A NUMERICAL STUDY OF SPRAY CHARACTERISTICS OF A PRESSURE SWIRL ATOMIZER

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ABSTRACT
This paper deals with the numerical analysis of 2d model of aPressure Swirl Atomizer, which is developed to study the spray characteristics of atomizer, the flow parameters are SMD, aircore diameter and spray cone angle. The variation in nozzle diameters are 1.5m, 2m and 2.5m using fuel is jet A and methodology affect flow over the atomizer. Results of CFD simulation indicated the optimum nozzle diameter of the atomizer, methodology required to have uniform flow and Spray characteristics within the atomizer. It also proved that CFD is a convenient tool for designing and optimizing the flow over the atomizer.

KEYWORDS: Computational Fluid Dynamics; Pressure Swirl Atomizer; Numerical Simulation.

INTRODUCTION
In modern aero gas turbine combustor, after a flame out at high altitude relight and pull away capability is challenging field, reliable ignition and low emissions from this the combustor design is more difficult. In case in-flight shutdown takes place due to an engine malfunction, climatic variations (such as like volcanic ash) or a delight shutdown default of pilot. In such cases the combustion chamber conditions (as pressure, velocity and temperatures), chamber volume and spray characteristics are greatly define the relight and pull away capability of the engine. The Pressure Swirl Atomizer plays important role of combustion efficiency, the spray characteristics are depend on the atomizer, the nozzle diameter of atomizer is optimization carried in this paper.

A short discussion of the previous studies of authors who attempted to focus on the Spray characteristics within the atomizer by design parameters are presented here.B. Sumer et.al [1] studied the influence of design parameters of atomizer on SMD and Aircore diameter.Pedro Teixeira Lacava et.al [2] proposed a translational flow of the atomizer carried out CFD analysis using water is fuel.Digvijay B. kulrishtha et.al [3] in this paper the modelhas compared with conventional pressure swirl atomizer, with same inlet pressure, same fuel, same mass flow rate and same injection pressure differential. L Durdina et.al [4] carried out theoretical and experimental analysis on optimization of the model of pressure swirl atomizer, using CFD analysis.

N. Grech et.al [5] in this paper has taken typical atomizer investigated the spray parameters using CFD tools softwares, solver is FLUENT. The droplet size and pressure distribution along the atomizer is observed. Increase in fuel flow the SMD value also increases. the actual velocity of the atomizer is not constant. Droplet penetration seems to be dependent on the linear wall friction.

The main objective of this project is to carry out the numerical simulation of the pressure swirl atomizer in order to achieve aaxisymmetric flow within the atomizer, resulting in good SMD value and spray cone angle gives complete combustion efficiency. To analysis the effect of nozzle diameter on the SMD value and spray cone angle of the atomizer.

MATHEMATICAL FORMULATION
THE PHYSICAL MODEL OF PRESSURE SWIRL ATOMIZER
The internal geometry of the pressure swirl atomizer studied as part of the internship program is given in Figure 3.2b, whichis taken from B Sumer et.al [1].three models have been created only nozzle diameter variations are 1.5m, 2m and 2.5m.

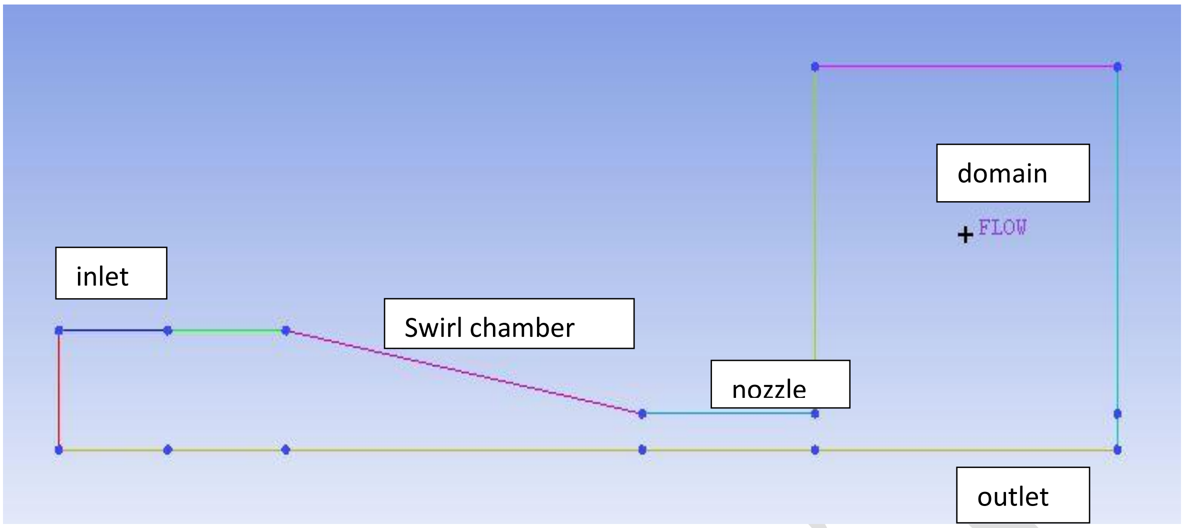

Fig.2.1. 2D of Pressure Swirl Atomizer

MESHING

- ✓ The model created using ICEM CFD software.
- ✓ The whole model is divided into different parts namely inlet, pressure outlet, wall and axis.
- ✓ Global Mesh parameters are defined which gives information regarding type of mesh. The global element seed size, part parameters are setup and mesh is computed which gives the mesh information regarding total number of elements.
- ✓ Anstructured hexahedral mesh is generated in order to perform computations with the Octree approach. After setting up part parameters for various parts, a mesh is generated with nearly 10334 lakh elements.

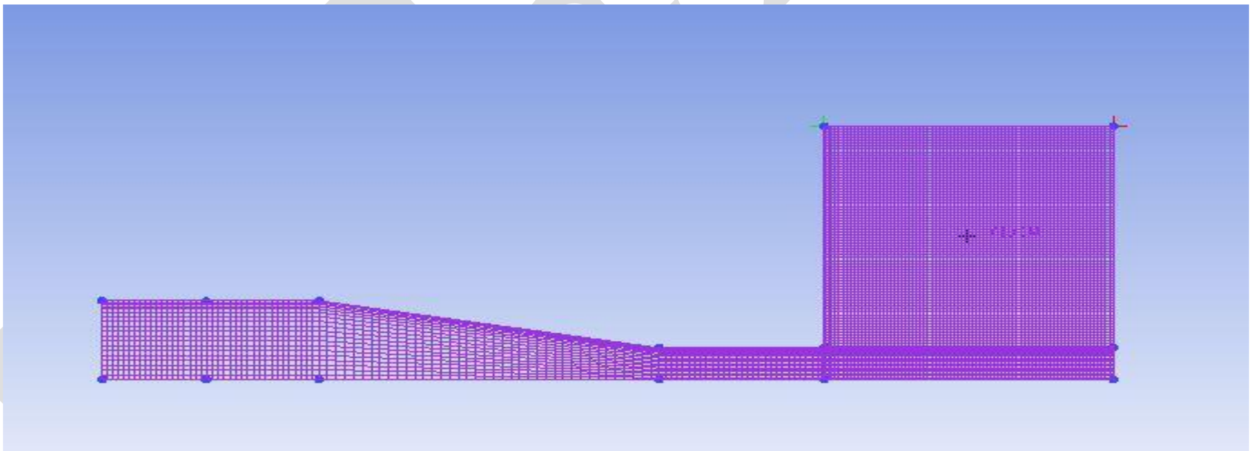

Fig.3.1 Meshed model of pressure swirl atomizer of 2m dia

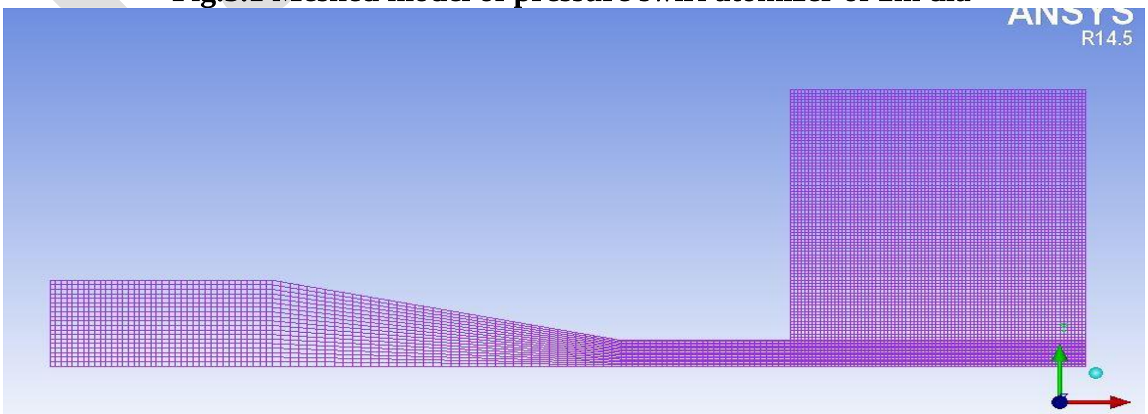

Fig.3.2 Meshed model of pressure swirl atomizer of 1.5m dia

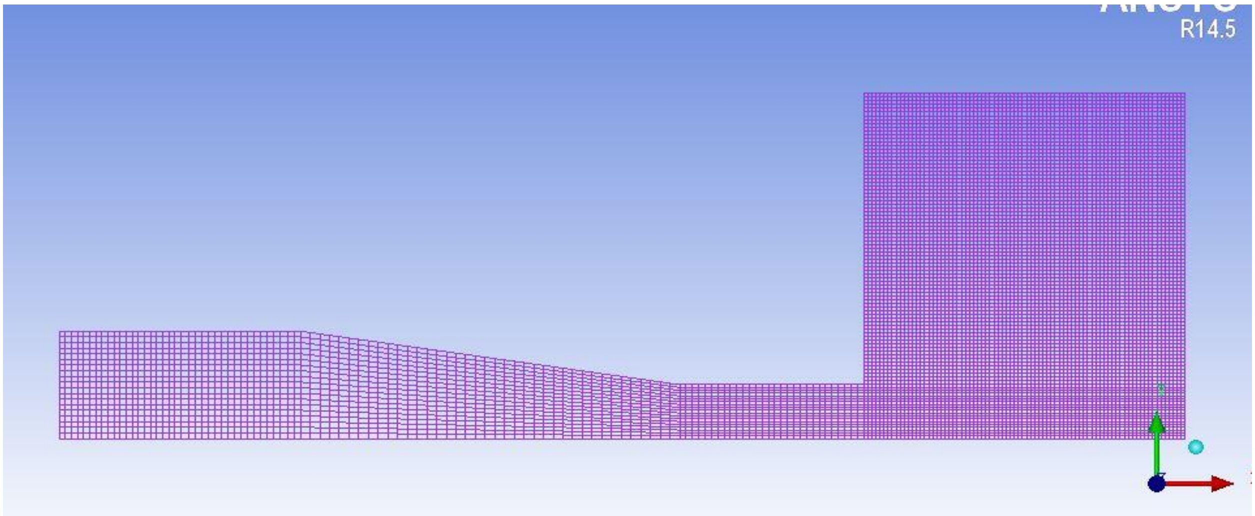

Fig.3.3 Meshed model of pressure swirl atomizer of 2.5m dia

BOUNDARY CONDITIONS

The applicable boundary conditions for the computation of the pressure swirl atomizer are as follows:

- ✓ Inlet: In the present analysis the mass flow inlet in axial direction is zero, radial direction is -0.1572 and tangential flow direction is 0.9866.
- ✓ Outlet: pressure outlet is set to zero.
- ✓ Wall: The no slip condition and smooth surface conditions are assumed.

Two domains were considered for the computation such as air and solidwall, both domains are stationary.

- ✓ Air and water is a fluid of domain and axisymmetric swirl model

CODE VALIDATION

The problem is solved using ANSYS CFX and the code is validated with the results of a research paper [1] for, it is found that it agrees well with the results of the published work as shown in figures 6.1 and 6.2.The mean pressure drop across the atomizer is predicted as 8.8 and 8.1 bars and the half spray cone angleis predicted as 28.5^{o} and 29^{o} for 2Dnumerical simulations respectively.

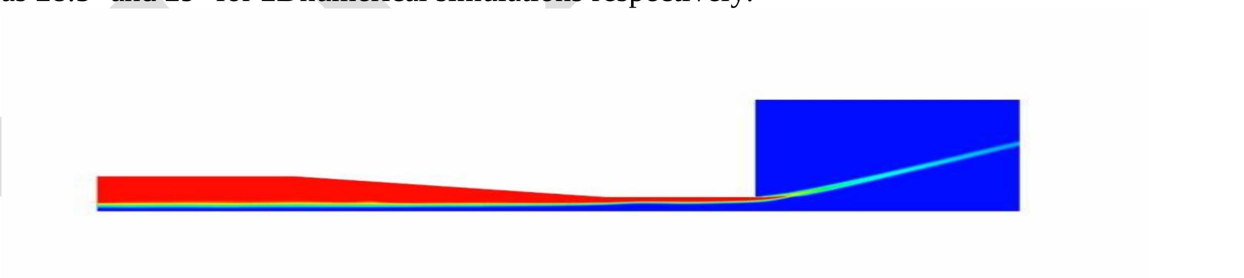

Fig6.1 Contours of air volume fraction (2D)

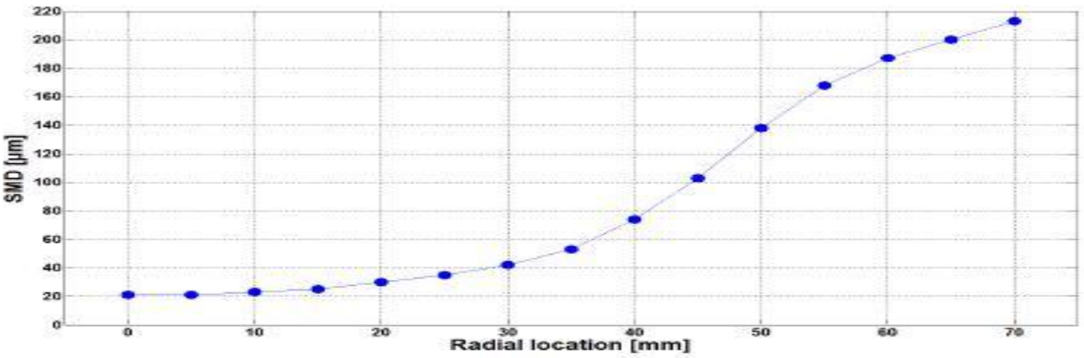

Fig 6.2 Radial profile of SMD along radial location.

6.1 MEASUREMENT OF AIRCORE DIAMETER

The pressure dropacross the atomizer is measured as 642074.9 Pas-s at mass flow rate of 0.053 Kg/sec.The mean aircore diameter at the exit of the atomizer is evaluated as 1.24 mm. The aircore diameter at the exit of the atomizer can also be estimated based on the geometrical and physical parameters as

$$d_{ac} = d_0 - 2t$$

$$t = 3.66[\frac{\mu_L d_o m^{\cdot}}{\rho_L \Delta P}]$$

where d_{ac} is the aircore diameter, d_o is the nozzle exit diameter, t is the liquid film thickness at the nozzle exit, $\rho_L$is the density of the liquid, μ_L is the dynamic viscosity of the liquid, ΔP is the pressure drop across theatomizer, $m^{\cdot}$ is the mass flow rate across the atomizer. The calculation of the aircore diameter at the nozzle exit using above equation with the measured parameters gives 1.2 mm the aircore diameter at the exit of the atomizer.

6.2 MEASUREMENT OF SPRAY CONE ANGLE

In the present design procedure, the criticalatomizer dimensions are accepted or not,depending on the calculated values of the spraysemiangle (θ) and the mean drop diameter. Thesemiangle (θ) can be estimated by theexpression developed by DemétrioBastos-Netto**,**[2] for a pressure-swirl atomizer:

$$sin\theta = \frac{(\frac{\pi}{2})C_d}{k(1+\sqrt{X})}$$

Where θ is spray cone angle, C_d is discharge coefficient,*K* = *Ap/(Ds.D0)* and *X* is the ratio between the air core area (*Aa*) and the nozzle orifice exit area (*A0*)

$$C_d = \frac{m_L^{\cdot}}{A_o\sqrt{2\rho_L \Delta P}}$$

The calculation of the spray cone angle using above equation with the measured parameters gives 28.74^0 the cone angle at the exit of the atomizer.

6.3 MEASUREMENT OF SAUTER MEAN DIAMETER

The Sauter mean diameter (SMD) of the resulting spray can be estimated using the empirical equationof Wang and Lefebvre[3]

$$SMD = 4.52(\frac{\theta\mu_L^2}{\rho_A \Delta P^2})^{0.25}(tcos\theta)^{0.25} + 0.39(\frac{\rho_L}{\rho_A \Delta P})^{0.25}(tcos\theta)^{0.75}$$

Where θis the spray cone angle, $\rho_A$is the density of the ambient medium, ρ_L is the density of the liquid, μ_L isthe dynamic viscosity of the liquid, ΔP is the pressure drop across the atomizer and t is the film thickness at thenozzle exit. The calculation of the SMD using above equation with measured parameters provides an SMD value of 248 micrometers (μ m)

PRESENT RESULTS AND DISCUSSION

In the present study the design parameters affecting the SMD,aircore diameter and spray cone angle are studied. It aims to optimize the nozzle diameter of the atomizer to obtain complete combustion efficiency. The following designs are considered for analysis

A) WATER IS A FUEL OF THE ATOMIZER

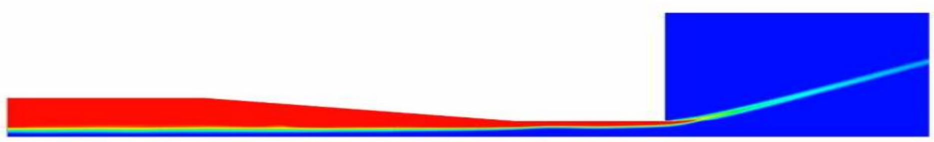

Fig.7.1 Contours of air volume fraction 2D

The pressure drop across the atomizer 642074.9 pas-s at mass flow rate 0.053 Kg/sec. The mean aircore diameter at the exit of the atomizer calculated as 1.211m. the spray cone angle obtained value is 28.74^0. The calculation of the SMD using above equation with measured parameters provides an SMD value of 218 to 226 micrometers (µ m).

B) JET A FUEL OF THE ATOMIZER

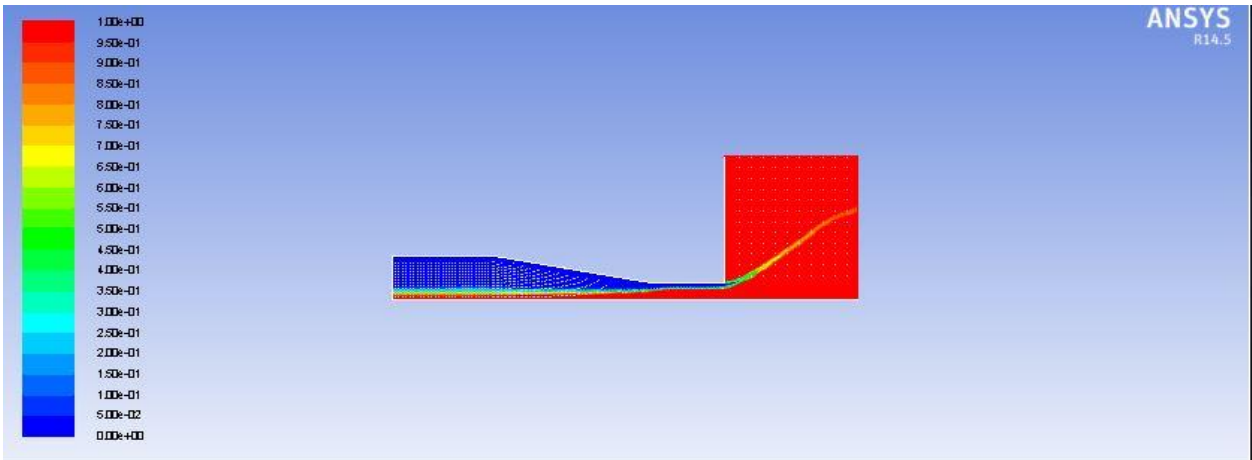

Fig.7.2 Contours of air volume fraction 2D

The pressure drop across the atomizer 973860.6 pas-s at mass flow rate 0.053 Kg/sec. The mean aircore diameter at the exit of the atomizer calculated as 1.735m. by using same formulae. The pressure drop of Jet A fuel is increased as comparing to water, the mean aircore diameter of the atomizer is also increased.The calculation of the SMD by using above equation with measured parameters provides an SMD value of 72.1 to 74.5 micrometers (µ m).

C) JET A FUEL OF THE ATOMIZER – 0.5 INCREASE THE NOZZLE DIAMETER

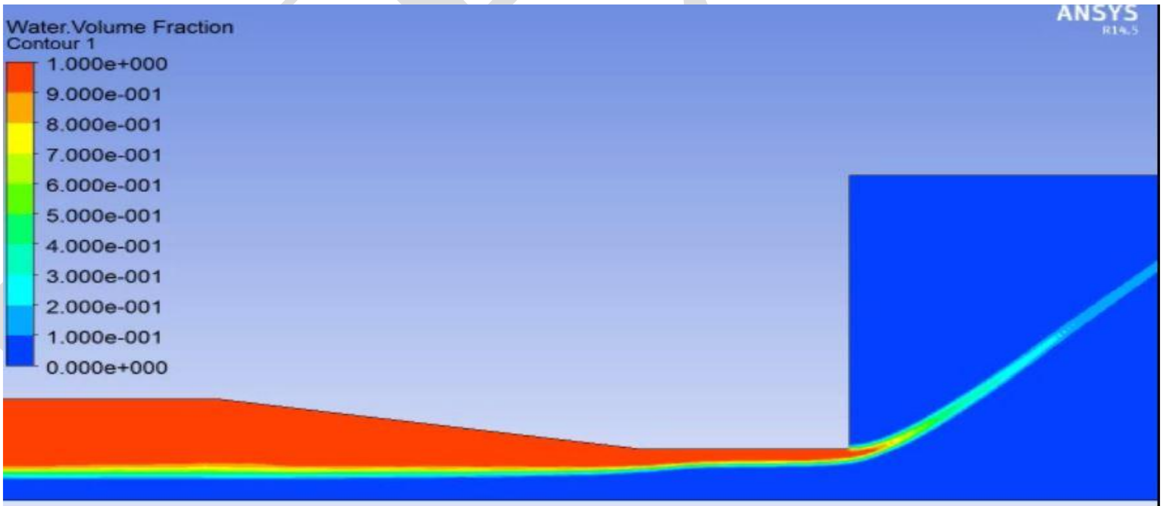

Fig.7.3 Contours of air volume fraction 2D

In this problem using Jet A fuel and nozzle dimension is increased gone through simulation. The Spray cone angle is calculated using the above formulae using the change of dimensions as 30.24^0. Comparing the above it has increased to 1.5^0.The pressure drop across the atomizer is 498873.7pas-s at the mass flow rate 0.053 Kg/sec. The mean aircore diameter at the exit of the nozzleis calculated as 1.686m while using above formulae.The calculation of the SMD by using above equation with measured parameters provides an SMD value of 95.4 to 100 micrometers (µ m).

D) JET A FUEL OF THE ATOMIZER – 0.5 DECREASE THE NOZZLE DIAMETER

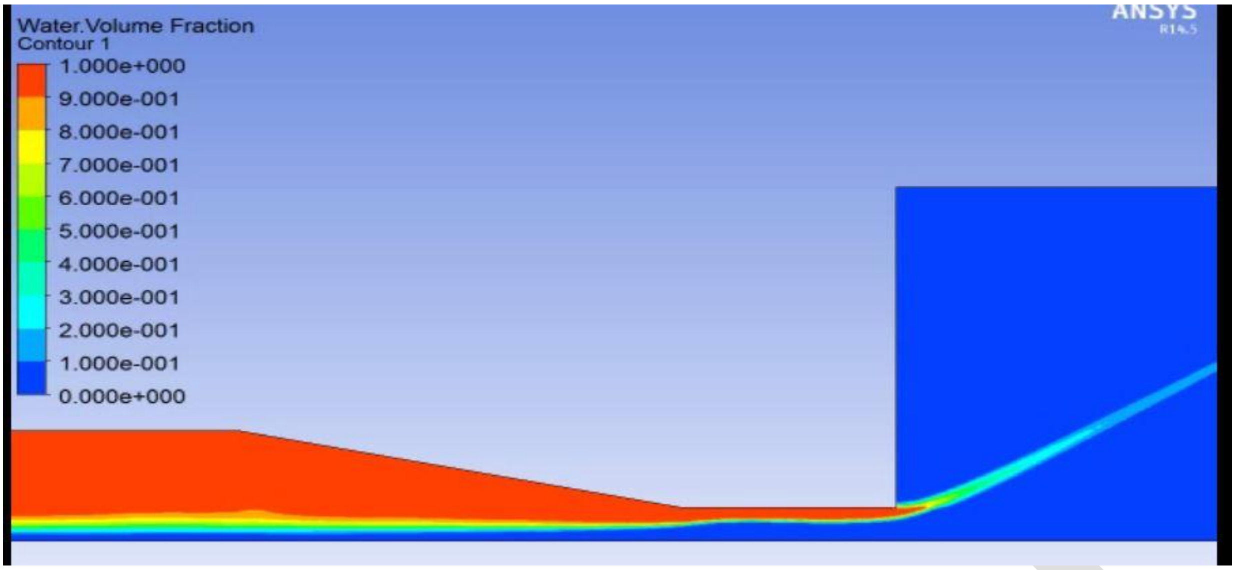

Fig.7.4 Contours of air volume fraction 2D

In this case also changes take place similarly like increases in diameter of the nozzle. The pressure drop across the atomizer is 89718.73 Pas-s at the mass flow rate 0.053Kg/sec. The spray cone angle calculated value is 23.36^{0}it is decreases as decreased dimension of the nozzle.
The mean aircore diameter of the exit of the nozzle is 1.79m obtained. The main spray characteristic parameter is SMD value is obtained as 48.1 to 49 micrometers (µ m).

DISCUSSION

Table.no.1 comparing of all cases and parameters

Fuel	Nozzle diameter(mm)	Pressure drop(Pas-s)	Spray cone angle	Aircore Diameter(m)	SMD(µ m)
Water	2	642074.9	28.74^{0}	1.211	226
Jet A	2	973860.6	28.74^{0}	1.735	74.5
Jet A	2.5	498873.7	30.24^{0}	1.686	100
Jet A	1.5	89718.73	23.36^{0}	1.79	49

In this table clearly obtain the all cases if the nozzle diameter changes the all parameters of the Pressure Swirl Atomizer. The best pressure drop is obtained in the case of diameter 2 in Jet A fuel. Engines must need more pressure in the combustion chamber Jet A fuel, diameter of nozzle is 2mm is better than other cases. The spray cone angle is good in that case it is not too small and not too big for fuel eject. The aircore diameter is inversely proportional to the nozzle diameter. The main SMD value is directly proportional to the nozzle diameter.

CONCLUSION

A CFD Analysis is carried out to investigate the flow analysis and Spray characteristics of fuel over the pressure swirl atomizer. Pressure swirl atomizer there are three sections on it, they are inlet, swirl chamber and nozzle. As nozzle diameter is the defining parameter, the model is varied with nozzle diameter as 1.5mm, 2mm and 2.5mm. ACFD analysis is carried out for the following three cases with varied nozzle diameter (1.5mm, 2mm, and 2.5mm) to find out spray characteristics which give better combustion efficiency of pressure swirl atomizer. From results and discussion it is found that the nozzle with diameter 2mm gives the better combustion efficiency with SMD (74.5µm), aircore diameter (1.735m) and spray cone angle (28.74^{0}) of the pressure swirl atomizer.

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