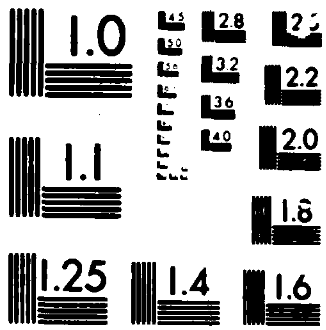
AD-A167 042 COHERENT STRUCTURES IN TURBULENT SHEAR LAYERS AND RELATION TO MIXING REACTION AND COMBUSTION(U) CALIFORNIA UNIV BERKELEY COLL OF ENGINEERING APR 86 1/1

UNCLASSIFIED N00014-80-C-0694 F/G 20/4 NL



MICROCOP

CHART

UNIVERSITY OF CALIFORNIA, BERKELEY
COLLEGE OF ENGINEERING
OFFICE OF RESEARCH SERVICES
BERKLEY, CA 94720

CONTRACT NO. N00014-80-C-0694

TITLE: COHERENT STRUCTURES IN TURBULENT ~~SHEER~~ Shear LAYERS AND RELATION TO MIXING REACTION AND COMBUSTION

FINAL REPORT

DATE: APRIL 1986

UNIVERSITY OF CALIFORNIA, BERKELEY

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO — SANTA BARBARA • SANTA CRUZ

College of Engineering
Office of Research Services

Berkeley, California 94720

April 3, 1986

Director, Mathematical & Information
Sciences Division
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217

Re: Final Technical Report
N00014-80-C-0694
Principal Investigator: Professor Gilles Corcos

At the request of Professor Corcos, I am transmitting the Final Technical Report for the above-referenced contract.

Bette Cooper
Bette Cooper
Grant Administration

encl.
cc: Professor Corcos
Sponsored Projects Office
Robin Simpson, ACO

Copies of this report sent to the following:

Office of Naval Research Western
Regional Office
1030 East Green Street
Pasadena, California 91106
1 copy

DODAAD Code N00173
Naval Research Laboratory
Washington, D.C. 20375
6 copies

✔ DODAAD Code S47031
Defense Technical Information Center
Building 5, Cameron Station
Alexandria, Virginia 22314
12 copies

Final Report for O.N.R. Contract
NR-062-665-N00014-80-C-0694

A) Introduction

In May 1980, the Office of Naval Research granted the above-numbered research contract titled Coherent Structures in Turbulent Shear Layers and their Relation to Mixing Reaction and Combustion. The contract was renewed in 1982 and expired September 30, 1984.

It included a theoretical, a numerical and an experimental program. Its purposes were detailed in the proposal, the contract renewal proposal, the proposal for a no-cost extension in 1984 (not granted) and the progress reports.

The general results of the work maybe summarized by saying that the theoretical objectives of the contract were fully achieved during the contract period while the experimental objectives were not, though they may well be in the future. The reason why the experimental work was not completed was given in our progress report of February 1984. Substantial progress was made between then and the expiration date of the contract so that the water facility was completed and is operational and the main components of specialized instrumentation have also been built. Thus we expect to be able to run the experiment in the future without further equipment and facilities support.

B) Summary of Completed Project

A number of numerical analyses served as experiments which led to a broad range of ideas about the dynamics of mixing layer. One theme which emerged early was the adversary role of vorticity and of deformation - two quantities which attempt to subjugate each other and whose competition is the subject matter of the development and growth of the shear flow. Another strand of the work follows a number of instabilities (two and three dimensional) which lead to recognizable non-linear motions. A third focus of the work relates vorticity and the mixing of scalars. The work started out to attempt to explain striking experimental results and ended by making a number of predictions which have not yet been experimentally established. A significant fraction, though not all of the typical motions which are dynamically plausible in a shear layer have been examined and given simple analytic representation. Finally the basis for the effective control of the shear layer has been laid.

C) Student Involvement:

The project supported the graduate research of six students. Three of these led to Ph.D. Theses, and three to Master's Theses and projects.

The Ph.D. Theses were:

The Evolution of Streamwise Vorticity in the Free Shear Layer
by Shyi-Jang-Lin (March 1981)

Do Large Vortices Control Their Own Growth in a Mixing Layer?
by Upender, Krishen Kaul (January 1982)

The Effect of Non-Uniform Strain on the Diffusion of a Scalar and on Vorticity
by Henry Ham Chung King

The Master's Theses and Projects were:

a) *The Construction of a Free Surface Water Mixing Layer*, by Charles Huizenga.

b) The Nature of Vorticity Perturbations Created Thermally by Periodic Heating of Wall Ribbons by Ho-Shang Lee.

c) An Unsteady Vorticity Perturbation Generator by Paul Kim.

D) Publications

The publications directly related to the research sponsored by the ONR contract are

The Mixing Layer: Deterministic Models of a Turbulent Flow:

Part 1. Introduction and the two dimensional flow.
Corcos, G.M. and Sherman, F.S., J. Fluid Mech. 139, 29 1984.

Part 2. The origin of the three dimensional motion.
Corcos, G.M. and Lin, S.J., J. Fluid Mech. 139 67 1984.

Part 3. The effect of plane strain on the dynamics of streamwise vortices.
Lin, S.J. and Corcos, G.M., J. Fluid Mech. 141, 139.

The Prevalence of two-dimensional motion in the turbulent mixing layer.
Corcos, G.M. 1983, Journal de Mecanique theorique et appliquee, Numero Special, p. 147-167.

The Role of Cartoons in Turbulence
Corcos, G.M. 1985, in Perspectives in Fluid Mechanics (D. Coles, Edit) from Jan. 1985 Pasadena Symposium of the same name (to appear).

E) Conclusions

Disposition of the experimental facility and equipment.

The experimental work is proceeding along the lines originally proposed, with the help of a N.A.S.A. grant which is in effect a fellowship for an experimental student. We still fully expect to reach the goals outlined in our contract proposal.

The Evolution of Streamwise Vorticity in the Free Shear Layer

Shyi-Jang Lin

Abstract

The work is a study of three dimensional motion in a free shear layer. An examination of the origin of this motion is by-passed. We postulate instead that streamwise vorticity appears as the result of an initial instability of the layer and we use a number of simplified models to describe its evolution when it is subjected to the dominant influence of the time-dependent two-dimensional flow. In particular the linear and nonlinear behavior of vortices subjected to axial strain is examined in detail. The role which these vortices play in enhancing molecular mixing is also explored. For sufficiently high Reynolds numbers, it is found that such vortices are unstable in shear and are transformed into smaller vortices. The nonlinear evolution of these vortices tends to increase their vorticity and to decrease the space they occupy. It is characteristic of the motions which we have studied that they all result in isolated vortices and the field of strain which they create between them produces thin elongated transport layers with expels the vorticity component parallel to the axis of these vortices.

Do large vortices control their own growth in the mixing layer? An assessment by a boot-strap method.

Upender K. Kaul

Abstract

This study makes a limited comparison between two different two-dimensional free shear layers: the T-layer which develops in time from an initial tangential velocity discontinuity across the x(streamwise) axis; and the S-layer which develops downstream of the point $x' = 0$ where two uniform streams of unequal velocity are brought into tangential contact.

The method of comparison is to assume that the vorticity of the S-layer is given parabolically by a Galilean transformation of that of the T-layer; to compute the velocity induced in the S-field by that vorticity; and to compare this velocity to that which can be derived from the velocity of the T-layer at corresponding points by a Galilean transformation of the velocity itself.

The purpose of the calculation is to assess approximately how far the flow in the S-layer is from parabolic and in particular, to what extent the perturbations induced upstream by large concentrations of vorticity found downstream are instrumental in hastening the subharmonic instability which leads to the formation of these large vortices.

The calculations suggest that this feedback is relatively weak.

The Nature of Vorticity Perturbations Created Thermally by Periodic Heating of Wall Ribbons

Ho-Shang Lee

Abstract

The periodic heating of a strip of wall adjacent to a developed laminar boundary layer generates viscosity fluctuations in the neighborhood of the strip. This in turn causes vorticity fluctuations which have been used to generate disturbances in water boundary layers. The theory of this experimental method is provided. It is shown that the perturbation is not confined to the wall and that as the ribbons streamwise extent increases the solutions reach an asymptotic state after an overshoot.

The Effect of Non-Uniform Strain

on the Diffusion of a Scalar and on Vorticity

By

Henry Ham Chung King

Abstract

Two problems are examined. First, the effect of a velocity field on the diffusion of a scalar is analyzed. Mixing is enhanced if a material interface is stretched. From a global analysis of the velocity field, it is found that the stretching associated with the rollup of a material interface is an adequate paradigm of stretching mechanisms which enhance diffusion. A necessary condition for a rollup is that the vorticity must be sufficiently intense and compactly distributed. The evolution of the shape of the interface can be used to determine the circulation of vortices which satisfy the rollup condition.

Second, the effect of a spatially non-uniform strain on a vortex is studied. Several models are considered: an integral method using a prescribed velocity distribution, some asymptotic analyses of the vortex tube (vorticity concentrated on the surface of the tube) and of the Rankine vortex (uniform vorticity inside the vortex), and a numerical simulation. Our results indicate that the radius of a vortex with strong vorticity remains virtually unaffected by the strain. The induced velocity inside the vortex is of the same order of magnitude as the external straining velocity and the induced length scale within the vortex is comparable to the radius of the vortex.

END

FILMED

6-86

DTIC