UDC 629.735

MASOUD HAJIVAND

National Aerospace University named after N. E Zhukovsky "KhAI"

EFFECT OF AXIAL SWIRLER PARAMETERS ON A METHANE-AIR COMBUSTION CHARACTERISTICS AND FORMATION OF NITROGEN OXIDE

CFD simulation of none-premixed methane-air combustion is performed. The purpose of this paper is to provide information concerning the effect of geometry of axial swirler vanes on the exhaust gas emissions of oxides of nitrogen (NO), for a can combustor of gas turbine engine. Effects of different swirler vane angles on NO formation, are shown. Air swirler adds sufficient swirling to the inlet flow to generate central recirculation region (CRZ) which is necessary for flame stability and air-fuel mixing enhancement. Therefore designing an appropriate air swirler is a challenge to produce stable, efficient and low emission of combustion with low pressure losses. Five axial flat vane swirlers with 20°, 30°, 45°, 55°, and 60° vane angle corresponding to swirl number of 0.28, 0.444, 0.769, 1.1 and 1.33 respectively, were used in this analysis to show vane angle effect on the internal flow field, temperature fluctuations and formation of NO. The simulation has been performed using the Computational Fluid Dynamics (CFD) commercial code ANSYS CFX release 16, including laminar flamelet model, for simulating the methane combustion mixing with air .k-ε model was also investigated to predict the turbulent combustion reaction. A thermal and prompt NOx formation is performed for predicting NO emission characteristics.

Key words: *Computational Fluid Dynamics (CFD), swirl number, oxide of nitrogen, emission, flame stabilization*

Introduction

There are several requirements that must be considered when designing a new gas turbine combustion chamber especially to meet the stringent regulation regarding emissions level from the exhaust. These requirements include stability limits, high combustion efficiency, high intensities of heat release, low burner pressure drop and low emissions production from the combustion processes such as NO and CO [1]. One-way to achieve this, is the use of swirling air flow. Swirling flow is used for the stabilization and control of the flame and to achieve a high intensity of combustion.

Radial and axial swirlers are most common swirlers to generate central recirculation region (CRZ) in primary zone of combustion process in a gas turbine combustor. In this study we performed all the numerical simulations, on the axial swirler. The most common method of generating swirl is, by using curved and flat vane swirlers in axial swirlers. One advantage of flat vanes is that they are cheap and easy to produce. Moreover, the flow striations associated with flat-vane swirlers, which are created by the stalled regions attached to each vane, tend to promote a more stable flame and reduce combustion noise. Another asset of the flat-vane axial swirler is that its exit velocity profile is less peaked and less biased radially outboard than that of the corresponding curved-vane swirler [2]. In consequence, it provides better aeration of the main soot-forming zone, which is normally located just downstream of the fuel injector [2].On swirling flows shows that curved vanes are more efficient aerodynamically than flat vanes. This is because they allow the incoming axial flow to gradually turn, which inhibits flow separation on the suction side of the vane. Thus, more complete turning and higher swirl- and radial velocity components are generated at the swirler exit, which results in a larger recirculation zone and a higher reverse flow rate Most conventional combustor employs the axial flow type swirlers.[2]

Swirling flow induces a highly turbulent recirculation zone, which stabilizes the flame resulting in better mixing and combustion (Gupta *et al.*, 1998). It has been suggested that the large toroidal recirculation zone plays a major role in the flame stabilization process by acting as a store for heat and chemically active species and, since it constitutes awell-mixed region, it serves to transport heat and mass to the fresh combustible mixture of air and fuel (Judd *et al.*, 2000).

Since the early times swirling flows have been employed to establish a recirculation zone which entrains the hot combustion products and creates a low velocity zone of sufficient residence time and turbulence levels such that the combustion process becomes self-sustained.[3].

The presence of swirl results in a rapid rate of mixing between the incoming air and fuel which reduces the flame temperature and hence lowers NOx formation. It is also well known that coaxial air provides a significant reduction of the NOx emission index of a simple jet flame, since it shortens the flame length and reduces the residence time for thermal NOx to be produced [4,5].

1. Swirl number

The level of swirl or swirl strength can be represented in term of swirl number which is defined as the ratio between axial fluxof the angular momentum to the axial momentum [2], which can given as:

$$S_N = \frac{\int_0^R (wr)\rho u 2\pi r dr}{R\int_0^R u\rho u 2\pi r dr} \qquad (1)$$

where w, u, ρ and r are the tangential and axial velocity components, density and radius respectively. For aflat vane axial swirler, the swirl number is:

$$S_N = \frac{2}{3}\left[\frac{1-(r_i/r_o)^3}{1-(r_i/r_o)^2}\right]\tan\theta \qquad (2)$$

where the inner radius is r_i and outer radius is r_o and θ is the vane angle [2].

For values of swirl number less than around 0.4, no flow recirculation is obtained, and the swirl is described as weak. Most swirlers of practical interest operate under conditions of strong swirl (that is, $S_N > 0.6$).

For a simple axial swirler, the minimum vane angle required to obtain strong recirculation ($S_N > 0.6$) for a typical swirler having $D_{hub}/D_{sw} = 0.5$ is calculated from Equation 4.36 as 38°. A simple geometrical parametrs of axial swirler is shown in Fig. 1 [2].

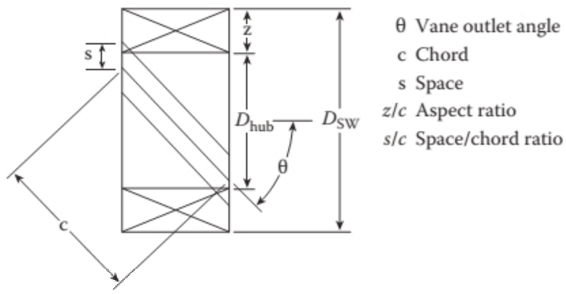


Fig. 1. Geometrical parameters of axial swirlers with flat vanes

2. Recirculation zone and swirler consideration

Air swirler introduces air tangentially into the combustion chamber, consequently the air is forced to change its path, which contributes to the formation of swirling flow. The balance in force could be demonstrated by the movement of static pressure in the combustion chamber and can be calculated by measuring the distribution of the tangential velocity. Low pressure in the core centre of the swirling flow is created and as a result, swirl vortex is formed [6]. The recirculation region in free swirl flow is shown in fig. 2.

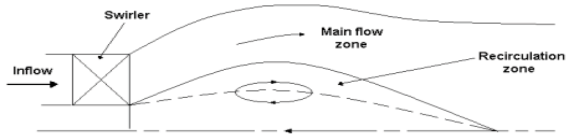


Fig. 2. Recirculation zone in swirling flow [7]

As the level of applied swirl increases, the velocity of the flow along the centerline decreases, until a level of swirl is reached at which the flow becomes stationary. As the swirl is increased further, a small bubble of internal recalculating zone is formed. This, the vortex breakdown phenomenon, heralds the formation of large-scale recirculation zone that helps in stabilizing the flame. It has been concluded [7,8] that the large torroidal recirculation zone plays a major role in the flame stabilization process by acting as a store for heat and chemically active species and, since it constitutes a well-mixed region, it serves to transport heat and mass to the fresh combustible mixture of air and fuel.

Previous researchers have studied the effect of varying the swirler blade angle, which in turn varies the swirl number, on combustion performance.

Drake and Hubbard [9] studied the effect of swirl on completeness of combustion and discovered that there was an optimum swirl blade setting. Claypole and Syred [10] investigated the effect of swirl strength with swirler numbers of 0.63 to 3.04, on the formation of NOx using methane as a gas fuel. They concluded that at swirl number of 3.04, much of the NOx in the exhaust gases was recalculated back to the flame front. The total emissions of NOx were reduced, however, at the expense of loss in combustion efficiency. Mestre [11] compared the effects of swirling and non-swirling systems on combustion characteristics. He clarified that the existence of swirl improves combustion efficiency, decreases pollutant gas-emissions and increases adiabatic flame temperature. In addition he observed that a shorter blue flame was generated with the presence of swirl, indicating a good mixing, while non-swirling combustion resulted in a longer yellow flame as a result of poor mixing. Chigier concluded in his study that swirling flow could stabilize the combustion process and improve the mixing of fuel and air as well; swirl flow affected the flame length, size, density, and stability. An important effect of swirl on the flow field is the generation of the recirculation zone or aerodynamic blockage, where adverse pressure gradient occurs in the direction of the flow [1]. This vortex breakdown phenomenon occurs only if the strength of swirl is large enough. For a weak swirl ($S_N < 0.4$), the slope of the axial pressure due to swirling motion is not big enough to produce an internal recirculation, whereas for a strong swirl ($S_N > 0.6$), radial and axial pressure slopes are formed downstream of the swirler exit plane creating a recirculation zone (Figure 3) in the axial direction [2].

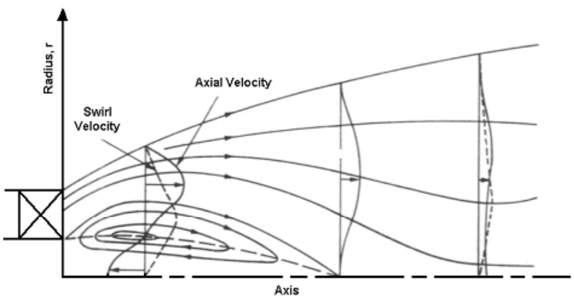


Fig. 3. Axial velocity profile and swirl inside astrong swirl

3. Governing equations, combustion and NOx modeling

The mathematical equations describing the fuel combustion are based on the equations of conservation of mass, momentum, and energy together with other supplementary equations for the turbulence and combustion. The standard k-ε turbulence model is used in this paper. The equations for the turbulent kinetic energy k and the dissipation rate of the turbulent kinetic energy ε are solved. For non premixed combustion modeling. All the numerical simulation has been performed using the Computational Fluid Dynamics (CFD) commercial code ANSYS CFX release 16, including laminar flamelet model for modeling non-premixed methane-air combustion with 17 spices and 55 reactions.

In the flamelet model chemical reaction rates are computed first (independent of the flow) and the relevant scalar properties are stored in lookup tables accessible by the flow solver. The instantaneous scalar properties φ (i.e., temperature, density, compositions) are represented as a function of the instantaneous mixture fraction Z and its variance $Z''2$, and the scalar dissipation χ: $\varphi = \varphi(Z, Z''2, \chi)$. Mean scalar properties are then computed by integrating the instantaneous φ over an assumed β-PDF, and the results are stored in the lookup tables. In the flamelet approach, transport equations for the turbulent kinetic energy (k), its dissipation rate (ε), enthalpy, mixture fraction Z, and its variance $Z''2$ (which is used to compute the scalar dissipation) are solved for each computational cell. These values are then used to extract mean scalar properties from the chemistry lookup tables. The flow field properties are updated and iterations continue until convergence criteria are met. The NOx formation model (based on thermal and prompt mechanisms) is also included.

When modeling NOx formation in methane-air combustion, the thermal NO and prompt NO are taken into account. In the simulation process, we solve the mass transport equation for the NO species, taking into account convection, diffusion, production and consumption of NO and related species. This approach is completely general, being derived from the fundamental principle of mass conservation. For thermal and prompt NOx mechanisms, only the following NO species transport equation is needed:[12]

$$\rho\frac{\partial Y_{NO}}{\partial t}+\rho u_i\frac{\partial Y_{NO}}{\partial x_i}=\frac{\partial}{\partial x_i}\left(\rho D\frac{\partial Y_{NO}}{\partial x_i}\right)+S_{NO}\,. \quad (3)$$

The source term S_{NO} is to be determined for different NOx mechanism. Y_{NO} is mass fraction of NO species in the gas phase and D is effective diffusion coefficient.

5. Geometry of combustor-meshing-boundary condition

The model of our domain of simulation, is a can type of combustor. The geometrical sizes of the combustor, fuel injection, air swirler and the fuel inlet (methane) and oxidizer inlet (air) is shown in fig. 4a. Methane and air are entered in the domain separately.

The length of combustor is 327.19 mm and the height is about 105 mm .The inner diameter of the swirler is 22 mm and the outer is 46 mm. The thickness of swirler vane is 0.75 mm. Methane is injected from 6 holes which each of their diameter is 2.5 mm on the surface of injection of 135 degree. The outlet diameter of combustor is about 73.5 mm. The 3D model of combustor and axial swirler are shown fig. 4b and fig. 4c. The model was meshed for simulating in a tetrahedrons meshing method, with about total number of 1015727 nodes, and 4 068 000 total number of elements including prismatic layers around the walls of combustor, that are shown in fig. 5a and fig. 5b.

The different boundary conditions applied for flow analysis of gas turbine can-type combustion chamber in this investigation, which they are inlet mass flow rate for both fuel and oxidizer entering the domain , outlet average static pressure and with no slip walls. Boundary condition information are shown in table1.

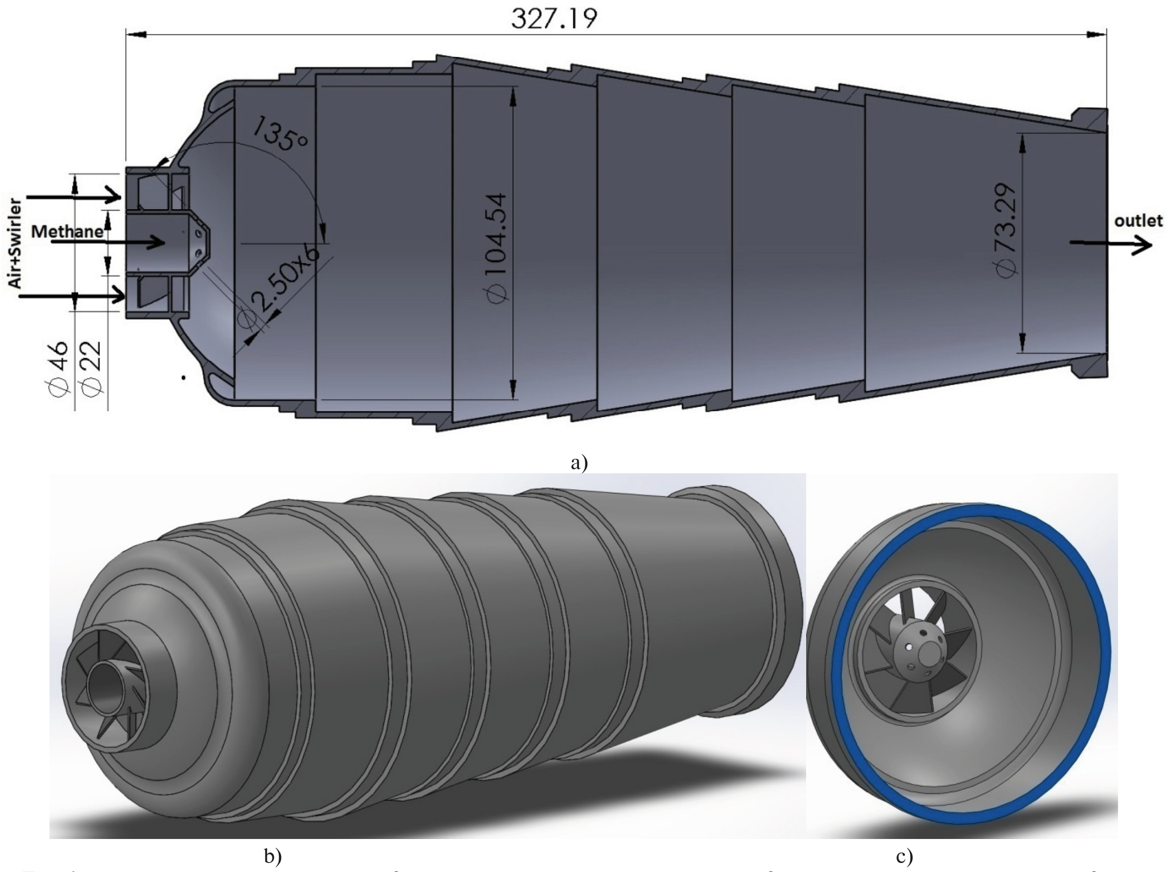


Fig. 4. a) The geometrical parameter of combustor and swirler b) 3D model of whole combustor c) 3D model of axial swirler

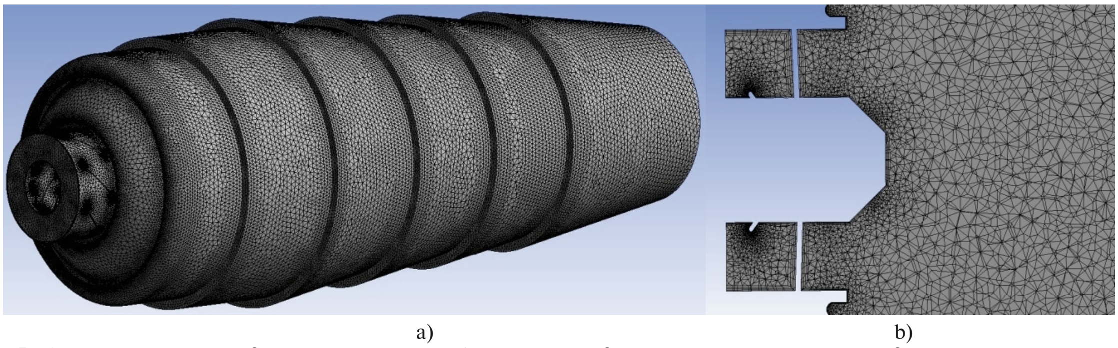


Fig. 5. a) Tetrahedron mesh for whole combustor b) detail view of tetrahedron mesh around the fuel injector with prismatic layers

Table 1

Boundary condition information of combustor

Swirler vane angles (degree)	20	30	45	55	60
Swirl number	0.28	0.444	0.769	1.1	1.33
Operating pressure (atm)			4		
Temperature entering in combustor [K]			450		
Oxidizer mass flow rate [kg/s]			0.2		
Temperature of fuel (K)			310		
Fuel mass flow rate [kg/s]			0.004		

6. Results and discussion of simulation-(Temperature distribution)

All of 5 cases of simulation was performed in ANSYS CFX. The convergence criteria in this simulation was at the RMS residual type with the 10^{-4} residual target. The physical timescale for this combustion simulation was 0.001[s]. All the simulation in 5 cases were converged successfully with solving the mass and momentum (U, V, W momentums), heat transfer (energy), turbulence (k-ε), mass fraction of NO, mixture fraction including mean and variance, temperature variance for predicting oxide of Nitrogen.

In order to achieve better mixing between fuel and air in a gas fuel combustor, turbulence flow must be generated to promote mixing. Turbulence energy is created from the pressure energy dissipated downstream of the flame stabilizer. In the radial swirler, turbulence can be generated by increasing the aerodynamic blockage or by increasing the pressure drop across the swirler. In fig.6 and fig. 7 all the temperature and NO mass fraction counters and distributions are presented along the XY plane of combustor for 5 various swirler vane angles (20˚, 30˚, 45˚, 55˚, 60˚) with swirl number of 0.28, 0.444, 0.769, 1.1, 1.33. In fig. 6.a- with the swirl number of 0.28 the maximum flame temperature is 2242 K. The recirculation zone in this case, is weaker, compare to the other cases, which effects on flame structure as shown and this can create the maximum flame temperature in the center of combustor. The maximum temperature in fig. 6 b - with the swirl number of 0.444 is 2239 K due to formation of recirculation zone and better air-fuel mixing. The shape and structure of the flame in this case in more uniform then the first case.In fig. 6 c - the swirl number is 0.769 with the vane angle of 45 degree. In this case of our study the maximum flame temperature is 2204 K. Due to a high swirl number here, obviously we can see a very stable and uniform flame structure because of a high quality of recirculation zone in the first zone of mixing and combustion. As we can see the formation of maximum flame temperature is closer to the combustor walls due to a high swirl number. In fig. 6 d - which we can say a very high swirl number of 1.1, the maximum flame temperature is 2172 K which is lower than the 3 cases before due to a higher swirl number. The flame structure is uniform but the maximum temperature is formed close to the walls of combustor. And the last case in fig. 6 e - which has the 2188 K maximum flame temperature. In this case swirl number is 1.33 which is the higher in this study and due to a very high swirl number and recirculation zone the maximum flame temperature has been created like a stream closer to the walls.

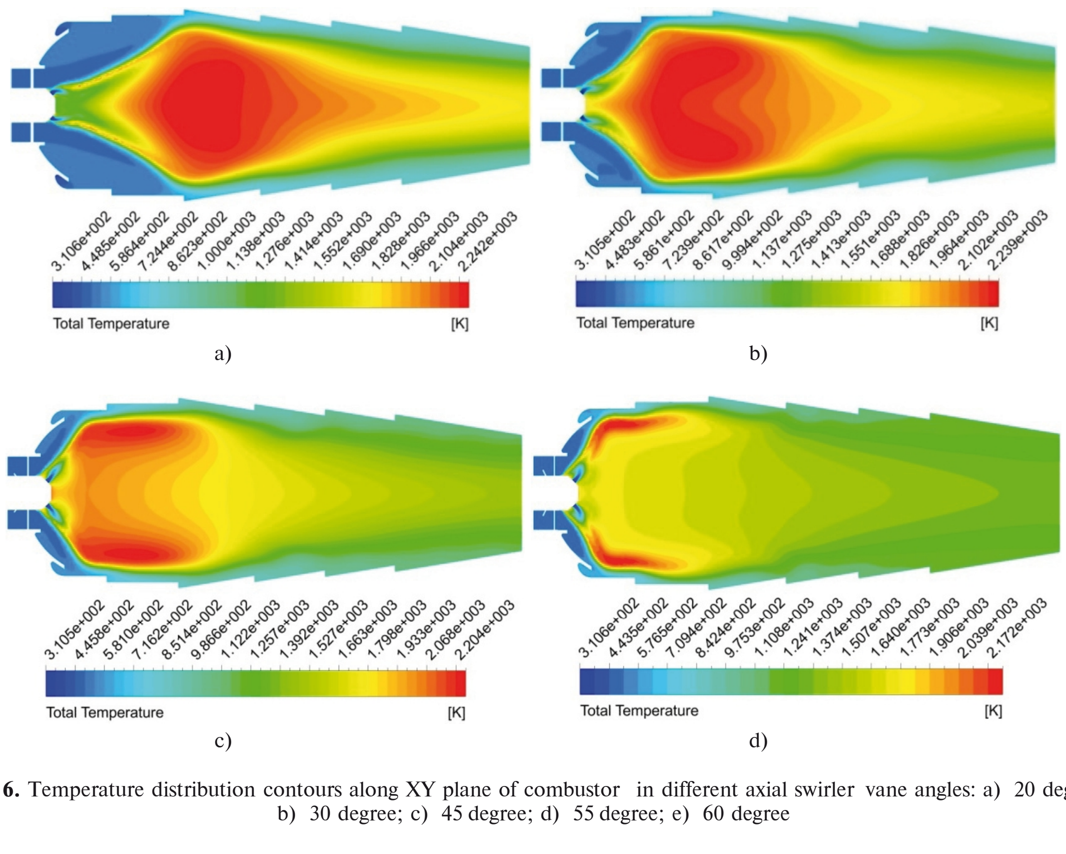
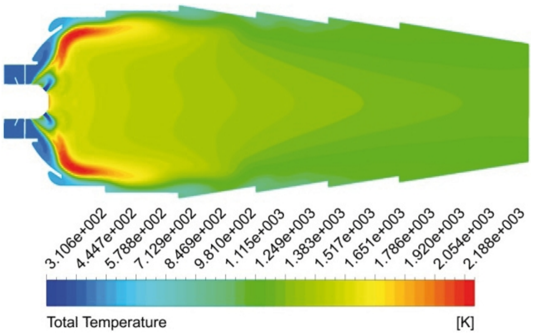


Fig. 6. Temperature distribution contours along XY plane of combustor in different axial swirler vane angles: a) 20 degree; b) 30 degree; c) 45 degree; d) 55 degree; e) 60 degree



e)

Fig. 6. continue-Temperature distribution contours along XY plane of combustor in different axial swirler vane angles: a) 20 degree; b) 30degree; c) 45 degree; d) 55 degree; e) 60 degree

7. Results and discussion of simulation-(NO distribution)

NO distributions along the XY plane of combustor are shown in fig. 7 in various swirl vane angles with various swirl number. As discussed in pervious section for temperature distribution along the combustor, the minimum temperature was in fig. 6 d and fig. 6 e due to a high swirl number and a high recirculation zone for better fuel-air mixing and reducing the temperature. And it was obvious that the maximum flame temperature was in fig. 6 a-6 b and 6 c. Actually the maximum NO mass fraction in fig. 7 a with swirl number of 0.28 is 0.0002496 . The formation of maximum NO is occurred at the high temperature zone of combustion, where this zone situated at the center of combustion zone far from the combustion walls. Maximum NO mass fraction in fig. 7 b is 0.0003423 when the swirl number is 0.444. The formation of maximum of NO in this case is started closer to the fuel injector due to a higher swirl number comparing to the first case. The swirl number in fig. 7 c is 0.769 which has the maximum NO of 0.0001555 for the 45 degree swirl vane angles. Due to the extension of recirculation zone along the Y plane closer to the wall of combustor. In fig. 7 d and fig. 7 e the maximum mass fraction is 0.00004451 and 0.00003,which is the minimum NO mass fraction is for fig. 7 e which has the 60 degree of vane angles with swirl number of 1.33 due to a high swirl number and recirculation zone.

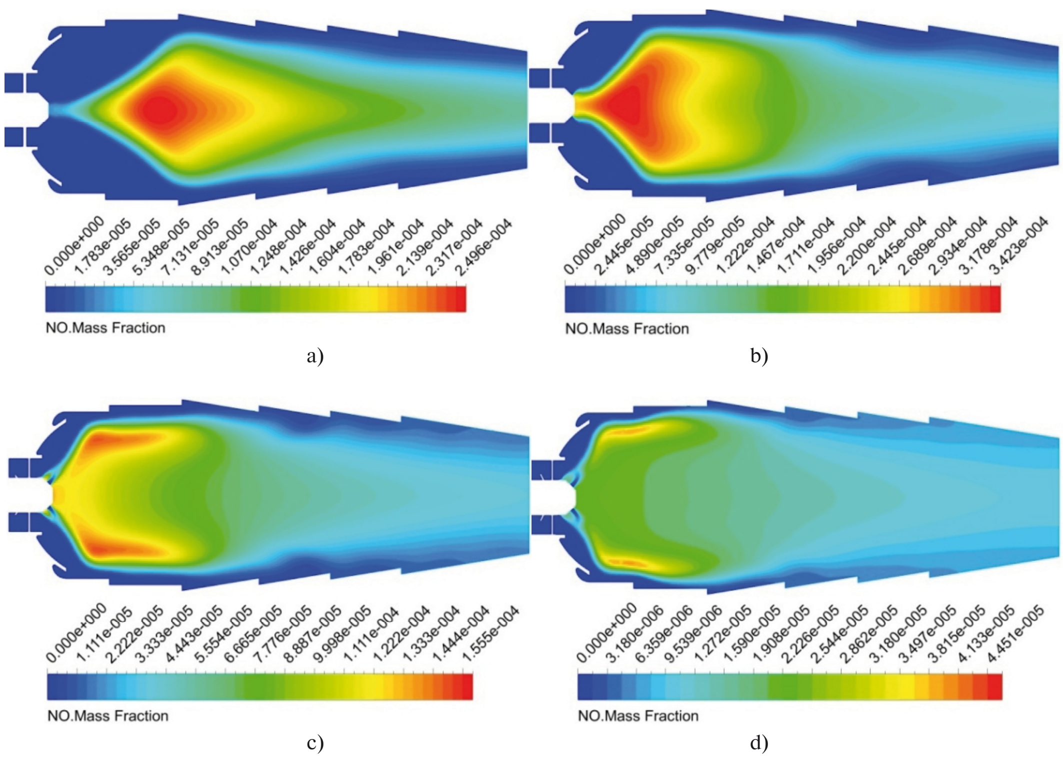
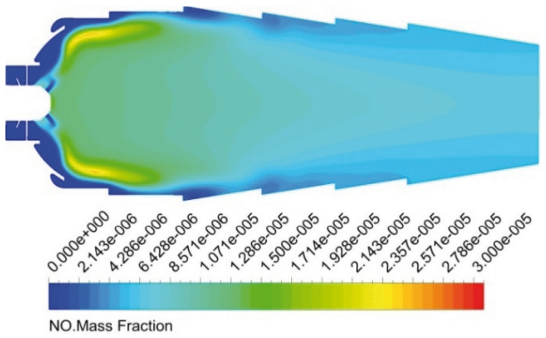


Fig. 7. NO mass fraction distribution contours along XY plane of combustor in different axial swirler vane angles: a) 20 degree; b) 30 dgree; c) 45 degree; d) 55 degree; e) 60 degree



e)

Fig. 7. continue-NO mass fraction distribution contours along XY plane of combustor in different axial swirler vane angles: a) 20 degree; b) 30dgree; c) 45 degree; d) 55 degree; e) 60 degree

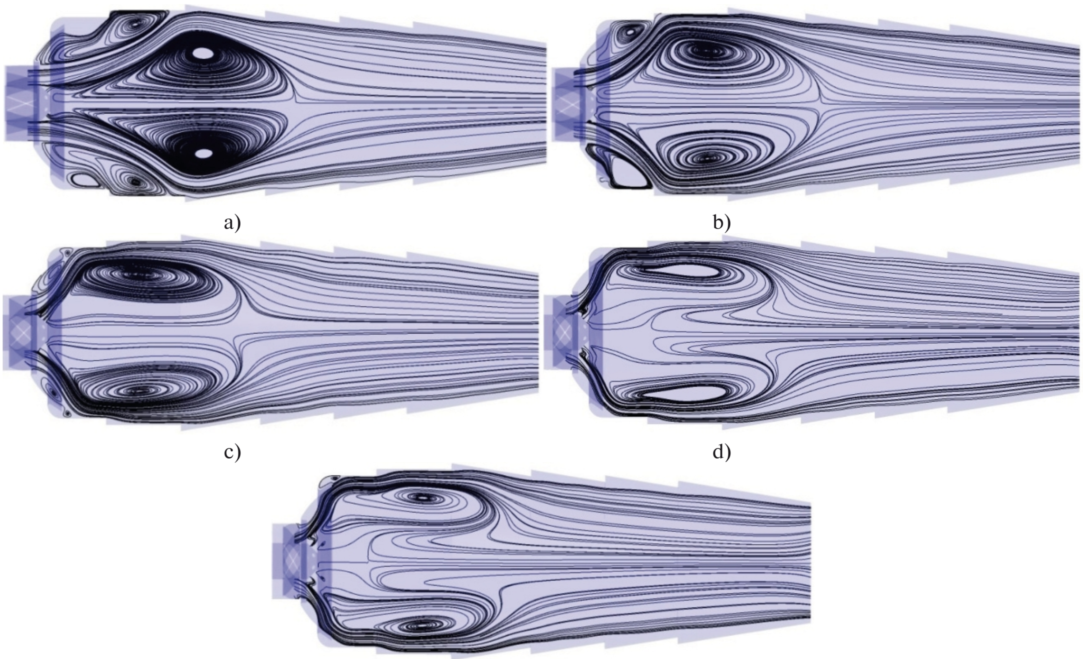
8. Outlet information table and flow streamlines

In Table 2. all the mass fraction and total temperature exiting from combustor outlet and pressure drop of various swirler vane angle are present. In figure 8 flow streamline of central recirculation region (CRZ*)* along the XY plane of combustor are presented for all model of various swirl vane angles.

Table 2.

NO mass fraction and total temperature exiting from combustor outlet and pressure drop of various swirlers

Swir vane angle (degree)	20	30	45	55	60
Outlet NO mass fraction	3.47136×10^{-5}	4.3995×10^{-5}	2.46321×10^{-5}	8.65701×10^{-6}	6.0731×10^{-6}
Outlet total temperature (K)	1295	1293	1285	1283	1283
Pressure drop %	1.0336	1.398	3.144	5.901	8.384

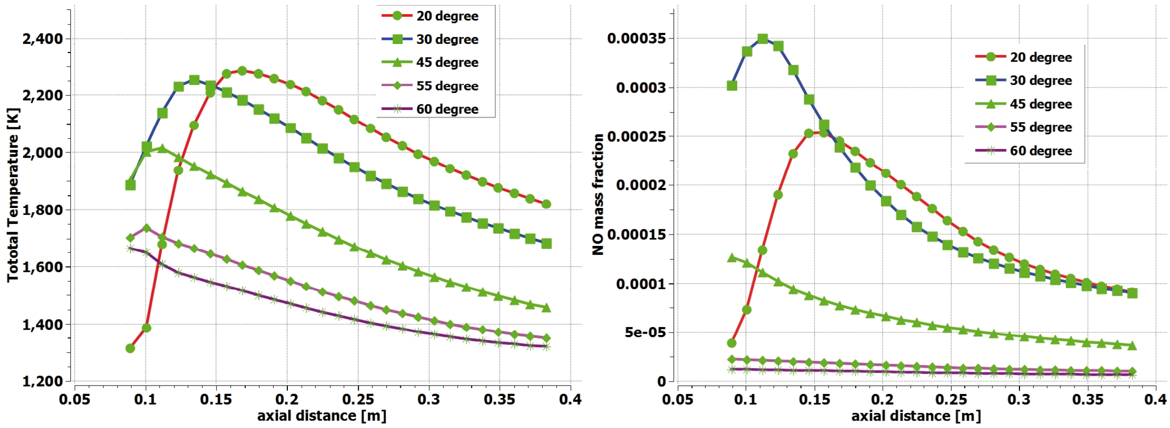


a) b) c) d) e)

Fig. 8. Flow streamline of central recirculation region (CRZ*)* along the XY plane of combustor in different axial swirler vane angles: a) 20 degree; b) 30 dgree; c) 45 degree; d) 55 degree; e) 60 degree

9. The diagrams of distribution of total temperature and NO distribution

The diagram of distribution of total temperature and NO mass fraction along the Y plane (axial distance),are shown in figure 9. We can say that, these diagram of changes are the general view of variations and fluctuations of total temperature and concentration of oxide of nitrogen (NO) along our domain of calculation (can combustor).It is clear that temperature and NO variations along the combustor are different from other with various swirler vane angle.



a b

Fig. 9. a) Total temperature distribution along the Y plane of combustor, b) NO mass fraction distribution along the Y plane of combustor

10. Conclusion

Swirling flow can increase combustor performance by aiding the fuel-air mixing process and by producing recirculation regions which can act as flame holders. Therefore, to reduce emissions and to enhance performance the proper selection of a swirler is needed. The variation in the swirler vane angle has a significant effect on the flow pattern inside the combustor. These can be concluded from the overall streamline pattern, the mean axial and tangential velocity distributions, and turbulence intensity near the inlet. As the swirl number increases, the length and the diameter of the central recirculation zone increases while the size of the corner recirculation decreases (as shown in fig. 8). Furthermore, the turbulence strength represented by the turbulence kinetics energy also increases. On the other hand, the increase in the swirl number results in more losses in the total pressure(pressure drop) which will affect the combustion performances.

The main purpose in this study is to show the effect of the low and high swirl number on flame stabilization, temperature fluctuation and determination of NO distribution along the combustor especially on outlet (exit area) of our domain. The results show that axial swirler with the vane angle of 20 degree and 0.28 of swirl number, has the maximum flame temperature of 2242 K and NO mass fraction of 0.0002496, due to a low swirl number and weak central recirculation zone(CRZ), which cannot provide a good fuel-air mixing rate to perform an acceptable combustion process, but in this case the pressure drop is 1.03% which is the minimum pressure loose in this simulation for this type of swirler angle.

In this study the minimum flame temperature (2172 K and 2188 K) and NO mass fraction of (0.00004451-0.00003) observed in swirler with vane angle of 55 and 60 degree with the swirl number of 1.1 and 1.33. But despite this these 2 cases have the maximum pressure drop of 5.901% and 8.384%, which is a very high.

As observed, the 60 vane angle swirler was able to produce the strongest circulation and highest recirculated mass flow inside the combustion chamber but on the contrary it has the disadvantages of the longest recirculation zone which makes the flame more susceptible to blow off and of the highest losses in total pressure. In the light of this discussion, it can be argued that, the 45° vane angle swirler could be considered as a compromise between turbulence production and pressure losses.

11. References

1. Yehia A. E. prediction of the flow inside a micro gas turbine combustor[Text] / A. E Yehia, J.M Johan, N.M. Mohammad // Jurnal mekanical-June-2008-Vol.25-P. 50-632- Lefebvre A. H. Gas turbine combustion [Text] / A. H Lefebvre, D. R Ballal // CRC press-Third edition- London, New York -2010. -539 p.

2. Syred N. Combustion in swirling flows [Text] / N. Syred, J. M. Beer // Combustion and Flame - 1974, Vol. 23. - P. 143-201.

3. Driscoll J.F. Blowout of non-premixed flames, maximum coaxial air velocities achievable, with and without swirl [Text] / J.F Driscoll, R.H Chen, Y. Yoon // Combustion and Flame - 1992. -Vol. 88.- P. 37-49.

4. Feikema D. Blowout of non-premixed flames: maximum coaxial air velocities achievable, with

and without swirl [Text] / D. Feikema, R.H Chen, J.F Driscoll // combustion and flame. -June 2005.- Vol. 86.-P.347-358.

5. Collin R. industrial Furnace Technology, short course [Text] / R. Collin, J. Ward // Jld. I and II. Porto Cenertec.- Centro De Energia E Technologia.- Portugal.-1990.

6. Fuligno L. An Integrated Design Approach for Micro Gas Turbine Combustors / L.Fuligno, D. Micheli, C. Poloni // ASME Turbo Expo.- Spaine.-2006.

7. Thring M.W The Aerodynamics of Annular Jet Registers [Text] / M.W Thring // Paper presented at 2nd Members Conference.-IFRF.- Ijmuiden, Holland.-1971.

8. Drake P.F. Effect of air swirl on the completeness of combustion [Text] / P.F. Drake, E.H. Hubard // J. Inst. Fuel.-1963. -Vol.-36.- 389 p.

9. Claypole T.C. The Effect of Swirl Burner Aerodynamics on NOx Formation [Text] / T.C Claypole, N.Syred // Eighteenth International Symposium on Combustion. -Vol. 8.- P. 81-89.

10. Mestre A. Efficiency and Pollutant Formation Studies in a Swirling Flow Combustor, Fluid Mechanics of Combustion, Edited by Dussord et al [Text] / A.Mestre // ASME.- New York.-1974

11. JIANG B. Study on NOx Formation in CH4/Air Jet Combustion [Text] / H. LIANG, G. Guoqiang, Xingang L // Chinese J. Chem. Eng., vol 14(6)-2006-p. 723—728.

Submitted to the editorship 16.07.2015

Масуд Хадживанд. Влияние параметров осевых завихрителей на характеристики горения метановоздушной смеси и образование оксида азота

Выполнено CFD моделирование метановоздушной смеси без предварительного смешивания. Цель этой статьи заключается в предоставлении информации о влиянии геометрии лопаток осевых завихрителей на выброс оксидов азота (NO) для трубчатой камеры сгорания газотурбинного двигателя. Показано влияние различных углов установки лопаток завихрителя на образование NO. Воздушный завихритель добавляет достаточное завихрение потоку на входе, чтобы генерировать центральную область рециркуляции (CRZ), которая необходима для стабильности пламени и повышения качества смешивания воздуха и топлива. Поэтому проектирование соответствующего воздушного завихрителя является важной задачей для получения стабильного и эффективного горения с низкими потерями давления и низким уровнем выбросов. В этом анализе использованы пять осевых плоских типов лопаток завихрителя с углами установки 20°, 30°, 45°, 55°, 60°, с числом завихрения 0.28, 0.444, 0.769, 1.1, 1.33, чтобы показать влияние угла установки лопаток на области внутреннего потока, флуктуацию температуры и образование NO. Моделирование выполнено с использованием программы вычислительной гидродинамики (CFD) ANSYS CFX выпуск 16, в том числе ламинарной flamelet модели для имитации горения метана и k-ε модели для турбулентного горения. Формирование термических и быстрых NOx выполняется для прогнозирования характеристики выбросов.

Ключевые слова: *вычислительная гидродинамика(CFD), число завихрения, оксид азота, эмиссия, стабилизация пламени.*

Масуд Хаджіванд. Вплив параметрів осьових завихрителів на характеристики горіння метаноповітряної суміші та створення оксиду азоту

Виконано CFD моделювання метаноповітряної суміші без попереднього змішування. Мета цієї статті полягає в наданні інформації про вплив геометрії лопаток осьових завихрителів на викид оксидів азоту (NO) для трубчастої камери згоряння газотурбінного двигуна. Показано вплив різних кутів установки лопаток завихрителя на створення NO. Повітряний завихритель додає достатнє завихрення потоку на вході, щоб генерувати центральну область рециркуляції (CRZ), яка необхідна для стабільності полум'я і підвищення якості змішування повітря і палива. Тому проектування відповідного повітряного завихрителя є важливим завданням для отримання стабільного та ефективного горіння з низькими втратами тиску і низьким рівень викидів. У цьому аналізі використані п'ять осьових плоских типів лопаток завихрителя з кутом установки 20°, 30°, 45°, 55°, 60°, з числом завихрення 0.28, 0.444, 0.769, 1.1, 1.33, щоб показати вплив кута лопаток на області внутрішнього потоку, флуктуацію температури і створення NO. Моделювання виконано з використанням програми обчислювальної гідродинаміки (CFD) ANSYS CFX випуск 16, в тому числі ламінарної flamelet моделі для імітації горіння метану та k-ε моделі для турбулентного горіння. Формування термічних і швидких NOx виконується для прогнозування характеристики викидів.

Ключові слова: *обчислювальна гідродинаміка (CFD), число завихрення, оксид азоту, емісія, стабілізація полум'я.*