REYNOLDS NUMBER EFFECT ON 3D TURBULENT OFFSET JET REATTACHING TO A FREE SURFACE

Mohammad Shajid Rahman[1], Mark F. Tachie[1] & Baafour Nyantekyi-Kwakye[1]
[1]*Department of Mechanical Engineering, University of Manitoba, Winnipeg, Canada*

Abstract Experimental study was carried out to investigate the effect of Reynolds number on 3D offset jet reattaching to above free surface. Sharp edged square nozzle was used to produce the jets, and the measurements were performed at the following six different Reynolds numbers: 2300, 3700, 5100, 7900, 10300 and 11900. Detailed velocity measurements were made in the symmetry plane. From the PIV data, the mean velocity and turbulence statistics were obtained to study the effects of Reynolds number on the salient features of the jet flow. Preliminary results on streamwise mean velocity decay along the nozzle centerline, contours of streamwise mean velocity and Reynolds shear stress are presented herein.

Keywords: 3D offset jet, Surface reattachment, Turbulence shear flow, PIV technique.

INTRODUCTION

Offset jets have diverse practical applications. Entrainment of surrounding fluid and mixing due to the presence of recirculation region are important features of offset jets which is utilized in burners, boilers, combustion chambers, fuel injection systems etc. A comprehensive study of this kind of flow structure is desired not only to reveal its complex flow physics but also to enhance the efficiency of different fluid-thermal systems closely related to jets.

The effects of Reynolds number, *Re* and offset height ratio on the characteristics of a wall attaching offset jet have been investigated experimentally [1]. Most of the previous research activities on offset jets were limited to 2D jet. 3D jets were studied also and in most cases, single-point measurement of turbulent statistics was investigated. Generally round shape nozzle was used in case of surface jet study. Reynolds number effect on surface jet was not studied extensively so far. In this paper, an experimental investigation of Reynolds number effects on the characteristics of 3D surface jet was undertaken using a particle image velocimetry. The goal is to elucidate how the mixing characteristics and turbulent transport processes in a surface attaching jet change with Reynolds number.

EXPERIMENTAL SETUP

The experiments were carried out in an open water channel of 2500 mm long. The square cross section area of the channel was 200 × 200 mm^2. The channel was made of acrylic plate for easy optical access. A sharp edge square nozzle with 10 mm width (d) was used to produce the jet flow. The center of the nozzle was located at 20 mm below the water level (h) so that the offset height ratio, $h/d = 2$. The experiments were performed at six different Reynolds numbers of 2300, 3700, 5100, 7900, 10300 and 11900. The Reynolds numbers were based on U_j and d where U_j is the maximum centerline velocity of jet exit. The flow was seeded using 10 µm silver coated hollow glass spheres and illuminated by a 120 mJ per pulse Nd:YAG double-pulsed laser. A 2048 × 2048 pixel CCD camera was used to capture the flow field. The measurements reported herein were performed in the x-y plane where x and y indicate streamwise and surface-normal direction of the flow respectively. The camera field of view was set to 84.1 × 84.1 mm^2.

PRELIMINARY RESULT

Streamwise mean velocity (U) along the nozzle centerline is shown in figure 1. The velocity decays for the flow of Reynolds numbers ranging from 3700 to 11900 show similar trend which are faster compared to the flow of 2300 Reynolds number case. It is also observed in this figure that the length of potential core, over which the velocity is independent of streamwise direction, for the case of Re = 2300 is larger than at the higher Reynolds number cases.

Contour plots of U/U_j for Re = 2300, 5100 and 10300 are displayed in figure 2. The observation regarding potential core region is consistent with those presented in figure 1. The recirculation region, which is the area surrounded by the zero velocity line, for Re = 5100 is larger than Re = 10300 case. In case of Re = 2300, the recirculation region cannot be identified clearly.

Contours of Reynolds shear stress (uv) in x-y plane normalized by U_j^2 for Re = 2300, 5100 and 10300 are presented in figure 3. The dashed lines indicate negative uv. Negative values of uv are observed from the nozzle centerline to the free surface. Large value of negative *uv* is noticed while the jet approaches to the free surface which is an indication of momentum transfer between the inner share layer and the reverse flow region.

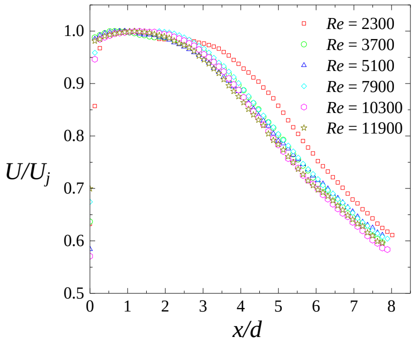

Figure 1. Streamwise mean velocity profile along centerline (at y/d = 0).

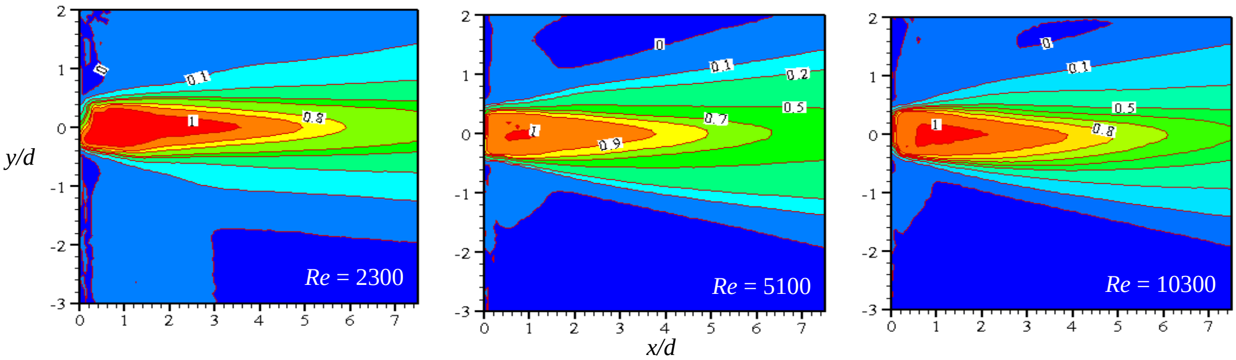

Figure 2. Contour of U/U_j.

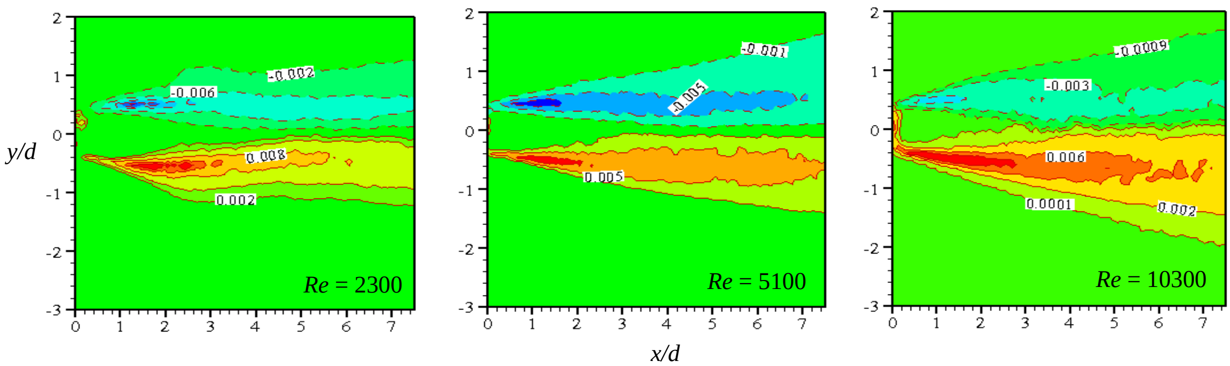

Figure 3. Contour of uv/U_j^2.

FINAL PAPER

A complete literature review and description of experimental procedure will be provided. Measurement uncertainty will also be presented and discussed. The effects of Reynolds number on the reattachment length, spread and decay rates, mean velocities, and Reynolds stresses and multi-point statistics will be discussed in detail.

References

[1] M. Agelin-Chaab and M. F. Tachie. Characteristics of turbulent three-dimensional offset jets. *International Journal of Heat and Fluid Flow* **32**: 608–620, 2011.

[2] J. R. R. Pelfrey and J. A. Liburdy. Mean flow characteristics of a turbulent offset jet. *Journal of Fluids Engineering* **108**: 82-88, 1986.