Experimental Study of the Behavior of Plane Turbulent Jets at Low Reynolds Numbers

G.P. Lemieux*
Royal Military College of Canada, Ontario, Canada
and
P.H. Oosthuizen†
Queen's University, Ontario, Canada

Abstract

THE effects of Reynolds number on the flow characteristics of plane turbulent jets have been investigated. The jets were produced by discharging air through a rounded-edged slot. The mean velocity and turbulence stresses in the flowfield were measured with hot-wire anemometers at six discharge Reynolds number values of 700-4200. It was found that the mean velocity profiles were unaffected by the discharge Reynolds number but that the rate of centerline velocity decay as well as the turbulence stress levels were strongly dependent upon the Reynolds number.

Contents

Introduction

A review of the previously published characteristics of turbulent jets indicates that, in addition to the effects upon the characteristics of turbulent jets due to variation in nozzle geometry, initial profiles, and upstream disturbances, there may be relatively large effects due to the discharge Reynolds number. For this reason, a study was undertaken into the behavior of low Reynolds number plane jets produced in an apparatus as depicted in Fig. 1. The nozzle was 1-cm high with rounded edges. The discharge plane velocity U_j could be varied 0-7 m/s, thus producing jets with discharge Reynolds number values of 700-4200.

Velocity and turbulence measurements were taken in the jet center plane to a downstream distance of 60 cm using commercial crossed-wire, constant-temperature, hot-wire anemometers calibrated in the nozzle discharge plane against a pitot probe connected to an electronic manometer. The signals from the anemometers were processed digitally using King's law and the "cosine-law" relationship.

Lateral profiles of mean velocity and turbulence stresses were taken at six equally spaced distances from the nozzle for discharge Reynolds number values of 700, 1900, and 4200. Similar measurements were also taken at close intervals along the jet centerline for discharge Reynolds numbers of 700, 1150, 1500, 1900, 2700, and 4200.

Results

As is common, the velocity and turbulence profiles were nondimensionalized with respect to the centerline velocity U_{max} and the jet half-width $Y_{0.5}$ as obtained from the mean velocity profiles. The profiles of mean velocity are shown in Fig. 2 in this dimensionless form.

It is seen that, in the far field, the central portion of the profiles is essentially unaffected by the Reynolds number indicating that self-similarity was approximately attained for all Reynolds numbers. The discrepancies in the outer region of the jets, particularly evident in the lowest Reynolds number jet, are due to the inadequacies of the anemometer calibration and the data processing scheme used and the flow reversals known to exist in that area.

The variation of centerline velocity with downstream distance is shown in Fig. 3 where a strong Reynolds number influence is observed. It is noted also that the influence of the Reynolds number is nonmonotonic. On the other hand, the spread rate of the jets was only affected slightly by the Reynolds number.

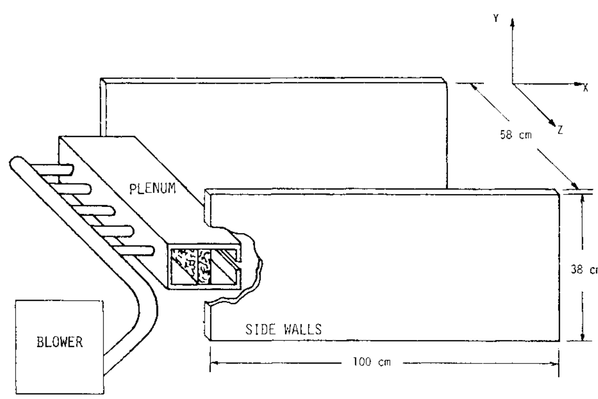

Fig. 1 Schematic of apparatus.

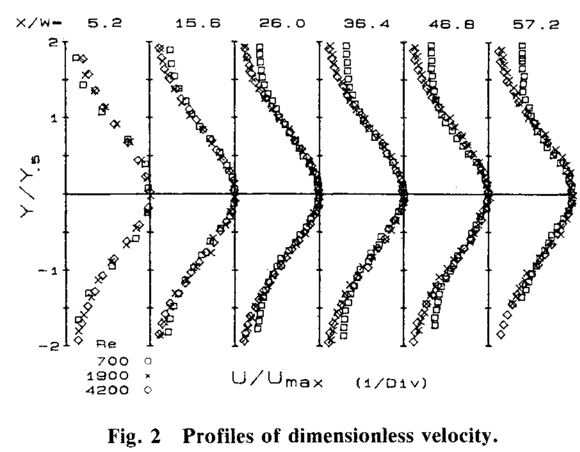

Fig. 2 Profiles of dimensionless velocity.

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*Associate Professor, Department of Mechanical Engineering.
†Professor, Department of Mechanical Engineering.

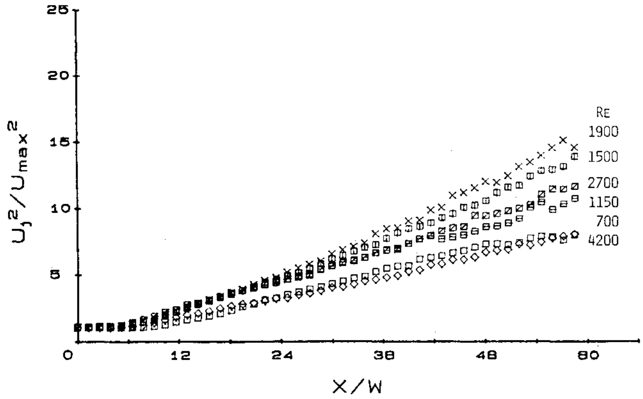

Fig. 3 Variation of centerline velocity with downstream distance.

Profiles of the turbulence transverse normal and shear stresses are shown in Fig. 4. Turbulence stresses in the central region of the jets are seen to have increased as the Reynolds number increased. The turbulence longitudinal normal stress levels were only affected slightly by the Reynolds number. Measurements in the nozzle discharge plane indicated that the discharge velocity profiles were flat (i.e., uniform discharge plane velocity) with the exception of the two boundary layers present on the lips of the nozzle; these boundary layers were laminar. In Fig. 4, it is observed that the lowest Reynolds number jet actually becomes turbulent only downstream of the first lateral traversing station.

A comparison of the turbulence levels and jet properties determined over the course of this study against those found in the literature indicates that the characteristics of the jet with a Reynolds number of 4200 are approaching those determined in higher Reynolds number jets, indicating that the structure of this jet may be approaching that found to exist in higher Reynolds number jets.

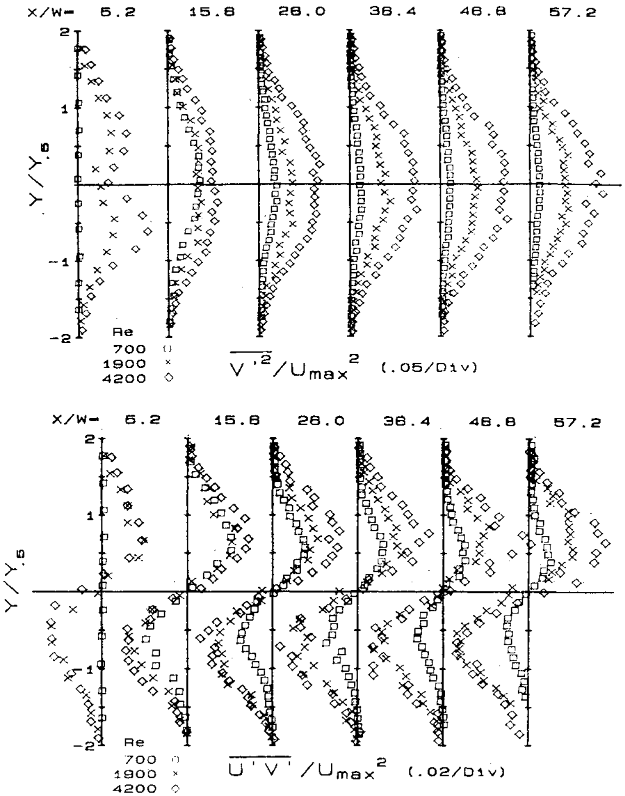

Fig. 4 Profiles of turbulence transverse normal and shear stresses.

Conclusions

The present study has indicated that the characteristics of a turbulent plane jet changed significantly in the Reynolds number range of 700-4200. Although the dimensionless mean velocity profiles are essentially unaffected by the Reynolds number, all other characteristics are affected to some lesser or greater degree.

Acknowledgment

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