Experiments on the free shear layer between adjacent supersonic streams
by Timothy L Brower

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering
Montana State University

Abstract:
A closed-form analytical theory has been developed to predict the flow field of two-dimensional, laminar, non-equilibrium free shear layers, shed from the trailing edge of a thin flat plate serving as a partition separating two dissimilar parallel flows. A Mach 3 supersonic nozzle in combination with either a Mach 1.6 or a Mach 2 supersonic nozzle were used to produce a free shear layer. The investigation was designed to provide experimental evidence by which free shear layer theories may be checked. A comparison of theoretical/experimental mean flow properties in the laminar, non-equilibrium region of the free shear layer were made. The theory showed good agreement qualitatively, but poor agreement quantitatively when compared to experimental data. The theoretically assumed initial velocity profile showed a 35 % difference in thickness compared to the experimental thickness. The theory predicts free shear layer thickness and minimum velocity growth rates that parallel the experimental results, although a quantitative error of between 20-50 % exists.

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APPROVAL

of a thesis submitted by

Timothy L Brower

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Signature Timothy J Brower

Date 3/16/83

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NOMENCLATURE

Symbol		Description
DSL	:	Dividing stream line
f	:	Frequency
FSL	:	Free shear layer
h	:	FSL thickness
M	:	Mach number
P	:	Momentum thickness ratio θ_1/θ_2
P_0	:	Stagnation pressure
P_s	:	Static pressure
r	:	Speed ratio U_2/U_1
Re	:	Reynolds Number
Re'	:	Unit Reynolds Number
$\overline{Re}'$	:	$(Re'_1 + Re'_2)/2$
SWT	:	Supersonic Wind Tunnel
T	:	Temperature
T_0	:	Stagnation Temperature
T.E.	:	Trailing Edge
U	:	Velocity
U_s	:	Velocity on the DSL
x	:	Distance from the T.E. (x positive downstream)
x^*	:	Same as x
x'	:	Non-dimensional x^*

NOMENCLATURE--Continued

Symbol		Description
y	:	Distance normal to FSL
$\tilde{y}$	:	Compressible transformed y
y'	:	Non-dimensional y
α	:	Deflected angle of FSL
δ	:	Boundary layer thickness at T.E.
θ	:	Momentum thickness at T.E.
β	:	$\theta_1 + \theta_2$
ρ	:	Density
λ	:	Non-dimensional speed ratio $(U_1 - U_2)/(U_1 + U_2)$, also wavelength in Appendix C
$(\ )_1$	:	Fast-side property
$(\ )_2$	:	Slow-side property
$(\ )_e$	:	Free stream property

ABSTRACT

A closed-form analytical theory has been developed to predict the flow field of two-dimensional, laminar, non-equilibrium free shear layers, shed from the trailing edge of a thin flat plate serving as a partition separating two dissimilar parallel flows. A Mach 3 supersonic nozzle in combination with either a Mach 1.6 or a Mach 2 supersonic nozzle were used to produce a free shear layer. The investigation was designed to provide experimental evidence by which free shear layer theories may be checked. A comparison of theoretical/experimental mean flow properties in the laminar, non-equilibrium region of the free shear layer were made. The theory showed good agreement qualitatively, but poor agreement quantitatively when compared to experimental data. The theoretically assumed initial velocity profile showed a 35 % difference in thickness compared to the experimental thickness. The theory predicts free shear layer thickness and minimum velocity growth rates that parallel the experimental results, although a quantitative error of between 20-50 % exists.

CHAPTER 1

INTRODUCTION

An analytical theory has been developed by Demetriades {1}[1] to predict the flow field of two-dimensional, laminar, non-equilibrium free shear layers, shed from the trailing edge of a thin flat plate serving as a partition separating two dissimilar parallel flows. The term free shear layer (FSL) is applied since the flow is not confined by solid walls. The theory applies to the non-equilibrium (non-similar) region of the free shear layer as shown in Figure 1. Figure 1 consists of a general nomenclature diagram and also a qualitative schematic diagram of a nozzle combination described in detail in Chapters 5 and 6. Downstream of the trailing edge (T.E.), the velocity profiles of the two parallel flows coalesce into a single profile in the FSL. The non-equilibrium region is identified by a trough (velocity decrease) in the velocity profile. The trough depth is greatest at the T.E. and progressively decreases with increasing distance downstream until finally the trough disappears and the profile becomes the equilibrium (self-similar) profile.

[1]The symbol { } will denote references cited. References cited are found following the appendices.