41st AIAA Fluid Dynamics Conference and Exhibit
27 - 30 June 2011, Honolulu, Hawaii

AIAA 2011-3085

An Experimental Study Into the Turbulence Characteristics of Laminar, Transitional and Turbulent Impinging Jets

L. Cameron*, J. M. Early†
The Queen's University of Belfast, Belfast, BT95 AH, United Kingdom

H. Medina‡
Coventry University, Coventry, CV1 5FB, United Kingdom

R. McRoberts$
The Queen's University of Belfast, Belfast, BT95 AH, United Kingdom

Particle Image Velocimetry (PIV) has been utilised to obtain instantaneous velocity fields for water jets impinging perpendicularly on a solid surface. Time-averaged turbulence statistics are presented for laminar, transitional and turbulent jets in the Reynolds number range 3000 - 10000. A vortex identification algorithm is also employed to calculate the probability of a vortex existing at each discrete grid point based on all of the instantaneous fields. Significant turbulent mixing is induced by increasing the Reynolds number from 3000 to 4000, indicating transition commences in this range. The transition onset is characterised by a sudden increase in mean turbulent kinetic and velocity fluctuations as well as the coalescence of small scale vortices into large scale coherent structures. Further increasing the Reynolds number results in a decrease in the levels of non-dimensional turbulent kinetic energy in the shear layer implying a lesser proportion of the initial energy possessed by the jet is lost through dissipation resulting in favourable heat transfer characteristics at the impingement surface. The transitional jet with Re = 4000 proves to be an interesting case producing a strong wall jet with intense turbulent fluctuations that may result in large heat transfer rates over a greater radial distance.

Nomenclature

u	=	instantaneous axial velocity
U	=	time-averaged axial velocity
u'	=	axial velocity fluctuation
v	=	instantaneous radial velocity
V	=	time-averaged radial velocity
v'	=	radial velocity fluctuation
y	=	axial coordinate measured from the nozzle exit plane
x	=	radial coordinate measured from the jet centerline
u'^3	=	skewness factor
k	=	mean turbulent kinetic energy
rms	=	Root mean squared
N	=	Number of instantaneous velocity vector fields
H	=	Distance between nozzle exit plane and impingement surface
d	=	Nozzle diameter

* Research Student, School of Mechanical and Aerospace Engineering, The Queen's University of Belfast, AIAA student member.
† Lecturer, School of Mechanical and Aerospace Engineering, The Queen's University of Belfast, AIAA senior member.
‡ Senior Lecturer, Faculty of Engineering and Computing, Coventry University, AIAA member.
$ Research Student, School of Mechanical and Aerospace Engineering, The Queen's University of Belfast, AIAA student member.