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Review of Swirl Generator Used In Gas Turbine Combustor

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Abstract

This paper discussed with the study of swirl generators on the basis of the results obtain by pre performed experiment and also the introduction of multiple swirl generator and novel swirl generator used in gas turbines combustors. A swirl generator is used for mixing air and fuel for combustion and stabilizing the flame. There are so many ways to mix fuel air and stabilize the flame for proper combustion that will not only improve the fuel efficiency by combustion of fuel but also reduces the emission and pollution significantly by creating the internal and central recirculation zone. In multiple types of swirl generator, flow is divided into multiple streams hence obtained efficient performance than any other swirl generator.

Keywords- swirl generator, swirl number, recirculation zone

1. Introduction

In design of gas turbine main threats is to improve the cycle efficiency by maintaining emission and pollution to its minimum level. So there is many ways to improve the fuel efficiency such as increasing combustion product temperature but it promote NOx formation and also leads the emission formation. If available oxygen is reducing for controlling the NOx formation consequently in greater amount of carbon- monoxide (CO) and unburned hydrocarbon is produced due to lack of oxygen. Major pollutant in gas turbine engine NOx , CO and to a lesser extent ,unburned hydrocarbon ,Sulfur dioxide, particulate matter (PM) and trace amount of hazardous air pollutants .[1]

2. Swirler

Swirlers are consisting of various vanes which are designed in such a way that it converts axial momentum of the flow into the tangential momentum which ultimately helps in the air fuel mixing. As swirl vanes rotate its turns flow into rotating motion and forms a low pressure zone such as internal recirculation zone and external recirculation zone which will help in mixing fuel air and stabilizing the flame in combustion chamber.

3. Type of Swirl Generator

a. Axial guide vane swirler

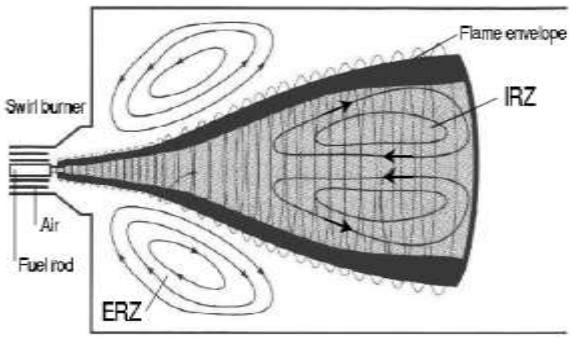
For the study of the axial guide vane it is important to take some data from the pre performed experiments. In these experiments PIV method is used to analyze the flow area. From experiments it can be seen that the velocity with average magnitude for the sufficient time period. The reporting cross section lies downstream with respect to the swirl generator but from the sudden expansion it is still at upstream.
The results of these data suggest no reverse flow [figure 1].

b. Tangential inlet swirler

The tangential inlet swirl is especially used for its feature of low pressure loss and swirl intensity.
Experimental studies from a performed experiment done by the Jiajun Chen, Brian S. Haynes and David F. Fletcher.
In their experiments the important feature that was founded out is achieving axisymmetric flow in the strong swirl no. 0.8.

c. Rotating pipe swirler

The rotating pipe swirlers are not used in combustion because it hasn't found wide application on the practice.



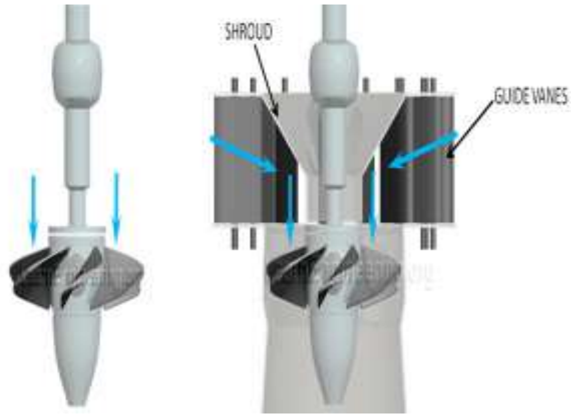


Figure 1, shows the Kaplan axial flow shroud guide vanes

Figure 2, shows the formation of internal and external recirculation zone

2. Swirl number

The degree of the tangential momentum is known as the swirl number, a dimensional parameter. It is also defined as the ratio of axial flux of tangential momentum over axial flux of axial momentum.

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

Here U = axial velocity component

W= tangential velocity component

R = swirl radius

The swirling has two subdivisions:-

1. Low swirl flow (swirl number less than 0.6)
2. High swirl flow (swirl number greater than 0.6)

Recirculation is generally not considered below the swirl number 0.4 and all the swirlers are designed for the swirl number greater than 0.6.

3 Vortex breakdown

It is a process in which vortex generated by the swirler is demolished due to low pressure zone in the center of the flow somewhere in the downstream, this is just because the fact that swirl flow spread as its moves downstream and the low pressure zone is created by the centrifugal forces acting upon it.

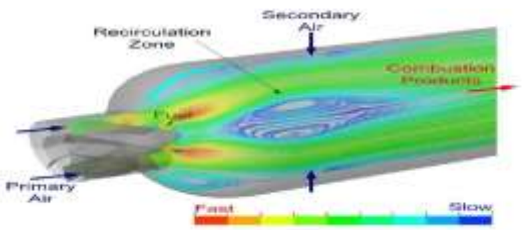


Figure 3, Shows the motion of combustion product

In a different point of view it can be also stated as desirable phenomenon because it provides sufficient time for complete combustion of fuel.

Swirling is the very important phenomenon as far as the combustion is concern; it produces many other effects which are mandatory for optimum combustion such as temperature control and emissions. These additional features of swirling motion may because of toroidal region forming in the flow.

4. Multiple Inlet Swirler

Almost all the current gas swirlers having the disadvantage of same swirl number at the low flow rate. We know that the performance of the gas turbine are depends upon the Reynolds number and at low Reynolds number it will be low due the formation of low turbulence or swirling effect.Shee et al (1996) gives a proper relation between the swirl number and the Reynolds number for the radial vane swirl generator in their experiments. In this relation the swirl number is directly proportional with the Reynolds number as well as the vane angle.

This equation was derived as- $S = C_1 (Re)*\sigma*(\theta)$

Here the C_1 depends on the Reynolds number and can be determined by this formula-

$$C_1 = 0.28*[1-\text{sech}(0.026Re^{0.67})]$$

Here the graph for the C_1 vs. Re is provided whish reveals that the C_1 becomes constant and its value can be taken as 0.28.

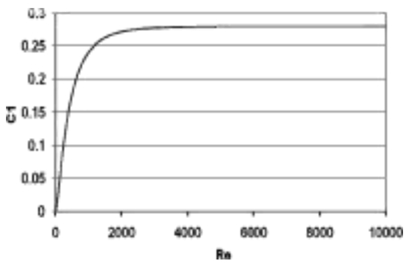
Reynolds number and swirl number relationship depends upon another term Ϭ. It is defined as the ratio of mean tangential velocity component of the swirl generator exit to the radial component.

$$\sigma(\theta) = \frac{1}{1-\Psi}\left[\frac{\tan\theta}{1+\tan\theta\tan(\pi/z}\right]$$

Here the z= number of guide vanes

Ψ=blockage factor

Multiple inlet swirls divides the flow into two streams. First stream will follow the conventional path while other will guided through the multi tangential vanes. This new concept was initially proposed by the Yehia A. Eldrainy, Hossm S. Aly, Khalid M. saqr, Mohammad Nazir Mohd. Jaffr. This concept comes with the major advantage that for the same inlet mass flows the swirl number can be vary in the fixed swirl configuration.



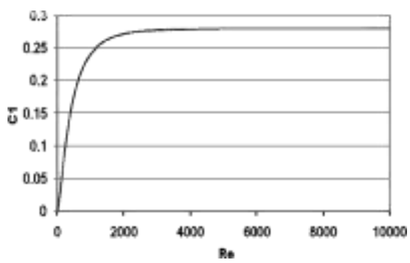


Figure 4, shows the Re vs. C_1 plot.

Figure 5, Design of new concept swirler

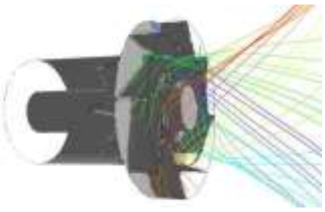


Figure 6:- It shows the axial path lines at the axial ports and vanes.

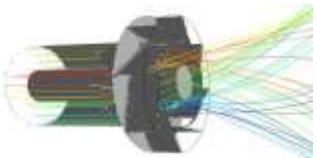


Figure 7, Tangential flow path lines coming out from the tangential vanes.

5. **Study of Result**

The CFD analysis of the Eldrainy et al on the multiple inlet swirl generator concludes that the phenomenon of vortex

breakdown is very much depends upon the Reynolds number and swirl number. Here it is mandatory to find the influence of the tangential to axial mass flow ratio for study of effects of the multiple inlet swirlers.

The one of the most important part of the analysis is to investigate the shape of Centre Recirculation Zone (CRZ). Here some of the CRZ shapes are shown I figure (5)From above analysis the thing which has to be emphasize is that when we increase the tangential to axial mass flow rate the circulation zones created at the corner diminishes hence it forms a dead zone, it has a negative effect on the combustion process. It also affects the uniformity of the temperature inside the combustion chamber.
As increase in tangential to axial flow rate gives the positive effect but also it has some disadvantages of increased low pressure zone.
Hence it is very important to perform a careful study with the range of mass flow rate.

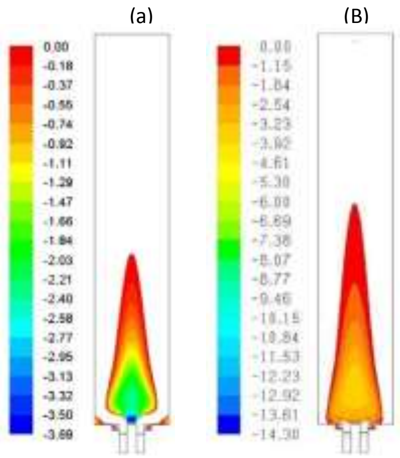


Figure 8, shows that how tangential to air mass flow rate and shape and size of the CRZ depends on each other.

6. **Conclusion**

It is concluded that the paper describes the study of multiple swirl generator which can be optimized in gas turbines in order to increase the combustion efficiency as it enhances the probability of proper mixing of air and fuel; it is one of most interested topic in aviation. In this paper we study the results of multiple swirler model designed by Eldrainy et al (2009). Here we found the advantages of using multiple swirlers in gas turbines. This paper reviewed some research paper and its references. In future we may use this paper for the purpose of our thesis report.

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