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Confined impinging twin air jets at high Reynolds numbers

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ABSTRACT

An experimental study is carried out to investigate flow characteristics of confined twin jets issuing from the lower surface and impinging normally on the upper surface. Pressure distributions on the impingement and confinement plates were obtained for Reynolds numbers ranging from 30,000 to 50,000, nozzle-to-plate spacing (H/D) in the range of 0.5–4 and jet-to-jet spacing (L/D) in the range of 0.5–2. Smoke-wire technique was used to visualize the flow behavior. The effects of Reynolds number, nozzle-to-plate spacing and jet-to-jet spacing on the flow structure are examined. The subatmospheric regions occur on both impingement and confinement plates at the nozzle-to-plate spacing up to 1 for all studied Reynolds numbers and jet-to-jet spacings in consideration. They lie nearly up to the same radial location at both surfaces and move radially outward from the stagnation points with increasing nozzle-to-plate spacing and jet-to-jet spacing. It is concluded that there exists a relation between the subatmospheric regions and peaks in heat transfer coefficients for low spacings in the impinging jets.

1. Introduction

Impinging jets have been widely used in many industrial applications to enhance the heat transfer rate in heating, cooling or drying processes. Applications include drying in paper industry, cooling and heating in food industry, annealing metallurgy, deicing of aircraft systems and cooling of heated components in gas turbine engines, computers and electronic instruments.

A single air jet and an array of jets are used for different purposes. A single jet is usually employed to produce localized heating and cooling. In many applications, a large surface area is required to be heated or cooled, or enhancement of global heat transfer is needed. Thus, it is necessary to apply multiple-jet system [1]. The visualization and characterization of a twin jets flow when impinging vertically to a solid surface, which is of primary importance to the understanding of the phenomena relevant to V/STOL type of aircraft performance and stability when operating in ground vicinity, during short take-off and landing. Many previous studies presented about this subject are concerned with heat transfer rates of unconfined and confined single and multiple jets impinging on a plate. However, little is reported about flow structure of the multiple impinging jets. Lytle and Webb [2] have investigated experimentally the flow structure and heat transfer characteristics of air jet impingement for nozzle-to-plate spacings less than one nozzle diameter in the Reynolds numbers $3600 < Re < 27{,}600$. Behbahani et al. [3] investigated the coherent structures in a circular impinging jet with flow visualization. An experimental investigation to determine velocity and turbulence characteristics of a confined impinging slot jet has been made by Ashfort-Frost et al. [4]. Ichimiya and Yamada [5] have reported that the presence of the recirculation regions on both impingement and confinement surfaces for low spacings and that, with the increase in Reynolds number and nozzle-to-plate spacing, the recirculation flow on the impingement surface moves downstream and its volume increases correspondingly. Tavfek [6] concluded that the pressure distributions along the impingement surface are similar and closer to the heat transfer variations at the same configurations for the nozzle-to-plate spacings $H/D > 6$. An experimental investigation on heat transfer characteristics of slot jets impinging on a cylinder was made by Nada [7]. Behnia et al. [8] noted that the effect of confinement is only significant in low nozzle-to-plate spacings. Only a few studies paid attention to the subatmospheric region. In the studies made by Baydar [9] and Baydar and Ozmen [10] for Reynolds numbers ranging from 500 to 50,000 in confined impinging jets, it has been observed that a subatmospheric region occurs on the impingement plate for $Re > 2700$ and the nozzle-to-plate spacing less than 2 and that there existed a linkage between the subatmospheric region and the peaks in local heat transfer coefficients. Tanaka [11] found that a particular feature of the two-dimensional parallel flow of twin jets was the appearance of a subatmospheric region between the jets, owing to the entrainment of the fluid by the turbulent jet. Abdel-Fattah [12] noted that a subatmospheric region occurs on the impingement plate and its effect decreases with increasing nozzle-to-plate spacing at the impinging circular twin-jet flow. Martin [13] and Polat et al. [14] reviewed the heat transfer characteristics of multiple impinging air jets. Koopman and Sparrow [15] noted that there are two types of interaction between

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