ing from the nozzle out-let grow with unstable amplitude within two to three wave length from the exit. These waves intern form ring of vortex core which rolls downstream. After one or two revolutions the vortices interact strongly with the waves behind and break down into turbulent eddies.

The boundary layer is quite likely to have more than one kind of coherent structures (vortical motion). These structures are belived to play a dominant role in the entrainment, mixing, noise generation and other transport phenomena. Recent researchers have provided considerable new informations and also raised new questions on these structures. The characteristic behaviour of these eddies enable the researchers to divide the turbulent jet into three principle regions, viz. initial region, transition region and developed region.

The formation of the eddy structures(through the shear layer instability, saturation and roll up) as well as their evolution and even successive interaction depends on the boundary and initial conditions. The boundary condition can also affect the coherent structure by feedback mechanisms(Dimotakis & Brown[4] and Hussain & Zaman[7]).

Accumulated data in the incompressible free shear layer, however reveal wide spread discrepancy even in its characterestics integral measures(Cha, Pao & Wygnanski[3], Hussain & Zaman[7]), thus including the lack of understanding of even this simpl flow.

The concept of asymtotic and local invariances suggests that the flow structure sufficiently downstream from the origin should be universal or self-preserving(i.e. become progressively oblivious of the initial condition), with increasing x. The coherent structures are also typically stronger(owing to larger gradient of velocity) in the near fields of free flows. Again the near field is important to majority of technological applications including mixing and noise production. So the present study gives special attention on the near field of free shear layer.

EXPERIMENTAL APPARATUS AND PROCEDURES

The experiments were carried out in a near field of a 7.6 cm(3 inch) circular jet by application of United sensor(USA) pitot static tube along with Furnace Control(UK) pressure transducer and Keithly(USA) data logger for measuring velocities and constant temperature hot-wire(DANTEC 56C00 system) anemometer for measuring longitudinal turbulence intensities.The hot-wire instrumentation along with probe setting and flow facility is shown in fig. 1 The measurements covered the jets Reynolds number range $27800 \leq Re_D \leq 61000$.

In the flow facility air flow was created by an axial flow fan. Air was first entered through a flow controller (twin flap butter fly valve) and entered into the 6° diffuser through a silencer section, and then through a honeycomb into the first settling chamber(attached with a loud speaker, used excited flow). The flow then went through a nozzle, a 6° diffuser, a number of screens(30 and 50 mesh/inch), and a honeycomb and ultimately exited through a 7.6 cm diameter nozzle in a laboratory with controlled temperature, humidity and traffic. The axisymmetry of the near field of mean and turbulenc intencities have been chacked before starting actual measurment. In the experiment two nozzles of the same parabolic profile, but with different prallel exist length were used. The nozzle with shorter exist is here named as normal neck (NN) nozzle and other with longer exist length is named as long neck (LN) nozzle. The two nozzles are shown in figure2(a).

The probes were traversed with precission with the help of a Mitutoyo(Japan) three coordinate(X,Y,Z) traversing mechanism. In order to minimize the effect of high turbulence intensity and transverse entrainment velocity on the zero-speed side, q is calculated upto $y_{0.1}$ and is denoted as $q_{0.1}$. In the turbulence measurement 5mm platinum wire miniature probe was used as the transducer.

The variation in the initial momentum condition was achieved with two nozzle of different neck length (Selim[8]) and different flow speeds were achieved by controlling the butterfly valve.

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Effect of Initial Conditions on Development of Axisymmetric Free Shear Layer.

Masud Ahmed Selim*
M. A. Taher Ali*

ABSTRACT

Experiments have been made on axisymmetric free shear layer with different initial conditions at subsonic speeds. In present study initial momentum thickness and Reynolds number were taken as characteristic identifiers of initial conditions. The Reynolds number and initial momentum thichness has little effect on mean flow characteristics but cause significant shifts in the virtual origin of the mixing layer. The effect of initial momentum thickness on turbulent flow characteristics is more pronounced than the mean flow characteristics.

NOMENCLATURE

B	shear layer width
C_1, C_2	constants
H	shape factor of velocity profile
Re	Reynolds number
X, Y	coordinate direction
U	mean axial velocity
u'	longitudinal component of turbulence intensity
x	distance in X coordinate
x_o	virtual origin
y	distance in Y coordinate
δ^*	boundary layer thickness
θ	momentum thichness

Subscripts

e	exit
m	maximum
w	wall
pe	exit peak

INTRODUCTION

Axisymmetric free shear layer is formed when a fluid is discharged from a nozzle into still air, and axisymmetric incompressible turbulent mixing layer is one of the simplest turbulent flows to investigate detail of physics of shear flow turbulence.

When the flowing fluid leaves the solid surface of the nozzle, the shear layer grows continuously with the entrainment of surrounding ambient air. In the shear layer the turbulence originates with the instabilities in laminar flow. Disregarding very small velocities of the flow, it is found that the jet becomes completely turbulent at a short distance from the point of discharge due to the instabilities of shear layer. Usiging flow visualisation tecnique (Hussain[7]) it has been shown that these instabilities generate waves due to interactions of viscous terms and non-linear inertia terms in the equation of motion. These waves start-

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* Department of Mechanical Engineering, BUET, Dhaka.

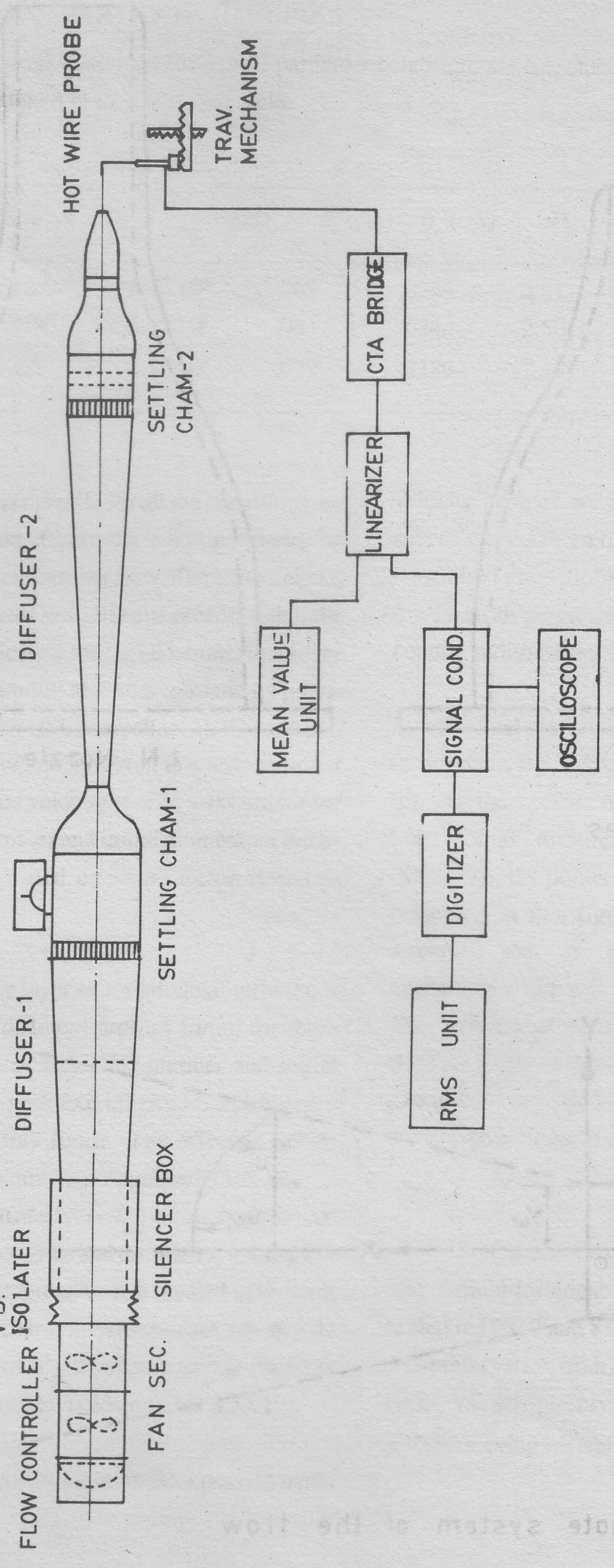
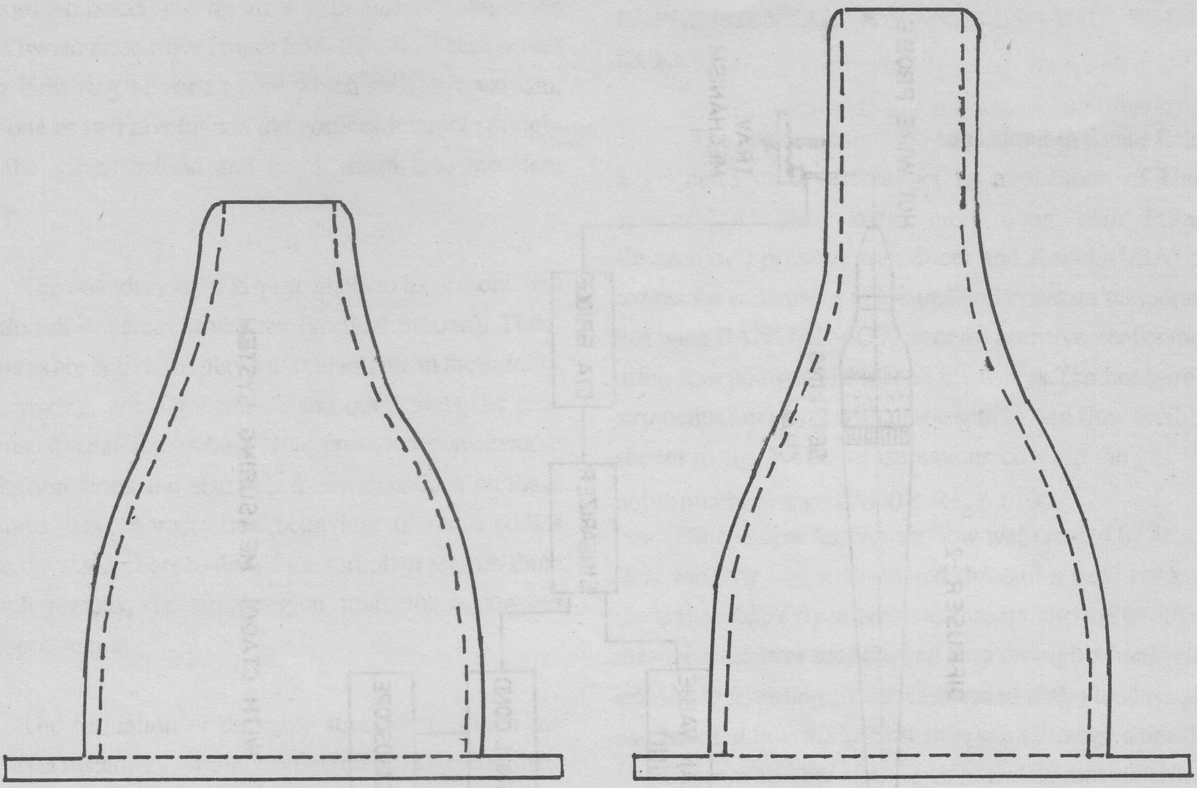


FIG. 1 SCHEMATIC DIAGRAM OF FLOW FACILITY WITH CTA001 MEASURING SYSTEM



NN Nozzle

LN Nozzle

Fig. 2a Nozzles

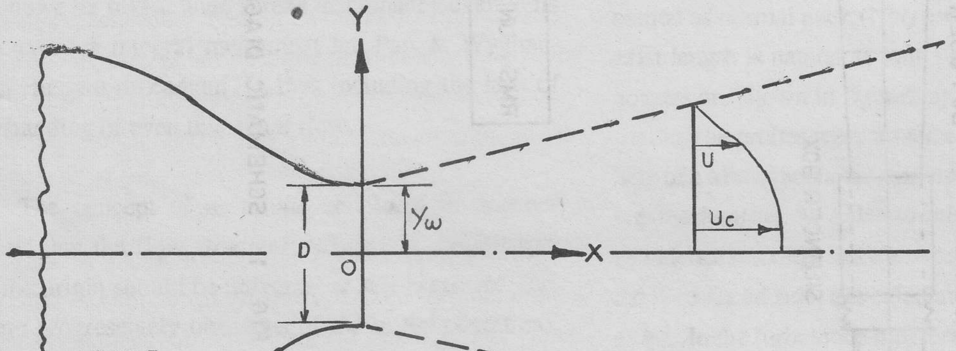


Fig. 2b Coordinate system of the flow

RESULTS AND DISCUSSION

In this study the results obtained from three particular conditions are presented and discussed in this section. These three conditions are as shown in the following table

Condition	Nozzle used	ReD	δ_e^*(cm)	θ_e^*(cm)	H_e	u'_{pe}/U_e	Symbol
1	NN	$4.5X10^4$	.069	.0264	2.61	.04	+
2	NN	$5.4X10^4$	.061	.0244	2.50	.054	O
3	LN	$4.5X10^4$	.072	.0289	2.49	.011	Δ

Exit boundary layer profile for all the conditions are ploted in Fig. no. 3. In this figure the solid line shows the Blasius profile for flat plate laminer flow. The experimental points are found to coincide with Blasius profile within the experimental scatter indicating the initial laminer boundary layer for all the cases. Simillar results also found by previous investigators viz. Crow & Champahne[2], Hossain and Zedan[6], Zaman and Hossain[9]. From this observation it can be assumed that initial velocity profile was laminer for the range of Reynolds number and initial momentum thichness, which is also supported by shape factor closed to Blasius value 2.59.

The exit boundary layer of longitudinal turbulence intensity (Fig-4) shows different profiles for all the three conditions. Dependence of Reynolds number and initial momentum thickness on peak exit longitudinal turbulence intensity is clear from this figure. The effect of initial momentum thickness is much pronounced than that of Reynolds number. Zaman and Hossain [9] reported simillar suppression of exit peak longitudinal turbulence intensity in exited flow but natural suppression like present case is not reported by other researchers. In present case LN nozzle shows 74% suppression of u'_{pe} compared to that found in NN nozzle case with same Reynolds number $4.5X10^4$.

The effect of initial momentum thickness on mean velocity profiles are almost insignificant in down stream side of the jet. From the mean velocity profiles at different x location, three profiles are presented in figs. 5(a), (b) and (c). From these profiles it is clear that the effect of initial condition diminishes from x/D = 1.5.

Longitudinal turbulence intensity profiles at three x/D location viz. 0.5, 1.5 and 3.0 are shown in Fig. 6(a), (b) and (c). As the effect of change of Reynolds number on longitudinal turbulence intensity is not prominent (Selim[8]), the points corresponding to condition 2 is not presented in this figure. From these profiles it can be discerned that the peak turbulence intensity remain unchanged which was also found by Hossain and Zedan[6]. The location of peak longitudinal turbulence intensity showed small shifting towards the core zone flow and distribution become more smoother with relatively higher momentum thickness in the initial condition.

Self preservation profiles of mean velocity and longitudinal turbulence intensity for condition 3 are presented in figs. 7 and 8 respectively. It is customary to infer self-preservation from congruence of mean velocity profile (U/U_e vs. self-preserving variable). In the present study self- preserving variable is considered as $(y-y_5)/\theta_{.1}$ which is

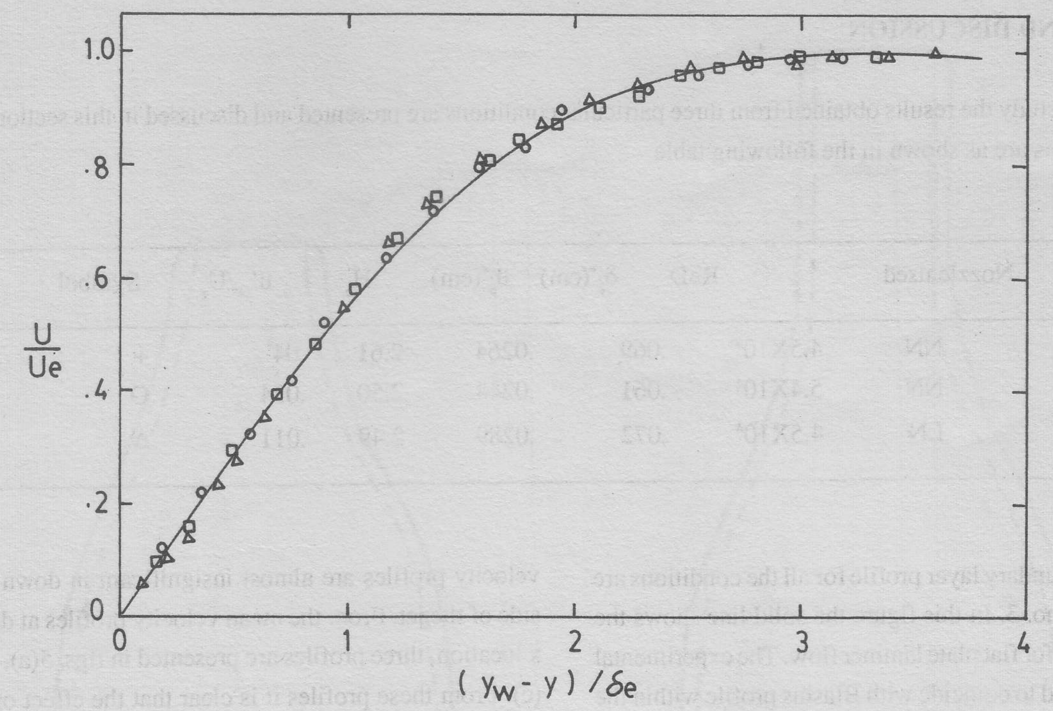


Fig. 3 Exit boundary layer profiles of mean velocity for different cases:— Blasius profile; □, $Re=4.5\times10^4$, NN: ○ $Re=5{\cdot}4\times10^4$, NN: △ $Re=4.5\ 10^4$, LN

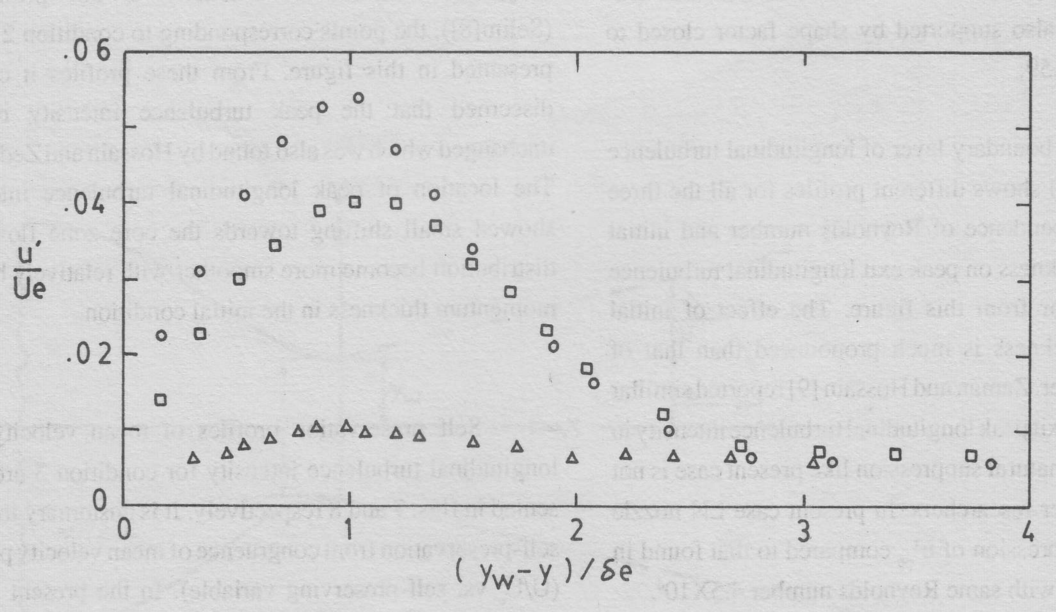


Fig. 4 Exit boundary layer longitudinal turbulence intensity profiles for different initial conditions; for symbols see fig. 3

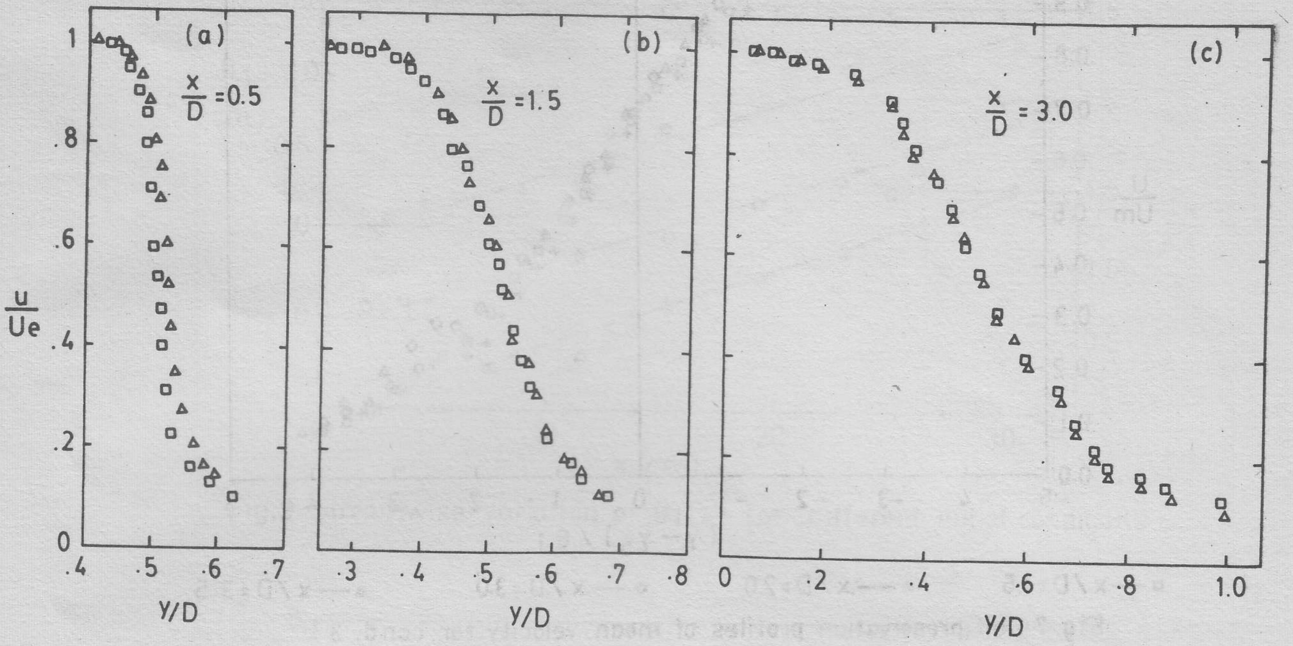


Fig. 5 Mean velocity profiles at three downstream location viz ; x/D=0.5, 1.5 and 3.0 for symbols see fig. 3

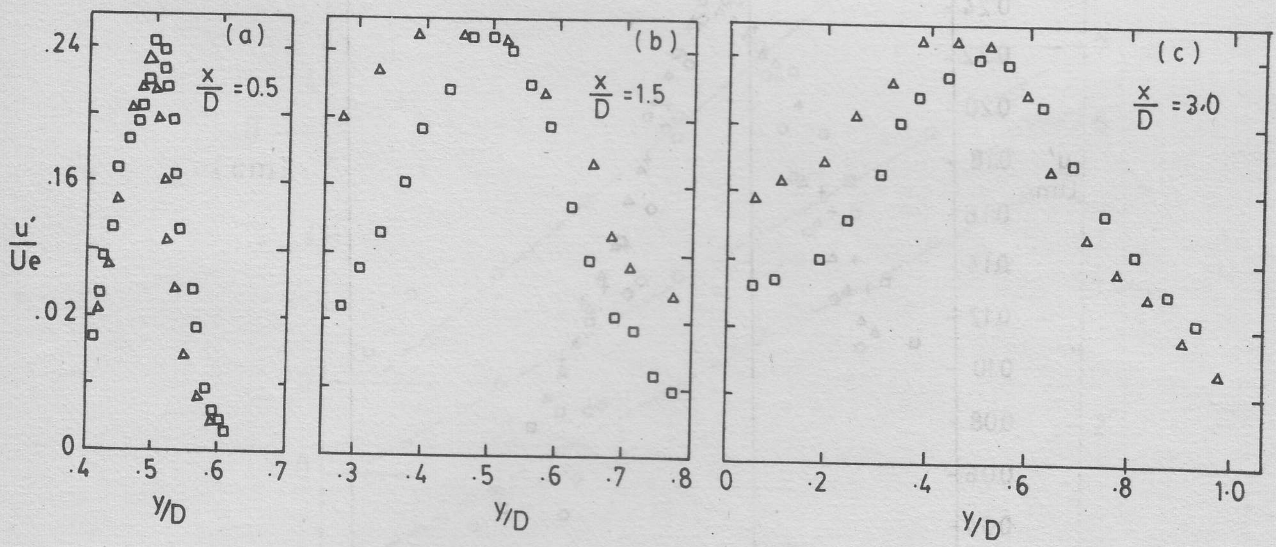


Fig. 6 Longitudinal turbulence intensity profiles at three different x/D locations ; for symbol see fig. 3

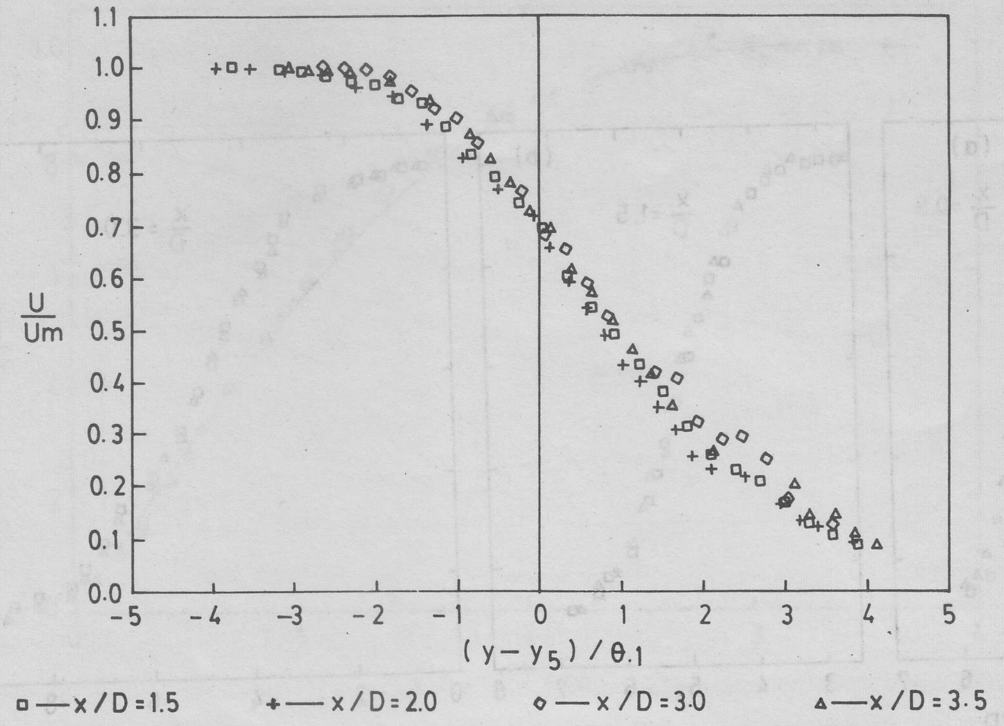


Fig. 7 Self preservation profiles of mean velocity for cond. 3

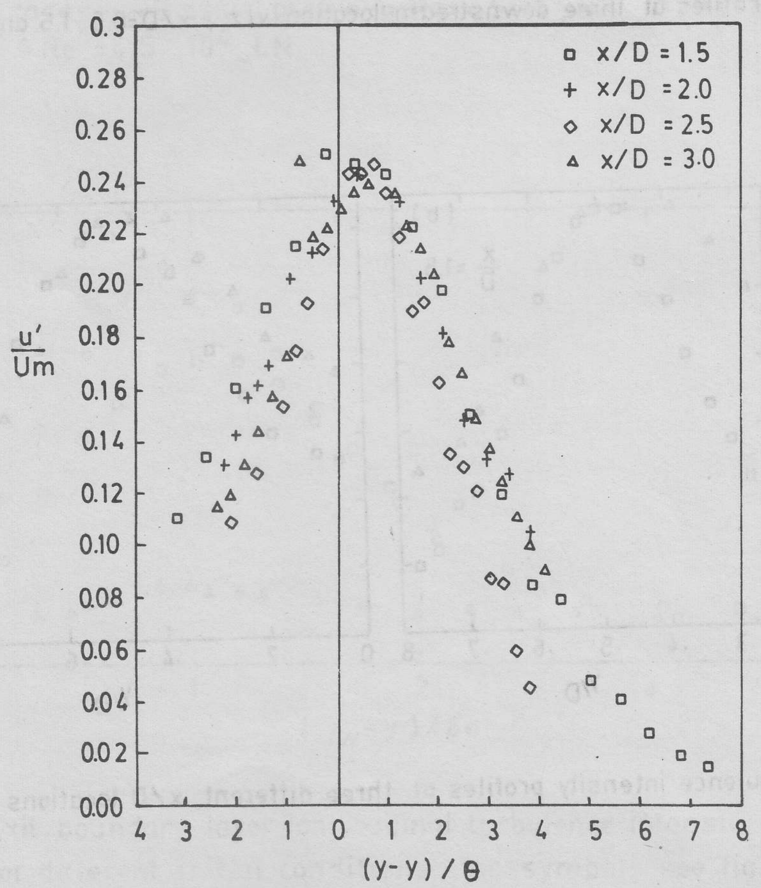


Fig. 8 Self preservation profiles of u′ for cond. 3

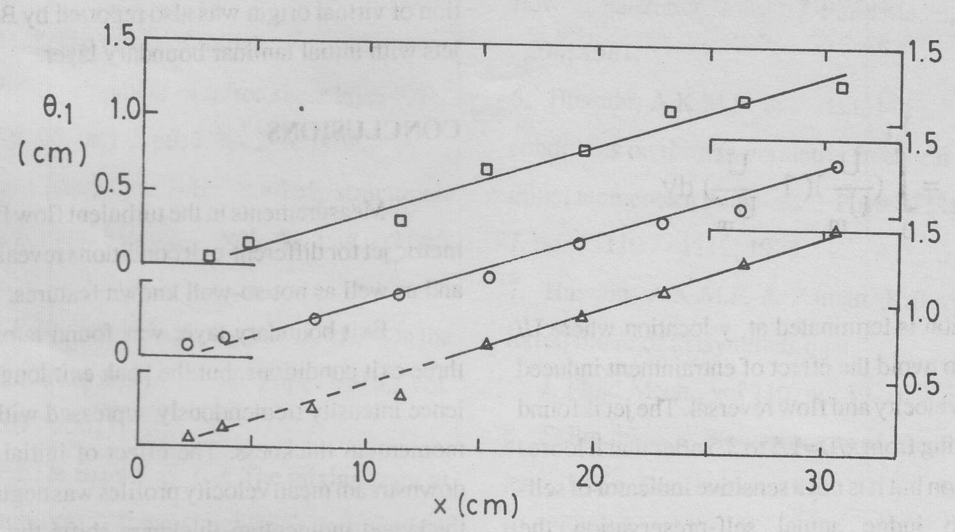


Fig.9 Streamwise variation of $\theta_1(x)$ for different initial conditions

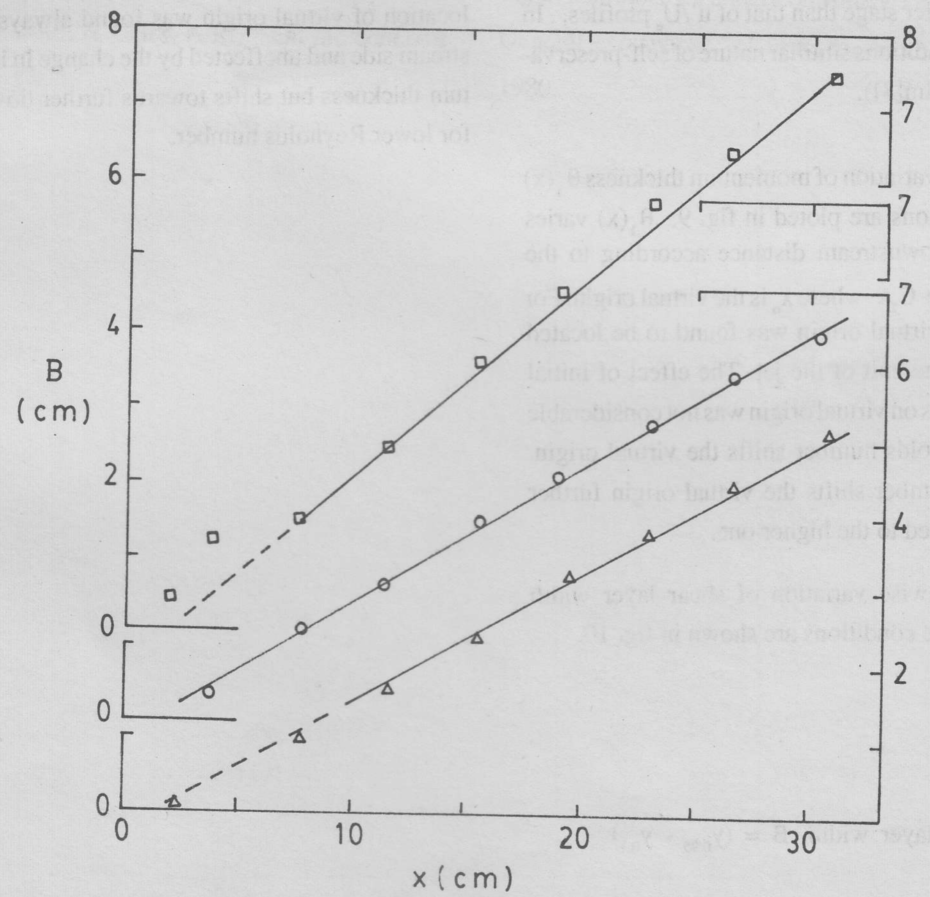


Fig. 10 Streamwise variation of shear layer width B

also considered by many other researcher including Zaman and Hossain[6], and Hussain and Clark[5].

where,

$$\theta_{.1} = \int_{0}^{y_{.1}} \left(\frac{U}{U_m}\right)\left(1-\frac{U}{U_m}\right) dy$$

here the integration is terminated at y-location where $U/U_e=0.1$ in order to avoid the effect of entrainment induced transverse mean velocity and flow reversal. The jet is found to be self-preserving from x/D=1.5 to 3.5 after that it looses its self-preservation but it is not a sensitive indicator of self-preservation. To judge actual self-preservation the fluctuating intensities come into consideration. Congruence of u'/U_e indicating attainment of self-preservation of u'/U_e profiles at a later stage than that of u'/U_e profiles. . In case of othertwo conditions simillar nature of self-preservation was found (Selim[8]).

Streamwise variation of momentum thickness $\theta_{.1}(x)$ for different conditions are ploted in fig. 9. $\theta_{.1}(x)$ varies linearly with the downstream distance according to the equation, $\theta_{.1}(x) = x_o + C_2x$ where x_o is the virtual origin. For all the three cases virtual origin was found to be located downstream from the exit of the jet. The effect of initial momentum thickness on virtual origin was not considerable but change of Reynolds number shifts the virtual origin. Lower Reynolds number shifts the virtual origin further downstream compared to the higher one.

Streamwise variation of shear layer width B(x), for all the three conditions are shown in fig. 10.

where,

Shear layer width, $B = (y_{0.95} - y_{0.1})$

Shear layer width shows grater spread rate at to lower Reynolds number which is also indicate further downstream location of virtual origin supporting the earlier comment from $\theta_{.1}$ distribution. Simillar downstream location of virtual origin was also reported by Bradshaw[1] for jets with initial laminar boundary layer.

CONCLUSIONS

Measurements in the turbulent flow field of axisymmetric jet for different exit conditions revealed both known and as well as not-so-well known features.

Exit boundary layer was found laminar for all the three exit conditions, but the peak exit longitudinal turbulence intensity tremendously supressed with higher initial momentum thickness. The effect of initial conditions on downstream mean velocity profiles was negligible. Initialiy thickened momentum thickness shifts the peak value of longitudinal turbulence intensity towards the core and also gives rise to a higher turbulence intensity in that side. The location of virtual origin was found always in the downstream side and uneffected by the change in initial momentum thickness but shifts towards further downstream side for lower Reynolds number.

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