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TURBULENT MIXING AND COMBUSTION OF MULTI-PHASE REACTING FLOWS I--ETC(U)

SEP 81 K C SCHADOW, M J LEE, K J WILSON

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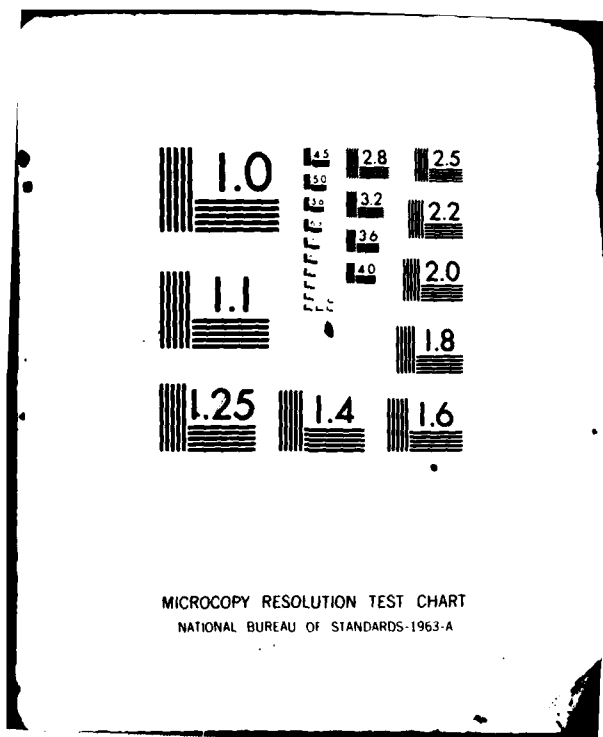
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An axisymmetric, 12.5 cm (5 inch) diameter laboratory ramjet combustor was built and checked out. Experiments were started to determine detailed flow data relevant to gas generator ramjets. Combustion temperature and species concentrations profiles indicate a significant effect of reaction kinetics and mixing on combustion in the beginning of the mixing region downstream of the gas generator nozzle. Comparison of the experimental data with model predictions by Science Application, Inc. was initiated. For the velocity and turbulence intensity measurements, data linkage between the two-color, three-beam laser doppler velocimeter and the computer was established and measurements were started.

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TURBULENT MIXING AND COMBUSTION OF MULTI-PHASE REACTING
FLOWS IN RAMJET AND DUCTED ROCKET ENVIRONMENT

K. C. Schadow
M. J. Lee
K. J. Wilson

Naval Weapons Center
China Lake, California 93555

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1. Research Objectives

Turbulent mixing and combustion of multi-phase flows are relevant to problems in many airbreathing propulsion systems, such as the gas generator ramjet (ducted rocket) with solid boron propellants and the slurry fuel ramjet. The ability to deal with the complex flow field in these systems requires detailed experimental and analytical knowledge of a number of coupled physical and chemical processes, including turbulent mixing, recirculating flow, and gaseous/particulate fuel ignition/combustion.

In recent years, considerable progress has been made towards development of analytical models to deal with the multitude of couple mechanisms, however, evaluation of the models has been hampered by the lack of detailed experimental flow-field information. The objective of this program is to obtain a comprehensive data base that would specifically aid evaluation and further refinement of analytical techniques developed by Sciences Applications Inc. (SAI) (Edelman and Harsha) under AFOSR funding. Because of the complexity of the phenomena to be studied, a systematic step-by-step approach will be taken for both the fuel characteristics (gaseous fuels, boron-laden gaseous fuels, liquid fuels, and slurry fuels) and the flow field (axisymmetric-coaxial, axisymmetric with dump, axisymmetric-noncoaxial, and three-dimensional).

Combustion tests will be made under realistic operational ramjet conditions to determine axial and radial profiles of temperature, pressure, species concentration, velocity, turbulence intensity, and particle/droplet size using intrusive probes and optical diagnostic methods (laser doppler velocimeter (LDV)).

Close interaction between NWC and SAI will continue throughout the program to improve/modify analytical modeling and refine test conditions.

2. Status of Research Effort

An axisymmetric, 5-inch diameter laboratory ramjet combustor was built and checked out. Experiments were started using (1) coated thermocouples for temperature measurement, (2) iso-kinetic probes and a gas chromatograph for gas sampling and analysis, and (3) an LDV and a hot-wire anemometer for velocity and turbulence intensity measurements.

A schematic diagram of the ramjet combustor is shown in Figure 1. For the fuel-rich plume mixing and combustion studies, the combustor consists of (1) a gaseous fuel gas generator with a hydrogen/oxygen torch igniter, (2) a powder feed system (Figure 1a), and (3) a ramjet combustor in which the particle-laden fuel-rich reaction products coaxially mix with the air (Figure 1b). Downstream of the air inlet, a perforated plate and a honeycomb grid are used to achieve an uniform air flow. Hot wire anemometer measurements were made to determine optimum design of the flow straightener arrangement to achieve axisymmetric air flow conditions (velocity and turbulence intensity). Downstream of the flow straightener, turbulence producing screens and swirlers are used.

Experiments were started to determine combustion temperature profiles with tungsten/rhenium thermocouples. To increase the oxidation resistance and reduce the catalytic reactions, the thermocouple beads were coated with beryllium and yttrium oxide. One example of radial temperature profiles at four axial positions is shown in Figure 1. In these tests, ethylene, oxygen, and nitrogen were precombusted in the gas generator and were injected at 1630°K and subsonic speed into the ramjet combustor. The combustion temperatures in the ramjet for $X/D < 0.85$ (see Figure 2) did not reach the maximum value of about 2600°K indicating the effects of reaction kinetics and mixing on combustion in the beginning of the mixing region.

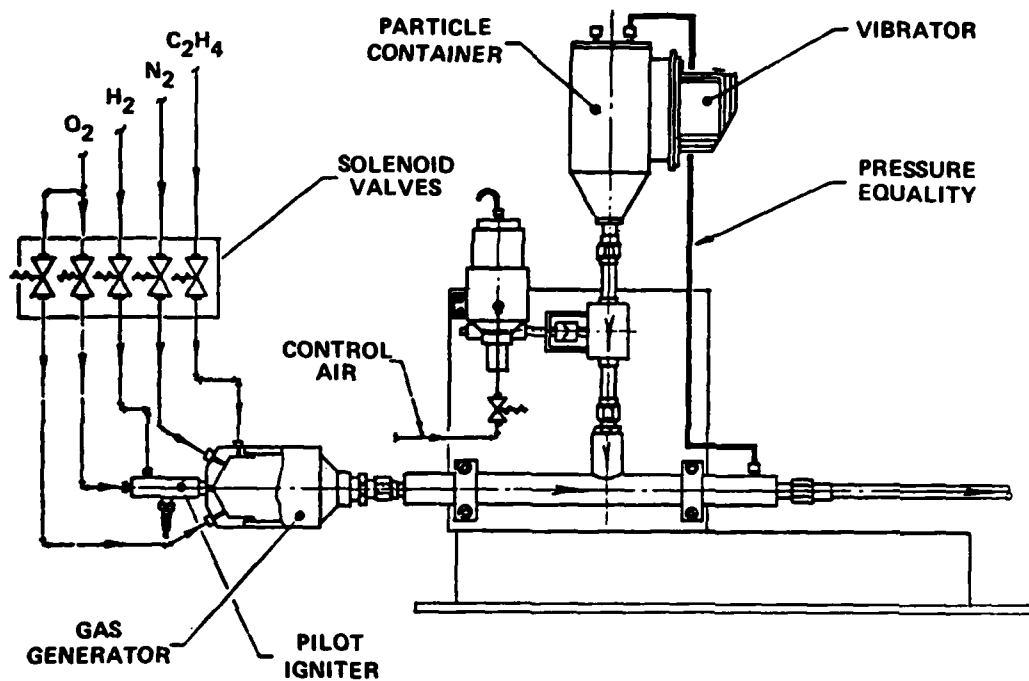
Further insight into the combustion process was gained from the species concentration profiles. For example, Figure 3 shows that inside the flame, oxygen and fuel coexisted to a significant amount. This also indicates that fast reaction assumptions in analytical studies fail to predict the real behavior of turbulent combustion under realistic gas generator ramjet operational conditions.

Comparison of the experimental data with model predictions was initiated. The described gaseous fuel combustion tests will serve as baseline for the tests with boron-laden fuels.

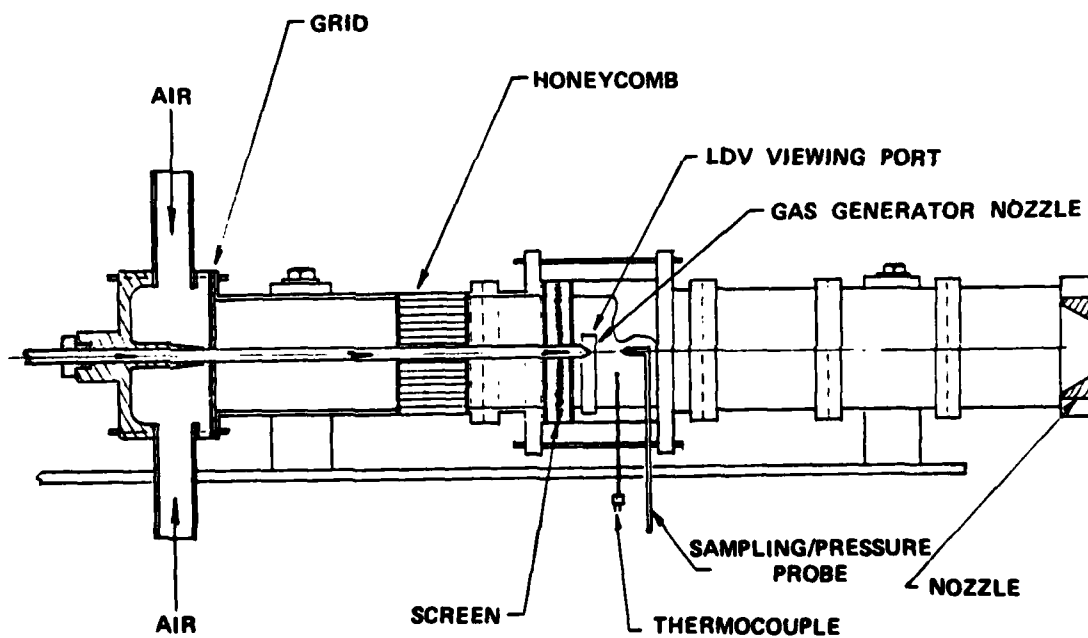
Tests were initiated to measure the air flow characteristics with an LDV. Data linkage between the two-color, three-beam LDV and the PDP 11/03 computer was established. Presently, the LDV is capable of measuring two perpendicular velocity components at 3000 samples per position. Available software enables one mean velocity to be calculated as well as the standard deviation for turbulence analysis. Also, skewness and kurtosis are derived and graphically displaced for comparison to the normal distribution.

3. Personal Responsibilities

The work is carried out in the Aerothermochemistry Division (Mr. Thomas L. Boggs, Acting Head). Dr. Klaus C. Schadow is the principal investigator. Co-principal investigators are Dr. Myung-Jae Lee who is performing the intrusive probe measurements and Mr. Ken Wilson who is performing the LDV measurements.



(a) Gas Generator



(b) Ramjet Combustor

Figure 1. Laboratory Ramjet Combustor.

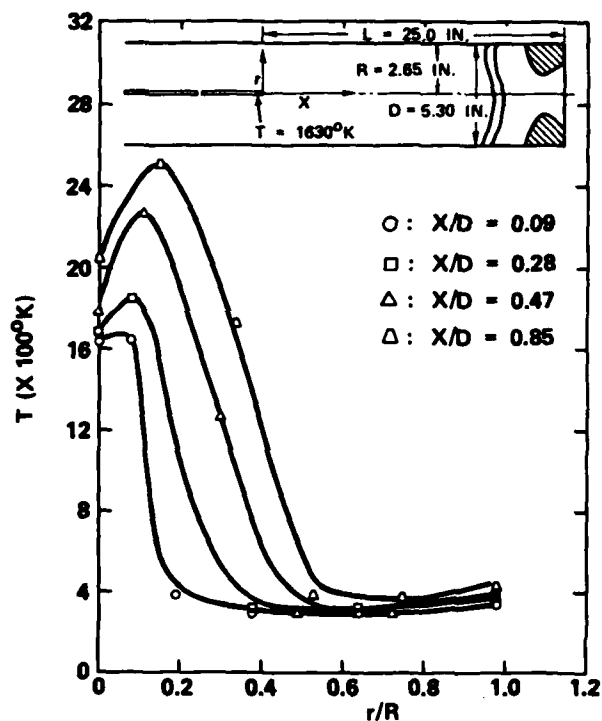


Figure 2. Temperature Distribution in Ramjet Combustion Zone.

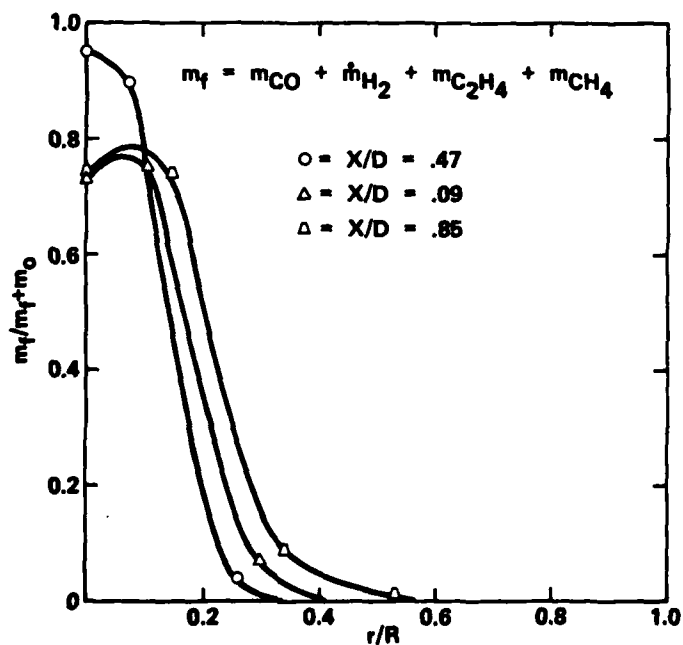


Figure 3. Fuel-to-Oxygen Ratio Distribution in Ramjet Combustion Zone.

