Interaction of Two Nonequal Jets

H. Elbanna* and J. A. Sabbagh†
King Abdulaziz University, Jeddah, Saudi Arabia

Nomenclature

t_p = jet nozzle width
U = mean velocity in the x direction
u', v' = rms of fluctuating velocity components along x and y, respectively
x = streamwise coordinate along centerline of the combined jet
y = coordinate normal to the centerline
$y_{0.5}$ = half-width of the mean velocity profile along the y axis
α = angle of interception of the two jets
θ = angle of deflection of weaker jet

Subscripts

M = centerline conditions
01 = exit plane conditions of the higher velocity nozzle
02 = exit plane conditions of the lower velocity nozzle

Introduction

THE interaction of jets is of practical importance in a wide variety of applications. It is encountered, for example, in powered high-lift systems of aircraft, burners, and fluidic devices. Interaction of jets has received considerable attention of previous investigators. However, most of the work reported in the literature was concerned with the confluence of parallel jets. Murai et al.[1] studied the confluence of two two-dimensional jets issuing from a common wall. Their work was confined to the calculation of axial momentum and energy flux. Multiple-jet mixing was studied by Krothapalli et al.[2,3] and Raghunathan and Reid.[4] The interaction of two nonequal jets was demonstrated by Foss[5] and Ram and Kar.[6] In the work of Foss, the normal control jet was separated from the power jet by two perpendicular setback and standoff walls. In this configuration, a positive pressure is developed in the region bounded by the two jets and the setback and standoff walls. This resulted in a decreased deflection angle of the weaker jet. Ram and Kar assumed potential flow and predicted the angle of deflection of the power jet for a flow geometry with a zero standoff wall. Their experimental results were conducted for U_{02}/U_{01} varying at 0-0.1315. In a recent work, Elbanna et al.[7] experimentally examined the interception of two equal free-standing, two-dimensional jets for different interception angles. The present study is directed toward examining the structure of the combined jet resulting from the interception of two nonequal free-standing jets for an interception angle α of 100 deg.

Apparatus and Procedure

A schematic representation of the flow geometry of the present study is shown in the insert on Fig. 1. The test setup, which is described elsewhere,[7,8] consists of two variable-speed centrifugal fans, two identical free-standing nozzle blocks, and two horizontal floor and ceiling plates between which the two nozzle blocks are held. The nozzle slot width t_p is 1.2 cm and its height is 49 cm. The nozzle slot spans the entire distance between the floor and ceiling walls. The floor and ceiling walls extend 200 cm downstream of the slots and 100 cm on each side of the midline between the two nozzles. The distance between the centers of the exit planes of the two nozzles is 12.5 t_p. Experiments were conducted with one of the nozzles having a nominal velocity U_{01} of 25 m/s corresponding to a Reynolds number of 2×10^4, while the velocity of the second nozzle U_{02} was adjusted such that U_{02}/U_{01} had different values between 0 and 1. The test setup was located in a large air-conditioned room.

Measurements were made with DISA 55M01 constant-temperature anemometers using DISA 55M25 linearizers. The details of instrumentation, calibration procedure, and accuracy of measurements are discussed in Ref. 8.

Results

For the two free-standing intercepting jets, mutual entrainment of the surrounding air creates a subatmospheric region between the two jets. This causes them to merge upstream of their geometric interception. Downstream of the confluent region, the two jets have a behavior of a single jet. When the two jets have different velocities, the combined jet centerline is tilted away from the midline between the two nozzles. Figure 1 shows the angle θ between the centerline of the combined jet and the axis of the weaker jet nozzle as a function of the velocity ratio U_{02}/U_{01}. The solid line shows the deflection angle

$$\theta = \cot^{-1}\left[\cot\alpha + \left(\frac{U_{02}}{U_{01}}\right)^2 \frac{1}{\sin\alpha}\right]$$

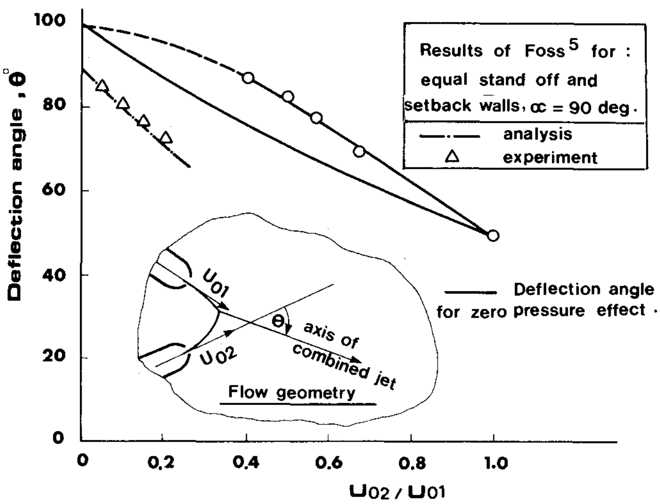

Fig. 1 Deflection angle of the weaker jet as a function of velocity ratio U_{02}/U_{01}.

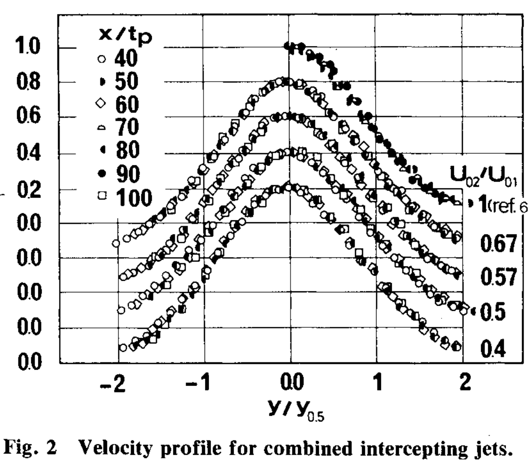

Fig. 2 Velocity profile for combined intercepting jets.

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*Assistant Professor, Department of Mechanical Engineering. Member AIAA.

†Professor, Department of Mechanical Engineering.

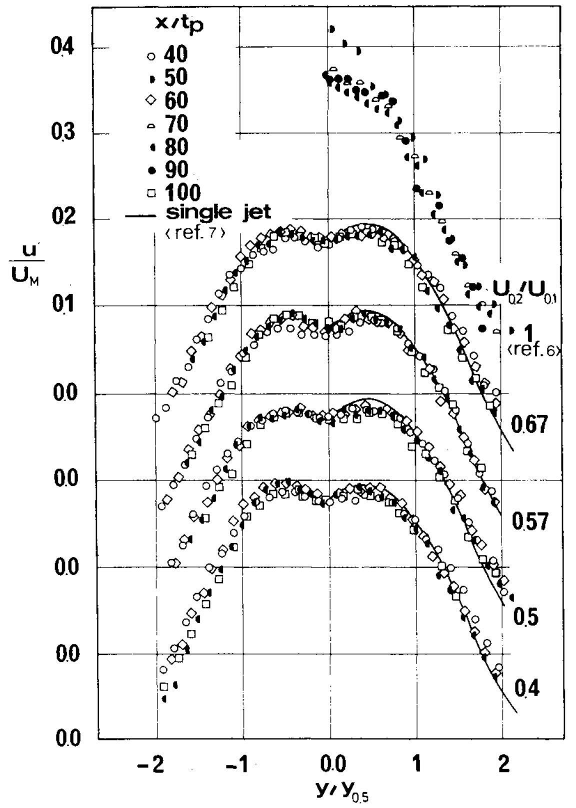

Fig. 3 Axial velocity fluctuations for combined intercepting jets.

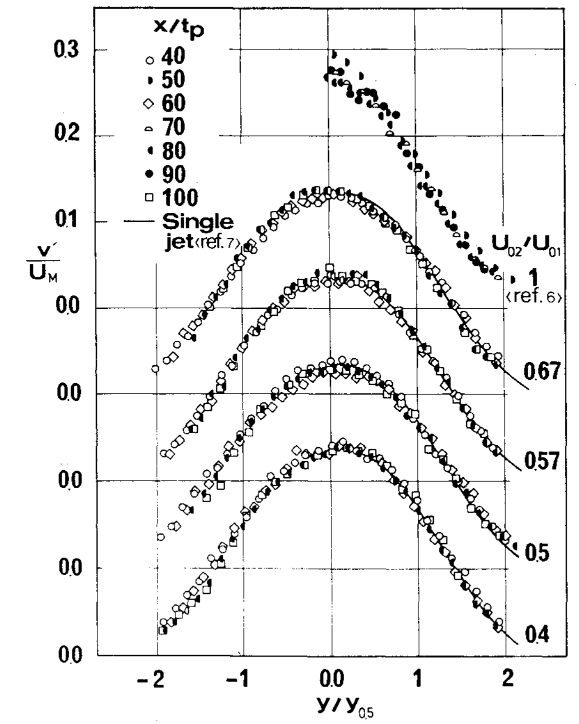

Fig. 4 Lateral velocity fluctuations for combined intercepting jets.

which would be obtained from simple momentum considerations if there were a zero net pressure force acting on the flowfield. Mutual entrainment of air by the two jets creates low pressure upstream of the merging region, which provides a transverse force tending to increase the deflection angle. However, due to confluence, high pressure is developed in and near the confluence region,[7] which results in an adverse effect on the deflection angle. The present results show a slightly smaller deflection angle as a net effect of the pressure field of the two merging jets. In the results of Foss[5] displayed in Fig. 1, positive pressure is developed in the pocket bounded by the two jets and the setback and standoff walls, resulting in a decreased deflection angle.

The growth of the half-width of the velocity in the combined jet is found to be linear with x, but with slightly lower rate than that for the single jet. The mean velocity profiles are shown in Fig. 2. The profiles are similar and agree well with that of a single jet.

The distribution of the axial velocity fluctuations u' are shown in Fig. 3. The plots show that the u' profiles are similar in the range of $x/t_p = 40 \sim 100$ and are close to the u' profile of the single jet. Figure 4 indicates that the lateral velocity fluctuations v' also have similar profiles in agreement with the v' profiles for the single jet.

Acknowledgments

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Inlet Vortex Formation due to Ambient Vorticity Intensification

H.W. Shin,* W.K. Cheng,† E.M. Greitzer,‡ and C.S. Tan§
Massachusetts Institute of Technology
Cambridge, Massachusetts

INLET operation near the ground is often associated with the presence of a strong vortex stretching between the ground and the inlet face. Investigations of this "inlet vortex" (or ground vortex) have identified two basic mechanisms

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*Postdoctoral Associate, Department of Aeronautics and Astronautics (presently with General Electric Co., Cincinnati, OH). Member AIAA.

†Associate Professor, Department of Mechanical Engineering. Member AIAA.

‡Professor, Director, Gas Turbine Laboratory, Department of Aeronautics and Astronautics. Associate Fellow AIAA.

§Research Associate, Department of Aeronautics and Astronautics.