Reactions in Turbulent Jets at Large Schmidt Numbers, California Institute of Technology, Ph. D. thesis.

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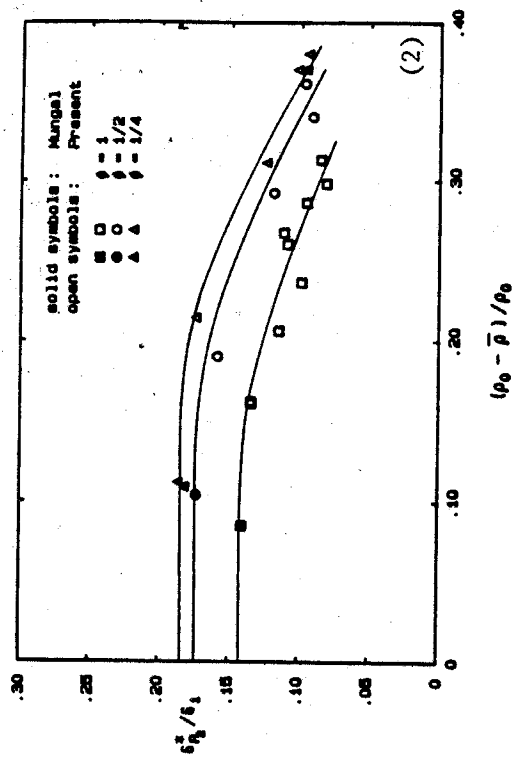
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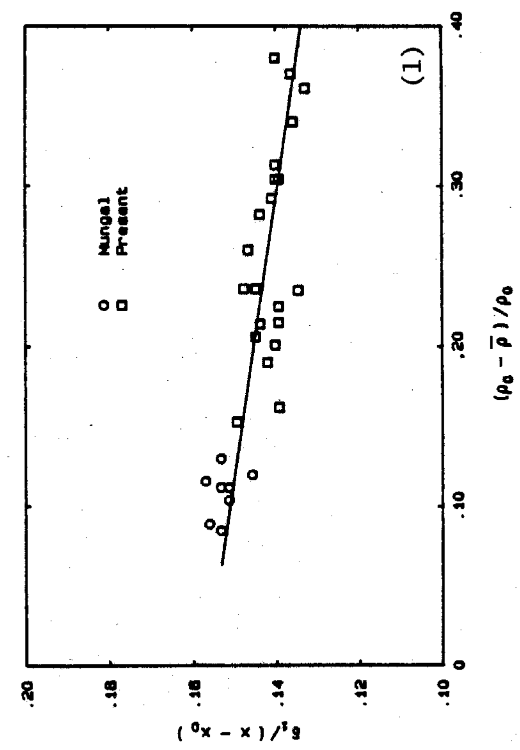
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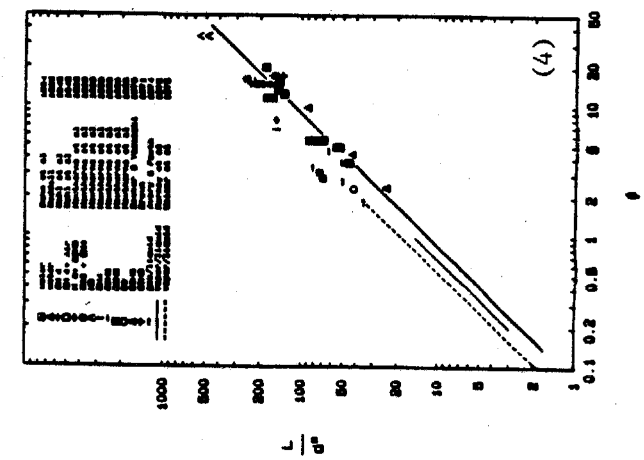
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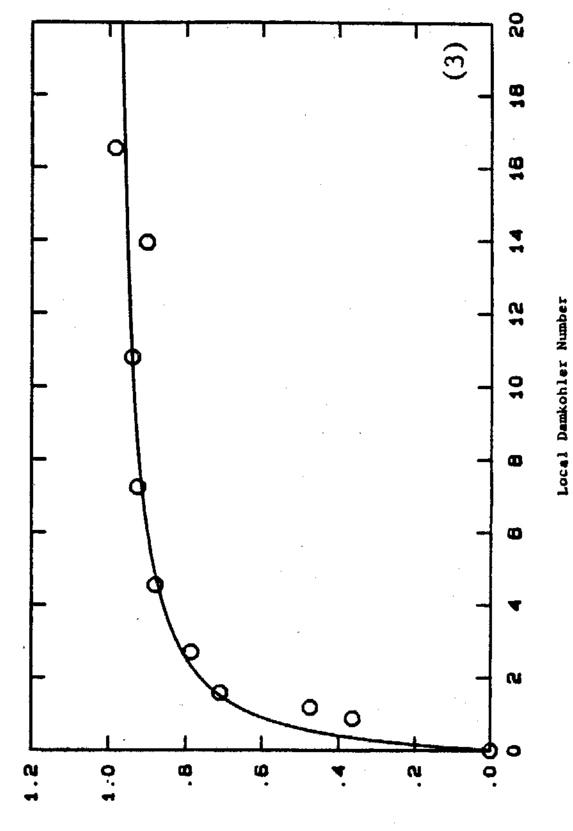
(3)
Normalized Product Thickness
Local Damkohler Number