Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 112 (2017) 194 – 203

Energy Procedia

Sustainable Solutions for Energy and Environment, EENVIRO 2016, 26-28 October 2016, Bucharest, Romania

Impinging Air Jets on Flat Surfaces at Low Reynolds Numbers

Ştefan-Mugur Simionescu[a*], Nicoleta-Octavia Tănase[a], Diana Broboană[a], Corneliu Bălan[a]

[a]REOROM Group, Hydraulics Department, University "Politehnica" of Bucharest, 313 Splaiul Independentei sector 6, 060042 Bucharest, Romania

Abstract

Many practical applications and developing devices assume impinging jets to be spreading on smooth surfaces or in narrow gaps with controlled wall roughness. This work presents results of an experimental investigation and a CFD numerical modeling regarding the impact of a laminar circular air jet on a wall with smooth surface. First, the tests are directed to the experimental study of a jet impinging on a perpendicular wall, then a CFD study in the same flow conditions is performed. Both cases study the evolution of the flow in the area where the jet is deflected from axial to radial direction. The non-stationary jet dynamics is characterized by small time scales, while in the stagnation region small length scales occur in the same time, so direct visualizations using high speed/resolution camera are performed. Because not all the flow parameters can be inferred from experiments, the visualizations are correlated with corresponding numerical simulations.
The present work brings the opportunity for new numerical simulations on jets impinging on walls with more complex geometries, where the right choosing of numerical test cases and parameters is of great importance.

Peer-review under responsibility of the organizing committee of the international conference on Sustainable Solutions for Energy and Environment 2016

Keywords: Structured surface, impinging jet, circular nozzle, wall shear stress;

* Corresponding author. Tel.: +4-074.390.5552; Fax: +4-021.318.1015.
*E-mail address:*stefan_simionescu@yahoo.com

Peer-review under responsibility of the organizing committee of the international conference on Sustainable Solutions for Energy and Environment 2016
doi:10.1016/j.egypro.2017.03.1083

1. Introduction

Due to their industrial importance, impinging jet flows have received considerable attention, with particular interest in modifying the heat transfer at the wall. In practical applications, impinging jets are efficient tools in

Nomenclature

d	nozzle diameter (m)	x, y	Cartesian coordinates
f	frequency (Hz)	Re	Reynolds number, $Re = \rho v d/\eta \quad (-)$
r	radius, radial distance (m)	Re_0	critical Reynolds number $(-)$
t	time (s)	St	Strouhal number, $fl/v \quad (-)$
z	axial distance between nozzle and target wall (m)	ρ	fluid density ($\mathrm{kg/m^3}$)
t^*	characteristic time of flow $t^* = d/v \ (s)$	τ_w	wall shear stress (Pa)
v	mean velocity (m/s)	η	fluid viscosity (Pa s)

cooling or heating systems through their ability to enhance heat transfer between the fluid and the impinged solid target. The aim of this work is to study the time evolution of an air jet impinging on a smooth solid wall, from both experimental and numerical point of view. The experiments will provide a validation mean for the CFD results, which could thus be extended to other similar cases.

The near-wall behavior of impinging jet flows has been extensively investigated experimentally. Some of the first studies are summarized in the review of Gauntner, Livingood & Hrycak [1], focused mainly on basic flow statistics. A comprehensive study was performed by Fitzgerald and Garimella [2] using laser-Doppler velocimetry.

A classification of the different parameters that characterize impinging slot jets is provided by Tahsini et al. [3]. The effect of the jet Reynolds number, nozzle to plate distance, jet confinement and turbulent intensity are discussed. Later studies involved the phenomenon of heat transfer from a solid surface in the presence of impinging jets, as the work of Jambunathan et al. [4] on single circular jet impingement. Geers et al. [5] studied turbulent structures and heat transfer from an array of impinging jets. Benmouhoub and Mataoui [6] and Jaramillo [7] show results on turbulent heat transfer from a slot jet.

More recently, it has been recognized that impinging jets, despite geometric simplicity, contain interesting physics. This makes them attractive for studying various features of jet dynamics, its interaction with the impinged wall and resulting effects on heat and mass transfer – Hadziabdic and Hanjalic [8]. Despite significant progress in understanding various phenomena in different configurations of impinging jets, many issues remain open because of limitations in the available measuring techniques.

CFD numerical simulations (RANS, LES and DNS), with their potential to provide the flow dynamics in both space and time, have thus been considered as a valuable instrument to providing comprehensive information and to complementing the experimental results.

2. Theoretical aspects

The flow structure of unconfined impinging jets is commonly divided into three main regions: free jet region, stagnation region and wall jet region. After the air jet exits from the nozzle's inlet, it is released into the surrounding ambient and the free jet begins to develop by entrainment of surrounding fluid. The second region is the stagnation region, where the jet hits the solid wall and is deflected to radial direction. After impinging, the jet develops as a wall jet over the target