Propellant Mixing Characterization of a Like-on-Like Doublet Impinging Injector

Project Number: 97-24

Investigators: H.P. Trinh/EP62
D. McDaniels/ED34

Purpose

The project was initiated to investigate the propellant mixing characteristics of a like-on-like doublet impinging injector using the cold-flow testing approach. Results of the study will enhance the capability of the propellant mixing assessment for the subject injector. Correlation and spray models will be updated and validated with available hot-fire data. The models, in turn, will be utilized to predict injector performance of future engines. Consequently, some technical uncertainties and associated development costs in designing the optimized injector would be reduced.

Background

The design of injectors for liquid propellant rocket engines has historically been an artful process based on experience and intuition. This design approach led to expensive, time-consuming development programs and often to marginal final designs. In the decade of the 70's, the injector design capability was improved significantly by the use of empirical and semi-empirical correlation models that characterize the combustion field and by cold-flow techniques to determine the mass, mixture ration, and drop size distributions.

Unfortunately, the models contain simplifying assumptions and originally were derived from limited databases not general enough to cover a broad range of geometric and engine-operating parameters.

The aim of this effort is to expand the knowledge base and the injector data by testing the subject injector at cold-flow conditions. The test matrix will contain a wide range of injector configurations and operating conditions for refining existing correlation models.

Approach

The tests are performed in an MSFC cold-flow facility at Building 4776 under ambient conditions. Water and silicon oil are used as simulants of liquid oxygen and RP–1, respectively. The propellant mixture issued from the injector will be collected at a given downstream surface plane with a mass and mixture ratio distribution (M&MRD) flow system on loan from Philips Laboratory, Edwards Air Force Base. A study of flow cavitation phenomenon, which may occur in an injector orifice at high injector pressure drops under the cold-flow conditions, has been conducted as a first part of the project. Seventeen injector configurations will be tested to investigate the propellant mixing characteristics. The multi-injection element effects normally significantly enhance the overall injector performance. The project will cover the testing of several injection element arrangements and injection element densities for this particular study. Finally, present empirical correlation will be updated for comparison with available hot-fire test data.

Accomplishments

- Single orifice injector models have been tested to investigate the flow cavitation and hydraulic flip phenomena, which appear on the cold-flow conditions as shown in figure 24.

- Initial test series revealed that the flow separation occurs at a pressure drop (Δp_{inj}) across injector of about 35 psi. When Δp_{inj} is

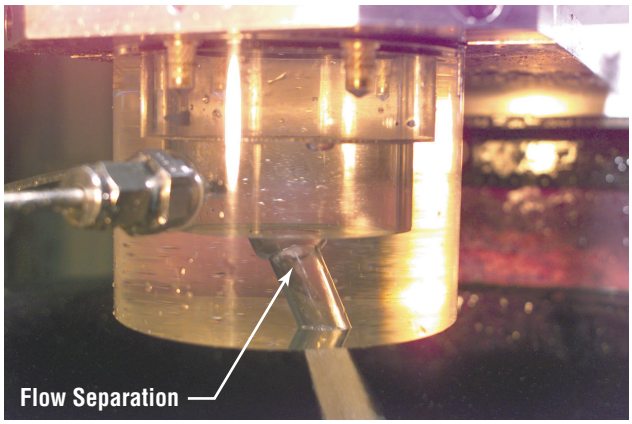

FIGURE 24.—Single-orifice injector model

at a higher value, pressure at the separation region approaches the vapor pressure, which is much lower than the ambient back pressure. The ambient gas, then, would enter the orifice. This is called a hydraulic flip. Consequently, orifice discharge coefficient drops (fig. 25) rapidly due to the flow restriction caused by the hydraulic flip phenomenon.

- Facility build-up for testing additional injector models is in progress.

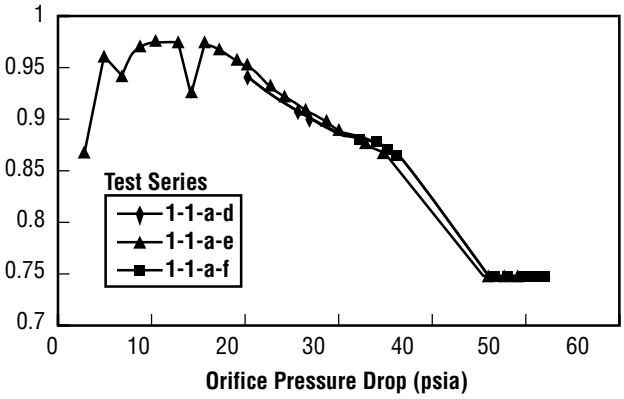

FIGURE 25.—Discharge coefficient of injector 1-1.

Planned Future Work

- Complete facility built-up and upgrade of the test rig as well as the M&MRD system.
- Fabricate the rest of injector models and complete testing them at various operating conditions.
- Validate the propellant mixing models with available hot-fire test data.

Funding Summary ($k)

About 85 percent of the total funding has been either spent or obligated.

	FY97
Funding request:	75.0
Spent/obligated:	64.4
Balance:	10.6

Status of Investigation

Project approved—January 1997

Estimated completion—June 1998