Experimental Investigation of Characteristics of a Double-Base Swirl Injector In a Liquid Rocket Propellant Engine.

F. Ommi, Ph.D.*, S.M. Hosseinalipour, Ph.D., A. Kargar, M.Eng., E. Movahed, and K. Nekofar, Ph.D.

*Faculty of Engineering, Tarbiat Modarres University, Tehran, Iran.

E-Mail: fommi@modares.ac.ir

ABSTRACT

Optimum injection and proper fuel distribution in the combustion chamber of a LPRE is one of the important factors determining the trust force and combustion stability. The advantages of dual-based swirl injection in comparison with other types include capability of producing desired spray-angle and effective droplet atomization. Based on the fundamentals of swirl D-B injectors an injector is manufactured. A laboratory was setup to measure the macroscopic spray characteristics such as droplet distribution, spray angle, and swirl effect under different pressure.

(Keywords: LPRE, liquid propellant rocket engine, swirl dual-based injector, propulsion, spray cone, spray angle)

INTRODUCTION

The double-based liquid-liquid injectors have various advantages leading into expansion of application in aircraft industries. Since fuel and oxidizer both exit from one injector, without any increase in the diameter of injector plate, a higher discharge rate of fuel and oxidizer can be obtained. This, in turn, gives higher pressure in the combustion chamber [Ditiakin, E.F., et al., 2007].

The injector has been designed in a way that the fluid may swirl around its axis. The swirl effects advantages include producing micro-diameter droplets, desirable spray angle which provide the optimized droplet atomization that reducing the probability of combustion instability, and increase propulsion force.

SWIRL INJECTOR DESIGN PROCEDURE

The initial data consists of the cone angle of spray, discharge rate, pressure difference of injector, and the entrance angle to nozzle, number of holes to the swirl chamber, density, and fluid viscosity [Sutton G. P., 1986].

Figure 1 shows a double-base injector. In this injector, fuel and oxidizer are mixed outside the nozzle. The injector parameters should be selected in a way that the fuel and oxidizer spray cones do not cut each other near nozzle outlet. Variables α_f and α_0 show the spray angle of fuel and the angle of oxidizer, respectively. In the d-b swirl injector, the governing equations are based on the principles of mass, angular momentum, energy conservation (Bernoulli's Equation), maximum flow rate and minimum energy laws.

The swirl injector should provide the necessary discharge rate of the fluid under a definite spray cone angle and the pressure difference [Bazarov V.G., et al., 1998].

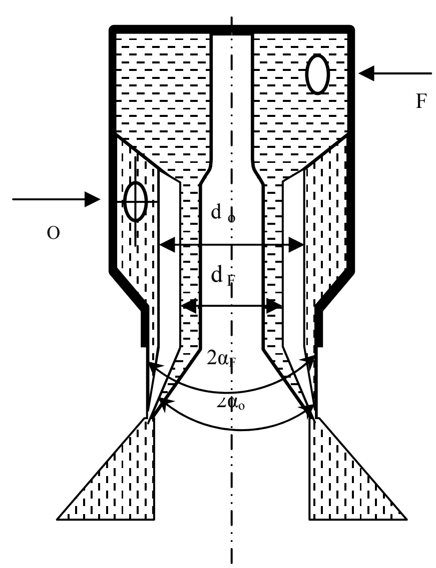

Figure 1: A Double-Base Swirl External Mixing Injector.

THE DOUBLE-BASE SWIRL INJECTOR CALCULATION RESULTS

The design procedure of a single injector is applied for designing the double-base injector. To design a double-base injector, the data of the internal and external nozzle should be input in the program separately in order to obtain its geometry. However, as mentioned, the radius of the external nozzle should be more than the external radius of nozzle in the inner injector. At the same time, the spray cone angle of inner injector should be more than the outer injector, therefore both spray cones would contact each other after discharging form injector [Vasiliov, A.P., et al., 1993].

According to the design condition, the internal nozzle must inject flow of 20 $^{cc}/_{sec}$ in defined pressure of 10 bars. The external nozzle must also inject 120 $^{cc}/_{sec}$ in 4 bars. The spray angles for the internal and external nozzles obtained 85° and 75°, respectively.

Manufacturing the Injectors

The injector is manufactured based on design calculations. The double-based swirl injector has three parts including internal nozzle, external nozzle, and lid. Brass metal was chosen due to its special characteristics for accurate machining and minute drilling. These three parts are brazed and assembled precisely as shown in Figure 2.

Figure 2: Assembled and Disassembled of a Manufactured Swirl Injector.

Hydrodynamic Test Laboratory

To measure the macroscopic characteristics of the spray such as distribution quality, spray angle, and swirl effect, a laboratory was set up with the following parts: Injector Stand, Pressurized Liquid Tanks, High Pressure Nitrogen Capsule, Manometers and Regulators, Sectional & Radial and Collector, Stroboscope, and High-Speed Camera [Paie B.U., et al., 1982].

EXPERIMENTAL INJECTOR TEST RESULTS AND DISCUSSION

Flow-Pressure Test:

This test is conducted to measure the flow changes under different working pressure for both internal and external nozzle as shown in Figures 3 and 4.

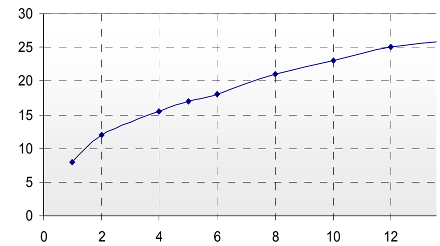

Figure 3: Flow Rate of Internal Nozzle $(^{cc}/_{sec})$ vs. Pressure (bar).

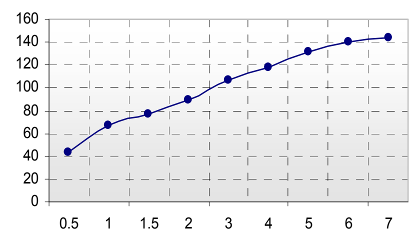

Figure 4: Flow Rate of External Nozzle $(^{cc}/_{sec})$ vs. Pressure (bar).

Spray Angle Test:

As Figure 5 displays, as fluid pressure increases, the spray cone gradually opens to become fully developed.

Figure 5: Spray Formation Stages Regarding to Fluid Swirl.

Figures 6 and 7 shows that the spray cone angle of the internal and external nozzle are approximately 70° and 80°, respectively, which are satisfactory in the light of theoretical calculations (Po=4 & Pf=10 bar).

Figure 6 and 7: Spray Angle of Internal (Left Photo) and External Nozzle (Right Photo).

Spray Symmetry and Homogeneity Test

Sectional and radial collectors are used to check the symmetry of the fluid spray. To obtain a symmetrical distribution of injection, the machining and drilling processes must be precise and accurate [Reitz R.D., et al., 1983].

Figures 8 and 9 show the spray distribution in each compartment of the collector.

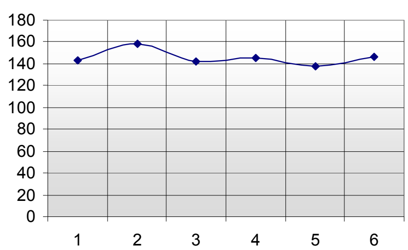

Figure 8: Spray Distribution of the Injector in each 60° Section.

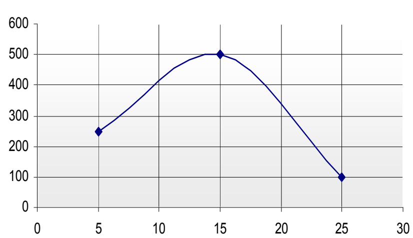

Figure 9: Spray Distribution of the Injector in each Cylinder.

CONCLUSIONS

According to design calculations and experimental results driven from the hydrodynamic laboratory set-up, as shown in Figures 2 through 9, it is concluded that the spray cone angles for internal and external nozzle of the swirl injector are that of had been expected before.

In Figure 5, the swirl effect on the spray is completely desired. As shown in Figures 8 and 9, the symmetry, homogeneity, and distribution quality of injector spray are acceptable and will lead to manufactured injectors which are flawless in operation.

REFERENCES

1. Bazarov, V.G. and Yang, V. 1998. “Liquid Propellant Rocket Engine Injector Dynamics”, *Journal of Propulsion and Power*. 14(5).

2. Ditiakin, E.F., Koliachko, L.F., Noikov, B.V., and Yagodkin, V.E. 1977. *Fluids Spray*. Moscow, USSR.

3. Paie, B.U. and Nijaquana. B.T. 1982. “The Characterization of Spray”. Paper No.1-4, pp. 29, The Second International Conference on Liquid Atomization and Spray System.

4. Reitz, R.D. and Bracco, F.V. 1983. “Mechanisms of Breakup of Round Liquid Jets”. In: *The Encyclopedia of Fluid Mechanics*. Cheremisnoff N. (ed.) Gulf Publishing: Houston, TX. 3(10): 233-249.

5. Sutton, G.P. 1986. *Rocket Propulsion Elements*. 15th Edition. John Wiley & Sons: New York, NY.

6. Vasiliov, A.P., Koderaftsov, B.M., Korbatinkov, B.D., Ablintsky, A.M., Polyayov, B.M. and Palvian, B.Y. 1993. *Principles of Theory and Calculations of Liquid Fuel Jet*. Moscow, Russia.

ABOUT THE AUTHORS

F. Ommi, has a Ph.D. in mechanical engineering, Faculty of Engineering Tarbiat Modares University (TMU), Tehran, Iran. He is happily married with four children.
http://www.modares.ac.ir/eng/fommi/

S.M. Hosseinalipour, was in the Top 5% of students (B.Sc. Sharif University, Iran, 1985), University Dean’s Honors List (Ph.D., McGill

University, Canada, 1996), Outstanding Student (M.Sc. Tarbiat Modaress University, Iran 1989). http://www.iust.ac.ir/printme-6.2061.1700.fa.html

A. Kargar, Master of Aerospace Engineering, is a postgraduate researcher in the department of mechanical engineering, Tarbiat Modarres University. He is a writer and has published widely in journal and conferences. E-mail address: amirkargar@yahoo.com

E. Movahed, Ph.D. Student of Mechanical Engineering, Tarbiat Modarres University. E-mail address; emovahed@yahoo.com. His research interest is in the area of automotive engine. He is presently working in the Iran Department of Environment.

K. Nekofar, Ph.D. in mechanical engineering from Moscow State University (2004). He is presently working in the Iranian Space Agency (ISA). He is happily married with one baby. nekofar@yahoo.com

SUGGESTED CITATION

Ommi, F., S.M. Hosseinalipour, A. Kargar, E. Movahed, and K. Nekofar. 2008. "Experimental Investigation of Characteristics of a Double-Base Swirl Injector In a Liquid Rocket Propellant Engine". *Pacific Journal of Science and Technology.* 10(1):132-135.

Pacific Journal of Science and Technology