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Investigation of heat transfer and fluid flow behavior between straight and inclined fins in tall duct

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ABSTRACT

This paper describes the flow behavior and flow patterns developed by straight and inclined fins and their affect on heat transfer characteristics. A detailed experimental investigation of the heat transfer and flow characteristics of finned surfaces was conducted for airflow (Re = 3824–12,747) in a tall duct corresponding to 200 mm height. In this experiment short rectangular fins were attached in 7 × 7 arrays to a heating surface and exposed to airflow. T-type thermocouples and an infrared camera with a 160 × 120-point In–Sb sensor were used to measure the wall temperature and to get the detailed heat transfer coefficient over the endwall and fin base. A thermal image and the iso-heat transfer coefficient contour give a complete picture of the heat transfer characteristics of the endwall surface. Smoke flow visualization reveals the longitudinal vortex generated by the inclined fins which significantly enhances the heat transfer in the inter-fin region and the fin surfaces. From the time averaged velocity profiles and spanwise velocity distributions a non-continuous curve caused by the detachment or reattachment of the flow was observed which confirms the existence of a longitudinal vortex in the case of inclined fins. But the horseshoe vortex appeared for both straight and inclined fins. The Nusselt number shows that heat transfer enhancement at a factor of more than three times than the finless duct is achieved for the inclined fins whereas straight fins could reach upto an enhancement of more than two times.

1. Introduction

Thermal management, or temperature control, is a great concern for heat generating bodies, for example, power plants, nuclear reactors, engines, motors, heat exchangers, process industries, generators, electronic equipment, and digital computers, even in space craft. If the heat generated in a machine is not removed at a sufficient rate, some problems, including breakdown, can take place in the machine due to overheating. This type of problem can only be overcome by a more efficient heat transfer. Fins are widely used as the primary means of heat exchange in devices. The need for more efficient cooling techniques in devices has recently prompted study into heat transfer and flow characteristics of various configurations of finned surfaces. The pin fin is a typical configuration that is often used to cool the trailing edge region of turbine blades; the internal passage of turbine blades can be very narrow, so the choice of cooling scheme is limited. Recently, an inclined rectangular fin attached to the endwall was found to be an effective vortex generator for heat transfer enhancement, wherein a longitudinal vortex is produced with intensity far downstream. It is expected that the heat transfer from the endwall and the fin surface can be improved and hence we have identified this configuration as being very promising. Heat transfer enhancement in arrays of rectangular blocks has been investigated by many researchers. Sparrow et al. [1,2] studied the heat transfer and pressure drop characteristics of arrays of rectangular modules commonly encountered in electronic equipment. In their experiment, heat transfer enhancements exceeding a factor of two were achieved by the use of multiple fences like barriers, with the inter barrier spacing and the barrier height being varied parametrically along with the Reynolds number. Igarashi [3] studied heat transfer from a square prism with different inclination angles and observed reattachment flow for inclination angles of 14°–35°. Turk and Junkhan [4] measured the spanwise heat transfer downstream of a rectangular fin mounted on a flat plate. Oyakawa et al. [5] studied the heat transfer of plate setting rectangular fins with an angle of 20° and showed that this configuration can enhance heat transfer. El-Saed et al. [6] investigated heat transfer and fluid flow with rectangular fin arrays and found that the mean Nusselt number increases with an increasing Reynolds number, inter-fin space and fin thickness, but they did not examine the endwall heat transfer.

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