Experimental investigations of the film cooling effectiveness of a Micro-Tangential-Jet Scheme on a Gas Turbine Vane

O. Hassan and I. Hassan

Abstract:

This paper presents experimental investigations of the film cooling effectiveness of a Micro-Tangential-Jet (MTJ) Film cooling scheme on a gas turbine vane using transient Thermochromic Liquid Crystal (TLC) technique. The MTJ scheme is a micro-shaped scheme designed so that the secondary jet is supplied tangentially to the vane surface. The scheme combines the benefits of micro jets and tangential injection. The film cooling performance of one row of holes on both pressure and suction sides were investigated at a blowing ratio ranging from 0.5 to 1.5 on the pressure side and 0.25 to 0.625 on the suction side. The average density ratio during the investigations was 0.93, and the Reynolds Number was 1.4E+5, based on the free stream velocity and the main duct hydraulic diameter. The pitch to diameter ratio of the cooling holes is 5 on the pressure side and 6.5 on the suction side. The turbulence intensity during all investigations was 8.5%. Minor changes in the Mach number distribution around the airfoil surface were observed due to the presence of the MTJ scheme, compared with the case with no MTJ scheme. The investigations showed great film cooling performance for the MTJ scheme, high effectiveness values and excellent lateral jet spreading. The performance of tangential injection over actual airfoil surfaces was found close, qualitatively, to that observed over flat plate. A 2-D coolant film was observed in the results, which is a characteristic of the continuous slot schemes only. The presence of this 2-D film layer helps minimize the rate of mixing between the main and the secondary streams. This film help establish uniform thermal loads on the surface. Furthermore, it was noticed that the rate of effectiveness decay on the suction side was lower than that of the pressure side while the lateral jet spreading on the pressure side was better than on suction side. The main disadvantage of the MTJ scheme is the increased pressure drop across the scheme, compared to traditional shaped schemes.

Keywords:

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Experimental Investigations of the Film Cooling Heat Transfer Coefficient of a Micro-Tangential-Jet Scheme on a Gas Turbine Vane

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Abstract:

This paper presents experimental investigations of the Heat Transfer Coefficient (HTC) performance of a Micro-Tangential-Jet (MTJ) Film cooling scheme on a gas turbine vane using transient Thermochromic Liquid Crystal (TLC) technique. The MTJ scheme is a micro-shaped scheme designed so that the secondary jet is supplied parallel to the vane surface. In order to supply the jet in a direction parallel to the vane surface, extra material was added on both pressure and suction sides. The film cooling performance of one row of holes on both pressure and suction sides were investigated at a blowing ratio ranging from 0.5 to 1.5 on the pressure side and 0.25 to 0.625 on the suction side, calculated based on the MTJ scheme exit area. The average density ratio during the investigations was 0.93, and the Reynolds number was 1.4E+5, based on the free stream velocity and the main duct hydraulic diameter. The pitch to diameter ratio of the cooling holes is 5 on the pressure side and 6.5 on the suction side. The turbulence intensity during all investigations was 8.5% and was measure two chords upstream the vane leading edge using the PIV technique. The investigations showed that the increase in the HTC ratio due to the presence of the MTJ scheme is very close to that resulting from the presence of normal traditional shaped schemes on the pressure side. Meanwhile, a reduction in the HTC ratio is recorded on the suction side. The performance is attributed to the small overall height of the scheme which helped keep the resulting turbulence to a minimum. Moreover, the HTC distribution downstream the MTJ scheme is uniform in the lateral directions which helps minimize the thermal stresses. The Net Heat Flux Reduction (NHFR) parameter is used to judge the overall performance of the MTJ scheme. The NHFR represents a combination of the effects of both the cooling effectiveness and the HTC. Great enhancement in the NHFR performance of the MTJ was observed compared to traditional shaped schemes. With the current MTJ scheme design and dimensions and under the previously mentioned Reynolds number and turbulence intensity it was observed that a blowing ratio close to unity, calculated based on the scheme exit area, provides an optimal film cooling performance on both pressure and suction sides.

Keywords:
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Numerical investigations of the effect of flow arrangement and number of layers on the performance of multi-layer microchannel heat sinks,

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