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Design Improvement of GTCP85-180 Micro Gas Turbine Combustor

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ABSTRACT: In this paper, combustion in a GTCP85-180 micro gas turbine combustor is simulated using ANSYS FLUENT in three dimensions by using non-premixed model and given temperature profile. In addition, the chamber is optimized. A Realizable k-ε model is used for turbulence modeling and DO model is used to obtain radiation intensity. The main fuel that is currently used in this type of micro turbine is JP4. Considering that this type of fuel is imported and also according to its pollution, methane as a more available as well as a clean and cheap fuel can be a viable alternative for this micro turbine. The main objective in this research is that without any changes in combustion chamber dimensions and inlet flow, besides achieving an appropriate pattern for methane injection as well as acceptable flame, to attain the optimized chamber. The Flame obtained in this study was acceptable and average outlet temperature of the combustion chamber is proportional to the performance of micro turbine. The results were compared with simulation results for this chamber with kerosene fuel showing the very low percentage of error. The design improvement results show that the temperature in the primary zone of the chamber which causes damage to the parts, has been reduced significantly.

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1- Introduction

An Auxiliary Power Unit (APU) is a device on a vehicle that provides energy for functions other than propulsion. Aircraft APUs generally produce 115 V alternating current (AC) at 400 Hz (rather than 50/60 Hz in mains supply), to run the electrical systems of the aircraft; others can produce 28 V direct current (DC). APUs can provide power through single or three-phase systems. The primary purpose of an aircraft APU is to provide power to start the main engines. The micro turbine that is mounted on this device is able to generate power to generate electricity, hydraulic system and compressed air for aircraft ventilation system and its main engine start. Micro-turbines that are currently mounted on this type of device use JP4 fuel, if switched to methane, in terms of emissions, and the cost of fuel, they have a much better situation. A summary of the research that has been done in the field of simulation of the combustion chamber are given here. Yeshayahou Levy et al. [1] designed and tested a microcombustor for thermal power of about 200 W. Guessab et al. [2] investigated effect of fuels on gas turbine can-type combustor using a CFD code. Aligoodarz [3] numerical simulated a SGT-600 gas turbine combustor and flow field under operation condition investigated. Aghnia [4] simulated GTCP85-180 micro gas turbine combustor with kerosene fuel.

In this paper, design improvement of the gas turbine can-type combustion chamber is investigated in order to reduce temperature of primary zone of combustion chamber.

2- Methodology

GTCP85-180 micro turbine is used to generate axial power and compressed air. Combustion chamber of this micro turbine is can-type. The basic geometry of the gas turbine can-type combustor chamber is shown in Fig. 1. Combustion chamber diameter is 170 mm and its length is 398 mm.

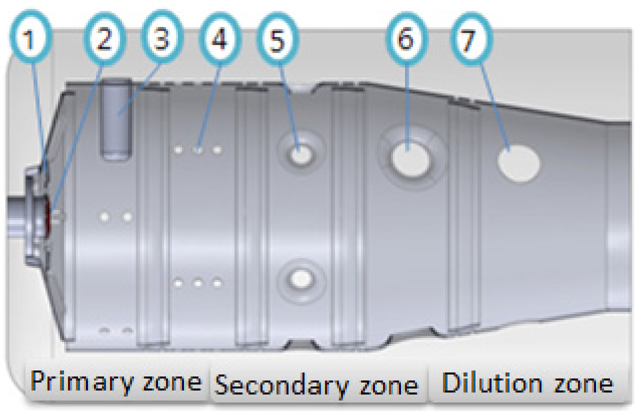

Figure 1. Combustion chamber geometry

1-swirler 2- fuel injector 3- ignitor 4- Cooling air holes 5- flame tubes 6, 7- dilution holes.

The total geometry has been created using the pre-processors SolidWorks and the analysis carried out in ANSYS FLUENT 14 [5] solver. In the present study, unstructured grid has been employed due to the complexity of combustor geometry. To study the independency of the results with respect to the grid size, three grids are used. To control the total number of cells and reduce computational cost, 7261796 nodes can be considered as reaching the required accuracy. The mesh is generated by automatic method and it has been shown in Fig. 2.

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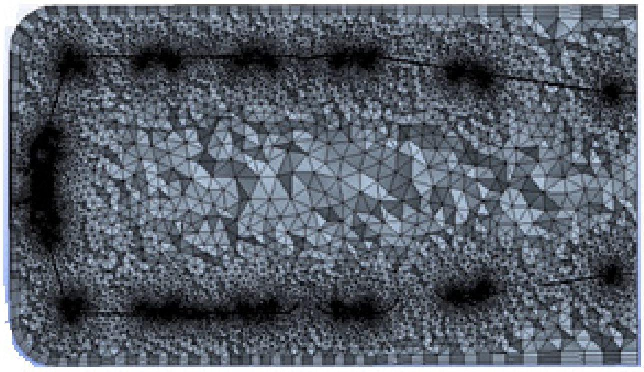

Figure 2. Mesh geometry of combustion chamber

3- Government Equations

The governing equations including the energy, continuity and momentum conservation are as below [6]:T

$$\frac{\partial}{\partial t}(\rho E)+\nabla(\rho V E)=\nabla.\left((K+K_t)\nabla T\right) +\nabla.(\tau V)-\nabla(PV)+S_r+S_h \qquad (1)$$

$$\frac{\partial \rho}{\partial t}+\nabla.(\rho V)=S_m \qquad (2)$$

$$\frac{\partial}{\partial t}(\rho V)+\nabla.(\rho V V)=\nabla.\left((\mu+\mu_t)\nabla V\right)+F \qquad (3)$$

A realizable k-ε turbulence model is used in turbulent combustion simulation [7].

$$\frac{\partial}{\partial x_i}(\rho k u_i)=\frac{\partial}{\partial x_i}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial_k}{\partial x_i}\right]+G_k+G_b -\rho\varepsilon-Y_M \qquad (4)$$

$$C_1=\max\left[0/43,\frac{\eta}{\eta+5}\right]$$

where

σ_k=1, σ_ε= 1.3, $C_{1\varepsilon}$= 1.44, C_2= 1.9

The Radiation heat Transfer Equation (RTE) for an absorbing, emitting and scattering medium at position r and direction s is [8]:

$$\frac{dI(r,s)}{ds}=-(a+\sigma_s)I(r,s)+an^2\frac{\sigma T^4}{\pi} +\frac{\sigma_s}{4\pi}\int_0^{4\pi}I(r,s')\Phi(s,s')d\Omega' \qquad (5)$$

4- Boundary Condition

The following boundary conditions are considered in the computations:

Inlet air mass flow rate is 2.188 kg/s, inlet air temperature is 524 K, fuel mass flow rate is 0.023 kg/s and fuel pressure is 10^5 pa. At the outlet of the combustion chamber, pressure outlet boundary condition is specified.

5- Results and Discussion

Temperature profile in combustion chamber has been shown in Fig. 3. It shows inappropriate heat focus in primary zone of combustion chamber.

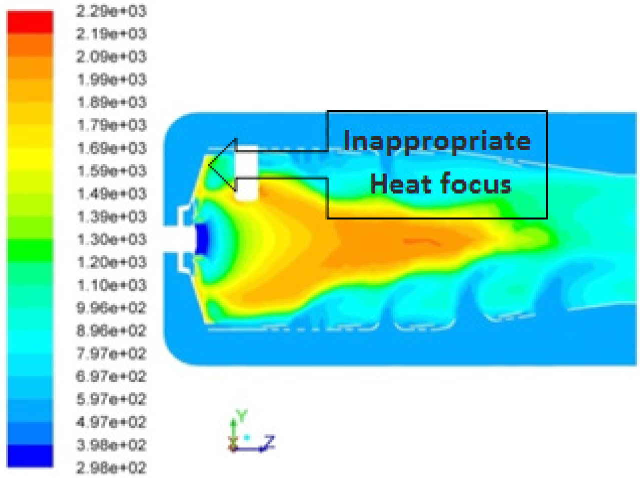

Figure 2. Temperature profile in combustion chamber

This is the reason for welds breaking in this zone. With creation of cooling grooves, without increasing percent of cooling air, the temperature of the wall contour is optimized that has been shown in Fig. 4.

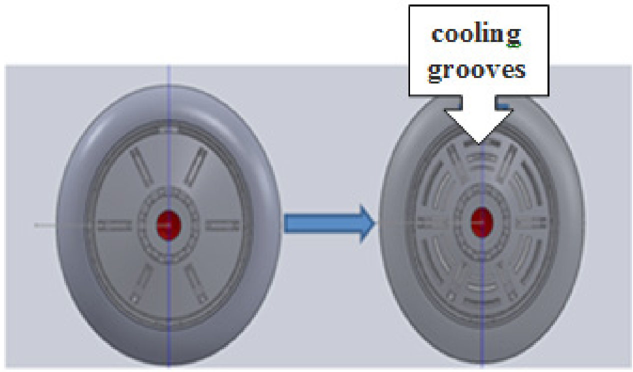

Figure 4. Optimization of primary zone

Temperature profile in combustion chamber has been optimized as shown in Fig. 5.

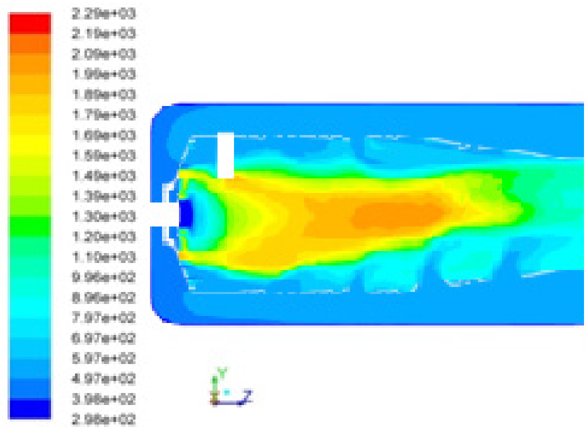

Figure 5. Temperature profile in optimized combustion chamber

6- Conclusions

To achieve proper outlet temperature that can deliver energy to engine speed to 41100 rpm, 0.023 kg/s mass flow rate of methane fuel must be provided with pressure of 10^5 Pa sprayed inside the combustion chamber. Outlet temperature of combustion chamber is 954.1 K, emissions speed is 178.8 m/s and the temperature of primary zone of combustion chamber is 1340.1 K.

After optimization, Outlet temperature of combustion chamber is 952.5 K, emissions Speed is 181.9 m/s and the temperature of primary zone of combustion chamber is 1058.1 K. It is seen that the temperature of the primary zone is cooler about 282 Kelvin.

References

[1] Y. Levy, V. Erenburg, Y. Goldman, V. Sherbaum, V. Ovcharenko, *CFD Assisted Design of MICRO GT combustor*, Faculty of Aerospace Engineering, Israel Institute of Technology, Haifa, 32000, (2009).

[2] A. Guessab, A. Aris, T. Benabdallah, N Chami, Effect of Fuels on Gas Turbine Can-Type Combustor using CFD Code, *Applied Numerical Mathematics and Scientific Computation*, ISBN, (2014) 9781-61804-253-8.

[3] M. Aligoodarz, Numerical simulation of SGT-600 gas turbine combustor and flow field under operation condition, *Journal of Modeling in Engineering*, 10 (31) (2013) 25-35.

[4] M. Aghnia, M. Sedighi, *Identify defects and optimize Micro-turbine combustion chamber numerically*, Master's Thesis in aerospace engineering, satari University of Science and Technology, (2014).

[5] ANSYS® Workbench 2.0 FrameworkTM,14.0.0, (2011) SAS IP, Inc

[6] Z. Orshesh, Numerical Study of Oxygen Enrichment on NO Pollution Spread in a Combustion Chamber, *World Academy of Science, Engineering and Technology*, (2012).

[7] T.H. Shih, W.W. Lion, A. Shabbir, Z. Yang, J. Zhu, A New k-ε Eddy-Viscosity Model for High Reynolds Numerical Turbulent Flows-Model Development and Validation Computers Fluids, (1995) 227-238.

[8] H. Zeinivand, Investigation of reactive two phase flow behavior in a RQL combustor, *fifth fuel and Combustion Conference of Iran*, Iran University of Science and Technology, (2013).

[9] M. Sedighi, M. Aghnia, V. Neisi, Numerical analysis of change Can-type Micro turbine's combustor to annular-type, *Thirteenth Conference of Iranian Aerospace Society*, Tehran university, (2013).

[10] T.O. 2G-GTCP85-23, *Maintenance Instruction Technical Manual* , USAF Series 197.

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