IJASRM

International Journal of Advanced Scientific Research and Management, Volume 3 Issue 12, Dec 2018

www.ijasrm.com

ISSN 2455-6378

Aerodynamic Flow Visualization through Multiple Inlet Swirler

R.Gowri Shankar[1], M.Senthil Kumar[2]

[1] Asst Professor, Department of Aeronautical Engineering, V.M.K.V Engineering College, Salem, T.N., India

[2]Asst Professor, Department of Aeronautical Engineering, V.M.K.V Engineering College, Salem, T.N., India

Abstract

The main objective of this project is to show visually the flow characteristics over various objects and swirl pattern through multi inlet swirler. For this flow visualization water tunnel is fabricated. The object whose flow characteristics to be visualized is placed in the test section of flow visualization water tunnel which is transparent and the mass flow of water in the test section is maintained equally i e., ($\dot{M}$ in=$\dot{M}$ out).Multi inlet swirler has an axial and tangential flow. It is fabricated using a aluminum dye cast. The vanes have an angle of 24.5 degree and the depth of the vanes (20mm) and the gap between the vanes is 24 mm.There are different techniques were being followed for the flow visualization. The type of visualization we used is the color dye injection and the tuft method. In color dye injection method the color dye is injected before the fluid strikes the object, whose flow character stick is to be visualized. The other method is the tuft method in this the weight less threads are affixed over the surface of the object and is placed in the flow field that is the test section. Now the tuft will move according to the flow character stick of the body which is placed.

Index Terms— swirler, flow visualization, water tunnel.

1. Introduction

1.1 Water Tunnel

Flow visualization has become one of the most important tools in experimental aerodynamics research and education. Several techniques of flow visualization are available in that Water flow visualization is characterized by being one of the most versatile and low cost techniques. The visualization is done by the injection of a coloring dye in the water flow through or around the target flow field. This setup is typically called a water tunnel. The aim of this project is to design, manufacture and operate a flow visualization water tunnel capable of visualizing flows in a wide range of fluid dynamics/aerodynamics problems. The tunnel has test section dimensions of 600x300x300mm, capable of producing 3 dimensional visualizations of the target flow fields. The tunnel runs on a 220V 50Hz regular power supply.

Several dye injection configurations are available and the tunnel capabilities may be extended by adding a hydrogen bubble visualization system, a force balance, an electronic image capturing and processing system etc. The tunnel may be used for research and educational purposes.

A water tunnel is nothing but an experimental facility for testing the hydrodynamic behavior of submerged bodies in water flow. It is very similar to a recirculating wind tunnel but with water as the working fluid, and related phenomena is investigated, such as measuring the forces on scale models of submarines or lifts and drags on hydrofoils. Sometimes water tunnels are used in place of wind tunnels to perform measurements because of its improved result and easiness in the techniques like Particle image velocimetry (PIV).

The result is valid as long as the Reynolds number is equal throughout the flow, whether a submerged water vehicle model is tested in air or an aerial vehicle is tested in water. Oil can be used as a medium in tunnel if Reynolds number is low. The increased kinematic viscosity will made the flow to be faster for the low Reynolds number and this is an advantage. For this low Reynolds number the flow will be faster whereas in wind tunnels the driving force is usually sophisticated through multi blade propellers with adjustable blade pitch. Pumps are used in water and oil tunnels for the circulation of fluid. Thus flow management is not needed for the water and oil tunnels.Water tunnel is sealed to increase the accuracy of presser values in cavitation studies. Similarly the wind tunnel is also screened before the inlet contraction section

1.2 Swirler

The flame stabilization in the combustion chamber is more important and is done by anchoring the flame at the locus point of the chamber. This is achieved by the use of swirler in the inlet of combustion chamber. Swirler decelerated the high-speed air and turbulent the flow in the combustion chamber whish made the flame speed equal to the air flow velocity.

This flame stabilization in the chamber can be achieved by various methods. The common technique used in a gas turbine combustor is to create a stagnation point. In modern gas turbine engine the flame stabilization is achieved the by using the vane swirlers.
The Swirl number gives the degree of swirl in a flow and the SN is given as

$$s_n = \frac{\int_0^R \rho U W r^2\, dr}{R\int_0^R \rho U^2\, r dr}$$

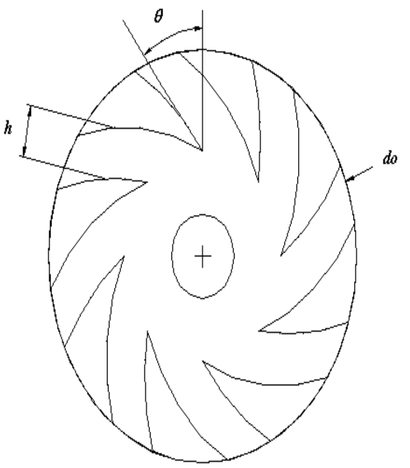

Fig-1 Basic swirler sketch.

Here U and W are the axial and tangential velocity components and R represents the swirler radius. This indicates the ratio of axial flux of angular momentum to axial thrust. Recirculation is usually not observed for swirl numbers less than 0.4, so majority of swirl-stabilized burners are designed more than 0.6.

The swirling flow spreads as it moves downstream and centrifugal force creates a low pressure zone in the center of the flow. At a certain point downstream, the low pressure region in the center of the flow causes the vortex to collapse inwards on itself in a process known as vortex breakdown. This creates a recirculation zone in the center of the flow.

It is very essential to give sufficient time, temperature and turbulence for a complete combustion of fuel. Swirl also gives other effects includes proper mixing of fuel and air and controls the emission. This is done with the help of the strong shear regions, turbulence and rapid mixing rates by the resulting toroidal zone and the swirling vortices.

In the swirler the swirl vanes used are often flat, but sometimes curved vanes are used due to their better aerodynamic properties. There is a disadvantage which is the independency of constant swirl in the inlet flow. In low loads, the inlet air flow rate is equally low.so the produced swirl and turbulence becomes low, which reduces the recirculation zone. Hence, the performance of gas turbine combustors is reduced at low operating conditions (i.e. low Reynolds number).

2. LITERATURE SURVEY

Mohd Jaafar M. N, Jusoff. K (2011), a study has been conducted to investigate the flow pattern in a gas turbine combustion chamber by simulation and experimental approaches. For the self-sustain of flame, increased combustion and flow pattern in the combustion chamber is the important factor. For the turning of air flow aerodynamically curved vanes are used. This induces flow separation on the suction side of the vane. Thus, with the added advantage of lower pressure loss complete turning and high swirl and radial-velocity components can be generated at the swirler exit. The swirl number changes from 0.49, 1.29 and 2.29 for straight vanes and only 1.57 for twisted vane. The largest swirl number of 2.29 for flat vane and 1.57 for curve vane are able to creating a clear reversal mass flow rate zone and larger swirl strength decreases the corner recirculation zone size and hence reduces the losses on the combustion process and the homogeneity of the wall temperature as well. Identical investigation can be done for higher swirl number for both types of swirler.

Selvakuma Kumaresh, Man Young Kim(2014) combustion phenomenon will be accomplished effectively by the development of low emission combustor. One of the notable factors influencing the entire Combustion process is the mixing between primary air and fuel. To study this fundamental flow, the chamber had to be made in such a manner that the combustion process to sustain itself in a continuous manner and the temperature of the products is sufficiently below the ultimate working temperature in the turbine. This study is used to give the effective combustion with low unburned combustion products by giving the concept of high swirl flow and motility of holes in the secondary chamber. The proper selection of a swirler is needed to reduce emission.. The capture of CO_2 is necessary to mitigate CO_2 emissions from natural gas. Thus the suppression of unburned gases in combustion chamber is a meaningful objective for the development of high performance combustor.

Vladisalav.A, Nazukin, Valery.G (2014), the most important part of modern lean low NOx combustors is a premixer where swirlers are often used for intensification of mixing processes and further formation of required flow pattern in combustor liner. Swirling flow leads to creation of complex eddy structures causing flow perturbations. It is able to cause combustion instability. Therefore, at design phase, it is necessary to give more attention to aerodynamics of pre-mixers. The lareg number of different eddys are grouped into three types and the features of each eddy type were defined subsequently.

Wang S.W, Hsieh S.Y, Yang V (2003), for many decades, gas turbines have been used widely in the internal combustion engine industry. Due to the less availability of fossil fuel and the concern of global warming, the used of bio-gas have been found out as one of most clean fuels in the application. To improve performance of lean combustion and minimize the production of NOX and PM, this is very useful. This review paper is to know the combustion performance using dual-fuel nozzle for a micro gas turbine that was generally designed as a natural gas fuelled engine. The nozzle characteristics of the micro gas turbine have been modified and the effect of multi-fuel used was investigated. The used of biogas as substitute for liquid fuel at constant fuel injection velocity, the flame temperature is increased, but the fuel low rate reduced. Applying the blended fuel at constant fuel rate which will increase the flame temperature as the hydrogen percentage increases. Micro gas turbines which show the uniformity of the flow distribution that can be developed without the increase of the pressure drop by applying the variable nozzle diameters into the fuel supply nozzle design. It also identifies that the combustion efficiency, better fuel mixing in combustion chamber using duel fuel nozzle with the largest potential for the future.

Yehia A. Eldrainy, Hossam S. Aly,(2011), the central recirculation zone (CRZ) in a swirl stabilized gas turbine combustor has a dominant effect on the fuel air mixing process and flame stability. Most of swirlers share one common disadvantage; the fixed swirl number for the same swirler configuration. Thus, in a mathematical sense, Reynolds number becomes the important parameter for controlling the flow characteristics inside the combustor. As a result, of low load operation, the generated swirl is more likely to become feeble affecting the flame stabilization and mixing process. This paper introduces a new swirler concept which overcomes the mentioned disadvantage of the modern configurations. The new swirler introduces air in both tangential and axial to the combustor through tangential vanes and an axial vanes respectively. Therefore, it provides varies swirl numbers for the same configuration by regulating the ratio between the axial and tangential flow momenta. The swirler aerodynamic performance was investigated using CFD simulations in order to demonstrate the impact of tangential to axial flow rate ratio on the CRZ. It was found that the length of the CRZ is proportional to the tangential to axial air flow rate ratio.

3. Fabrication of water Tunnel

The basic materials used for the fabrication of a simple water tunnel for the flow visualization are

[1] Acrylic Sheet (600x300x300mm)
[2] Pump
[3] Reservoir
[4] Chloroform (Binder)
[5] PVC pipes
[6] Control Valve
[7] Flange
[8] Reducer
[9] Coupling
[10] Teflon Tape
[11] PVC solution (PVC bonder)
[12] Flexible hose

3.1Reservoir

It is the most important part of a water tunnel set up, which is used to store the water for the experiment pulpous. In a closed circuit water tunnel the water from the test section is again poured in the reservoir. In some of the tunnels were dye is used as a medium of visualization the water will not be recalculated because of its change in color which will reduce the visibility of the result when it is used again for the testing. The capacity of the water reservoir depends on the size of the text section.

3.2 Pump

The water from the reservoir is pumped in to the test section with the help of pump. The mass flow rate and the velocity of the water from the out let of the pump should be calculated. This will help in finding out the mass flow entering the test section.

3.3 Flow lines and control valves

The pipe line connections are the most important work to be done in a very careful manner. Because this pipelines are the only way to produce the laminar flow in the test section. The elimination of air bubbles in the inlet of the test section is an important one to improve the result. For this a T section is fixed at the test section inlet.

3.4 Test section

This is the place where the experimental model is placed and the experiment is conducted. The size of the test section depends on the scale of the model going to be tested.

Fig-2 Experimental Setup of a Water Tunnel

4. Fabrication of Swirler

Swirler is a dye cast of an impeller type model. It is then machined to the required diameter. Machining is carried out in a lathe and process like facing, boring and drilling was carried out to remove the pores in the cast model. The diameter of the swirler is fabricated as required to the test section and the inlet of the test section.

Fig-3 Swirler

Swirler is fitted to an acrylic sheet (280x280mm). It's a fixed type swirler and it consists of a snout as in a general gas turbine engine to concentrate the flow to the swirler. Swirler is affixed with tuft to have the flow visible. Vanes are fitted with a red tuft to visualize the tangential flow and for the axial flow white thread is affixed. This gives the difference between axial and tangential flow.

Fig-4 Mound For the swirler

5. Result and Discussion

The vortex breakdown process in swirling flow is mainly deepens on the inlet flow Reynolds number and swirl number. And also it is affected by the downstream boundary conditions. To explore the effects, the new swirler design on the swirling flow field, the influence of tangential to axial inlet mass flow ratio on swirling flow has to be investigated.

Figures 5 and 6 shows the pictures taken during the experimental tests for multiple inlet flow of a swirler in the water tunnel test facility. Light weight tufts were used in this experiment to help in visualizing the formation of recirculation zones. Red tuft visually shows the tangential flow and the white tuft shows the axial flow. In this experiment, the swirling motion of the flow and the expansion of the flow from the multiple inlet swirler is clearly visualized.

The Fig 5 shows the dispersion expands as it moves further from the swirler. Which show the swirling flow as it occurs in the combustion chamber with air and fuel. And similarly the Fig 6 shows the spiraling motion can be seen which shows the amount of swirling flow in the central recirculation zone in combustion chamber. There four a perfect mixing of the air and the fuel will take which leads to a complete burning of the mixture in the combustion chamber.

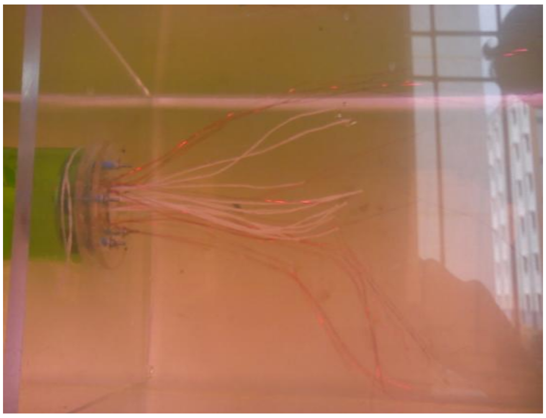

Fig -5 Expansion through the swirler.

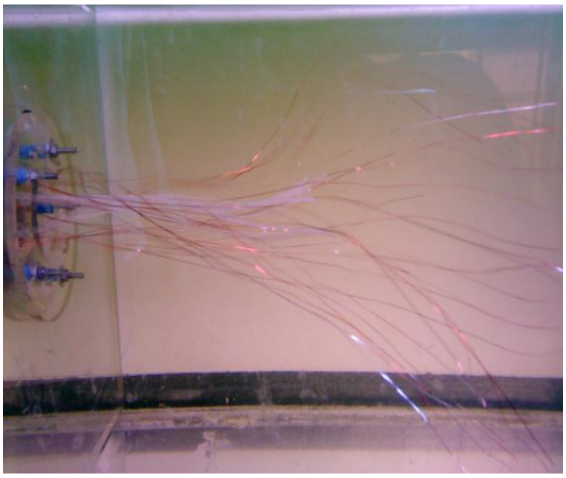

Fig-6 Spiraling motion through multi-inlet swirler.

5. Conclusion

A new type of multiple inlet swirler is tested and visualized for gas turbine combustors. This swirler eliminates the dead zones proved to have negative effect on the combustion process. With this the unsteady flame in the combustion chamber can be eliminated and also the mixing of the air and fuel will be perfect which leads to a complete burn. Since the wastage of fuel as an un burnt element is completely eliminated which leads to the elimination of after burner for thrust augmentation since maximum efficiency of the combustion chamber is achieved. It is important to study the effect of tangential to axial mass flow ratio on the combustion efficiency, emissions and flame stability.

6. References

[1] Mohd Jaafar M. N, Jusoff. K " Combustor aerodynamic using radial swirler" (2011)

[2] Selvakuma Kumaresh, Man Young Kim "Combustion and Emission Characteristics in a Can-type Combustion Chamber" (2014)

[3] Vladislav A. Nazukin, Valery G. Avgustinovich, Vakhtang V. Tsatiashvili "Analysis of Vortical Structures Generated by the Swirler of Combustion Chamber" (2014)

[4] Wang S.W, Hsieh S.Y, Yang V, Proceedings of the 3rd Int. Symp. Turb. Shear Flow Phenom, pp. 905–910 (2003).

[5] Yehia A. Eldrainy, Hossam S. Aly, "A Multiple Inlet Swirler for Gas Turbine Combustors" International Journal of Aerospace and Mechanical Engineering (2011)