Langley Facility for Tests at Mach 7 of Subscale, Hydrogen-Burning, Airframe-Integratable, Scramjet Models

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Theme

AT the Langley Research Center there is an effort directed toward developing the technology for a fixed-geometry, hydrogen-burning, scramjet engine module suitable for an integrated engine-airframe configuration. When integrated into an airframe design the scramjet promises significant advances in performance, efficiency, and payload capability. The design concept which uses the aircraft fuselage to process air entering and leaving the engine tends to maximize thrust per unit capture area with low external drag.

In addition to the basic fluid mechanic and combustion research as well as the engine component and structural research, subscale aerothermal tests of the scramjet engine are needed as an economical and expeditious approach to evaluate interactions between components, to refine the engine design, and to provide convincing performance data. The considerations and analyses that influenced the design and configuration of the facility in which to perform subscale tests are described, and preliminary data on the flow and arc-heater performance are presented.

Contents

An existing electric arc-heater facility was modified to conduct tests on a subscale, hydrogen-burning engine module. Existing equipment being used consists of a large portion of a blowdown facility, including high pressure air and vacuum, and a 20 MW power supply. Major items required for the modification were a new arch-heater, nozzle, and hydrogen fuel supply.

In order to make the tests duplicate the Mach 7 flight, the stagnation temperature must be 2220°K. To use an off-the-shelf arc-heater with the existing power supply at Langley, the heater does not handle the entire flow but overheats a portion of it which then mixes with three times as much unheated air to achieve a maximum 2.27 kg/sec test flow.

A Huels type arc-heater was purchased which operates from two 10 MW d.c. units in series. As originally designed, the arc heater performance was somewhat eratic and had troublesome unsteadiness in the arc column. The cause of the unsteadiness was attributed to poor electrical contact at the exit end of the downstream electrode. A correction was made by incorporating eight internal flexible cables from the electrode to the external housing.

This and other modifications improved the heater performance. Figure 1 compares the time history of the arc voltage, arc current, stagnation pressure at the upstream electrode end, and the total enthalpy of the flow entering the throat obtained before and after the modifications.

The arc-heated air after mixing with cold air expands through a partly water cooled nozzle to Mach 6 which is the condition a scramjet engine would actually experience in flight behind the bow shock wave of a hypersonic airplane. The nozzle exit area measures 27.2 by 30.5 cm.

The effective size of this nozzle is increased to some extent by an unheated peripheral flow technique. Additional unheated air forms a 0.13 m thick flow at $M=3.6$ on the bottom and two sides of the test flow. The static pressure of the peripheral flow matches that of the central Mach 6 flow.

To date, only a preliminary pitot profile has been measured at the nozzle exit. Figure 2 shows data taken when the static pressures of the heated and unheated flows were not ideally matched. Nevertheless, the profiles are quite uniform. The profiles represent a slightly higher than design value of nozzle Mach number. The discrepancy indicates a thinner boundary layer than anticipated.

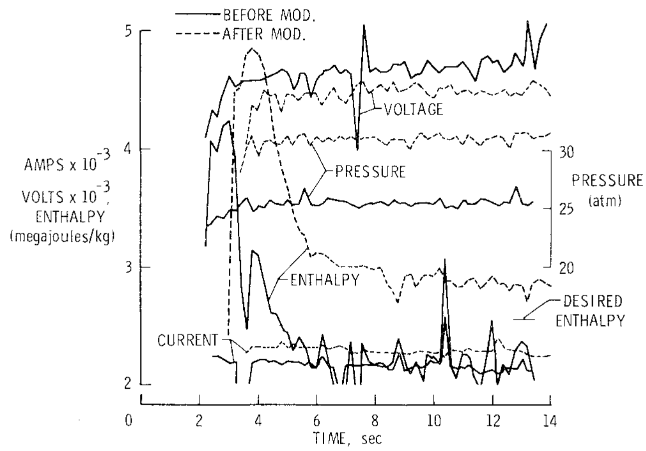

Fig. 1 Time variation of arc voltage and current, and heater enthalpy and pressure.

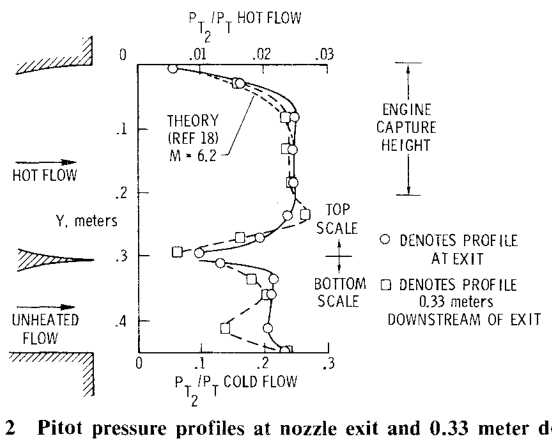

Fig. 2 Pitot pressure profiles at nozzle exit and 0.33 meter downstream of exit. Preliminary test. Static pressures of hot and unheated flows were not matched.

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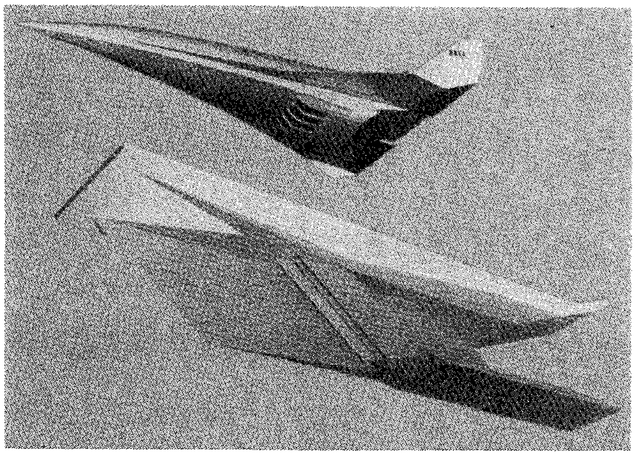

Fig. 3 Airframe-integrated supersonic combustion ramjet.

A cutway of the scramjet engine is shown in Fig. 3. The inlet design permits a large amount of downward spillage, and wind tunnel tests show this fixed geometry inlet can start as low as Mach 2.29. Fuel is supplied through internal swept-back struts.

The subscale engine model is about ½ to ⅓ the size of an engine that might be used on a research airplane. This model will undergo the first series of tests and will be instrumented to measure pressures, temperature, heating rates, and engine thrust. The model has its sides parallel to the airstream so external pressure forces are minimized.

The model is made of copper with water cooling only in critical locations. It is primarily a heat sink. It will be hydraulically injected into the test flow to avoid preheating. Calculations show that the few cooling channels used in the model contribute to a satisfactory wall temperature distribution that will prevent excessive thermal stresses.

Using a computer program developed for a hydrogen fueled engine, estimates have been made of the performance of the three-dimensional scramjet model. The analyses uses real gas properties and considers a one-dimensional change in the flow properties through the engine. The computer program can account for heat losses, and considers losses due to inlet flow spillage, fuel temperature, and plume drag. Calculated results show there is a strong increase in thrust as more fuel is used and that there is a marked effect on thrust when nozzle exit area is increased.

Computations have also been made to show what boundary-layer effects the scramjet model will experience in the tunnel, in comparison to computed boundary-layer effects a larger engine must experience in flight. Comparison of the tunnel boundary layer, which will be ingested by the engine model, with the boundary layer that a flight vehicle might ingest from its vehicle forebody, shows a difference in the density distribution through the boundary layer.