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Numerical Study on the Effects of Truncated Ribs on Film Cooling with Ribbed Cross-Flow Coolant Channel

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Abstract : To evaluate the effect of the ribs on internal structure in film hole and the film cooling performance on outer surface, the numerical study investigates on the effects of rib configuration on the film cooling performance with ribbed cross-flow coolant channel. The base smooth case and three ribbed cases, including the continuous rib case and two cross-truncated rib cases with different arrangement, are studied. The distributions of adiabatic film cooling effectiveness and heat transfer coefficient are obtained under the blowing ratios with the value of 0.5 and 1.0, respectively. A commercial steady RANS (Reynolds-averaged Navier-Stokes) code with realizable k-ε turbulence model and enhanced wall treatment were performed for numerical simulations. The numerical model is validated against available experimental data. The two cross-truncated rib cases produce approximately identical cooling effectiveness compared with the smooth case under lower blowing ratio. The continuous rib case significantly outperforms the other cases. With the increase of blowing ratio, the cases with ribs are inferior to the smooth case, especially in the upstream region. The cross-truncated rib I case produces the highest cooling effectiveness among the studied the ribbed channel case. It is found that film cooling effectiveness deteriorates with the increase of spiral intensity of the cross-flow inside the film hole. Lower spiral intensity leads to a better film coverage and thus results in better cooling effectiveness. The distinct relative merits among the cases at different blowing ratios are explored based on the aforementioned dominant mechanism. With regard to the heat transfer coefficient, the smooth case has higher heat transfer intensity than the ribbed cases under the studied blowing ratios. The laterally-averaged heat transfer coefficient of the cross-truncated rib I case is higher than the cross-truncated rib II case.

Keywords : cross-flow, cross-truncated rib, film cooling, numerical simulation
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