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Numerical Simulation of Film Cooling Around a Gas Turbine Blade via Partially Averaged Navier-Stokes Approach (PANS)

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ABSTRACT

In the present research, film cooling around a gas turbine blade has been studied numerically via partially Navier-Stokes simulation (PANS) approach which is one the approaches of Very Large Eddy Simulation (VLES) in turbulent flow. For detail investigation of flow around gas turbine blade (airfoil with film cooled holes on leading edge) have been simulated in three dimensions and inlet temperature and blade surface temperature has been considered 409.5 K and 297.7 K respectively. Inlet Reynolds number is 8.42×10^5. Inlet flow is fully turbulent and turbulence intensity has been set on 0.052 meanwhile secondary flow effect in up and bottom of blade has been waived. Numerical calculation has been done by Fluent and PANS have been applied to fluent by UDF's. The obtained results from PANS method have been compared with existed experimental data and other RANS two-equations models in other researches and it demonstrate that PANS approach results has admissible correspondence with experimental data. In addition, the results are more accurate than RANS two- equations models.

KEYWORDS:

Gas Turbine Blade, Film Cooling, Turbulence Flow, PANS Approach.

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1- Introduction

The first row of high pressure gas turbine blades are always exposed to high temperature damages. Hot exhaust stream of a combustion chamber passes through blades with a temperature higher than the melting point of the blades metal. Different cooling methods are used for protecting the blades that have been exposed to such high temperature. In film cooling method, part of cold air of compressor via several ducts which are contrived in blades are blown on blade surfaces in order to create a protective layer on them. Due to three-dimensional and complex nature of injected jets to mainstream flow, achieving to an optimal performance cooling system is very difficult. Hence for designing of proper cooling system, it is necessary to know the nature of this complicated flow.

The aim of current research is numerical study of film cooling flow and recognition of coherent structures which affect flow behavior. For this purpose, one of the "very large eddy simulating methods" which is known as "the partially averaged Navier-Stokes (PANS)" has been used.

The governing equations include the continuity, momentum and energy and additional equations for modeling of sub grid scales which have been used by assuming of incompressibility and constant fluid properties.

Grid generation was done by gambit software and numerical calculation was performed by Fluent. In addition, for solving turbulent flow regime by PANS equations, several UDF's have been developed in C++ and exerted to Fluent.

2- Methodology, Discussion, Results

For investigation of flow around gas turbine blade, in first step, required equations have been obtained as below:

$$\frac{\partial k_u}{\partial t}+U_j\frac{\partial k_u}{\partial x_j}=P_u-\beta^* k_u\omega_u+\frac{\partial}{\partial x_j}\left[\left(\frac{\nu_t}{\delta_k}\right)\frac{\partial k}{\partial x_j}\right] \quad (1)$$

$$\frac{\partial \omega_u}{\partial t}+U_j\frac{\partial \omega_u}{\partial x_j}=\alpha\frac{P_u\omega_u}{k_u}-\beta' \omega_u{}^2+\frac{\partial}{\partial x_j}\left[\frac{\nu_u}{\delta_{\omega u}}\frac{\partial \omega_u}{\partial x_j}\right] \quad (2)$$

Which the first equation is for unresolved kinetic energy and the second equation is for unresolved specific dissipation rate.

In second step, related UDF's have been written and added to Fluent in order to solve the flow filed by PANS method. For validating the results, we used flow around a cylinder as a benchmark test case and grid study also has been done for reaching to an optimum grid resolution.

Below Figure 1 shows simulation of the flow around the cylinder at Reynolds 1.4×10^4.

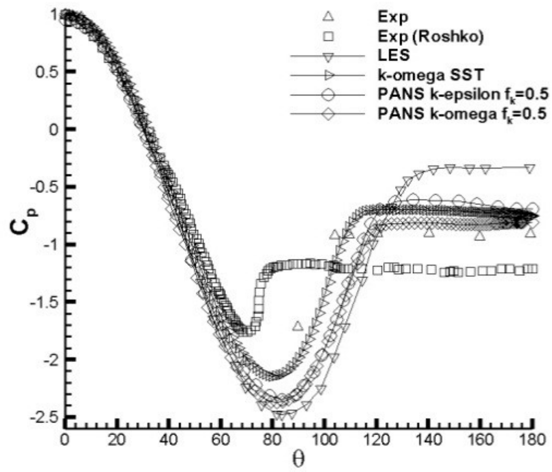

Figure 1. Pressure coefficient curve on the upper half of cylinders

By comparing the results of current research and the existed numerical and experimental data on studies [23,24] expected accuracy has been achieved.

At the final step we apply these UDF's on the Fluent platform for investigation of flow filed around a gas turbine blade. Again the grid study has been done for blade mesh as well.

The result shows data on pressure side is more better that of suction side. The suction side of the blade has more higher reverse-gradients on flow filed in comparison to pressure side of blade and due to this most of two-equations turbulent models have a same problem.

3- Conclusions

In this paper, numerical simulation of film cooling around a gas turbine via "the partially averaged Navier-Stokes (PANS)" has been studied and the main results are as follows:

- k-ω (PANS) has good ability to simulate high Reynolds flow and considering that the cut-off of filter of this method is in Taylor's scale, hence the larger share of turbulent energy spectrum has been solved directly.
- In areas which the flow is high isotropies and has the non-equilibrium effects, for example the suction side of gas turbines blade and cooling jet entry points into the mainstream, these models will reach to answers that are

ultimately over-diffuse. It means that the turbulent viscosity which has been calculated by this method is higher than real amount.

4- References

[1] M. Consigny, and B. E. Richards, 1981. "*Short Duration Measurements of Heat-Transfer Rate to a Gas Turbine Rotor Blade*", International Gas Turbine Conference and Products Show, Houston, Texas, March 9-12.

[2] R. Kiock, F. Lehthaus, N. C. Baines, and C. H. Sieverding, 1985. "*The Transonic Flow Through a Plane Turbine Cascade as Measured in Four European Wind*", International Gas Turbine Symposium and Exposition, Beijing, People's Republic of China, September 1-7.

[3] V. G. Garg, and A. A. Ameri, 1997. "Comparison of Two-equitation Turbulence Models For Prediction of Heat Transfer on Film-Cooled Turbine Blades" *Numerical Heat Transfer*, Part A, Issue 31, p.p. 347-371.

[4] S. S. Girimaji, E. Jeong, , and R. Srinivasan, 2006. "Partially Averaged Navier-Stokes Method for Turbulence: Fixed Point Analysis and Comparison With Unsteady Partially Averaged Navier-Stokes" *Journal of applied mechanics*, 73, Issue 1, p.p. 422-429.

[5] S. Lakshimpathy, 2004. "*PANS Method for Turbulence:Simulation of High and Low Reynolds Nymber Flows Past a Cyrcular Cylinder*" , M. Sc. Thesis, Texas A&M University, December.