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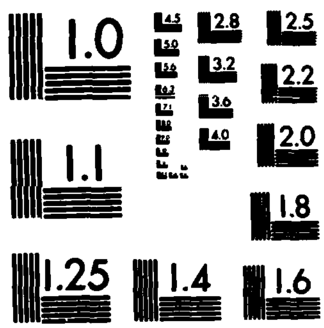

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FLAME PROPAGATION AND STABILIZATION STUDIES USING RAYLEIGH SCATTERING AND LASER DOPPLER VELOCIMETRY

Final Report

AFOSR Contract #F49620-80C-0065

Principal Investogators: L. Talbot
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University of California, Berkeley

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Studies of premixed turbulent flame propagation have been carried out using laser tomography, two-point Rayleigh scattering, and combined Rayleigh-LDV single point measurements. Probability density functions of intermediate states, correlation coefficients and correlation length scales within the reaction zone have been measured. A theoretical model has been developed which predicts these quantities, and very good agreement between theory and experiment is obtained.

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RESEARCH OBJECTIVES

1. The purpose of this research program has been to characterize experimentally the fluid mechanical structure of turbulent combustion through detailed measurements, both qualitative and quantitative, of selected combustion configurations representative of practical combustion systems and suitable for laboratory study. Laser-based diagnostics for measurement of instantaneous fluid density (Rayleigh scattering), velocity (laser-Doppler-velocimetry) and high speed photography (aerosol light scattering and Schlieren) have been employed, and applied to the investigation of the detailed structure of a V-shaped pre-mixed flame stabilized on a rod in a turbulent flow. The findings include an improved understanding of the processes involved in the evolution of the turbulent flame structure, and more precise quantitative information on the intensities and length scales associated with the density and velocity fluctuations within the turbulent reaction zone. These results are expected to contribute to an improved understanding of the turbulent combustion process, and to better numerical modeling of combustion systems of technical interest.

RESEARCH RESULTS

During the contract period several experimental programs were pursued successfully.

1. A laser tomography technique was developed for flame flow

visualization. This method consists of seeding the combustible mixture with light-scattering aerosol droplets which evaporate when they encounter the reaction front. Upon illumination with a sheet of laser light, the reaction front appears as a boundary between a light-scattering region and a dark zone. High speed photography is used to record the motion of the reaction front.

The laser tomographic technique has been applied to the study of the interaction of a Kármán vortex street with a rod-stabilized premixed ethylene-air flame. This combustion flow field, which represents an idealization of the fluid-dynamical processes associated with the behavior of large-scale turbulent structures in reaction zones, has been studied experimentally by us (Namer, et al., 1984) using Rayleigh scattering and laser-Doppler velocimetry techniques, and has also been modeled numerically (Karasalo & Namer, 1982). A paper describing the method has been accepted for publication (Hertzberg, et al., 1984) and will be presented at the Twentieth International Combustion Symposium.

2. Rayleigh scattering measurements on premixed turbulent flames have been extended to two-point measurements, which yield joint probability density functions of density within the reaction zone, and exhaustive measurements have been made on a V-shaped rod-stabilized flame at several levels of upstream turbulence. Some of the early results were reported at the Nineteenth International Combustion Symposium (Namazian, et al., 1982). These measurements make possible

better interpretation of the flame structure, and indicate that for the conditions of our experiment, the flame is basically a wrinkled laminar flame, with a low probability of the existence of "flamelets" (islands of burned gas surrounded by unburned mixture). The two-point data have been analyzed in terms of correlation coefficients and correlation lengths to provide relationships between the free stream turbulence scales and the characteristic lengths associated with the flame structure. A theoretical model has been developed which predicts the probability density of intermediate states (densities lying in the range between the unburned and burned values). The model also predicts the correlation length scales and power spectra for density fluctuations within the reaction zone. Good agreement with experiment is obtained. A paper describing this work (Namazian, et al., 1984) has been accepted for presentation at the Twentieth International Combustion Symposium and will be published in the Proceedings.

3. An experimental method has been implemented to combine Rayleigh scattering density measurements with simultaneous LDV measurements of velocity at a point in the flow field, on a time resolved basis. This technique yields the joint probability density function (jpdf) of gas velocity and density, and the velocity-density correlation function $R_{\rho v} = \overline{\rho' v'}$. Results have been obtained in the flame brush of a V-shaped turbulent flame, which indicate that the mechanism of "counter-gradient diffusion" can be explained in terms of fluctuations of the flame sheet. This work is continuing.

4. A numerical study of the structure and propagation of wrinkled laminar flames has been initiated. The flame is modeled as a surface of connected line segments which propagate normal to themselves into the unburned gas by means of a Huygens-type construction and act as volume sources which simulate the effect of density changes associated with heat release during combustion. The impact of vorticity on this modeled flame front is presently under investigation utilizing the Random Vortex Method.

PUBLICATIONS

Bill, R. G., Jr., Namer, I. and Talbot, L. (1982) "Density Fluctuations of Flames in Grid-Induced Turbulence," Combustion and Flame 44, 277-285.

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