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Effects of Channel Orientation on Heat Transfer in a Rotating Rectangular Channel with Jet Impingement Cooling and Film Coolant Extraction

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Abstract : The turbine blade's leading edge is usually cooled by jet impingement cooling technology due to the heaviest heat load. For a rotating turbine blade, however, the channel orientation (β, the angle between the jet direction and the rotating plane) could play an important role in influencing the flow field and heat transfer. Therefore, in this work, the effects of channel orientation (from 90° to 180°) on heat transfer in a jet impingement cooling channel are experimentally investigated. Furthermore, the investigations are conducted under an isothermal boundary condition. Both the jet-to-target surface distance and jet-to-jet spacing are three times the jet hole diameter. The jet Reynolds number is 5,000, and the maximum jet rotation number reaches 0.24. The results show that the rotation-induced variations of heat transfer are different in each channel orientation. In the cases of 90°≤β≤135°, a vortex generated in the low-radius region of the supply channel changes the mass-flowrate distribution in each jet hole. Therefore, the heat transfer in the low-radius region decreases with the rotation number, whereas the heat transfer in the high-radius region increases, indicating that a larger temperature gradient in the radial direction could appear in the turbine blade's leading edge. When 135°<β≤180°; however, the heat transfer of the entire stagnant zone decreases with the rotation number. The rotation-induced jet deflection is the primary factor that weakens the heat transfer, and jets cannot reach the target surface at high rotation numbers. For the downstream regions, however, the heat transfer is enhanced by 50%-80% in every channel orientation because the dead zone is broken by the rotation-induced secondary flow in the impingement channel.

Keywords : heat transfer, jet impingement cooling, channel orientation, high rotation number, isothermal boundary
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