ABSTRACT

Reduction of the specific fuel consumption of gas turbines can be achieved by maximizing the turbine inlet temperature. So it will be important to develop the cooling performance in order to ensure safe and economical operation of the engine. Cylindrical holes film cooling technique is one of the common film cooling techniques. But in cylindrical holes film cooling technique, there are pair of counter rotating vortices due to the intersection between the coolant inclined jet and the mainstream. These vortices cause the jet to lift off.

An Experimental test rig is constructed to study different configurations of the anti-vortex film cooling technique. This technique depends on adding a pair of cylindrical anti-vortex holes branching out from the main cylindrical film cooling holes to mitigate the effect of kidney vortices that causes the jet to lift off. Four different values of velocity ratios VR, (coolant jet velocity/main stream velocity) namely 0.5, 1.0, 1.5, and 2.0, are studied with three different positions of anti-vortex holes. A single row of 30^o angled holes on a flat surface, under zero pressure gradient, along the downstream test surface, is taken as a baseline. An applied pressure gradient (adverse pressure gradient) is also studied experimentally for all cases to simulate the pressure gradient on turbine blades.

A numerical study is carried out by using *k-ε turbulence model* on FLUENT Program. The density ratio is taken into consideration. Numerical results are first compared with experimental values of temperatures and film cooling effectiveness and the comparisons verified the numerical model. The numerical solution helps in finding a good explanation for the behavior of the interaction between the coolant jet and the mainstream flow. The numerical model is used to study three different pressure gradients (two adverse and one favorable pressure gradient).

Both of experimental and numerical studies show that the used anti-vortex technique improves the film cooling effectiveness. The numerical boundary layer velocity vectors showed that the anti-vortex holes create

reverse vortices against the main vortices that are created by the main hole. These reverse vortices help in keeping the coolant jet flow near the surface.

The use of the first studied adverse pressure gradient gives a significant effect with the anti-vortex cases in which the anti-vortex holes are located upstream the main film cooling hole as compared with the same ZPG (Zero Pressure Gradient). It reduces the film cooling effectiveness by about 12.3 % for case 1(in which the anti-vortex holes branched out far upstream from the main hole) up at VR=2.0 and about 9.2 % for case 1 at VR = 0.5. The adverse pressure gradient gives no considerable effect for all other cases studied. Further increase of the value of adverse pressure gradient shows higher reduction of film cooling effectiveness. It shows that the overall area - averaged film cooling effectiveness is reduced by about 21.4% for case 1 at VR = 2.0 and about 25.7 % for case 1 at VR = 0.5.

The favorable pressure gradient shows little enhancement in the film cooling effectiveness. It increases the film cooling effectiveness by about 3.4 % for case 1 at VR = 2.0 and about 5.3% for case 1 at VR = 0.5 as compared with case 1 under ZPG.

It is concluded that the use of anti-vortex holes produced a considerable effect on the overall area-averaged film cooling effectiveness. The increase ranges from 40% for VR = 0.5 to 606% for VR = 2. Film cooling effectiveness is not considerably affected by pressure gradients.