Numerical Simulations on Heat Transfer inside an Integrated Impingement Cooling System for Higher TIT Turbine Blades

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1. Introduction

This paper deals with extensive numerical studies on heat transfer characteristics and fluid dynamics inside several configurations of impingement cooling device combined with pins. Great attention was paid to turbulence model and its screening inspection was executed to choose the turbulence model from those available in the software which was able to reproduce the experimental heat transfer characteristics best. Parametric studies are then made to clarify effects of important dimensions, such as pin height, pin pitch, upon local and averaged heat transfer characteristics as well as pressure loss generated in the devices. This study also introduced an index derived by the combination of the averaged heat transfer characteristics (Nusselt number) and the pressure loss coefficient.

2. Methodology

Figure 1 shows a schematic of the cooling device of concern that consisted of two plates, i.e., impingement plate and target plate, and pins. Also shown is the grid system for analysis using CFX4.4. The pins were equally-spaced in the x and y directions with the pitches of P_x and P_y. The impingement plate had impingement holes of x direction pitch P_x and y direction pitch $2P_y$. Discharging holes on the target plate had the same pitches as those of the impingement holes. For simplicity, all diameters of the impingement hole, discharging hole and pin were the same and equal d throughout this study. In the baseline case each of the impingement holes or discharging holes was located at the center of the rectangular formed by 4 pin centers, P_x and P_y equal $2.5d$.

3. Conclusions

(1) The adopted CFD solver with $k-\omega$ turbulence model reproduced the experimental heat transfer.

(2) For the baseline configuration, the averaged Nusselt number on the pin as well as the pressure loss decreased with the pin height, whereas the averaged Nusselt number on the target plate exhibited very weak dependency to the pin height.

(3) The pin with the height of more than 2 times pin diameter did not contribute to the increase in effective wetted area.

(4) The averaged Nusselt number increased with the Reynolds number almost in a linear fashion on the target plate as well as the pin.

(5) The pin played a very important role in the enhancement of overall heat transfer or heat exchange performance. In this sense relative pin position to the impingement hole should be carefully selected when applying this technology to actual turbines.

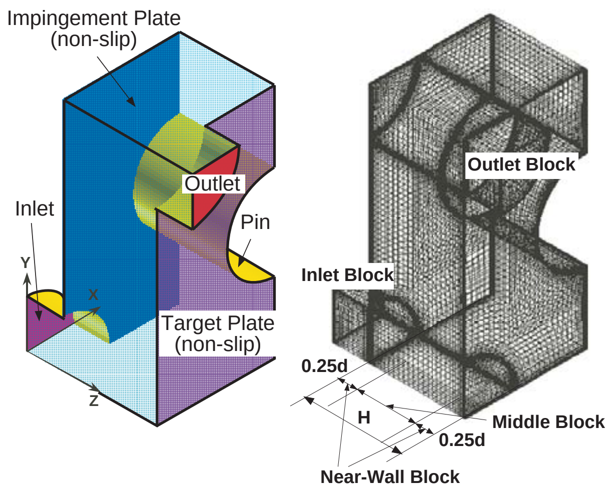

Figure 1 Schematic of the target cooling device and its grid system for CFD analyses

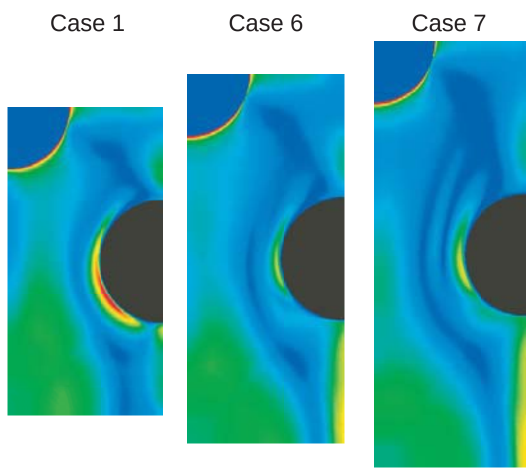

Figure 2 Heat transfer distributions on the target plate for three configurations

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