SHOCK TUNNEL STUDIES OF SCRAMJET PHENOMENA

FINAL TECHNICAL REPORT - NAGW - 674

Initially, work done under the grant was directed towards obtaining data at high enthalpies which could point to effects which may have a bearing on the NASP program. Therefore work focussed on a large number of preliminary studies of supersonic combustion in a simple combustion duct - thrust nozzle combination, investigating effects of Mach number, equivalence ratio, combustor divergence, fuel injection angle and other parameters with an influence on the combustion process. This phase lasted for some three or four years, during which strongest emphasis was placed on responding to the request for preliminary experimental information on high enthalpy effects, to support the technology maturation activities of the NASP program.

As the need for preliminary data became less urgent, it was possible to conduct more systematic studies of high enthalpy combustion phenomena, and to initiate other projects aimed at improving the facilities and instrumentation used for studying scramjet phenomena at high enthalpies.

The combustion studies were particularly directed towards hypersonic combustion, and to the effects of injecting fuel along the combustion chamber wall. A substantial effort was directed towards a study of the effect of scale on the supersonic combustion process. The influence of wave phenomena (both compression waves and expansion waves) on the realization of thrust from a supersonic combustion process was also investigated. The effect of chemical kinetics was looked into, particularly as it affected the composition of the test flow provided by a ground facility. In the process, a comparison was made of results obtained in the T-4 shock tunnel facility at the University of Queensland and results obtained in the "Hypulse" expansion tube facility at General Applied Science Laboratories, Ronkonkoma, N.Y. The effect of injection of the fuel through wall orifices was compared with injection from a strut spanning the stream, and the effect of heating the fuel prior to injection was investigated. Studies of fuel - air mixing by shock impingement were also done, as well as mass spectrometer surveys of a combustion wake.

At an early stage, the application of a free piston driver to an expansion tube was studied, as an alternative means of producing high enthalpy flows. Initial experiments led to the development of a theory explaining the nature of disturbances to the test flow, indicating how these could be eliminated, and this was confirmed by experiment. Study of the effects of expansion tube diaphragms were done, and a new type of driver, involving a compound piston, was developed. The use of a hypersonic nozzle with an expansion tube was investigated.

Development of the shock tunnel facility was pursued, with a technique for designing hypersonic nozzles for non-equilibrium flow. Because of its importance in interpreting scramjet data, measurements of transition in T-4 were made. Tests on a Shuttle model were made, and the results compared with flight data as a means of encouraging confidence in shock tunnel data.

A new method was developed for measuring the forces acting on a model in less than one millisecond. The method made use of the stress waves produced by loading the model, and therefore is described as the "stress wave force balance". It has been used to measure the drag force on cones, both sharp and blunted, the net thrust delivered by a nozzle at the end of a combustion duct, and the net axial force on a scramjet model. It has also been used to measure the axial force on a completely integrated scramjet model, including a fuel supply, and it was found that it could produce a net positive thrust. The technique has been extended to become a three component force balance for very simple models.

Because of the importance of skin friction drag at hypersonic speeds, particularly for scramjet propelled vehicles, considerable effort has been devoted to the measurement of skin friction. A piezo electric skin friction gauge has been developed, and has been used to measure the skin friction in high enthalpy laminar boundary layers. After further development, this type of gauge could also be used to measure turbulent skin friction.

A time-of-flight mass spectrometer has also been developed for use in the shock tunnel. As already noted, it has been used to measure species concentrations in a combustion wake. It has also been used to measure the freestream composition in the shock tunnel, indicating lower levels of frozen atomic oxygen concentrations than current theories predict.

It should be noted that this work has ben carried out as a collaborative effort, with funding not only from NAGW-674, but also from the Australian Research Council, and from the University of Queensland. However, the funding which came from NASA was a very important part of the total, and we would like to express our sincere appreciation and thanks for the support given our work through NAGW-674.

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