Characterization of Swirl Vane Injector

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Abstract— In this paper, swirl airflow Are characterized for various air Swirler geometries. The number of vanes, vane angle, Vane curvature, Sauter mean diameter and air velocity are varied for the swirling Airflow. Injector is one of the vital devices in liquid Propellant rocket engine (LPRE).Injector Parameters that play the important role in the performance of liquid propellant rocket engine. There are several mechanisms of liquid atomization such as swirling. The injector internal geometries reviewed are limited to swirler geometry, mixing chamber diameter, mixing chamber length, Aeration hole diameter, discharge orifice diameter and discharge orifice length. Introducing a swirl component in the flow can enhance the propellant atomization and mixing whereas introducing bubbling gas directly into the liquid stream inside the injector leads to finer sprays even at lower injection pressures. Wider spray cone angle is beneficial for widespread of fuel in the combustion chamber for fast quiet ignition and a shorter breakup length provides shorter combustion chamber to be utilized and small SMD will result in fast and clean combustion. This work may aid in the specific inquiry of physical mechanisms relating to the effect of flow states on spray distribution. It is found that improved atomization and mixing performance are a result of increase in swirl number.

Keywords: Swirling, Wide spread, Curved vanes, Sauter mean diameter (SMD)

I. Introduction

Liquid Propellant rocket engine, Turbo fan, Gas turbine engines are widely used in Aviation industry and so on for continuous power Generation. Swirler vane injector is mounted on the dome of gas turbine combustor for swirl generation and flame stabilization. Combustion of liquid fuels in diesel engines, spark ignition engines, gas turbines, rocket engines, and industrial furnaces is dependent on effective atomization to increase the specific surface area of the fuel and they achieve high rates of mixing and evaporation. In most combustion systems, reduction in mean fuel drop size leads to higher volumetric heat release rates, easier light up, a wider burning range, and lower exhaust concentrations of pollutant emissions.

The swirl injector is used to atomize the liquid propellants through the formation of liquid film, primary breakup and secondary atomization. Atomization is a process during which the interfacial area of liquid increases gradually because the bulk liquid is transformed into small droplets.

Figure.(1), propellants enter the device through tangential inlet orifices, and flow away from the exit orifice in the form of hollow conical sheet, usually with fuel in the inner cone and oxidizer on the external part.

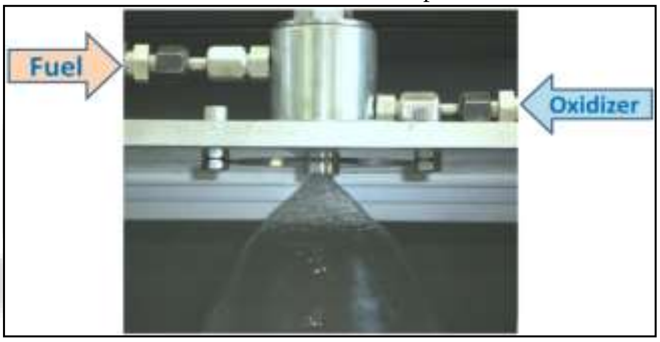
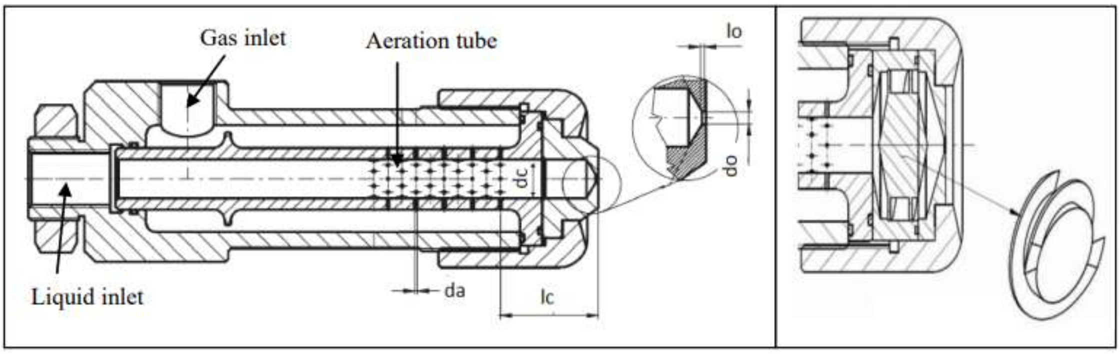


Fig. 1: Swirl injector



(a) (b)

Fig. 2: Injector internal geometries (a) Full body without swirler (b) with Swirler

II. Characterization of Swirling Airflow

The effects of air swirler geometry on the essential flow Parameters. It is evident that the non dimensional length and width of the recirculation zone, turbulent intensity, maximum reversal velocity magnitude, and pressure loss gradually increase with the number of vanes. the size of recirculation zone, turbulence intensity, and pressure loss increase sharply with an increase in the vane angle. Presents the variation in the length of CTRZ and the maximum turbulent kinetic energy (kmax) at different airflow Reynolds numbers (Rea) for flat vane swirlers having 30, 45,60 vane angle values. For a fixed swirler geometry, when the inlet air velocity is changed, all velocity components change in the same proportion. Resulting in the same re-circulation zone

	Flow conditions	Length of recirculation zone (LRZ/L_d)	Width of recirculation zone (WRZ/W_d)	Maximum turbulent intensity (TI_{max}) (%)	Maximum reversal velocity (V_{rm}) (m/s)	Pressure loss factor (PLF)
Vane number	4 ($Re_a = 1.38\times10^5, S_G = 0.41$)	0.26	0.53	34.17	6.03	3.01
	6 ($Re_a = 1.37\times10^5, S_G = 0.41$)	0.27	0.53	34.83	6.37	3.17
	8 ($Re_a = 1.35\times10^5, S_G = 0.41$)	0.28	0.56	35.28	6.45	3.32
	10 ($Re_a = 1.33\times10^5, S_G = 0.41$)	0.28	0.55	35.96	6.683	3.54
	12 ($Re_a = 1.32\times10^5, S_G = 0.41$)	0.29	0.54	37.22	7.02	3.78
Vane angle	30° ($Re_a = 1.35\times10^5, S_G = 0.41$)	0.28	0.56	35.28	6.45	3.32
	45° ($Re_a = 1.35\times10^5, S_G = 0.71$)	0.64	0.66	45.01	9.93	8.76
	60° ($Re_a = 1.35\times10^5, S_G = 1.23$)	0.73	0.76	61.62	13.25	25.69

Table 1: Effects of vane number and vane angle of Swirler on airflow field parameters.

III. EXPERIMENTAL SETUP

A. Sauter Mean Diameter

Sauter Mean Diameter (SMD) it is defined as the diameter of a sphere that has tha same volume/surface area ratio as the entire spray described as size of particle such that its mass or its surface is the mean value for all the particles in the system. Based on Lefebvre analysis, for combustion applications only SMD can properly indicate the fineness of a spray, thus SMD is to be used to describe atomization Quality. the atomization quality reduced with the increase of discharge orifice diameter but there is no significant changes with the variations of aeration hole diameter.

B. Breakup Length

There are two types of breakup length: slant breakup length and vertical breakup length. The slant breakup length characterize the distance between the breakup position of liquid film and the injector exit, while the vertical breakup length characterize the vertical distance between them. Breakup length is defined as the distance between the Discharge Orifice to the point of the producing sprays completely atomized. the injector provides shorter breakup length is very important in combustion application to clarify that shorter combustion chamber could be produced and easier utilization That the reduction of breakup length is influenced by the increase of GLR and decrease of discharge orifice diameter.

C. Spray Cone Angle

The spray cone angle tends to converge or diverge with increasing distance from the spray converge varies with spray angle. the spray angle is assumed to remain constant throughout the entire spray distance. spray angles are important in coating applications to prevent over spraying of the coated materials. in combustion engine to prevent wetting of the cylinder wall, and in fire sprinklers to provide adequate coverge of the protected property. Spray cone angle are liquid distribution with in tha cone pattern depend on the vane design and location relative to the exit orrifice Better dispersion of fluid through injector is desirable in various applications such as spray combustion. Generally, an increase in spray cone angle increases the exposure of the droplets to the surrounding air or gas, leading to improved and to higher rates of heat and mass transfer.

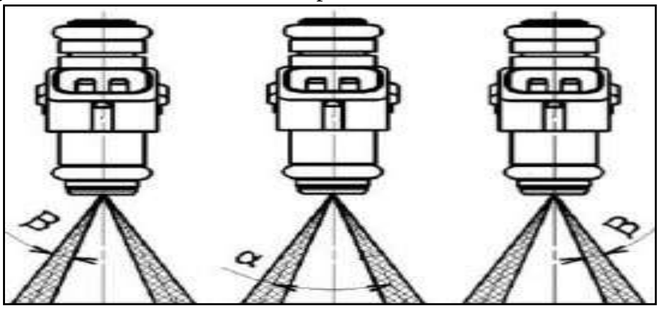


Fig. 3: Schematic diagram of spray cone angles: left beta angle (left), alpha angle (middle) and right beta angle (right).

D. Cold Flow Test

The advantage of cold flow test is that the pure fluid atomization.The performance of an injector is verified by performing cold test with stimulant liquids instead of reactive propellants. fluid is being used frequently to confirm pressure drops through the fuel and oxidizer side at different flows and this will allow determination of the pressure drops with propellant and discharge coefficients. A cold flow injection test is an alternative to static firing test, where the original propellants are replaced by a simulated fluid which can be water or other liquids. It is a preliminary investigation of the swirl injector performance.

E. Injector

An injector is a system of ducting and nozzle used to direct the flow of high pressure fluid in such a way that a lower pressure fluid is entrained in the jet and carried through a duct to a region of high pressure. is a fluid dynamic fixed pump with no moving parts excepting a valve to control inlet flow. it uses the venture effect of a converging-diverging nozzle on a steam jet to convert the pressure energy of the steam to velocity energy. Reducing the pressure to below that of the atmosphere, which enables to entrain a fluid .the mixed fluid is fully condensed, releasing the latent heat of evaporation of the steam which imparts extra velocity.

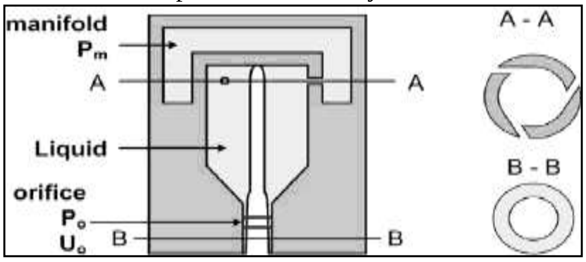


Fig. 4: simplex swirl injector

IV. Conclusions

This paper presented Based on the literature, that the result find spray cone angle increase with the increase of injection pressure and swirling effect in the injector. SMD has found to decrease with increasing of injection Pressure. It is also found that, breakup length decrease with the increase of injection pressure, increase of GLR and decrease of discharge orifice diameter. This can be attributed to the smoother guidance of swirl airflow by the curved vanes. That can be used for sizing swirl injectors, with focus on achieving the specified mass flow. Modifications were incorporated to an existing theoretical model, creating a new situation where the exit orifice area is responsible for setting the spray cone angle, while the inlet orifice area is primarily responsible for setting the required mass flow through the injector.

References

[1] Atomization and Sprays: (Arthur) H.Lefebvre, Vincent G. mcdonell (BOOK)
[2] George P. Sutton and Oscar Biblarz, Rocket Propulsion Elements, seventh ed., John Wiley & Sons, Canada, 2001.
[3] M.A. Rahman, Scaling of Effervescent Atomization and Industrial Two-Phase Flow, Ph. D. thesis, University of Alberta, 2011.
[4] Arthur H. Lefebvre and Dilip R. Ballal, Gas Turbine Combustion (Alternative Fuels and Emissions), third ed., Taylor & Francis Group, Florida, 2010.
[5] J.D. Whitlow and A.H. Lefebvre, Experimental Studies on Effervescent Injectors with Wide Spray Angles, AGARD (Advisory Group for Aerospace Research and Development) Meeting on Fuels and Combustion Technology for Advanced Aircraft Engines, May 1993.
[6] J. Jedelsky and M. Jicha, Novel Modifications of Twin-fluid Injectors: Performance, Advantages and Drawbacks, ILASS – Europe 2010, 23rd Annual Conference on Liquid Atomization and Spray Systems, Brno, Czech Republic, September 2010.
[7] Byung-Joon Rho, Shin-Jae Kang, Je-Ha Oh and Sam-Goo Lee, Swirl Effect on the Spray Characteristics of a Twin-Fluid Jet, KSME International Journal. 5 (1998) 899-906.
[8] F. Barreras, A. Lozano and J. Barroso, Experimental Characterization of Industrial Twin-Fluid Atomizers, Atomization and Sprays. 16 (2006) 127-145.
[9] Syred N and Beer JM. Combustion in swirling flows: a review. Combust Flame 1974; 23: 143–201.
[10] Gupta AK, Lilley DG and Syred N. Swirl flows. Tunbridge Wells: Abacus Press, 1984.
[11] Hadef R and Lenze B. Effects of co-and counter-swirl on the droplet characteristics in a spray flame. Chem Eng Proces 2008; 47: 2209–2217.
[12] Rajamanickam K and Basu S. Insights into the dynamics of spray–swirl interactions. J Fluid Mech 2017; 810: 82–126.
[13] Shih TH, Liou WW, Shabbir A, et al. A New K-eddy viscosity model for high Reynolds number turbulent flows Comput Fluids 1995; 24: 227–238.
[14] Schmidt DP, Nouar I, Senecal PK, et al. Pressure-swirl atomization in the near field. SAE technical paper 1999-01-0496, 1999.
[15] Taylor GI. The shape and acceleration of a drop in a high speed air stream. In: Batchelor GK (ed.) The scientific papers of G. I. Taylor, vol. 3. Cambridge: Cambridge University Press, 1963, pp.457–464.
[16] Haider A and Levenspiel O. Drag coefficient and terminal velocity of spherical and nonspherical particles. Powder Technol 1989; 58: 63–70.
[17] Coghe A, Solero G and Scribano G. Recirculation phenomena in a natural gas swirl combustor. Exp Therm Fluid Sci 2004; 28: 709–714.
[18] Lefebvre AH. Atomization and sprays.1st ed. Boca Raton, FL: CRC Press and Taylor and Francis Group, 1989
[19] Khavkin YI. Theory and practice of swirl atomizers. London: CRC Press, 2003.
[20] S.Pandey and A.Kushari, A Controllable Twin-Fluid Internally Mixed Swirl Atomizer, Recent Patents on Mechanical Engineering. 1 (2008) 45-50

