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Performance Evaluation of Combustor by Using Different Swirler

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Abstract - The main objective of this investigation is to obtain physical insight of the main vortex responsible for the efficient mixing of fuel and air. Such models are necessary for predictions and optimization of real gas turbine combustors. Air swirler can control the combustor performance by assisting in the fuel-air mixing process and by producing recirculation region which can act as flame holders and influences residence time. Thus proper selection of a swirler is needed to enhance combustor performance and to reduce NOx emissions. Three different axial air swirlers were used based on their vane angles i.e. 30°, 45°and 60°.

Swirl is used in vortex burners and chemical reactors to stabilize the flame front and to increase the surface area across which heat and mass transfer exchange occurs. The Swirler Vane angle and Number of swirl vane exert much influence on the size of recirculation in the dome of combustor and little influence on the velocity distribution of centre line in the recirculation zone.

Experiment Performed on the combustor by using different Swirler and its effect on combustion temperature along with axial distance by the use of air swirler and without swirler at same mass flow rate by using diesel as fuel. The result on the performance indicate that as atomizing air pressure increases there will be increase the combustion temperature. Swirler play important role in the fuel atomization and hence emissions were decreases at the same time combustion efficiency were increase

Keywords: - Combustion chamber, Air Swirler, Swirl Number, Gas temperature, Emission.

I. INTRODUCTION

A. Combustion process

The primary purpose of combustion is to raise the temperature of the airflow by efficient burning of fuel. From a design viewpoint, an important requirement is a means of relating combustion efficiency to the operating variables of air pressure, temperature, mass flow rate and to the combustor dimensions. Unfortunately, the various processes taking place within the combustion zone are highly complex and a detailed theoretical treatment is precluded at this time. Until more information is available, suitable parameters for relating combustion performance to combustor dimensions and operating conditions can be derived only through the use of very simplified models to represent the combustion process. One such model starts from the well-established and widely accepted notion that the total time required to burn a liquid fuel is the sum of the times required for fuel evaporation, mixing of fuel vapor with air and combustion products, and chemical reaction

B. Combustion chamber

The combustion chamber is the place where two major events take place; at the inlet fuel will mix completely, or to a sufficient degree, with air. In some combustors fuel mixes with air before combustors, however, in order to achieve a smooth burning, air and fuel should be mixed before burning. Depends on when fuel will mixes with air, Second event is burning. In the combustion chamber, due to the high temperature, the gaseous mixture which consists of fuel and air will ignite and raise the temperature. Rise in temperature will increase the volume which will drive the fluid forward. There are number of facts that make this part of gas turbine important. In order to make this clear, we will address problems in a poorly designed combustion chamber. There are several problems that can occur:

1) *Poor mixing:* When fuel is not mixed enough with air, it can burn incompletely which results in increased levels of CO, soot, NOx and unburned hydrocarbons (UHC).
2) *Uneven combustion:* This happens when temperature of a section goes high but the neighboring sections are colder, thus this can result in extra thermal stresses. Thermal stresses may in time lead to material fatigue and failure.
3) *Environment:* incompletely burned gases or unburned hydrocarbons (UHC) can poison the environment. UHC, NOx and soot are

important factors for each burning device. The design should lower them as much as possible.

4) *Economy:* With increasing price of oil, it is important that gas turbines have high efficiency and therefore low fuel consumption. One of the most important parts, in order to achieve high efficiency, is the combustion chamber

a) *Need of swirler:* Combustion processes, such as those occurring in a gas turbine combustor, require the flame to be anchored at a zone within the flow field. In order to stabilize the flame, the incoming high-speed air must be decelerated to a velocity below the turbulent flame speed. The flame stabilizes along the locus of points where the air velocity is equal to the flame speed .This flame stabilization can be achieved by various methods. The most common techniques used in a gas turbine combustor involve creating a stagnation point. By far, the most common method to stabilize the flame in modern gas turbine combustors is swirl stabilization in which a swirl velocity is imparted to the inlet air using vane swirlers. A common method of achieving a more uniform combustion temperature distribution and higher fuel efficiency is by fitting a swirler nozzle to the inlet to the combustion chamber. Swirlers are comprised of a set of stationary vanes that are set at an angle to turn the incoming air and induce heavy rotation in the flow in the combustor primary zone. Vane configurations can be aligned to induct air axially, as found in axial swirler, or tangentially, as seen in radial swirler. Fuel injectors are located inside the swirler and spray fuel into the rotating flow. The high degree of rotation caused by the swirler enhances air and fuel mixing which improves combustion fuel efficiency while reducing pollutant production. If the rotation is large enough, a low pressure core forms in the exiting flow from the swirler and can cause the core flow to move in the upstream direction while the outer flow continues downstream. This behavior is widely used to enhance mixing within the combustion chamber and can be designed to bring burnt combustion gasses back into the swirler. This gives the swirler the ability to act as a means of flame stabilization and a method of preheating the inlet airflow.

b) *Types of swirler:*

i) *Axial Swirler:* The conventional notation for axial swirlers is indicated in Figure, This figure shows a flat-vanned swirler whose vane angle is constant and equal to θ With curved-vane swirlers, the inlet blade angle is zero and the outlet angle is θ. An important design requirement is that the swirler should pass the desired airflow rate for a given pressure drop ΔPsw, which is usually assumed to be equal to the liner pressure drop, ΔPL

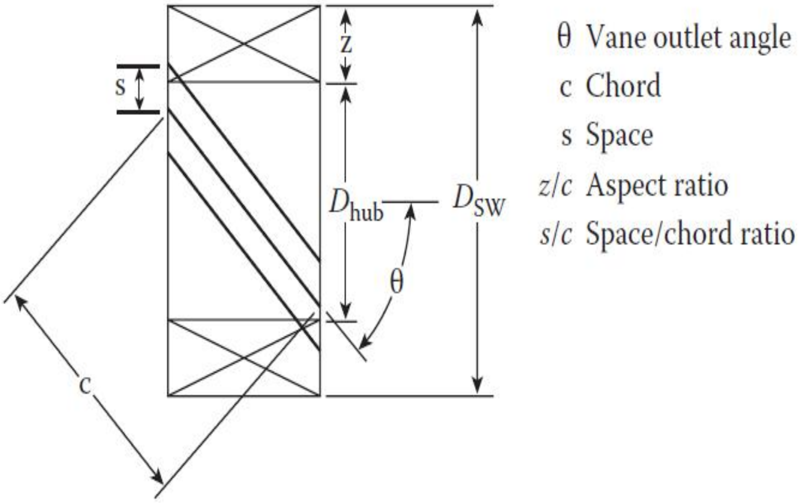

Fig. 1.1 Sketch of axial swirler

ii) *Radial Swirler:* Radial inflow swirlers are now widely used in both conventional and dry Low emissions (DLE) combustors. Their flow characteristics have not been Studied to the same extent as those of axial swirlers, but experience has Shown that the flow fields generated by the two different swirler types are broadly the same. Thus, the design rules established for axial swirlers can provide useful guidance in the design of radial swirlers.

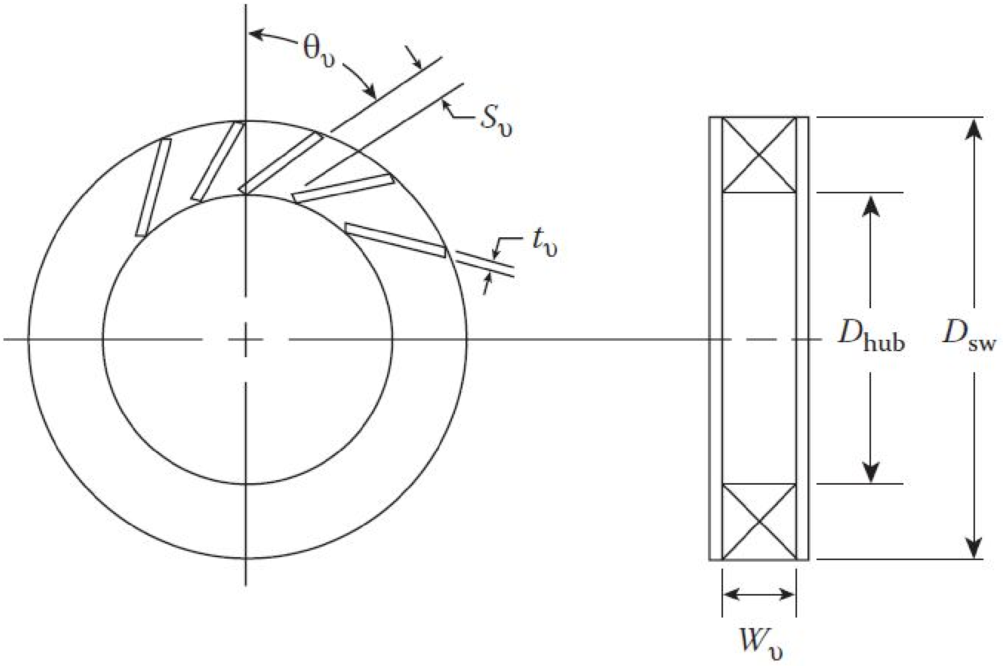

Fig. 1.2 Sketch of radial swirler

The airflow into the swirler is determined by the effective flow area at the trailing edge of the vane. This can be calculated as

$$A_{sw}= ή_{v}\, s_{v}\, w_{v}\, C_{D}$$

where $ή_V$ is the number of vanes, S_v is the vane gap, W_V is the vane width, and C_D is the vane discharge coefficient. According to Dodd's and Bahr, for preliminary design purposes an appropriate value for CD is 0.7.The dimension w_v can then be adjusted during combustor development to obtain the desired swirler airflow rate.

C. *Formation of CO, HC and NO_X Emission in a combustor*

1) *CO Formation:* When a combustion zone is operating fuel-rich, large amounts of CO are formed owing to the lack of sufficient oxygen to complete the reaction to CO_2.If, however, the combustion zone mixture strength is stoichiometric or moderately fuel lean, significant amounts of CO will also be present due to the dissociation of CO_2. In practice, CO emissions are found to be much higher than predicted from equilibrium calculations and to be highest at low-power conditions, where burning rates and peak temperatures are relatively low. This is in conflict with the predictions of equilibrium theory, and it suggests that much of the CO arises from incomplete combustion of the fuel, caused by one or more of the following:

a) Inadequate burning rate in primary zone, due to that a fuel/air ratio that is to low and /or insufficient residual time

b) Inadequate mixing of fuel and air, which produces some regions in which the mixture strength is too weak to support combustion, and others in which over-rich combustion yields high local concentrations of CO

2) *HC Formation:* UHC include fuel that emerges from the combustor in the form of drops or vapor, as well as the products of the thermal degradation of the parent fuel into species of lower molecular weight. They are normally associated with poor atomization, inadequate burning rates, the chilling effects of film-cooling air, or any combination of these. The reaction kinetics of UHC formation are more complex than for CO formation, but it is generally found that those factors that influence CO emissions also influence UHC emissions and in much the same manner.

3) *NO_x Formation:* Most of the nitric oxide (NO) formed in combustion subsequently oxidizes to NO_2. For this reason, it is customary to lump NO and NO_2 together and express results in terms of NOx, rather than NO.This is produced by the oxidation of atmospheric nitrogen in high-temperature regions of the flame and in the post flame gases. The process is endothermic and it proceeds at a significant rate only at temperatures above around 1850 K .Most of the proposed reaction schemes for thermal NO utilize the extended Zeldovich mechanism$O_2 = 2O$ $N_2 + O = NO + N$ $N + O_2 = NO + O$ $N + OH = NO + H$.

NO formation is found to peak on the fuel-lean side of stoichiometric. This is a consequence of the competition between fuel and nitrogen for the available oxygen.

II. LITERATURE REVIEW

Literature reviewed in order to get the relevant information on various design of swirler. A number of experimentations have been conducted to determine the effect of a swirler on combustion chamber and its efficiency to reduce the pollutants such as nitrogen oxide and carbon monoxide by proper mixing of fuel with air is studied.

Ying huang (2005) For each swirl number, calculations were performed for about four flow-through times (around12 m/s) after the flow field had reached its stationary state to obtain statistically meaningful data for analyzing the flow dynamics. Three distinct recirculation zones are observed in the low-swirl number case with S = 0.44, including a separation wake recirculation zone (WRZ) behind the center body, a corner recirculation zone (CRZ) due to the sudden enlargement of the combustor configuration, and a central toroid recirculation zone (CTRZ) resulting from vortex breakdown. The wake recirculation zone, however, disappears at the high swirl number of $S_N = 1.10$. If there is no swirl, only the wake and corner recirculation zones exist. As the swirl number increases and exceeds a critical value, vortex breakdown takes place and leads to the formation of a central recirculation zone. As the swirl number increases further, the central recirculation zone moves upstream and merge with the wake recirculation zone.

Tomohiko Furuhata et al. (2007) Studied a low NOx combustor for kerosene-fuelled micro gas turbine based on a new concept was proposed, and the combustion characteristics of the prototype combustor were investigated. The new concept combustor consisted of primary and secondary combustion zones, and they were connected by a throat. A swirler was set between the primary and secondary combustion zones. In order to enhance the recirculation of burned gas in the primary combustion zone, the combustion air was introduced through the swirler and forced to flow upward to the combustor bottom, from where fuel spray was supplied through a nozzle. An optimum configuration of the primary combustion zone such as length of primary zone, swirler vane angle, diameter of throat, etc. were investigated to achieve high combustion stability and low emission in wide ranges of fuel flow rate and excess air ratio. The result shows that when the length of primary zone was 109 mm, the lean combustion limit was higher and CO and NOx concentrations at the combustor exit were lower than those in the other lengths. In the case of 175 mm, the flame in the primary zone changed to luminous flame and the CO and NOx concentrations in exhaust gas were increased.

Ishak et al. (2009) conducted experimental investigations and developed a liquid bio-fuel burner system with various radial air swirler attached to combustion chamber of 280 mm inside diameter and 1000 mm length has been investigated. All tests were conducted using crude palm oil as fuel. A radial flow air swirler with curved blades having 50 mm outlet diameter was inserted at the inlet plane of the combustor to produce swirling flow. Fuel was injected at the back plate of the swirler outlet using central fuel injector with single fuel nozzle pointing axially outwards. The swirler vane angles and equivalence ratios were varied. Tests were carried out using four different air swirler having 45°, 50°, 60°and 70° vane angles. NOx emissions reduction of about 12% was obtained at swirl number of 1.911 as compared to 0.780 at the same equivalence ratio of 0.83. In addition, emission of carbon monoxide decreased as the swirl number increased. The results shows that a proper design of air swirler has a great effect on mixing process and hence the combustion and emission.

Shang Yong et.al (2010) studied A concept of forced swirl combustion chamber in diesel engine is proposed. It can be used to enhance the intensity of swirl flow in the cylinder and accelerate the rate of air-fuel mixture process by designing the special structure in the combustion chamber Firstly, the calculative result of double swirl combustion chamber by CFD code FIRE is calibrated by the method of Validation & Verification with experiment data. By the effect of the special structure of the ridge and slope in partial swirl combustion chamber, the rate of air-fuel mixture and combustion process has been accelerated twice by comparing with the calculative result of these two combustion chambers. At the same time, the utilization of air in squish zone has been improved. The characteristic of double-peak has appeared within main combustion duration on the instantaneous heat release rate curve of partial swirl combustion chamber. The result of calculation shows that NOx and soot mass fraction of partial swirl combustion chamber is lower than that of double swirl combustion chamber by 8.2 and 7.4 % respectively, and indicated heat efficiency is 2.2 % higher.

Yehia A.Eldrainy et al. (2011) studied the characteristics of 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 state of the art swirlers share one disadvantage, the fixed swirl number for the same swirler configuration. Thus, in a mathematical sense, Reynolds number becomes the sole parameter for controlling the flow characteristics inside the combustor. As a result, at low load operation, the generated swirl is more likely to become feeble affecting the flame stabilization and mixing process. A new swirler concept was developed which overcomes the mentioned Weakness of the modern configurations. The new swirler introduces air tangentially and axially to the combustor through tangential vanes and axial vanes respectively. Therefore, it provides different swirl numbers for the same configuration by regulating the ratio between the axial and tangential flow momenta. The swirler aerodynamic performance was investigated using four 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 directly proportional to the tangential to axial air flow rate ratio.

S. Baghdar Hosseini et al. (2011) The experiments are carried out on a axisymmetric cylindrical combustion chamber. Numerical investigation is conducted using Fluent computer code. The standard k–e model is used for modeling of the turbulence phenomena in the combustion chamber .The eddy dissipation model is used for the simulation of transport combustion. The experimental and numerical result show that the exhaust gas temperature. the levels of NOx and CO_2 emission increase with increase of swirl number and then decrease. The CO emission declines with increase of swirl number. From that they found Exhaust gas temperature is increased with increase of swirl number due to improvement of combustion from non-swirl air flow to swirl flow with swirl number 0.72. The region of maximum flame temperature is tended to inlet of combustion chamber with increase of swirl number.

James F. Driscoll et al. (2011) This paper first reviews recent ideas that explain why swirl has a strong stabilizing effect on a flame. While swirl is known to have several beneficial effects that improve the mixing and flame stabilization within a gas turbine combustor, swirl also can lead to some undesirable effects. A processing vortex core can be a source that drives a combustion instability. In addition, swirl affects the unsteady anchoring location of a flame, which also can lead to combustion instabilities, as are observed in the experiment.

Lijunwang et al. (2012) For the purpose of reducing NOx emission in gas turbine engines, lean premixed (LP) combustion is adopted as a high effective combustion mode. Highly swirling flows create an internal flow recirculation zone that entrains and circulates apportion of the hot combustion products in the gas turbine combustor dome. This recirculation zone not only acts as a heat source, but it plays an active role in better mixing, improving combustion stability, reducing the combustor length and lowing NOx emissions. The reaction rates and the flame speed decrease for leaner mixture. If the stabilization method used is not sufficient to sustain the flame inside the combustor, the flame is convicted out of the combustor, and this is called blow out of the flame or combustor. The equivalence ratio at which blowout occurs is referred to as the lean blowout (LBO)limit. Flow field analysis can give a crude estimate of the LBO limit for some specified operating condition.

M.A abdel-Al (2013) developed a new burner and its performance is experimentally studied. The principle of this new burner, circumferential alternative air and fuel burner (CAFB) is to admit fuel and air circumferentially alternative patterns. This burner also allow for swirling both fuel and air jets injecting from different circumferential holes. The outlet angle of air and fuel jet is changed between 0, 15, 30, 45 and 60 injection angles. A new definition and number for swirl is defined, this is called the Injection Swirl Number (ISN) and found to be accurate to describe the flame characteristics. Complete test rig was developed to facilitate characterization of the new burner. A new micro controller traverse mechanism was programmed and fabricated to control the sensitively moving of the thermocouple and gas analyzer sampling probe in all directions. Measurements of gas temperature at different positions, and the oxygen concentrations at the flame centerline were made. The thermal and chemical flame heights were obtained from the maximum temperature and oxygen concentration at the flame centerline. The visible flame height was obtained from direct photography and Infrared (IR) radiometry. The vortex breakdown creation period as a results of a high intensity swirling flow were been captured by the infrared radiation camera. Comparisons of the new CAFB with other flames have also been performed. Experiments showed that the flame height decreases with the increase of the injection jet angles which improves the mixing between air and fuel generating an intense combustion zone and, hence, shortens the flame length. A new injection swirl ratio has been introduced for the new CAFB burner namely the injection swirl number (ISN), ISN = tan θ, where θ is the injection angle. The injection swirl number (ISN) used is 0, 0.26, 0.58, 1 and 1.75 which corresponding to the injection angles 0, 15, 30, 45 and 60 degree respectively. An empirical correlation has been derived for the new CAFB burner flame length as a function of the new derived (ISN).

E. Oliveira et al. (2014)In this paper research relates the positioning of the air intake holes for the primary and the swirler blade stagger angle of a tubular combustion chamber designed for ethanol use aiming minimize the pattern factor and CO emissions of the gas exhausted from the combustor. The combustor was designed based on the available literature on combustion chambers design to fossil fuel, adapted to the use of ethanol. For design is used operational envelope data of an existent midsize power gas turbine aircraft. Are used one-dimensional design criteria with subsequent verification of the flow quality inside the combustion chamber through computational simulations (CFD) in order to calculate the 3D flow, viscous, compressible, turbulent and reagent, with spray. Correlations between the results of 3D calculations and parameters used in the sizing for ethanol are obtained for tubular chambers.

III. CONCLUSION

A. Effect of increasing swirl Number shows that there will be reduction in Percentage of NO_X

B. Effect of increasing Swirl Number shows that there will be reduction in Percentage of CO

C. As the Equivalent ratio increases from lean to stoichiometric condition There will increase in temperature and then temperature fall on richer side.

IV. ACKNOLEDGEMENT

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REFERENCES

[1] Ying Huang and Vigor Young.(2005), "Effect of swirl on Combustion dynamics in a lean-premixed swirl-stabilized combustor", Elsevier, 1775–1782.

[2] Tomohiko Furuhata, Shunsuke Amamo.(2007),"Development of can- type low NO_x combustor for micro gas turbine fundamental characteristic in a primary combustion zone with upward swirl", Elsevier, 2463-2474.

[3] Ishak M., Jaafar M. and Eldrainy Y. (2009), "The Effect of Radial Swirl Generator on Reducing Emissions from Bio-Fuel Burner System", Modern Applied Science, 3(6), 45-51.

[4] Shang Yong,Liu Fu-shui. (2010), "Numerical Simulation on Forced Swirl Combustion Chamber in Diesel Engine", International Conference on Digital Manufacturing and Automation,china,34-36.

[5] Eldrainy Y., Aly H., Saqr K. and Jaafar M. (2011),"A Multiple Inlet Swirler for Gas Turbine Combustors", International Journal of Aerospace and Mechanical Engineering, 5(2),106-109.

[6] Hosseini S. B., Bashirnezhad K, Heravi H. M.(2011)," Combustion and Emission Characteristics in a Biodiesel Combustion Chamber at Different Swirl Number" , Proceedings of the European Combustion Meeting, 2011.

[7] Driscoll J. F., and Temme J. (2011), "Role of Swirl in Flame Stabilization", 49th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition 4 - 7 January 2011, Orlando, Florida.

[8] LijunWang, Dongdong QI, Haifeng YANG (2012), "Flame Symptom Modelling Near Lean Blowout in A Swirl-Stabilized Gas Turbine Model Combustor", Proceedings of 2012 International Conference on Mechanical Engineering and Material Science (MEMS 2012).

[9] Abdel-Al M., Yehia M., Taha M. and Abou-Arab T. (2013), "Effect of Fuel and Air Injection Pattern on Combustion Dynamics in Confined and Free Diffusion Flame", International Journal of Modern Engineering Research (IJMER), 3(2) , 928-938.

[10] Surjosatyo A. and Ani F. (2011), "Study of Enhancing the Swirl Burner Performance on a Small scale Biomass Gasification", International Journal of Engineering & Technology IJET-IJENS, 11(4), 20-29.

[11] Silva R. and Lacava P. (2013), "Preliminary Design of a Combustion Chamber for Micro turbine based in Automotive Turbocharger", 22nd International Congress of Mechanical Engineering, COBEM, Brazil, 412-422.

[12] Lefebvre A. and Ballal D. (2010), "Gas Turbine Combustion", Third Edition New York, CRC press.