RESEARCH ARTICLE

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Experimental Study of Heat Transfer Coefficients on the Plate with Confined Impinging Jet Array

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This work investigated the local and mean heat transfer characteristics of the plate under the confined impinging jet array. The transient liquid crystal method was employed to obtain the detailed measurements of heat transfer coefficients. Variable parameters were the ratio of the impinging distance to the jet nozzle's diameter (*H/d*), the ratio of axial lengths of the oval jet nozzle (*AR*), the mode of the exit flow orientation and the jet Reynolds number. Experimental results indicated that the peak values of Nu of the circular-jet-nozzle systems ($AR = 1$) were higher than those of oval-jet-nozzle systems ($AR = 0.5$ and 2). Additionally, the peak values of Nu reduced much more at the more downstream regions, especially for the single-exit flow orientation modes (Mode I and III) or the oval-jet-nozzle systems. Increasing *H/d* would decrease $\overline{Nu}$ significantly. Furthermore, the $\overline{Nu}$ of circular-jet-nozzle systems ($AR = 1$) were generally higher than those of oval-jet-nozzle systems ($AR = 0.5$ and 2). The systems of $AR = 0.5$ and 1 had the similar sensitivity of Re to $\overline{Nu}$. The system of $AR = 2$ had the worst sensitivity of Re to $\overline{Nu}$. Finally, based on all data, this work provided the empirical relationships between the $\overline{Nu}$ and *Re*.

Keywords: Impinging Jet Array, Transient Liquid Crystal Method, Heat Transfer.

1. INTRODUCTION

Improving the heat transfer on fluid and solid surfaces has been an important issue in engineering, such as micro-electronic parts, heat exchangers, cooling of gas turbines, etc. Among the technologies for improving heat transfer, the impinging jet flow is one of the most effective methods for improving local heat-transfer coefficients. There are abundant literatures discussing impingement cooling technologies, basically, these literatures can be divided into two types, namely single-hole impingement cooling related studies and multi-hole impingement cooling related studies, according to the physical parameters and size parameters.

Behnia et al.[1] used numerical implementation to discuss the turbulent heat transfer of confined and unconfined impingement cooling. Beitelmal et al.[2] studied the effect of plate surface roughness on the impingement heat transfer, and found that the average Nu value when the coarse particle height was 0.5 mm was increased by about 6% compared with smooth flat plate. Li[3] created an experimental system and experimental method to discuss natural convection on the horizontal disc and the heat transfer characteristic of horizontal rotary disc. The experimental result showed that the disc surface temperature distribution is a bell-shaped curve, the highest temperature occurs at the disc center, and the lowest r point is near the disc edge. Therefore, the distribution of local Nusselt number is a bowl-shaped curve, the highest point is at the disc center, and the lowest point is at the disc edge. The definition parameter Gr/Rer1.6 defines three heat transfer zones: pure rotary forced convection zone, mixed convection zone and pure natural convection zone. Two average Nusselt number experiment relationships containing rotation and natural convection effects are proposed for rotary mixed convection to compare the predicted average Nusselt number with experimental data.

Katti et al.[4] used the impinging jet flow arranged by multiple hole matrices, and confined side outflows after impingement. The Reynolds numbers were 3000, 5000, 7500 and 10000. The distance between the jet nozzle and the test board was round hole diameter D, 2D, 3D, the longitudinal round hole spacing was 5D, the lateral spacing was 2D, 4D, 6D, the test board was stainless steel sheet plate, the temperature distribution in different parts was measured by thermal imager. Chiu et al.[5] used oval nozzle hole, the axial length ratio $AR = 4, 2, 1, 0.5$ and 0.25, the Reynolds number range was 2000~4000, the distance between jet nozzle, and test board was 1.5 to 4.5 times of nozzle diameter. Three jet nozzle array forms, namely bilateral, middle and interlaced types, were used. The result showed that the heat transfer effect increases as the Reynolds number increases, and the heat transfer increases as the distance between jet nozzle and test board decreases. The middle type jet nozzle array has better heat transfer than the other two arrays, as for the AR value. The result showed the optimal heat transfer is $AR = 1$. In the study of Yan et al.[6] jet nozzle's $AR = 4, 2, 1, 0.5$ and 0.25, and

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