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Compound Angle Sister Hole Location Effect on Film Cooling Performance.

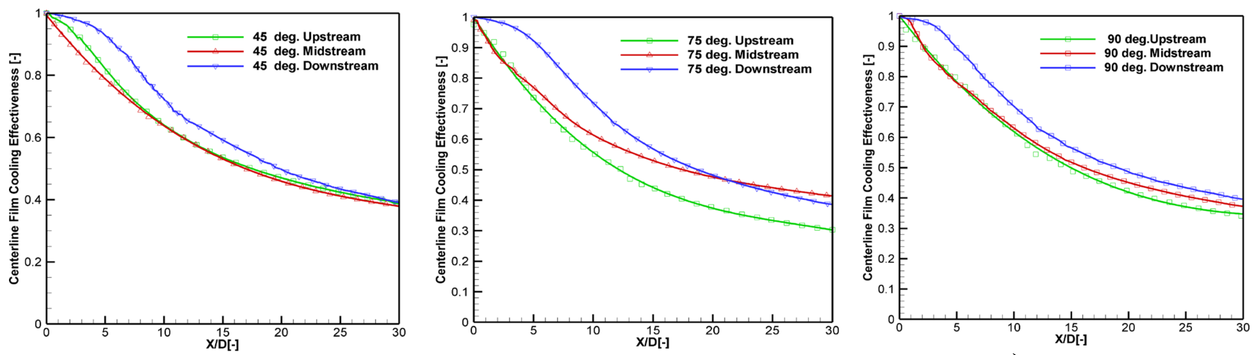
Abstract

The recent increase in the economic and environmental demands requires to operate the gas turbine engines at the highest performance which can be achieved by operating the engines at a maximum turbine inlet temperature. As such, advanced cooling techniques are used to enhance the thermal protection of turbine blades. Compound angle sister holes (CASH) are simple and effective hole configuration proposed to improve the film cooling performance. In which, two small round compound sister holes are injected at several compound angles β = 45°, 75°, and 90°, while the main hole is streamwise injected at 35° on a flat plate model. In the present numerical study, the effect of the streamwise location of the compound angle sister holes relative to the center of the main hole is investigated whereas three locations are examined, namely: Upstream, Midstream, and downstream for each CASU. The simulation is carried out in Fluent ANSYS by solving the 3D RANS equations, and the analysis is conducted at two blowing ratios M= 0.5 and 1.5 and density ratio (D.R=2). Compound angle sister holes exhibit a notable improvement in film cooling effectiveness at low and high blowing ratios. At each examined CASH at β = 45°, 75°, and 90°, it was found that the best centerline effectiveness is obtained by placing the compound angle sister holes downstream the main hole for the entire downstream region at M=0.5 compared to the other two locations, whilst at M=1.5 the downstream location gives the highest centerline effectiveness mostly in the hole vicinity region at 5 > X/D > 10. The optimum laterally averaged film cooling performance is attained for each CASH by placing the compound angle sister hole in a midstream location for both M=0.5 and M=1.5. Furthermore, it is found that when comparing the centerline and lateral film cooling effectiveness of various β = 45°, 75°, and 90° at a specific location, the location of compound angle sister holes has a significant effect only at high blowing ratio M=1.5. The anti-counter-rotating vortices that appear in the flow structure results have a major effect on the present cooling performance.

1. Introduction

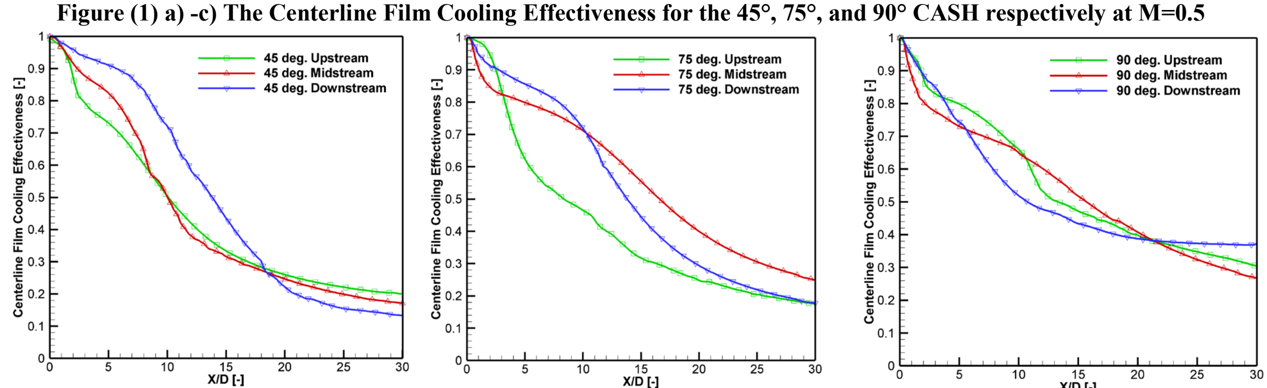
Increasing the thermal efficiency and power output of gas turbine engine and maintaining the techno-economic demand of its marketplace are continuously pushing towards an increase in the turbine inlet temperature (TIT) which can be achieved by advanced turbine cooling [1]. A typical (TIT) in today's engine reached around 2000 [K] [2]; which is way above the material melting point of the turbine blades. Thus, to prevent the turbine blades from thermal failure, film cooling is commonly used and considered as an efficient cooling technique [3], [4]. For better performance, the sister holes film cooling is one of the methods proposed to enhance the film cooling performance from multiple round holes. Ely and Jubran [5]–[7] performed several early studies that introduced the sister holes film cooling concept whereas the sister holes are injected to the streamwise direction. This study uses the compound angle sister holes (CASH) as a simple and effective hole configuration to improve the film cooling performance and investigate the influence of compound angle sister holes location on the performance. In which, two small round compound sister holes are injected at several compound angles β = 45°, 75°, and 90°, while the main hole is streamwise injected at 35° on a flat plate model. The effect of the three streamwise locations of the compound angle sister holes relative to the center of the main hole is examined and analyzed, namely: Upstream, Midstream, and downstream for each compound angle sister holes.

2. Results



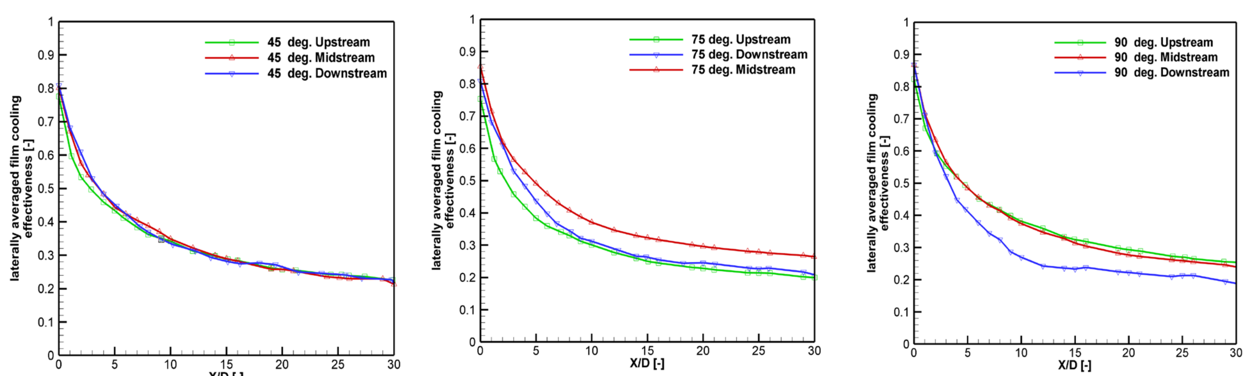
a) 45° CASH b) 75° CASH c) 90° CASH

Figure (1) a) -c) The Centerline Film Cooling Effectiveness for the 45°, 75°, and 90° CASH respectively at M=0.5



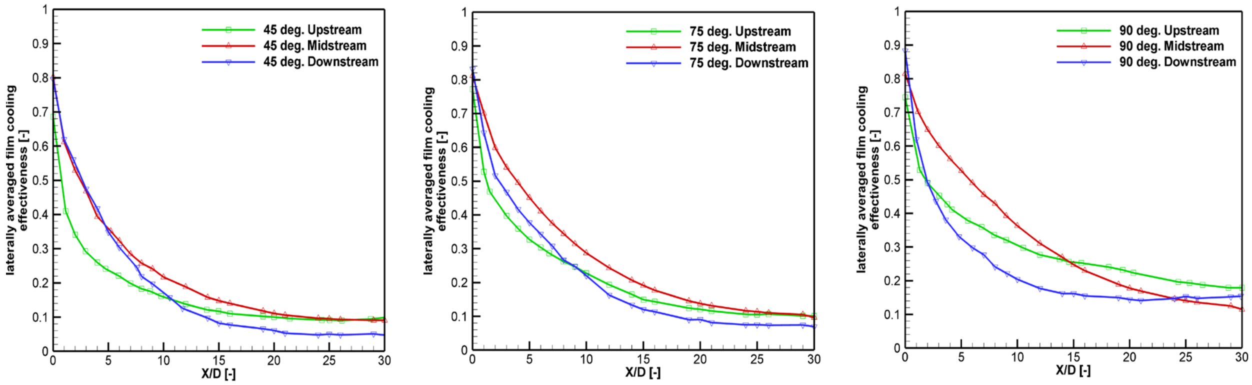
a) 45° CASH b) 75° CASH c) 90° CASH

Figure (2) a) -c) The Centerline Film Cooling Effectiveness for the 45°, 75°, and 90° CASH respectively at M=1.5



a) 45° CASH b) 75° CASH c) 90° CASH

Figure (3) a) -c) The Laterally Averaged Film Cooling Effectiveness for the 45°, 75°, and 90° CASH respectively at M=0.5



a) 45° CASH **b) 75° CASH** **c) 90° CASH**

Figure (4) a) -c) The Laterally Averaged Film Cooling Effectiveness for the 45°, 75°, and 90° CASH respectively at M=1.5

3. References

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