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FUNDAMENTAL STUDY OF THREE-DIMENSIONAL TWO-PHASE FLOW IN COMBUS--ETC(U)

AUG 81   B EWAN, J SWITHENBANK   AFOSR-80-0174

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19. Key Words Combustion, Mixing, Gas Turbines, Mathematical Modelling, Reactors, Tracer techniques.

20. Abstract A fundamental approach to combustor modelling is being extended by the coupling of combustor flow fields and fuel droplet trajectories. The iterative procedures, which have been applied to a gas turbine, evaluate reacting flow fields and indicate the conditions under which fuel is able to escape incompletely evaporated from the burner. Important advances have also been made in the application of a valid turbulence model to the calculation of flow fields in non-isotropic swirling flows. This has important implications for combustor designing for a wide range of systems including gas turbines and ramjets.
The development of a non-intrusive and rapid method for residence time distribution measurement has progressed to the point of application to a gas turbine combustor. This involves the optical detection of an electrically generated pulse of mercury vapour and can give residence times in real time.

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Annual Report 1980-81

USAF/EOAR Report of Research Activities 1980/81

Title **Fundamental Study of Three-Dimensional Two-Phase Flow in Combustion Systems.**

Principal Investigator **Professor J. Swithenbank**

Current Research Objectives

The overall program is directed towards providing a rational and comprehensive design method for the range of combustion systems (e.g. gas turbine, ramjets and rockets) of interest to the USAF. In the present period, this is being realised by a comprehensive modelling procedure which computes combustion rates by coupling the combustor flow field and evaporating droplet trajectories. As part of the experimental approach, it is desired that a method be developed to measure the residence time distribution of species in the combustor.

Methods of Approach

Since it has been realised for some time that fuel preparation and its delivery to the combustor are as important as the combustor flow field in determining efficiency, pollution and operation range, the present modelling approach has sought to incorporate both of these factors by coupling three dimensional Lagrangian equations describing the motion of evaporating droplets with the Eulerian computations of the combustor flow field.

This interactive coupling of the two computational methods represents a major advance in the development of analytical design procedures which will ultimately contribute to the minimisation of development time and cost of government and industrial projects.

On the experimental side, an important element of the approach has always been to develop non-intrusive and rapid optical measurement methods and this has been applied to the present residence time study which uses optical detection of tracer.

Progress during the past 12 months

During this period there have been two important developments in the area of modelling. The first of these concerns the coupling of the Lagrangian and Eulerian procedures discussed above.

In the first part of the year we concentrated on extending the existing two dimensional procedure for calculating evaporating droplet trajectories for a given flow field to three dimensions and simultaneously developed the iterative procedures required for hot flow calculations. This was necessary since real combustors have flow fields which are almost invariably three dimensional, examples being gas turbines which have transverse air inlets at downstream stations to tailor the combustion gases to the correct exit temperature profile for the turbine.

The results of this study consisted of hot and cold flow fields and droplet trajectory patterns for a gas turbine combustor can and the work clearly demonstrated that larger droplet often impinge on combustor walls and some pass through unevaporated, particularly at idle. This of course reduces engine efficiency and produces severe pollution. The computational method however, permits sensible changes in combustor geometry and fuel droplet size distribution and cone angle to be made to eliminate these problems.

In combustion calculations this procedure involves the iteration to self consistency for a statistically large number of droplets and it is clear that further work can be usefully be spent in speeding up the calculation to the point where it is practical for industrial use.

The second important development has been the resolution (in conjunction with support from NATO and SRC) of a modelling difficulty which is present with swirling flows and concerns the discovery of a valid modelling method for turbulence by means of Reynolds stresses in non-isotropic situations. This advance has wide implications for Government and industrial interests since many [illegible]bine and ramjet dump combustors incorporate significant swirl. The experimental checking of these modelling procedures is clearly an important area of activity for the next research period.

On the measurement side of the work the development of a residence time distribution method has progressed to the point where it is presently being applied to the gas turbine can for which previous combustor modelling was applied. This method involves the generation of a short pulse of mercury vapour by means of a surface electrical discharge between two mercury amalgam electrodes contained in a small probe. At the appropriate downstream position, the vapour pulse is detected by its absorption of 254 nm light generated by a mercury lamp.

Due to the high absorption cross section of mercury vapour, this method gives very good signal to noise ratio even when high dilution factors are involved and when small observation apertures are used. In the limit of an infinitely narrow vapour pulse, the output signal is the residence function and this is closely approached with the present method which produces pulses of vapour of around 1.5 msec, which can be compared with residence time widths of around 20 msec.

The major appeal of the method is that it is non-intrusive, provides a real time result and avoids the uncertainties associated with tracer sampling. Future work in this area may usefully be directed towards the development of an optical point sampling method based on the present technique. This can be achieved by observing a small volume in a direction at right angles to the sampling light and observing the resonantly scattered radiation. Due to the lower signal to noise level however, an averaging procedure such as pseudo-random vapour pulse input may have to be employed.

Tecnological significance

These results and techniques are already being employed to help the design and development of fuel injectors for combustion systems by e.g. Parker-Hanneffin, Lycoming, Pratt and Whitney, etc. The full exploitation of the computation methods which we are currently researching will take some time, however methods previously developed, such as stirred reactor modelling, are currently being used in the gas turbine industry. Our earlier work on the role of turbulence in high intensity combustion, and the fundamental energy balances in the use of turbulence generators are now finding application indirectly in the use of turbulence promoters to increase the efficiency of ramjet dump combustors.

Major Expressions of Interest

Invitations to visit the laboratories in the U.S.A. to lecture and advise are too numerous to mention individually but include : Pratt and Whitney, General Electric, Lycoming, Southwest Research Institute, Sandia, Garett AiResearch, Northern Research, etc.
Requests for papers and reprints amount to several hundred each year.
Specific cooperation with Lycoming and Garett-AiResearch has been arranged on a continuing basis.

Report Bibliography.

a) Technical Reports

i) "Droplet Trajectories in Three-Dimensional Flow Fields", W.H.Ayers, F.Boysan and J.Swithenbank. Sept 1980, Report No. HIC 355.

ii) "Fundamental Modelling of Reacting Flow in Ramjet Dump Combustors", J.C.Dutt, Nov. 1980

b) Publications

i) "Pseudo Random Stimulus Response of Combustion Systems", A.Turan, J.Swithenbank, S.A.Billings and P.Salib. Journal of the Inst. of Energy, Dec. 1980, p. 181-190

ii) "Numerical prediction of Confined Turbulent Vortex Flows", F.Boysan and J.Swithenbank. Presented at ASME Symposium on Swirling Flows, Chicago, Nov. 1980.

iii) "Three Dimensional of Spray Combustion in Gas Turbine Combustors", F.Boysan, W.H.Ayers, J.Swithenbank and Z.Pan. Presented at AIAA meeting, St.Louis, Jan. 1980

Names of Contributors

Principal Investigator - Professor J. Swithenbank

At present th AFOSR principal investigator is not participating in any other U.S. Government Grant or Contract projects.

USAF Post Doctoral Research Fellow - Dr. B. Ewan (formerly Dr.J.Dutt)

SRC Post Doctoral Research Fellow - Dr. F. Boysan

Contributors cont'd

Univ. Senior Experimental Officer	- Dr. D.S.Taylor
NATO Research Student	- Y. Pala
SRC Programmer	- W.H.Ayers
Technician Grade VI	- Mr. A. Jackson

Degrees Awarded

Dr. A. Turan was awarded a Ph.D. degree.

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