AD-A166 223 APPLICATION OF RAYLEIGH SCATTERING TO TURBULENT FLOW WITH HEAT TRANSFER A..(U) CALIFORNIA UNIV BERKELEY DEPT OF MECHANICAL ENGINEERING L TALBOT 07 AUG 85 1/1

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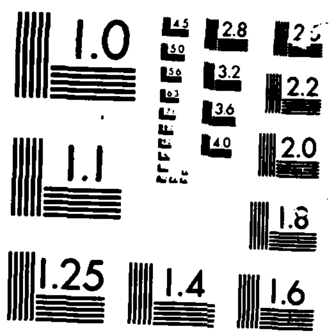

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ANNUAL REPORT

AFOSR GRANT 84-0124

Application of Rayleigh Scattering to Turbulent Flow with Heat Transfer and Combustion

Principal Investigator: L. Talbot
University of California, Berkeley

RESEARCH OBJECTIVES

The objective of this research program has been to investigate experimentally the fluid mechanical properties of premixed turbulent flames, through detailed measurements and flow visualization techniques. The combustion configuration investigated is a V-shaped, unconfined, rod-stabilized flame propagating into a turbulent, essentially uniform flow. Laser-based diagnostics for the measurement of instantaneous density through Rayleigh scattering, and velocity through Doppler velocimetry are the principal quantitative experimental techniques, while laser-tomographic high speed cinematographic flow visualization provides qualitative information on the behavior of the flame. The research has focused on two central goals: to determine (a) the detailed structure underlying that which in the large constitutes a turbulent flame brush; and (b) to what extent this structure can be described theoretically by models such as the Bray-Moss-Libby (BML) model.

RESEARCH RESULTS

During the last year, several experimental programs were pursued.

1. Two-point Rayleigh scattering measurements within the turbulent flame brush of ethylene-air and methane-air V-flames were extended to provide more extensive information on such features of the reaction zone as the spectral distribution of the density fluctuations, their autocorrelation functions and integral scales, and mean density profiles. Some of the findings include:

a) The mean density profiles through the reaction zone at different distances downstream of the flame holder are self-similar when scaled by the profile maximum slope thickness which is a function of the equivalence ratio and the upstream turbulence intensity, for a given reactant. This maximum slope thickness is found to grow linearly with distance from the flame holder. The probability function for the location of the wrinkled laminar flame sheet within the turbulent flame brush was found to be accurately represented by a gaussian function.

b) The probability density of 'intermediate states' was measured at various locations downstream of the flame holder. Contrary to the assumptions generally employed in the BML model, the contribution to the overall probability density function (pdf) contains a significant contribution from the intermediate states, rather than being composed of two delta functions associated with the reactants and products. An extension of the BML model to take account of the intermediate states, which are due to the finite thickness of the wrinkled laminar flame sheet, was developed and shown to be in good agreement with the measured density fluctuation intensities and covariances. This extension of the BML model of the pdf also provides a means for introducing finite-rate chemistry into the production term of the model, although this has yet to be tested.

2. Experiments now in progress are being carried out to investigate the structure of the reaction zone close to the flame holder, the object being to determine how the flame stabilization and recirculation zone evolves into a thin flame sheet. It is possible that this region cannot be described adequately by

the BML model, even in limit of very fast chemistry. Since in this transition region density changes can be the result of conduction/convection heat transfer as well as combustion, the location of the reaction front cannot be uniquely determined by Rayleigh scattering measurements. We are therefore combining the Rayleigh scattering measurements with ionization probe measurements, which we hope will permit us to discriminate between the different contributions to the density variations and delineate more accurately the reaction region.

3. A considerable effort was expended during the past year to put into operation the Linear Array for Rayleigh Scattering (LARS) system which was funded under the DoD-University Research Instrumentation Program, through the AFOSR Grant 83-0229. Although most of the components of the LARS system were obtained commercially, their interfacing turned out to be in some instances a non-trivial task. Additionally, software provided by one of the vendors proved to be inadequate and had to be re-written. The LARS system is now operational, and is described in the Final Report of the above-cited Grant.

4. We have continued to maintain a close collaboration with Professor K.N.C. Bray, of Cambridge University, and with Professor Paul A. Libby of University of California, San Diego, sharing our data with them and suggesting possible extensions of their theoretical model.

PUBLICATIONS

Hertzberg, J.R., Namazian, M., and Talbot, L. 1984 "A Laser Tomographic Study of a Laminar Flame in a Karman Vortex-Sheet", Combustion Science and Technology, Vol 38, pp. 205-216. Presented at the Twentieth Symposium (International) in Combustion.

Namazian, M., Talbot, L., and Robben, F. 1984 "Density Fluctuations in Premixed Turbulent Flames", Twentieth Symposium (International) on Combustion, The Combustion Institute, (to appear).

Namazian, M., Shepherd, I.G., and Talbot, L. "Characterization of the Density Fluctuations in Turbulent V-Shaped Premixed Flows", presented at the 1984 Fall Meeting, Western States Section/The Combustion Institute, Stanford, CA, Oct. 22-24. Submitted for publication to Combustion Science and Technology.

PROFESSIONAL PERSONNEL

Dr. L. Talbot, Professor, Mechanical Engineering Department, University of California, Berkeley.

Dr. Frank Robben, Senior Staff Scientist, Division of Applied Science, Lawrence Berkeley Laboratory.

Dr. Mehdi Namazian, Assistant Research Engineer, Mechanical Engineering Department, University of California, Berkeley (6 months).

Dr. Ian G. Shepherd, Assistant Research Engineer, Mechanical Engineering Department, University of California, Berkeley (6 months).

Ms. Jean R. Hertzberg, Graduate Research Assistant, Mechanical Engineering Department, University of California, Berkeley.

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Studies of premixed turbulent V-shaped flames have been carried out using two-point Rayleigh scattering. Density fluctuation intensities, two-point density covariances, and mean density profiles were found to be in good agreement with a wrinkled laminar flame model which is an extension of the Bray-Moss-Libby model. The probability density function for the location of the flame sheet within the turbulent flame brush was measured and found to be approximately gaussian. Mean density profiles of the turbulent flame brush were found to have a self-similar behavior when scaled with the maximum slope thickness.

A new optical system was developed to make time-resolved Rayleigh scattering measurements along a length of a laser beam, thus extending the two-point technique to a multipoint one.

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