Abstract

Turbine blades require better cooling technique to cope with the increase in the operating temperature with each new engine model. Film cooling is one of the most efficient cooling methods used to protect the gas turbine blades from the hot gases. Holes arrangement offers reliable technique to improve the effectiveness of the film cooling.

The present work concentrates on the experimental and numerical investigations of film cooling performance for two rows of circular holes. Seven models with different holes arrangement, holes orientation and inclination angle, are investigated. Each model is provided with two rows of holes, one of these models is inline and the others are with stagger arrangement. The diameter of the hole is 4mm, the space between rows is four times the diameter, and the span to diameter ratio is 3. Three blowing ratios of (BR= 0.5, 1.0, and 1.5) were investigated during the experimental and numerical program, therefore three mainstream Reynolds number based on hole diameter (Re_d) of (3000, 4500 and 9000) were achieved.

The numerical model is suitable to design holes arrangement futures of film cooling system by introducing staggered oriented jet holes row over single jet holes row and it is casted using computer code Fluent. The numerical investigation predicts well the flow behavior of the injected cooled jet to the hot mainstream, and shows that two large vortices have been detected,(i.e.) large counter rotating vortex pair generated from the hole rims, and horseshoe vortices, and both have major effects on cooling performance.

The film cooling effectiveness and the local heat transfer coefficient for different jet holes arrangement have been investigated experimentally on a flat plate. The experimental work was carried out using a single test

transient IR thermography technique. Evaluation of the cooling performance is obtained by using both film cooling effectiveness and heat flux ratio technique.

The experimental results showed that using upstream oriented jet holes row over conventional single jet holes row did enhance the average cooling performance by 20.7%, 28.9%, and 37.8% at BR= 0.5, 1.0, and 1.5 respectively. For the present approach, the result showed that for the same inclination and orientation angles, the staggered arrangement gives better cooling performance than the inline arrangement by (28%, 17%, 13%) for the blowing ratios of (0.5, 1.0, 1.5) respectively. The staggered model gives better thermal performance at an orientation angle of 180º and inclination angle of 20º in the upstream row and an orientation angle of 0º and inclination angle of 30º in the downstream row. Decreasing the upstream row jet inclination angle to 20º leads to an increase in the vortex strength in the parallel plane to the mainstream flow, as well as enhance the film cooling effectiveness. The results showed also that when introducing trench within the downstream hole row provides significant improvement to the average cooling performance by (40.3%, 33.4%, 55%) over the rang of the tested blowing ratio. The evaluation of cooling performance did detect well by using heat flux ratio technique rather than effectiveness technique whereas the later did not detects the effects of resistance of heat transfer created by film coolant.