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Assessment of RANS Turbulence Models for Prediction of Adiabatic Film Cooling Effectiveness for Shaped Film Holes

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Abstract

Film cooling is one of the superior cooling technologies utilized in high-performance gas turbines. Accurate numerical simulations play an important role in designing and analyzing film cooling systems. Comparison of results from existing mathematical models with experimental results is essential to validate models and select suitable models for applications. In order to perform the comparison, three selected RANS turbulence models of Standard k-ω, SST k-ω and realizable k-ε were used to predict the adiabatic film cooling effectiveness without any modification. An experimental case of shaped cooling hole was set up in ANSYS Fluent with the blowing ratio of 3 and density ratio of 1.5 while free stream turbulence was 0.5%. The injection angle of the hole was set to 30^0 while the laidback angle and lateral angle were 7^0. The computational domain consists of a single hole with symmetry boundary conditions while the pitch to diameter ratio was maintained at 6. ANSYS Mesh was used to generate the required mesh for the domain. Mesh sensitivity analysis was performed to identify the mesh independent solution. The Y+ value near the adiabatic hot surface was set to 1.

The numerical results from a realizable k-ε model with enhanced wall treatment have shown good agreement in laterally averaged film cooling effectiveness compared to the other two models. The same model has presented a similar effectiveness pattern in the lateral direction while the other two have shown a bimodal pattern as well as jet skewness. The increase in lateral spreading of the effectiveness in the downstream direction has been captured by a realizable k-e model better than the other two models. The centerline film cooling effectiveness has been over-predicted by the three turbulence models. The over-prediction of centerline effectiveness can be found in the past studies, which has been estimated due to the inability to model the anisotropy of two equation turbulence models. The predictions of realizable k-ε at the downstream location of X/D = 5 have been closer to the experimental results than that of X/D = 30. Thus it can be concluded that the lateral spreading of film cooling effectiveness is not predicted well far downstream.

Keywords: *Adiabatic effectiveness, film cooling, shaped hole, turbulence modeling*

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