ISSN (online): 2349-784X

Review "Design and Experimental Investigation of Internally Mixed Pressure Swirl Atomizer"

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Abstract

Pressure-swirl atomizers are widely used in air-breathing gas turbine engines as they have good atomization characteristics and are relatively simple and inexpensive to manufacture. To reduce emissions, it is critical to design fuel atomizers that can produce spray with a droplet size and drop distribution at the desired combustor location. The present work is an attempt to design and experimentally investigate the internally mixed pressure swirl atomizer for Micro Gas Turbine application. In the beginning it gives the introduction to atomizer & atomization processes. The design philosophies for the design of internally mixed pressure swirl atomizer and manufacturing of designed atomizer are done for investigation of the different parameter like spray cone angle, spray penetration length, and drop diameter and drop distribution.
Keywords: Swirl Atomizers, Air-Breathing, Spray, Nozzle Mixed Pressure

I. INTRODUCTION

Protecting and improving the global environment and leaving the earth in a habitable environment for the generations to come is the key international issue of the 21st century. Combustion of liquid fuels in gas turbines engines, rocket engines, and industrial furnaces is dependent on effective atomization to increase the specific surface area of the fuel and thereby 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 concentration of pollutant emissions Liquid atomization, the process of producing a large number of droplets from bulk liquid, is used in a variety of engineering applications, in pharmaceutical industries, process industries, fuel injection in combustion applications, and in agricultural sprays. A number of spray devices have been developed for this purpose, and they are generally designated as atomizers or nozzles. Among these, pressure-swirl atomizers or simplex atomizers are commonly used for liquid atomization due to their simple design, ease of manufacture, and good atomization characteristics.

A. Atomization

The process of atomization is one in which liquid jet or sheet disintegration by the kinetic energy of liquid itself, or by exposure of high velocity air or gas, or as a result of mechanical energy applied externally through a rotating or vibrating device. It represents a disruption of the consolidating influence of surface tension by the action of internal and external forces. In the absence of such disruptive forces, surface tension tends to pull the liquid into the form of a sphere, which has the minimum surface energy. Liquid viscosity has an adverse effect on atomization because it opposes any change in system geometry. On the other hand, aerodynamic forces acting on the liquid surface promote the disruption process by applying an external distorting force to the bulk liquid. Breakup occurs when the magnitude of the disruptive force just exceeds the consolidating surface tension force.

Fig. 1: Spray produce by pressure swirl atomizer.

The atomization process is generally regarded as comprising two separate processes—*primary* atomization, in which the fuel stream is broken up into shreds and ligaments, and *secondary* atomization, in which the large drops and globules produced in primary atomization are further disintegrated into smaller droplets. There are various mechanisms whereby a jet or sheet of fuel issuing from an atomizer is broken down into drops. A distinction is made between the two basic mechanisms of atomization—classical and prompt. The process of jet disintegration is of great importance for the design of plain-orifice pressure nozzles and plain-jet air blast atomizers, whereas the mechanism of sheet breakup has direct relevance to the performance of pressure-swirl and pre-filming air blast atomizers.

II. LITERATURE REVIEW

P. T. Lacava & D. B. Netto They suggest a procedure for designing a pressure swirl atomizer. The discharge coefficient, the spray cone angle and the Sauter Mean Diameter were evaluated experimentally and compared with the theory used to design the atomizer. Figure 2.1 shows schematically a pressure swirl atomizer. The liquid is fed to the injector through tangential passages giving the liquid a high angular velocity, and forming, in the swirling chamber, a liquid layer with a free internal surface, thus creating a gas-core vortex. The liquid then is discharged from the nozzle in the form of a hollow conical sheet which breaks up into small droplets.

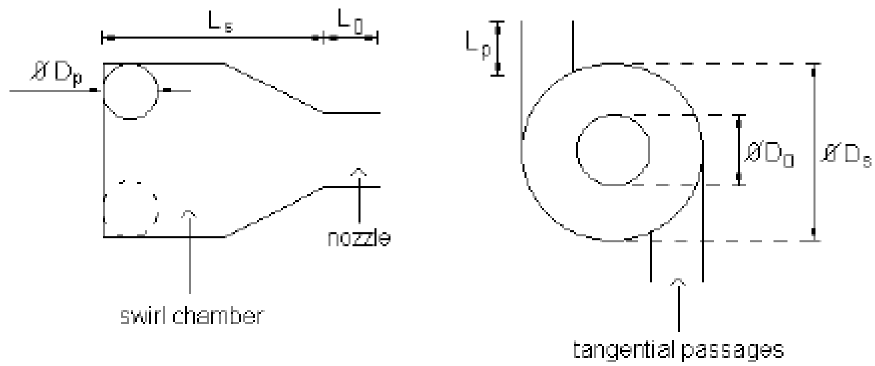

Fig. 2: Pressure-swirl atomizer schematics

They found that the spray semi angle increasing as the injector pressure differential increases, which is expected for the injector was not changed and the mass flow rate also increases with the injector pressure differential. For SMD it is observed the theoretical curve has the same qualitative behavior of the experimental results (indeed they are nearly parallel to each other); however, the experimental values are 1.75 times the predicted ones.

Javier Ballester and César Dopaz They carried out experiment on simplex pressure-swirl nozzles for atomizing heavy oil & study the influence of atomizer dimensions and injection conditions on discharge coefficient and spray angle. They manufactured twenty nozzles of different geometries including orifice diameters down to 0 .45 mm. The test fluid was heavy oil customarily used in utility boilers. Its physical properties were determined as a function of temperature. The oil temperatures were 100, 110, 120, and 135°C. The pressures selected for injection were 12, 14, 17, and 20 bars. As the variation of viscosity within the temperature interval 100 to 120 °C is over 250% then surface tension which is less than 6%.

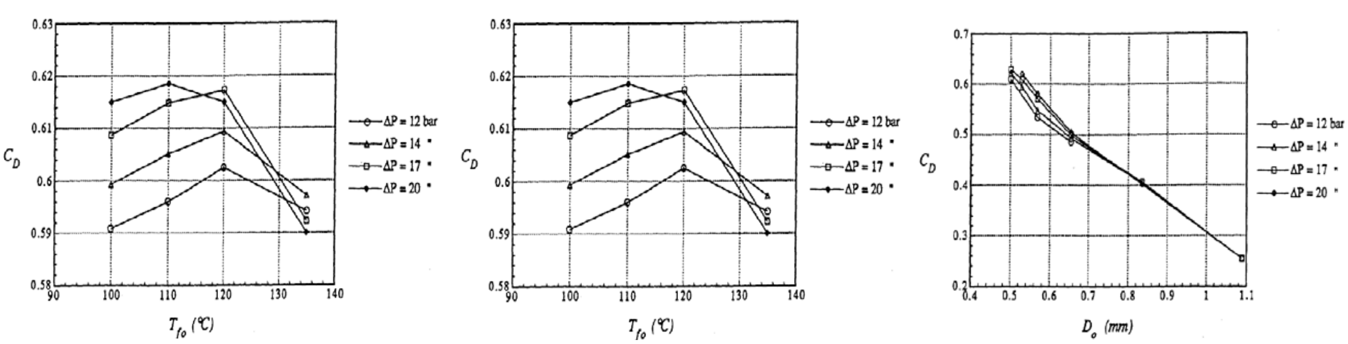

Fig. 3: Effect of T_{fo} on C_D *(b) Effect of D_o* on C_D.

Exhibit the maximum in C_D that is characteristic of pressure-swirl atomizers as the fluid viscosity decreases. They found that at low temperatures, the viscous friction prevents the formation of a central air core and the liquid exits as a full jet.

J. T. Yang et.al They experimentally studied the effects of channel configuration (curved and plat) of micro atomizers on spray characteristics through the analysis of flow number, SMD, and axial velocity. The spray features were evaluated with flow visualization techniques and Phase/Doppler Particle Anemometry (P/DPA). The schematics of the pressure-swirl atomizers fabricated by the LIGA micro processes are illustrated in Figure. The depth of the swirl chamber further varied from 0.655 mm (PWA type) to 0.779 mm (PWB type) for investigating the swirl effect. For the mass flow rate and flow number they found that the mass flow rate increased with the increase of injection pressure. The atomizers with curved-channel had less mass flow rate than that of plat-channel where as a lower value of flow number corresponds to stronger swirl effect, and thus takes in lots of air to form large air core. The curved-channel atomizers have lower flow numbers than those of plat-channel

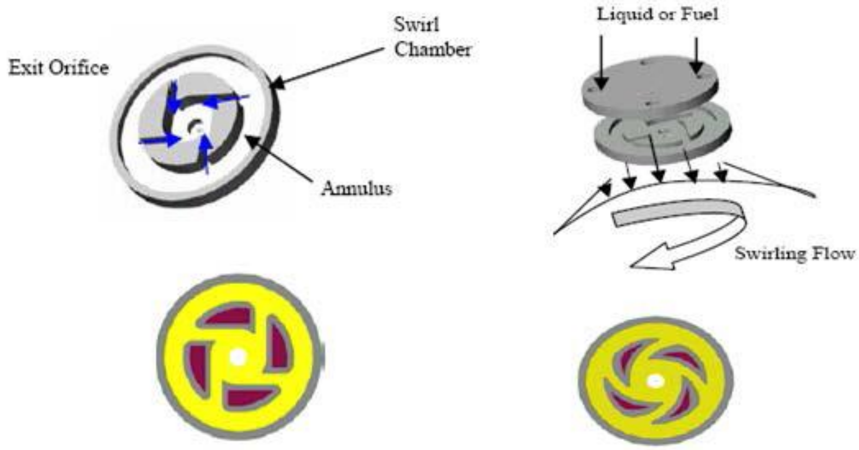

Fig. 4: Schematics of configurations of the (a) Flat-channel (b) Curved-channel atomizers

They found that the curved-channel atomizer had smaller droplets size over the entire flow field and state that curved-channel atomizer had smaller flow number was due to their better swirl effect. For the influence of atomizer thickness on spray characteristics they found that with fixed atomizer thickness, the curved-channel atomizer had better swirl effect than that of plat-channel atomizer.

Jianqing Xue He developed a two-dimensional axi-symmetric computational fluid dynamics (CFD) model based on the Arbitrary-Lagrangian-Eulerian (ALE) method to predict the flow in pressure-swirl atomizers. The developed code was validated by comparison of predictions with experimental data for large scale prototype and with semi-empirical correlations at small scale. The computational predictions agreed well with experimental data for the film thickness at the exit, spray cone angle, and the pressure drop across the atomizer as well as velocity field in the swirl chamber. The geometric parameters of atomizer covered in this study include: atomizer constant (K), the ratio of length to diameter in swirl chamber (Ls/Ds), the ratio of length to diameter in orifice (lo/do), the swirl chamber to orifice diameter ratio (Ds/do), inlet slot angle (β), trumpet angle (θt), trumpet length (lt), and swirl chamber convergent angle (θc). The effects of these geometric parameters on the atomizer performance were studied for a fixed mass flow rate through the atomizer as well as for a fixed pressure drop across the atomizer. The atomizer performance was described in term of dimensionless film thickness at the exit (t*), discharge coefficient (Cd) and spray cone half angle (θ).

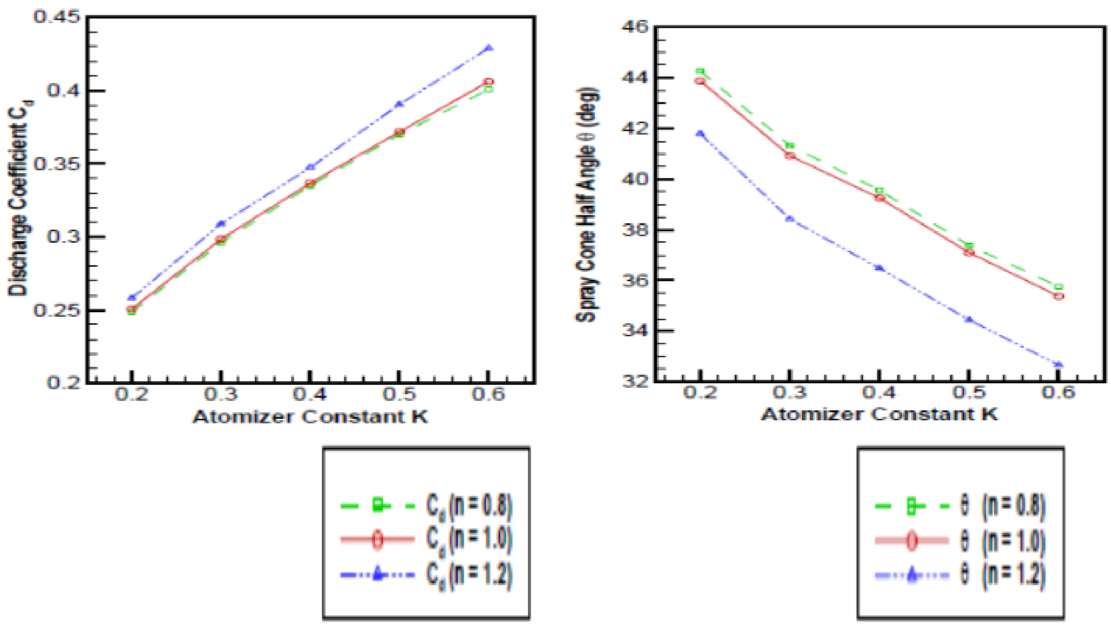

Fig. 5: (a) Variation of discharge coefficient with atomizer constant (b) Variation of spray cone angle with atomizer constant

Among the geometric parameters considered here, atomizer constant was found to be the most dominant parameter. With the atomizer constant (K) increasing from 0.1 to 0.6, dimensionless film thickness at the exit increases by about 0.15; the discharge coefficient increases by about 0.2; and the spray cone half angle decreases by about 25%.With other parameters, the dimensionless film thickness and spray cone half angle variations are not always monotonic and exhibit optimal conditions (small thickness and large cone angle) at certain parameter values. This may be of interest in designing atomizers.

B. A J. Yule and I. R. Widger

Swirl atomizers producing water sprays are investigated by them experimentally to give information on atomizer performance at supply pressures up to 15.2 MPa. Some broad agreement of trends for discharge coefficient, drop diameter and spray angle is found with results obtained at lower supply pressure. All 157 atomizer configurations were tested, having a typical geometry and notation as shown in Fig

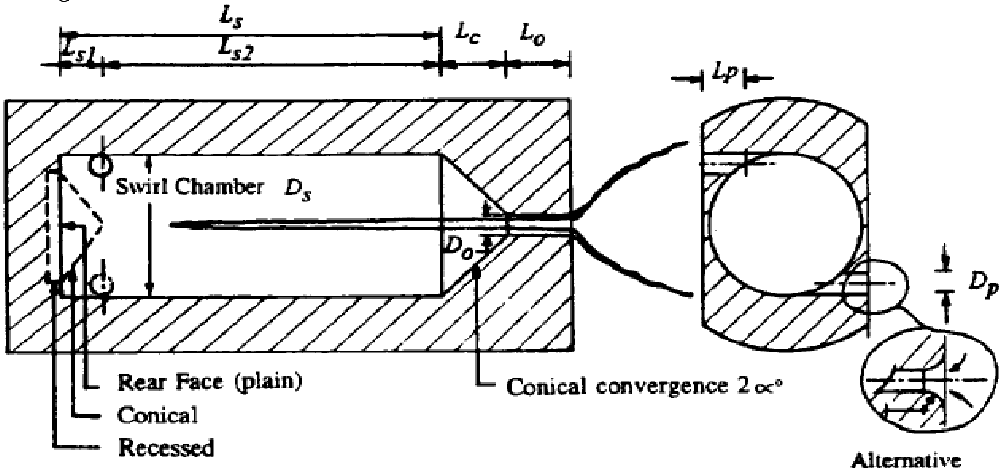

Fig. 6: Geometry and notation for a swirl atomizer

They found that mass median drop diameter reduced with reducing inlet port area and, to a greater extent, with increasing supply pressure. Significant increase in discharge coefficient *Cd* occurred for reduction in exit orifice diameter and for increase in the lengths of both the exit orifice and also the swirl chamber.

C. Design Methodology

The aim of the design is to determine the dimensions of a atomizer for the given flow rate, (m) injection pressure (ΔP), nozzle angle (α) and fuel properties (fuel density ρ and kinematic viscosity υ).

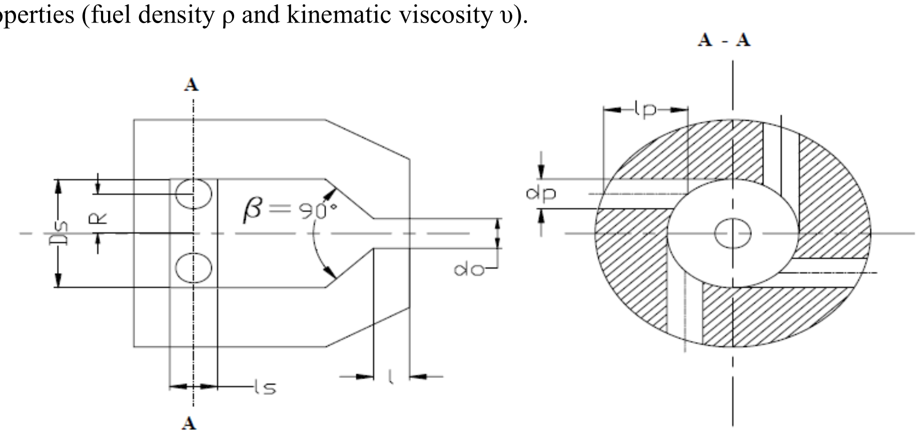

Fig. 7: Basic dimensions of a Simplex Pressure Swirl Atomizer.

III. CONCLUSIONS

The effect of injection pressure of fuel on the Penetration Length, Cone Angle and Drop Diameter of internally mixed pressure swirl atomizer for Kerosene type fuel has been investigated at constant air pressure. The simple modification in pressure swirl atomizer is undertaken for the development of internally mixed pressure swirl atomizer. The experimental investigations suggest that spray half cone angle tends to decrease with increase in injection pressure for conventional pressure swirl atomizer. This is expected as atomization improves with increase in the injection pressure differential. The decrease in spray cone angle has led to the increase in penetration length with increase in injection pressure. The modified pressure swirl atomizer, called internally mixed pressure swirl atomizer, gives lower spray cone angle and larger penetration length compared to conventional pressure swirl atomizer.

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