RESEARCH NOTE

STATIC PRESSURE DISTRIBUTION IN AN EXCITED JET: SOME OBSERVATIONS

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Abstract A plane subsonic jet was subjected to periodic oscillations in the near nozzle region by a twin vane system. During excitation, the jet was found to spread significantly and entrain mass much more than its steady counterpart. Time averaged static pressure measured in the flow field with a disc probe exhibited prominent well defined suction regions different from that of a steady jet.

Key Words Plane Jet, Static Pressure, Entrainment, Excited Jet

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INTRODUCTION

Excitation of plane jets has attracted fluid dynamicists as well as engineers in the last few years on account of its practical applications [1-5]. Greater mixing coupled with higher entrainment, a significant feature of an excited jet, can be used with advantage in combustion and in forced convective cooling. Furthermore it has application in an ejector system. When a plane jet is subjected to oscillations of finite amplitude, it initially performs a mere flapping motion without any additional entrainment. However beyond a certain critical stage yet to be defined precisely, large coherent vortices are generated on both sides of the flow. These vortices engulf additional mass into the system, as a result, a significant increase in the spread of the jet as well as in entrainment takes place. It is observed that this behaviour is possible in a plane jet only if the oscillations imparted to flow are in the antisymmetric mode, while a round jet is sensitive even to mass fluctuations. Further, it is noticed that the amplification stated above occours even at lower strouhal numbers significantly less than 0.25, a value observed by Sato [6], with infinitisimal disturbances.

So far, the investigations on excited plane jet have been mainly confined towards the develompment of various mechanisms to impart periodic oscillations to the flow [1-5]. Recently a twin vane oscillator has been developed which seems to have an edge over other techniques on account of its high efficiency [7]. The present study employs this system with the aim of investigating the static pressure and velocity distributions in the excited jet. It is well known that even in the case of a steady jet, the static pressure is not the same as that of ambient as

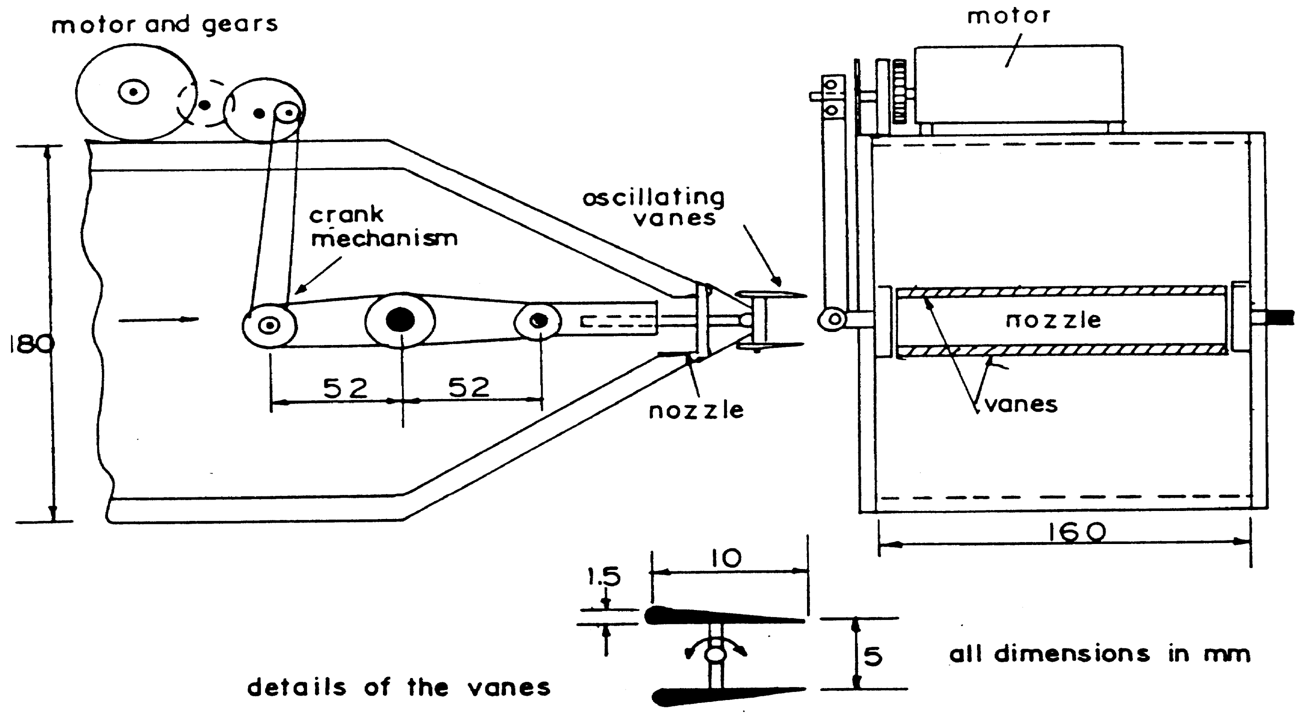

Figure 1. Details of the oscillating vane set up.

conceived for a long time and this aspect has to be considered for momentum analysis. Hence it is natural to expect that even for an excited jet, the variation in the pressure field should be significant; both in space and time. Since the measurement of instantaneous static presure is a formidable job, as a preliminary measure, an attempt was made in this investigation to measure at least the time averaged static pressure using a disc probe. The results indicated some trends significantly different from those of a steady jet.

EXPERIMENTAL SET-UP

The experiments were carried out in a plane jet whose width was 0.5cm and length 16cm. A centrifugal blower was employed to generate the flow. Between the nozzle and the blower, a settling chamber containing a honeycomb and a set of graded screens were incorporated to damp out disturbances from the blower. The nozzle was machined from an aluminium block with a suitable contraction to produce a uniform velocity profile with boundary layers of negligible thickness at the exit.

Oscillations to the jet were imparted by a pair of vanes each 5mm width and spanning the entire length of the nozzle (Figure 1). They were of symmetric airfoil shape and kept parallel to each other 5mm apart so that their surfaces graze the edge of the jet when kept in the neutral position. The ends of the vanes were attached to spindles on both sides which were kept away from the flow. A gap of 5mm was maintained between the nozzle and the leading edge of the vanes. A crank-link mechanism coupled to a variable speed motor was attached to the spindles to impart oscillations in the pitching mode. The angle of pitch was 5 degrees (half angle) and the frequency was 20Hz.

A 1.5mm diameter pitot-static tube with a

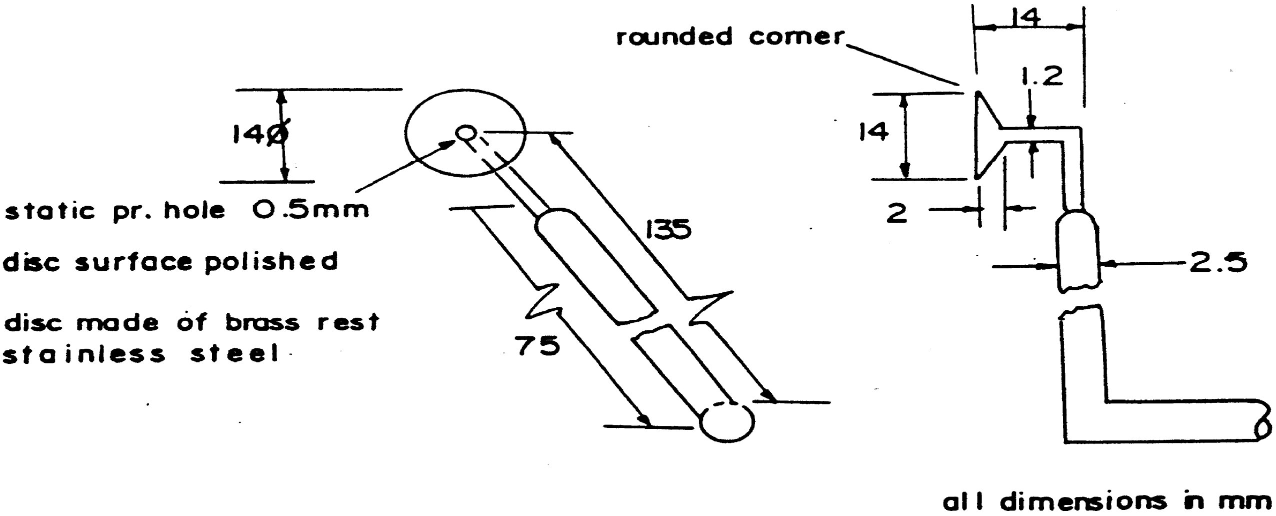

Figure 2. Disc probe used for static pressure measurements.

spherical nose was employed to measure the mean velocity. The differential pressure generated by this probe was read using an electronic digital manometer capable of recording pressures with an accuracy of 0.01mm of water. Static pressure in the excited jet was measured with a disc probe (Figure 2) and it was aligned parallel to the flow. The static pressure hole in the pitot-static tube was also employed in the steady jet to examine the accuracy of alignment of the disc probe. The output from the probes were averaged over a peirod of 60 seconds using the intergrating system available with the elctronic manometer.

EXPERIMENTAL RESULTS AND DISCUSSIONS

The mean velocity profiles in the jet were measured with the pitot-static tube. Even though the use of this technique in unsteady flows is questionable, earlier investigations by Collins et. al [3] had shown that in an excited jet the difference between the pitot-static tube and laser doppler anemometer measurements was not too large; hence to obtain gross features of the flow, the first method was adopted in the absence of more sophisticated instruments.

STEADY JET

The mean velocity profiles for the steady jet are shown in Figure 3 and they exhibited Gortler similarity [8]. The growth of the jet, the decay of centerline velocity and entrainment ratio along the steamwise direction were in near conformity with those of a standard plane jet [8] (Figures 4-6). In estimating the entrainment, the mean velocity profile was integrated at each x-location only up to 95% of u_e.

To begin with, the static pressure distribution in the jet was measured (Figure 7) using the static pressure port in the pitot-static tube and the results compared well with those of Hussain

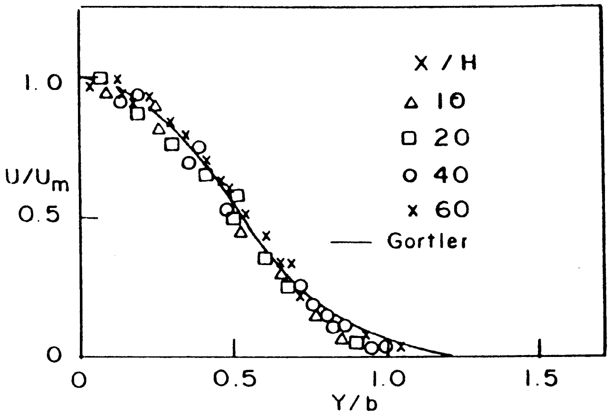

Figure 3. Mean velocity profile of steady jet.

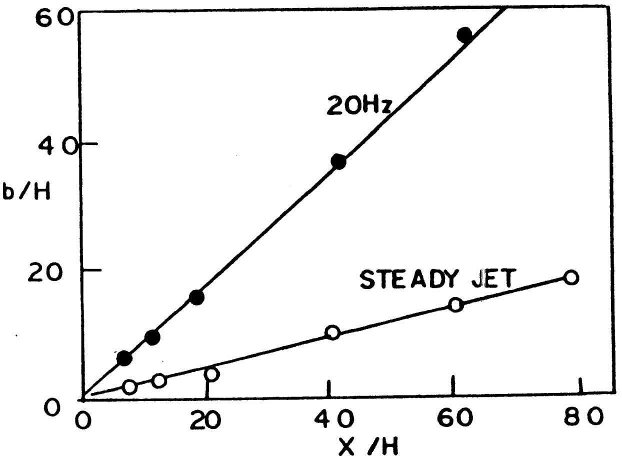

Figure 4. Effect of excitation on the growth of the jet.

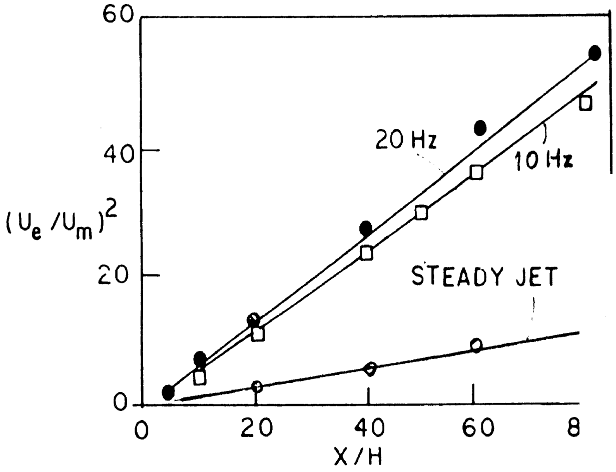

Figure 5. Decay of center line velocity.

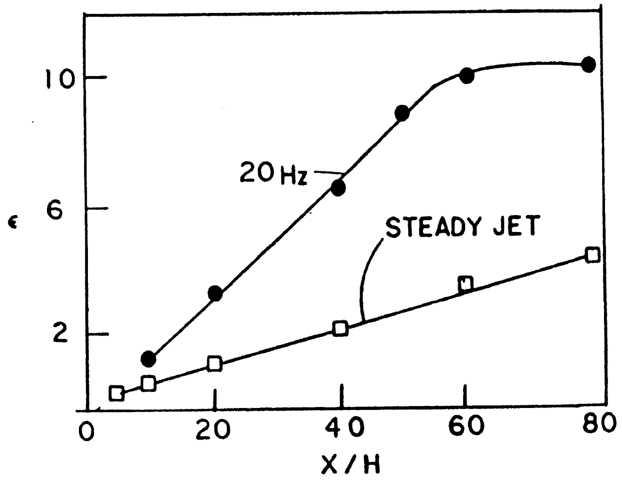

Figure 6. Entrainment in the jet.

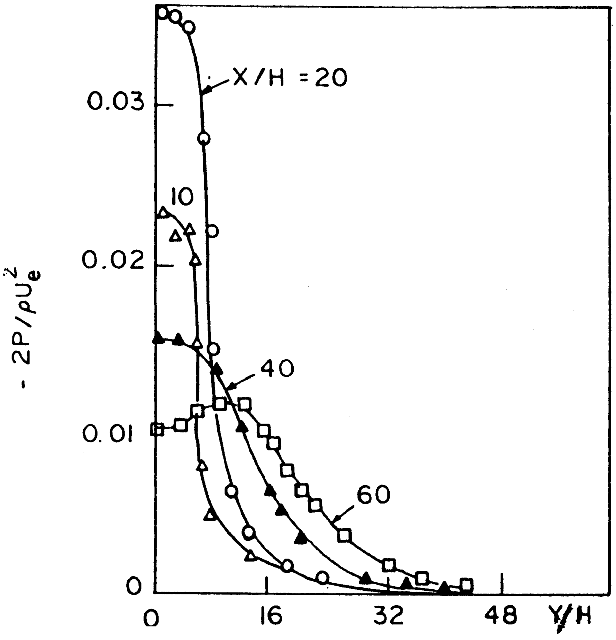

Figure 7. Static pressure distribution.

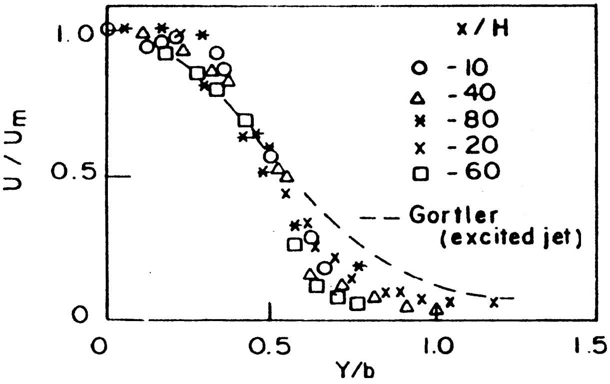

Figure 8. Mean velocity profile.

and Clark [9]. Subsequently the disc probe was employed. Both the instruments yielded the same result within 5%.

EXCITED JET

The jet with the same exit velocity (50m/s) as that the steady case was excited at 20Hz. Mean velocity profiles measured at several spanwise stations along the midspan (Figure 8) indicated significant spread of the jet more than that of the steadycase. Entrainment increased linearly up to x/H of 50 and later remained nearly constant (Figure 6). The centerline velocity followed the relation $(U/U_m) = 0.64\ (x/H-3.0)$, while for the steady jet $(U/U_m) = 0.11\ (x/H = 5.0)$ (Figure 5). The mean velocity profiles exhibited considerable deviation from that of the standard Gortler profile. While the inner region (below $U/U_m = 0.5$) tended towards Gortler's profile at large spanwise distances, the outer region did not but settled towards a different equilibrium state.

Static pressure measurements made across the jet at x/H of 10, 20, 40 and 60 (Figure 9) using the disc probe, indicated considerable variation from that of the steady jet. Large suction humps could be seen in them, a smaller one near the centerline followed by a larger one in the outer region. These humps were conspicuous only beyond x/H = 20. The distance (b) between the second peak and the centerline increased linearly with x and it was nearly the same as that of the half width (b) of the excited jet. For the steady jet, the integral values of the momentum (M) of the mean velocity and the pressure (P) were nearly equal, a result which was in confirmity with that of Hussain and Clark [9]. In the case of the excited jet, however, M decreased slightly upto x/H = 30, later followed by a rapid increase in the streamwise direction, while the integrated pressure P decreased linearly with x (Figure 10). A comparison of the pressure distribution between the steady and the excited jet indicated larger variation in the case of the latter; say at x/H = 50, P = -0.12 and -0.20 for the steady and excited cases respectively. With the limitations posed by the data, it can only be speculated that the presure field generated by the oscillating jet might play a considerable role in the dynamics of the flow.

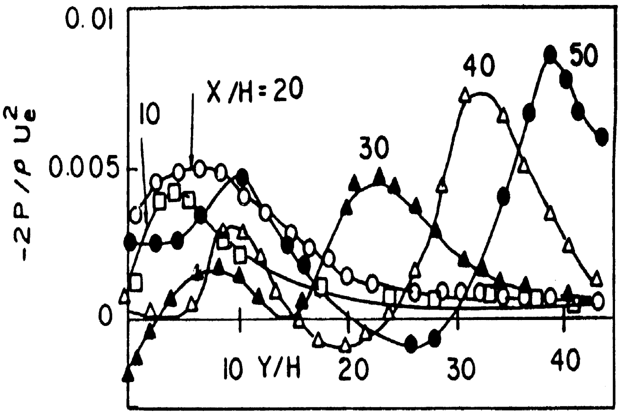

Figure 9. Static pressure distribution across the excited jet.

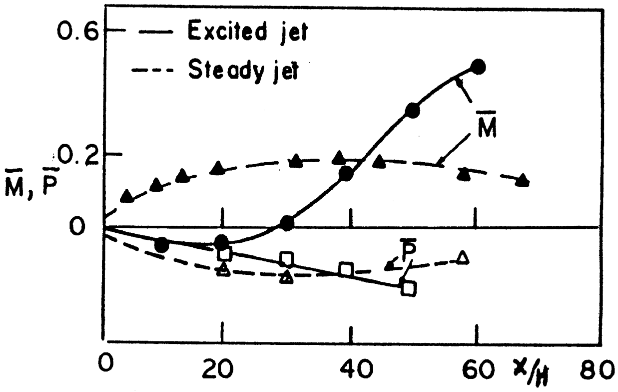

Figure 10. Momentum and integrated pressure.

SYMBOLS

x	Coordinate in the streamwise direction; x=0 at the exit
y	Coordinate in the perpendicular direction; Y=0 along the center line.
b	Half width of the jet
H	Width of the nozzle
U	Mean velocity
U_m	Maximum value of U at any streamwise location
U_e	Exit velocity
ˋM	$\overset{+È}{\underset{-E}{r\ ß}}\ U^2$ dy/ r U_e^2 H
p	Static pressure
ˋp	$\overset{+È}{\underset{-E}{ß}}$ p dy/r U_e^2H
Q	$\overset{+È}{\underset{-E}{r\ ß}}$ U dy
Q_o	Q at X=0

e $(Q-Q_o)/Q_o$

f Frequency of excitation

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