AD-A115 897 OHIO STATE UNIV COLUMBUS DEPT OF AERONAUTICAL AND AS--ETC F/G 20/4
FLUID DYNAMICS OF MULTIPLE NOZZLE ARRAYS.(U)
MAY 82 S L PETRIE AFOSR-80-0216
UNCLASSIFIED AFOSR-TR-82-0490 NL

1 of 1
AD
A115897

END
DATE
FILMED
7 82
DTIC

AFOSR-TR- 82-0490

RF Project 762187/712893

Report No.

(1)

FINAL

REPORT

By

THE OHIO STATE UNIVERSITY
RESEARCH FOUNDATION

1314 KINNEAR RD.
COLUMBUS, OHIO 43212

To DEPARTMENT OF THE AIR FORCE
Air Force Office of Scientific Research
Bolling Air Force Base, D.C. 20332

Grant No. AFOSR-80-0216

On FLUID DYNAMICS OF MULTIPLE NOZZLE ARRAYS

For the period June 1, 1980 - May 31, 1981

A

Submitted by Stuart L. Petrie

Department of Aeronautical and Astronautical Engineering

Date May 13, 1982

Approved for public release;
distribution unlimited.

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER **AFOSR-TR- 82-0490**	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) FLUID DYNAMICS OF MULTIPLE NOZZLE ARRAYS		5. TYPE OF REPORT & PERIOD COVERED Final 6/1/80-5/31/81
		6. PERFORMING ORG. REPORT NUMBER 762187/712893
7. AUTHOR(s) Stuart L. Petrie		8. CONTRACT OR GRANT NUMBER(s) Grant No. AFOSR-80-0216
9. PERFORMING ORGANIZATION NAME AND ADDRESS The Ohio State University Research Foundation 1314 Kinnear Road Columbus, Ohio 43212		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 61102F 2307/A2
11. CONTROLLING OFFICE NAME AND ADDRESS AIR FORCE OFFICE OF SCIENTIFIC RESEARCH Bolling Air Force Base, D.C. 20332		12. REPORT DATE May 13, 1982
		13. NUMBER OF PAGES 6
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) turbulence modelling nozzle arrays electron beams arc-heated wind tunnels		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Theoretical and experimental research has been conducted to investigate the fluid dynamic interactions present in the supersonic free shear layers typical of those in multiple nozzle arrays. Steady state and fluctuating temperature measurements were made with an electron beam in an arc-heated wind tunnel and the results were compared with those from various turbulence models.		

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

FINAL REPORT

FLUID DYNAMICS OF MULTIPLE NOZZLE ARRAYS

by

Stuart L. Petrie
The Department of Aeronautical and Astronautical Engineering
THE OHIO STATE UNIVERSITY
Columbus, Oh

Final Report
to
Air Force Office of Scientific Research
on
Grant No. AFOSR-80-0216

INTRODUCTION

Comprehensive experimental and theoretical studies have been conducted at The Ohio State University to provide Characterization of mixing layers in supersonic flow fields. Particular emphasis has been placed on obtaining information on temperature turbulence. Measurements have been made with an electron beam in an arc-heated, supersonic wind tunnel. A number of papers, Petrie, (Refs. 1-5), Komar and Petrie (Ref. 6), Komar (Ref. 7), Gasperas (Ref. 8), Gasperas and Petrie (Ref. 9) and others have resulted from these studies.

In these studies, assessments of the relative influences of parameters such as turbulent scale and intensity, energy spectrum and density fluctuations on the mixing layer structure were made. A versatile experimental facility was assembled and experimental techniques were developed to measure the steady state and certain of the time-resolved gasdynamic flow properties. Supporting theoretical analyses were also conducted which allow variation of the turbulence model employed to characterize the mixing within the shear layer. The more salient aspects of both the theoretical and experimental studies are summarized below.

EXPERIMENTAL STUDIES

The experimental studies on mixing layers have been conducted in a continuous flow, direct current, arc-heated wind tunnel facility. Two overall nozzle configurations were available. In the baseline configuration both nozzles were supplied from the arc-heated reservoir. In the two-stream system, one nozzle was supplied by the arc-heated reservoir while the other was separately supplied with an arbitrary unheated gas. The latter configuration was designed to allow study of large velocity, temperature and density differences.

Both contoured and wedge nozzle blocks were available for both configurations. In addition, the center nozzle element was designed for ease of replacement to allow a variety of mixing layer injection schemes to be investigated. The nozzle block holder permitted rapid alteration of the nozzle array configuration for different Mach numbers or internal injection methods. Operating with either air or molecular nitrogen, typical reservoir pressures and temperatures were 1.0 atmosphere and 2000 degrees Kelvin, respectively.

An electron beam provided the primary instrumentation system for analysis of the mixing region. In this technique, a narrow beam of electrons was projected across the flow in a direction perpendicular to the gas velocity. Profiles of the gas properties were obtained by examining various points along the length of the electron beam and measurements were made at various stations downstream of the nozzle exit.

In conventional application of an electron beam, only the steady state gas properties are measured. However, during the course of the studies, theoretical and experimental analyses were conducted to allow isolation of the rotational temperature turbulence, independent of fluctuations in other gas properties and electron beam operating parameters. This technique allowed direct measurement of the temperature turbulence at arbitrary locations within the flow field and yielded data which could be used to judge the applicability of various turbulence and mixing models. In addition to the electron beam, conventional pitot pressure and mass flow probes were also used to examine the mixing region.

THEORETICAL STUDIES

Particular emphasis was placed on the development of a versatile numerical model for turbulent mixing of co-planar flows. The resulting computer program is capable of calculating turbulent two-dimensional compressible boundary layer flows along a body and in wakes and free shear layers. Heat transfer to the nozzle wall is included in the analysis and appears to be particularly important for nozzle flows where the boundary layer is subject to very high heat transfer rates in the region near the nozzle throat. Additonally mass diffusion of a binary mixture is permitted in the shear layer subject to the assumption of unity Lewis number.

Closure of the system of equations can be accomplished with a number of models. These include:

1. the Cebeci-Smith model
2. a Glushko single transport equation model
3. the two-equation model
4. the Donaldson transport equation model

Since the static temperature fluctuation was the principal quantity measured in the experimental studies, significant effort was devoted to obtaining accurate predictions of the temperature turbulence.

SUMMARY OF RECENT WORK

During the past year of the Grant, the experimental studies with the baseline nozzle configuration were completed. Detailed scans of the shear layer at three locations downstream of the nozzle exit were conducted to obtain both the steady state and fluctuating rotational temperatures.

The theoretical analyses of the shear layer flow were also completed during the past year. Detailed numerical experiments with the computer code were conducted to provide comparisons with the experimental results. In general, the steady state data compared well with the theoretical results. However, the comparisons between the theoretical and experimental turbulence results were poor.

Complete comparisons of the theoretical and experimental results are contained in Ref. 8

The research conducted to date fills an important gap in the information available for free shear layer flows, since it deals with the supersonic case. However, additional experiments are clearly needed and other fundamental fluid quantities should be measured. For example, one level of modelling can be eliminated by comparing turbulence levels for velocity rather than temperture. In addition, Reynolds stress measurements would be extremely helpful in understanding the structure of the shear layer. Such measurements can be made with a laser Doppler velocimeter.

REFERENCES

1. Petrie, S. L., ''Flow Field Analyses in a Low Density Arc-Heated Wind Tunnel'', Proceedings of the 1965 Heat Transfer and Fluid Mechanics Institute, Stanford University Press (1965).
2. Petrie, S. L., ''Fluid Dynamic Interactions in Multiple Nozzle Arrays'', Paper presented at the Tri-State Chemical Laser Symposium, 19-21 February 1975.
Also as AFOSR-TR-0690.
3. Petrie S. L., ''Temperature Turbulence Studies in Supersonic Chemical Laser Configurations'', Paper presented at the Tri-State Service Chemical Laser Symposium, 18-20 February 1976.
4. Petrie, S. L., ''Electron Beam Diagnostics applied to High Density Gas Dynamic Laser Mixture'', AIAA Journal, Vol. 15, No. 6, June 1977, pp 829-834.
5. Petrie, S. L., ''Application of Electron Beam to Vibrational Temperature Measurements in Gas Dynamic Laser Mixtures at High Densities'', AIAA 9th Fluid and Plasma Dynamics Conference, Paper No. 76-369 (1976).
6. Komar, J. J. and Petrie, S. L., ''Investigations of Fluid Dynamic Interactions within Multiple Nozzle Arrays'', 9th AIAA Fluid and Plasma Dynamics Conference, Paper No. AIAA 76-342.
7. Komar, J. J., ''Investigation of Fluid Dynamic Interactions within Multiple Nozzle Arrays'', Ph.D. Dissertation, The Ohio State University, 1975.
8. Gasperas, G., ''Near Wake Temperature Distributions in Supersonic Shear Layers'', Ph.D. Dissertation, The Ohio State University, 1981.
9. Gasperas, G. and Petrie, S. L., ''Temperature Turbulence Measurements in a Supersonic Free Shear Layer'', To be published in AIAA Journal.

LMED

8