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Jet impingement heat transfer from lobed nozzles

R. Herrero Martin*, J.M. Buchlin

von Karman Institute for Fluid Dynamics, Chaussée de Waterloo 72, 1640 Rhode Saint Genèse, Belgium

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ABSTRACT

The paper presents an experimental investigation of heat transfer obtained with impinging gas jets. Lobed nozzles are tested. The study parameters are the lobe geometry, the jet Reynolds number, Re, and the normalised standoff distance, z/D. The quantitative infrared thermography associated with the thermofoil technique is applied. At high Reynolds number ($Re \geq 15{,}000$)) and small normalised standoff ($z/D \leq 1$), the three-lobe nozzle affords performance better than the other nozzles. As the normalised standoff distance increases and exceeds $z/D = 7$, the 4-lobe yields better performance.

1. Introduction

Among heat transfer devices, impinging fluid jets are extensively exploited because of their ability to produce high local transport coefficients. The large heat transfer rate obtained with impinging streams, compared with classical boundary layer flows explains the popularity of this technique. In addition, impingement is often attractive for the designer, who can easily control the area and the distribution of thermal exchange. Impinging jet systems are present in many industrial and engineering processes where heat and/or mass transfer prevail. Typical examples are the annealing of metal and plastic belts, the tempering of glass sheets, the drying of paper and textiles, the cooling of turbine blades, the chemical vapour deposition, propulsion jet- to- flaps interaction in STOL aircraft and thermal anti-icing systems of wings.

The jet can be formed by round (SRN) or slot nozzles (SSN) depending on the application. Reviews on impinging jets have been the subject of numerous works [1–5]. Prior experimental works were carried out by Gardon and Cobonpue [6] who reported the heat transfer distribution for an impinging circular jet for nozzle-to-plate distances $z/D > 2$, for a single jet and an array of jets, also Gardon and Akfirat [7] studied the effect of turbulence on the heat transfer for a two dimensional impinging jet. The same authors, in a later work [8], studied the effect of multiple two-dimensional jets on the heat transfer distribution. Later, Hrycak [9] and Baughn and Shimizu [10] also carried out experimental works to evaluate heat transfer for a round jet using different methods to measure the surface temperature.

At low nozzle-to plate distances, Lytle and Webb [11] investigated the local heat transfer distribution of an impinging circular air jet. Lee et al. [12] analysed the effect of nozzle diameter of an impinging jet on heat transfer and fluid flow. More recently, Beitelmal et al. [13] studied 2D impinging jets and correlated heat transfer at the stagnation point, stagnation region and wall jet region. Hofmann et al. [14] performed an experimental study of the flow structure and heat transfer from a single impinging round jet. In 2007, O'Donovan and Murray [15,16] carried out a very interesting study of the mechanisms that influence the magnitude and location of secondary convective heat transfer peaks.

The effect of nozzle design on heat transfer for impinging air jets has been the subject of several works: Lee and Lee [17] specially emphasized the effect of nozzle edge configurations, Brignoni and Garimella [18] studied the effect of nozzle inlet chamfering on pressure drop and heat transfer characteristics in a confined impinging air jet, Lee and Lee [19] conducted an experimental work on the effect of nozzle aspect ratio on the local heat transfer characteristics of elliptic impinging jets, Zhao et al. [20] studied numerically the heat transfer performance of square, elliptic, and rectangular jets. More recently, Zhou and Lee [21] examined the

* Corresponding author. Present address: Departamento de Ingeniería Térmica y de Fluidos, Universidad Politécnica de Cartagena, C/Dr. Fleming, s/n Campus Muralla, 30202 Cartagena, Murcia, Spain. Tel.: +34 968 32 59 85; fax: +34 968 32 59 99.
E-mail address: ruth.herrero@upct.es (R. Herrero Martin).

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