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VOL. 11, NO. 1, JANUARY 1973 AIAA JOURNAL

An Experimental Study of a Plane Mixing Layer

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Examination of existing literature is revealing in that although many investigations have been carried out for a plane mixing layer, only a few present turbulence measurements. It is well-known that both mean velocity and turbulence structure in a plane mixing layer are self-preserving, however there appears to be some variations in these measurements. This investigation presents new data on the mean velocity and the turbulence properties of a plane mixing layer. The turbulence measurements differ by about 25% from those obtained by previous investigators and this is attributed to differences in the experimental set up (i.e., presence or absence of a solid wall in the plane $x = 0$) and errors associated with hot-wire probes (i.e., longitudinal cooling and thermal wake interference). To avoid difficulties experienced by previous investigators in calculating shear stress distribution from a measured nondimensional mean velocity profile a new method is suggested and this provides good agreement between the calculated and the measured shear stress distribution.

Introduction

RECENTLY, considerable effort has been directed towards the study of free turbulent shear flows. In this group of shear flows a plane, turbulent, incompressible mixing layer between a uniform stream and quiescent surroundings is a comparatively simple flow to investigate both theoretically and experimentally. However, except for a few investigations (as for example Garshore[1]; Hackett and Cox[2]) dealing with mean velocity measurements not much renewed attention appears to have been given to the plane turbulent mixing layer since the appearance of the work of Liepmann and Laufer.[3] It should be recalled that Liepmann and Laufer did not measure both the lateral turbulent intensity and the shear stress $\langle \rho uw \rangle$ presumably because $\langle w^2 \rangle$ is expected to be of the same magnitude as $\langle v^2 \rangle$ and $\langle uw \rangle$ is expected to be zero. Furthermore, techniques of hot-wire anemometry have developed considerably since their investigation and therefore it is of interest to reinvestigate the plane mixing layer.

Since the completion of the present investigation Wygnanski and Fiedler[4] have reported extensive and sophisticated turbulence measurements in this type of flow. An interesting aspect of their investigation was the geometry of the experimental apparatus. They used a trip wire and a solid wall on the zero velocity side in the plane $x = 0$. They also used conventional DISA x-wire probes to measure the turbulence parameters and it is now known that the conventional DISA x-wire probes are contaminated by the "thermal cross talk."[5] The measurements of Wygnanski and Fiedler are compared with the results of the present investigation obtained with single hot-wires in a plane mixing layer without a solid wall in the plane $x = 0$. It is anticipated that such a comparison would show up differences, if any, due to the geometry of the experimental apparatus and the probes.

Recently Spencer and Jones[6] have investigated a general problem of a mixing layer between two parallel streams and as a special case they have reported some data on a plane mixing layer. This information consists of the spreading rate and the mean velocity profile. Although not directly related to the
present investigation it is worthwhile to note that the i
technique used by them to calculate shear stress d
for their mixing layer between two parallel stream
quite sum to zero. For a plane mixing layer Lie
Laufer had also experienced this difficulty.

It was mentioned that Hackett and Cox[2] have also in
a plane mixing layer. They did not measure the sh
distribution but calculated it from the mean velocity
compared their results with those of previous inv
They found that there was a need for a unified ap
calculate the shear stress distribution from mean veloci
In the calculation of the shear stress distribution the
arises from the nonexistence of well defined boundaries
mixing layer. To overcome this difficulty a method is
in this paper.

The present experimental investigation for a pla
layer was carried out in the Aerodynamics Laboratory
University. The mixing layer was formed at the e
McGill 43.2×76.25 cm blower cascade wide tunnel. An
tion regarding the two-dimensionality of the flow
from this tunnel is given by Patel.[7] Furthermore
present measurements were made an investigation on
of freestream turbulence intensity on free shear flow w
out. It was found that for freestream turbulence intensi
than 0.6% the characteristics of the plane mixing
independent of the effects of stream turbulence (Patel
present investigation the freestream turbulence inte
0.5% and $U_1 v = 18 \times 10^5$ per meter.

The results include mean velocities and Reynolds
three stations, (28 cm $< x <$ 102.5 cm). These were
by using a linearized constant temperature hot-wire an
(only single wire probes were used) and include the lo
cooling corrections where appropriate (for the lo
cooling corrections to the results obtained by inclined
the reader is referred to Patel[9] and Champagne et al.
details of instruments, experimental techniques, etc. ar
Patel.[8]

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