Renewable Energy and Power Quality Journal (RE&PQJ), ISSN 2172-038 X, No.9, 12th May 2011, Reference Paper: 320

Two Distinct Regions in a Pulsed-Axisymmetric Jet

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Abstract. This research concerns on the axial measurement of a pulsed-axisymmetric jet to investigate the decay of inverse of mean centerline axial velocity with the use of a single normal hot-wire anemometer. The measurement is performed by controlling mean exit velocity and pulsing frequency.

The axial measurement reveals that the pulsation method leads to the appearances of two distinct regions namely the pulsed dominated- and the high turbulence steady jet-regions. However, the existence of the two regions can be controlled by adjusting the mean exit velocity and pulsing frequency. At a high mean exit velocity and low pulsing frequency, the high turbulence steady region is not seen, hence the transition region can not be found. Furthermore, at a high pulsing frequency and a constant mean exit velocity, the pulse dominated region becomes shorter.

The present study has provided a comprehensive knowledge in that the trend of the decay rate is very clear under the wide range of pulsation method imposed on the jet. This inclusive understanding becomes a substantial consideration for mixing processes as well as can be used to verify the k-ε turbulence model to predict the decay of normalized mean centerline-axial velocity.

Keywords. Pulsed-axisymmetric jet, pulsation method, decay rate of mean centerline velocity, hot-wire anemometer.

1. Introduction

In many widespread industrial applications such as mixing processes, unsteady jets can be of a considerable practical interest due to their more enhanced mixing and entrainment characteristics when compared to steady jets ([1], [2], [4], [5], [6], [10], [11], [12], [13], [20], [21], [23]). Such jets can be produced through mechanically (for example:, [4], [5], [6], [20]) or acoustically perturbation techniques (for example: [10], [18], [25]).

Of various types of mechanically perturbed jet, a fully pulsed jet which is generated by a pulsing valve is of the most important consideration in a number of studies since such a jet has higher level of entrainment than the other jets ([2], [20]). However, the jet still provides little structural information in terms of its axial properties due to limited measurements performed in the past ([3], [4], [6], [9], [12], [22], [23]).

An early investigation in the fully pulsed jet with a single mean exit velocity, U_e of 36.6 m/s and pulsing frequency, f_p of 10 Hz ([4]) revealed a striking interesting phenomenon which is shown by the suddenly change of decay growth of inverse of axial-centerline velocity, U_e/U_0 with a wider area of axial measurement (x/d up to 100 diameters downstream) were performed from a previous study (x/d up to 17 diameters downstream) with a constant mean exit velocity, U_e of 36.6 m/s and varying pulsing frequencies, f_p of 10 and 25 Hz ([6]). At the upstream positions (x/d < 50) the decay rate is slower than that of a steady jet while after the downstream position, x/d of 50 the decay growth switches to that of a steady jet.

A few years later, [23] continued the pulsed jet study with a constant mean exit velocity, U_e of 35 m/s and varying pulsing frequencies, f_p of 5, 10, 15, and 25 Hz. The researcher also found the similar interesting results with those of [4] associated with the suddenly change of decay rate but is of different scales with the results of [4] over 100 diameters downstream. Subsequently, [3] simulated the previous results [4] over 100 diameters downstream using the k-ε turbulence model. Nevertheless, they found that this model shows significant discrepancy in the further downstream regions but is consistent with the experimental results in the downstream regions (x/d below 50), therefore, the change in slope of the centerline velocity decay of a fully pulsed jet still needs more explanation.

Continuing the former works ([3], [4], [23]), [12] experimentally investigated the fully pulsed jet with a single mean exit velocity, U_e of 36.6 m/s and pulsing frequency, f_p of 10 Hz over some downstream distances (40 < x/d < 80) which are considered to be the transition regions of decay growth. It was shown that the change in the decay rate is not clearly seen over this region.

Furthermore, [22] experimentally examined the fully pulsed jet up to 100 diameters downstream with a wider range of mean exit velocity (10 m/s $\leq U_e \leq$ 35 m/s) and a constant pulsing frequency, f_p of 10 Hz. [22] confirmed that the change in the decay rate was found.

In attempts to verify the experimental results of [22], [9] studied the pulsed jet with a range of mean exit velocity (10 m/s $\leq U_e \leq$ 36.6 m/s) and a constant pulsing frequency, f_p of 10 Hz over 100 diameters downstream. However, the most recent results do not confirm the existence of transition region of the change in the decay rate of a fully pulsed jet.

Considering the abovementioned existing problems, it is the purpose of this present study to broaden the knowledge of a fully pulsed by carrying out an axial measurement up to further downstream in order to study the decay of inverse of mean centerline axial velocity. In line with the goal of this current work, the effects of varying mean exit velocity and pulsing frequency on the basic properties of the jet are