Experiment Into the Air Inlet to Gas Turbine on Flame Stability and Temperatures Distribution

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***Abstract* – This study is focused on investigating experimentally the effect of air swirl inlet into gas turbine combustion chamber on flame stability, and temperatures distributions. The combustor performed consists of two casing one inside the other ,the outer casing proceeding in the flow direction of the secondary air. The inside casing is called flame tube which provided with fifty-six (56) holes tangentially with an angle (45o). Two combustion chamber are made the first one has the holes with (5 mm in diameters) and the second one the holes with (10 mm in diameters) to introduce the secondary air. The combustion chamber provided with six small holes on one line at the top of the combustion chamber for entering the thermocouples to measure the temperature distribution .The experimental results show a significant effect of secondary air swirl and swirl strength on flame stability and temperatures distributions. On the other hand the low temperatures are recorded at the wall along the combustor, and a significant temperatures distributions at exit of the combustion chamber. Also the secondary air swirl and swirl strength cause a reduction in the flame diameter and flame length, and the flame is turning around away from the flame tube wall and stable.**

Key words: flame stability, secondary air, combustion chamber, temperatures distributions.

1- Introduction

The gas turbine is in many respects the simplest type of power apparatus available. It is completely self-contained requiring no boiler or external heat source as burns fuel and converts heat released into mechanical power within a single assembly. It is very important to investigate ways of improving the combustion efficiency, flame stability, and temperature distribution.

The combustion chamber consists of at least three basic parts: a casing, flame tube, and fuel injection system. The casing must withstand the cycle pressures and may be a part of the structure of the gas turbine. It encloses a relatively thin-walled flame tube within which combustion takes place, and a fuel injection system.

The flame stability, temperature distribution and flow pattern play an important role in the performance of gas turbine combustor. Therefore , the studies and investigations of the combustion characteristics (flame stability, temperature distribution), and flow pattern in gas turbine combustor is of a prime importance. The gas turbine combustor is divided into three zones, (i) Primary zone,(the purpose of the primary zone is to anchor the flame, provide sufficient time, and turbulence to achieve essentially complete combustion of the fuel), (ii) Secondary zone, (the secondary zone is the region that lies between the primary and dilution zones, it serves principally as an extension to the primary zone, provide increase residence time for complete combustion).(iii) Dilution zone, (provide an outlet stream with a mean temperature and a temperature distribution that are acceptable to the turbine).

Swirling is the most important parameter that controls both the flow pattern and combustion process in gas turbine combustors. Therefore, the effect of air inlet into combustor on flame stability temperature distribution and combustion in gas turbine combustors to be investigated. several investigation of combustion phenomena and performance of gas turbine combustors to avoid and overcome some of practical problems related to flow patterns, the fuel atomization, and swirling effect on combustion. Ahmed [1] measured the flow field characteristics of a confined isothermal strongly swirling flow in a combustion model using three component fiber-optic Laser Doppler Velocity-meter. Guillaume and La Rue [2] show that inducing swirl can be generated and has the strength necessary to produce the required recirculation zone. Non-reacting fluid flow fields generated by multi swirler arrays with two different port configurations are investigated experimentally by Cai et al [3]. These two cases include a co-swirling array, where all swirlers act in the same direction, and a counter-swirling array. Also Jian et al [4] studies and investigate the turbulent reacting flow in a swirl combustor with staged air injection, the air injected into the combustor is composed of the primary swirling jet and the secondary non-swirling jet. A three dimension-laser particle dynamic analyzer (PDA) is employed to measure the instantaneous gas velocity. The flow pattern in a gas turbine combustion chamber are studied and investigate by Jusoff M., et al [5] by simulation and experimental approaches using three flat swirlers with vane angles 40°,50°,and 60°. The structure of swirling flame, stability of flame, and the characteristics of the flame with swirling flow are studied and investigated by [6,7,8,9,&10] therefore, the effect of swirling of secondary air on combustion process and temperature distribution in Gas turbine combustors has to be studied.

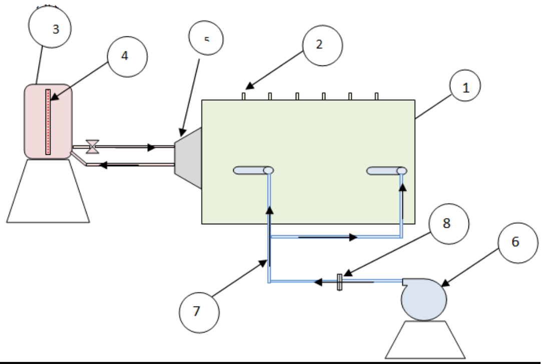
II. Experimental Work

Gas turbine combustion chamber must satisfy a wide range of requirements such as complete combustion of fuel, minimum pressure losses, flame stability and good distribution of the temperatures inside and outlet of the combustor.

In this study an experimental test rig is made to study and investigate the effect of secondary air entranced (with swirling through a number of holes made with an angle of (45^o) tangentially) into gas turbine combustion chamber on flame stability and temperatures distributions.

A. Test Rig

The gas turbine test rig is constructed as shown in the Figs.(1 , 2 & 3) and photo (1) which consist of : (i) Combustion chamber, (ii) Burning unit, (iii) Secondary air supply system, (iv) Instrumentation and the fuel tank provided with fuel level indicator.



1-combustor. 2-measuring holes. 3-fuel tank. 4-fuel level indicator. 5-burning unit. 6-air blower 7-secondry air line 8-orifice meter

Fig(1) Schematic diagram of combustor test rig.

Photo (1) Combustion chamber

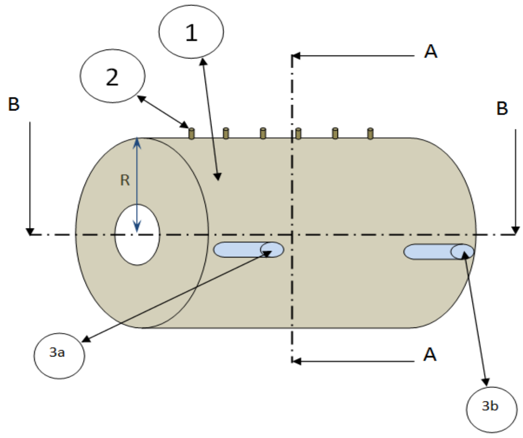
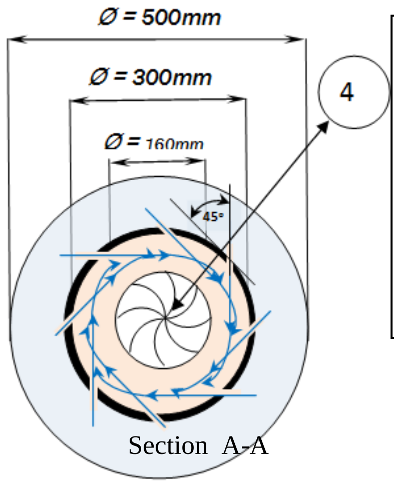


Fig 2 Details of the combustor.



1-combustor. 2-hole of measuring. 3a-inlet of secondary air from back. 3b-inlet of secondary air from front. 4-primary air swirl 5-holes of inlet air.

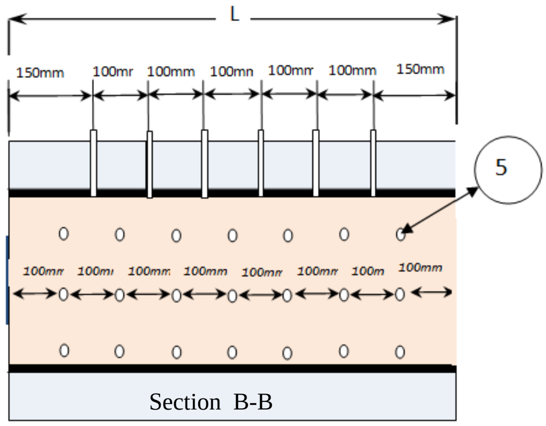


Fig 3 Arrangements and cases details of the secondary air entry.

B. Experimental Procedure.

A number of experiments are carried out in order to study and investigate the influence of secondary air swirl on flame stability and temperature distribution in a can type gas turbine combustor.

The air blowers are started to supply the primary and secondary air to the combustor. Vane type swirler is used for the primary air swirl. the secondary air swirl is provided by entering the secondary air through the holes made tangentially with an angle (45^o) around the combustor flame tube.Two ways are used to introduce the secondary air between the flame tube and the outer casing of the combustor, (from the front and the back) of the combustor see fig (2 & 3) & photo (1).

The secondary air swirl intensity is changed by changing the diameters of the fifty-six (56) holes of secondary air entrance. Two diameters of holes (10 mm & 5 mm) are used, case (A) & (B) respectively.

Case (A) the diameter of each hole is (10 mm), and the velocity of the secondary air inlet through the hole is (2.55 m/s).

Case (B) the diameter of each hole is (5mm), and the velocity of the secondary air inlet through the hole is (8.8 m/s).

The pressures and the mass flow rates of the primary air and the fuel are kept constant throughout the experimental work. The fuel flow rates are measured by taking the average of several readings of the flow from the fuel indicator with time. The combustion is kept for some time until the flame become stable. Then the Thermocouple is inserted through the six measuring holes at the top of the combustor starting with upstream one. Measurements of the temperatures are taken in a radial and axial direction of combustor. For each hole six readings at different radial distance (from the wall to the center line of combustor), assuming the combustor is identical.

III. Results and Discussion

The results of the experimental studies of the effect of the secondary air swirl and swirl intensity on the temperatures distributions, and flame stability in a can type combustion chamber are presented in this study.

The experiments are taken under the same conditions such as constant primary air to fuel ratio, same mass flow rate of secondary air, and concurrent swirl flow, (primary and secondary swirl in the same direction). But the swirl intensity is changed by changing the inlet velocity of the secondary air into the combustion chamber flame tube through the holes which are made with different diameter, with an angle (45^o) tangentially. Two cases are investigated.

Case (A) the diameter of each hole is (10 mm), and the velocity of the secondary air inlet through the hole is (2.55 m/s).

Case (B) the diameter of each hole is (5 mm), and the velocity of the secondary air inlet through the hole is (8.8 m/s).

The studies also include two ways to introduce the secondary air between the flame tube and the outer casing of the combustor, (from the front and the back) of the combustor see fig (2 & 3).

A. Temperature Distribution.

The results of the temperatures distribution in the radial and axial directions inside the combustion chamber for all cases are shown in figs (1 to 8).

Figures (1 to 4) show the temperatures distribution in the radial and axial direction for case (A), for the secondary air inlet from the front and back of the combustor. From the figs (1 & 2) it can be seen that the temperature at the wall of the combustor flame tube are low, and it increase in the direction to the center line of the combustor. While the maximum temperature are recorded in the flame region where (r/R from 0.6 to 1) at (x/L=0.313 & x/L=0.438). But there are a large difference between the temperatures at upstream where (x/L=0.313 to 0.563) specially for the back entry of the secondary air, That mains the inlet of the secondary air from the front of the combustor is better than from the back.

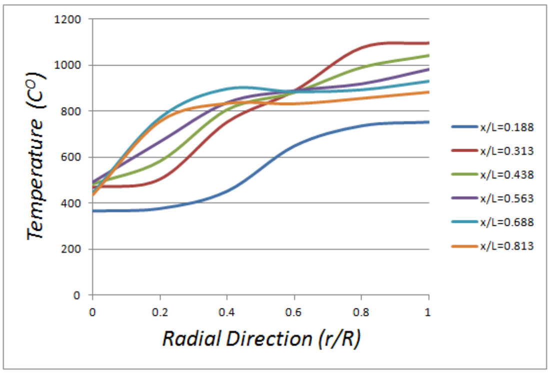


Fig 1Temperature distribution in Radial direction in the combustion chamber, for case (A) (Secondary Air inlet from front).

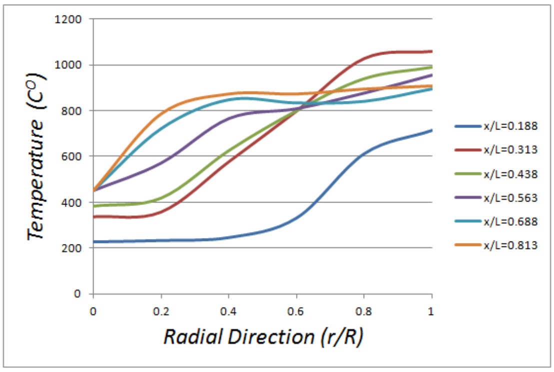


Fig 2 Temperature distribution in Radial direction in the combustion chamber, for case(A) (Secondary Air inlet from back).

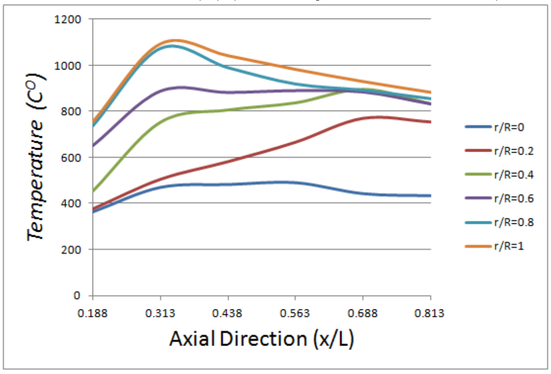


Fig 3 Temperature distribution in axial direction in the combustion chamber, for case (A) (Secondary Air inlet from front).

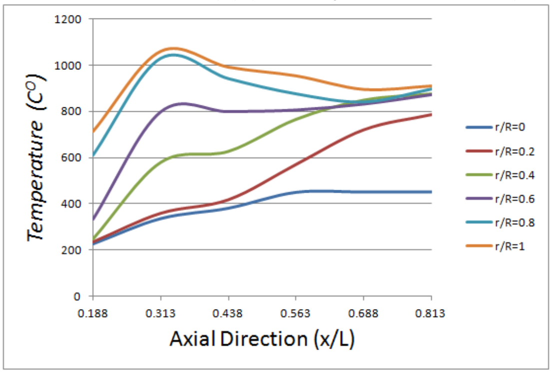


Fig 4 Temperature distribution in axial direction in the combustion chamber, for case(A) (Secondary Air inlet from back).

The temperatures distribution in the radial and axial direction for case (B) are shown in figs (5 to 8).The results show that the temperatures near the wall of the combustor flame tube are low, and high in the region of the flame [as in case (A)] at (r/R from 0.6 to 1) and (x/L from 0.313 to outlet). But the difference between the temperature are very small i.e (homogeneous , good distribution).

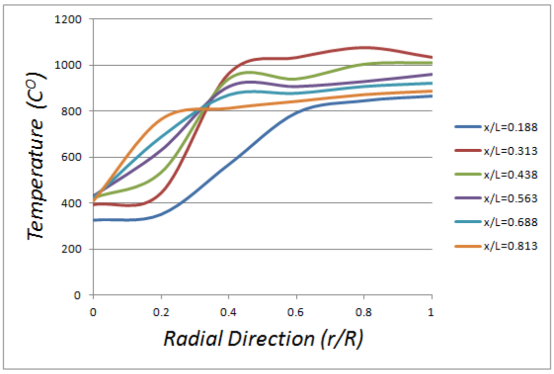


Fig 5 Temperature distribution in radial direction in the combustion chamber,for case (B) (Secondary Air inlet from front).

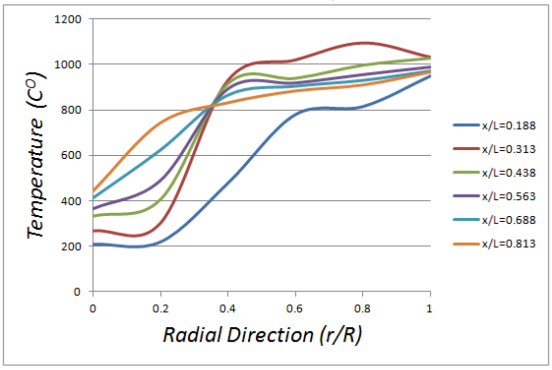


Fig 6 Temperature distribution in radial direction in the combustion chamber, for case(B)(Secondary Air inlet from back).

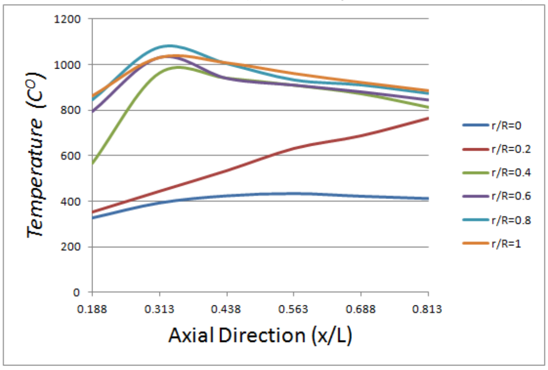


Fig 7 Temperature distribution in axial direction in the combustion chamber, for case(B)(Secondary Air inlet from front).

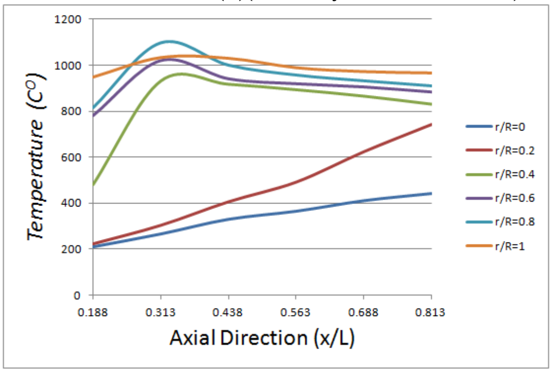
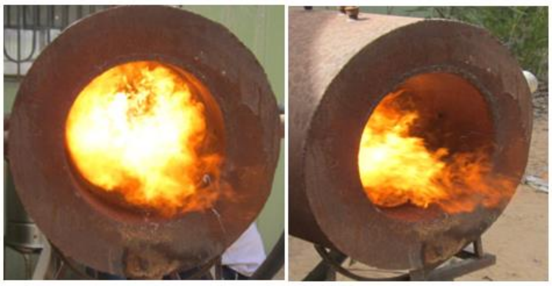


Fig 8. Temperature distribution in axial direction in the combustion chamber, for case (B)(Secondary Air inlet from back).

B. Flame Stability

The flame structure (shape, diameter, length) is shown in photos (2 to 4). Photo (2) shows the flame with primary air swirl only, it can be seen that the flame fill the combustor flame tube, and along the combustor length .The effect of secondary air swirl on the flame is shown in photos (3 & 4), case (A) & (B). The photo (3) for case (A) shows a reduction of the flame diameter and flame length, and the flame is turning around away from the flame tube wall and stable.

The photo (4) for case (B) show the flame more stable, smaller in diameter, and shorter.



Photo(2) With primary air swirl only.

Photo(3)With primaryair and secondary swirl (Case A)

Photo(4)With primaryair and secondary swirl(CaseB).

IV. Conclusions

The conclusions obtained from the experimental results summarized as the following:-

1-The temperature distribution inside the combustor flame tube for the two cases (A & B) are better when the secondary air is introduced from the front inlet.

2-The temperature for case (A) (Low secondary air swirl) near the wall of the combustor flame tube are low, and very high in the region of the flame. But the difference between the temperatures are very large at upstream (x/L=0.313 to x/L=0.563).

3-The temperature for case (B) (High secondary air swirl) near the flame tube wall are lower, and the temperatures distribution all over the combustor are good.

4-The temperature distribution at outlet are nearly the same for case (A & B), but a little lower, and more uniform when the inlet of the secondary air between the flame tube and casing of the combustor from front of the combustor.

5-The flame with primary air swirl is only filling the combustor flame tube, and along the combustor length.

6-The flame with secondary air swirl case (A) there is a reduction in the flame diameter and flame length, and the flame is turning around away from the flame tube wall and stable.

7-For case (B) the flame more stable, smaller in diameter, and shorter.

8-The increase of secondary air swirl gives more time for the fuel droplet inside the flame reign to burring completely.

9-Increasing of the swirl strength decreases the flame diameter and length that refers to reduce the size of the combustion chamber to become smaller and cheaper.

Reference

[1]-Ahmed, S.A, "Three component Velocity Measurements of An Isothermal Confined Swirling Flow" proceedings of The Institution of Mechanical Engineers, part G: Journal of Aerospace Engineering V211, N2, p113, - 122, 1997.

[2]-Guillaume D. W., and La Rue J. "Effect of Induced Swirl on Mixing" Journal of Fluids Engineering, Transactions of The ASME V.119, N2 P471-473, Jun. 1997.

[3]-Cai J., Jeng S. M., and Tasina R. "Multi Swirler Aerodynamics: Comparison of Different Configurations " Proceedings of ASME Turbo Expo 2002, Amsterdam, The Netherlands, June 3 -6,2002.

[4]-Jian Z., Yong P., and Lixing Z., "Turbulence Characteristics of Swirling Reacting Flow in a Combustor with Staged Air Injection" Chinese J. Chem Eng., 14(5) 634-641, China, 2006.

[5]-Jusoff M. N. M., K., Osman M .S. and Ishak M.S.A "Combustor aerodynamic using radial swirler" International of the Physical Seiences Vol. 6(13), pp. 3091-3098, 4 July, 2011.

[6]-Osaka, N., Macku, N., Ogawa, K., and Kastuki, M. "Turbulent Characteristics of A Swirling Flame Flame for Gas Turbine Combustor" American society of Mechanical Engineers, International Gas Institute (Publication) IGTI V8P (213-217). Publ. By ASME, New York 1993.

[7]-Gaffarpour M. and chehroudi B. "Experiments on Spray Combustion in A Gas Turbine Model Combustion Seincs and Technology, V. 92 Nol-3, 1993.

[8]-Aref A. A., and Gollahalli S. R. "Effect of Secondary Air Swirling on The Lift off and Combustion Characteristics of A Burning Jet A Fuel Spray" Emerging Energy Technology American Society of Mechanical Engineers, Petroleum Division (publication) PD V. 66, Pl-9 ASME, New York USA, 1995.

[9]-Sehefer R. W. "Combustion of Hydrogen Enriched Methane in A Lean Premixed Swirl Burner" Proceedings of The DOE Hydrogen Program, Review NREL/CP-570-30535, 2001.

[10]-Mustafa. M. I et al "Effect Secondary Air swirl an Combustion characteristics in Gas Turbine combustor" Researches of the 4th Scientific Conference intiteld, Held at alkums on 15/1/2014.