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K. Schulz

**MEASURING TECHNIQUES
FOR
TRANSONIC AND SUPERSONIC FLOW
IN CASCADES AND TURBOMACHINES**

PROCEEDINGS OF THE 9TH SYMPOSIUM HELD IN OXFORD
ON MARCH 21 - 22, 1988

Editor: N C Baines

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**MEASURING TECHNIQUES FOR TRANSONIC AND SUPERSONIC
FLOW IN CASCADES AND TURBOMACHINES**

Proceedings of the 9th Symposium held at
St. Catherine's College, Oxford on
21st - 22nd March, 1988

Edited by: N. C. Baines
Department of Mechanical Engineering
Imperial College
Exhibition Road
London SW7 2BX

PREFACE

The Ninth Symposium on Measuring Techniques in Transonic and Supersonic Flows in Cascades and Turbomachines was held on 21st - 22nd March, 1988 at St. Catherine's College, Oxford. 48 participants presented 25 contributions on the topics:

Test Facilities
Unsteady Flow and High Frequency Measurement
Optical Techniques
Wet Steam
Measurement in Boundary Layers
Heat Transfer Measurement
Probes and Probe Calibrations.

These presentations are gathered in the present volume. The editor wishes to thank the contributors who made available their presentations for publication. To avoid delays these have been printed as they were received from the authors, with a minimum of editorial intervention.

Special acknowledgement is due to the following organisations for their sponsorship of the Symposium:

GEC Mechanical Engineering Laboratory
GEC Turbine Generators Ltd.
NEI Parsons Ltd.
Rolls-Royce plc
Royal Aircraft Establishment, Pyestock
Ruston Gas Turbines Ltd.

In organising the Symposium and presenting this volume of contributions, the editor wishes to acknowledge the support of the late Professor D. L. Schultz, at whose initiative the Symposium was brought to Oxford, and who made the initial arrangements before his sudden and tragic death; and Mrs. J. M. Hoare, whose secretarial assistance has been tireless and invaluable.

Professor C. Sieverding has kindly offered to host the next Symposium at the Von Karman Institute, Belgium, and we extend to him our best wishes.

N. C. Baines

C O N T E N T S

LIST OF PREVIOUS MEETINGS

LIST OF PARTICIPANTS

Session 1 - Test Facilities

1. Measuring Techniques at the High-Speed Cascade Wind Tunnel of the University of the Federal Armed Forces Munich
N. Römer, M. Ladwig and L. Fottner
2. The Steam Test Rig at Kwu and its Cascade Wind Tunnel
H. G. Hosenfeld
3. The Whittle Laboratory Transonic Annular Cascade Wind Tunnel
R. G. Dominy
4. A New Radial-Inflow Turbine Test Facility
N. C. Baines and M. Lavy
5. The Influence of Tailboards with Various Wall Porosity on Transonic Turbine Cascade Flow
J. M. Henne and H. E. Gallus

Session 2 - Unsteady Flow and High Frequency Measurement

6. Preliminary Experience of High Response Pressure Measurements in a Multistage, High Speed Compressor
J. D. Bryce and M. A. Cherrett
7. Turbulence Measurements with a High Response Pressure Probe
G. Ruck
8. Semiconductor Wedge Probes for Unsteady Flow Measurement
W. Elemendorf and G. Kauke
9. Transonic Cascade Performance Measurements using a High Speed Probe Traversing Mechanism in a Short Duration Wind Tunnel
C. H. Sieverding, T. Arts and M. H. Pasteels

Session 3 - Optical Techniques

10. A Laser Anemometry Technique for Measurements in a Single-Stage Supersonic Compressor
I. Trebinjac and A. Vouillarmet
11. Application of a Copper Vapour Laser to Investigation of Shock Interaction in a Shock Tube
R. J. Parker and J. B. Brownell

Session 4 - Wet Steam

12. Wet Steam Turbines: Steam Temperature and Subcooling Measurement by Fibre Optic Sensor
A. Kleitz and P. Ferdinand
13. An Investigation of the Shock Wave Structure in a Condensing Wet Steam Cascade
S. A. Skillings

Session 5 - Measurement in Boundary Layers

14. Detection of Separation Bubbles by Heated Thin-Film Sensors in Transonic Turbine Cascades
F. Kost, W. Bräunling, E. Schüpferling and R. Göhl
15. Three-Dimensional Endwall Disturbances in the Entrance Region of a Supersonic Cascade
H. A. Schreiber
16. Design Features of a Flat Plate Experiment for Boundary Layer Studies
R. M. Watt

Session 6 - Heat Transfer Measurement

17. The Use of Wide-Bandwidth Heat Transfer Gauges to Diagnose Unsteady Turbomachinery Flows
M. L. G. Oldfield and R. W. Ainsworth
18. Instrumentation Developments for Heat Transfer Measurements under Rotating Conditions
R. W. Ainsworth, J. L. Allen, M. A. Hilditch and M. L. G. Oldfield
19. A Cold Heat Transfer Tunnel Employing Liquid Crystals for Measuring Full Surface Heat Transfer Coefficients over Turbine Blade Passages
P. T. Ireland, Z. Wang, T. V. Jones and A. R. Byerley

Session 7 - Probes and Probe Calibrations

20. Problems Involved on Transonic Probe Calibration in Open Tunnel
S. Cabitza and N. Mandas
21. A New Transonic Probe
M. Brunot
22. Development and Investigation of Cone-Type Five-Hole Probes for Small Gas Turbines
W. Kbschel and P. Pretzsch
23. An Investigation into the Effects of Reynolds Number and Turbulence upon and Calibration of Five-Hole Probes
H. P. Hodson and R. G. Dominy
24. A General Theoretical Constraint at $M=1$ for Intrusive Probes and some Transonic Calibrations of Simple Static and Flow Direction Probes
P. E. Hancock
25. Change of Flow Conditions due to the Introduction of an Aerodynamic Probe during Calibration
T. H. Fransson, F. Schaller and K. Schultz

LIST OF PREVIOUS MEETINGS

- 1969 Von Karmen Institute, Bruxelles
"Transonic cascades", "Overpressure", "Measurements behind cascades"
- 1971 DFVLR - AVA, Göttingen
"Choice of measurements location", "Instationary effects due to shock - boundary layer interaction"
- 1974 ONERA, Paris
"Comparison of probe types", "Blockage problems due to probes"
- 1976 Ecole Polytechnique Fédérale, Lausanne
"Probes", "Laser anemometry", "New measuring techniques", "Instationary effects"
- 1979 Central Electricity Research Laboratories, Leatherhead
"Probe effects", "Flow measurements techniques", "Loss and deviation problems", "Laser anemometer", "Wet steam"
- 1981 Laboratoire Mécanique des Fluides, Ecully
"Probe calibration problems", "Measurements and data reduction problems", "Optical measurement techniques", "Wet steam", "Other measurement techniques"
- 1983 Institut Für Strahlantriebe und Turboarbeitsmaschinen, Aachen
"Plane and annular cascades with fixed and vibrating blades", "Compressor test rigs", "Boundary layer measurements", "Optical methods", "Wet steam", "Probe calibration channels", "Probe calibration and probe measurements"
- 1985 Università Degli Studi di Genova
"Tunnels", "Measurements on Turbomachines", "Optical Techniques", "Probe Calibration".

LIST OF PARTICIPANTS

Dr. R. W. Ainsworth,
University of Oxford,
Department of Engineering Science,
Parks Road,
Oxford.
OX1 3PJ

J. L. Allen, Esq.,
University of Oxford,
Department of Engineering Science,
Parks Road,
Oxford.
OX1 3PJ

Dr. N. C. Baines,
Imperial College of Science & Technology,
Mechanical Engineering Department,
Exhibition Road,
London
SW7 2BX

Dr. F. Bakhtar,
Department of Mechanical Engineering,
University of Birmingham,
P. O. Box 393,
Birmingham.
B15 2TT

Dr. - Ing. W. Bräunling,
D.F.V.L.R.,
Institute for Experimental Fluid Mechanics,
Bunsenstrasse 10,
D-3400 Göttingen,
West Germany.

A. J. Brooks, Esq.,
Procurement Executive,
Ministry of Defence,
Royal Aircraft Establishment,
Pyestock,
Farnborough
Hants.
GU14 OLS

M. M. Brunot,
Electricite de France,
6Quai Watier,
78400 Chatou,
France.

LIST OF PARTICIPANTS, CONT'D

Dr. J. D. Bryce,
Principal Scientific Officer,
Propulsion Department,
Turbomachinery Division,
Procurement Executive,
Ministry of Defence,
Royal Aircraft Establishment,
Pyestock,
Farnborough,
Hants.
Gu14 OLS

Professor S. Cabitza,
Universita degli Studi di Cagliari,
Dipartimento di Ingegneria Meccanica,
09100 Cagliari,
Italy.

Dr. J. Camus,
Whittle Laboratory,
University Engineering Department,
Madingley Road,
Cambridge.
CB3 ODY

M. Cherett, Esq.,
Scientific Officer,
Propulsion Department,
Turbomachinery Division,
Procurement Executive,
Ministry of Defence,
Royal Aircraft Establishment,
Pyestock,
Farnborough,
Hants.
GU14 OLS

Dr. B. J. Davidson,
Central Electricity Research Laboratories,
Kelvin Avenue,
Leatherhead,
Surrey.
KT22 7SE

R. G. Dominy, Esq.,
Whittle Laboratory,
University Engineering Department,
Madingley Road,
Cambridge.
CB3 ODY

LIST OF PARTICIPANTS, CONT'D

Dipl. -Ing. W. Elemendorf,
RWTH Aachen,
Institut für Strahlantriebe und Turboarbeitsmaschinen,
Templergraben 55,
D-5100 Aachen,
West Germany.

M. T. H. Fransson,
Laboratoire de Thermique Appliquée,
EPF-Lausanne,
Switzerland.

Dr. P. Hancock,
University of Surrey,
Mechanical Engineering Department,
Guildford,
Surrey.

Dr. -Ing. J. M. Henne,
Abt EWV,
MTU München,
Dachauerstrasse 665
D-8000 München 50,
FR Germany.

Mrs. M. A. Hilditch,
University of Oxford,
Department of Engineering Science,
Parks Road,
Oxford.
OX1 3PJ

Dr. H. P. Hodson,
Whittle Laboratory,
University Engineering Department,
Madingley Road,
Cambridge.
CB3 ODY

Dipl. -Ing. H. -G. Hosenfeld,
Kraftwerk Union AG,
Abt. TVLT,
Wiesenstrasse 35,
4330 Mülheim/Ruhr,
West Germany.

Dr. P. T. Ireland,
University of Oxford,
Department of Engineering Science,
Parks Road,
Oxford.
OX1 3PJ

LIST OF PARTICIPANTS, CONT'D

Dr. T. V. Jones,
University of Oxford,
Department of Engineering Science,
Parks Road,
Oxford.
OX1 3PJ

M. A. Kleitz,
Head of Research Group,
Electricité de France,
6 Quai Watier,
78400 Chatou,
France.

Herr H. Kögl,
Daimler-Benz AG,
Mercedesstrasse 136,
D-7000 Stuttgart 60,
West Germany.

Dipl. -Phys. F. Kost,
DFVLR,
Institute for Experimental Fluid Mechanics,
Bunsenstrasse 10,
D-3400 Göttingen,
West Germany.

M. J. -C. Magedlenat,
Alsthom,
Service 54 R.D.A.,
55 Avenue Jean Jaures,
95350 Le Bourget,
France.

Prof. N. Mandas,
Universita degli Studi di Cagliari,
Dipartimento di Ingegneria Meccanica,
09100 Cagliari,
Italy.

Dr. J. Morrison,
GEC Turbine Generators Ltd.,
Aerodynamic Group,
Barton Works,
Barton Dock Road,
Urmston,
Manchester.
M31 2LB

Dr. M. L. G. Oldfield,
University of Oxford,
Department of Engineering Science,
Parks Road,
Oxford,
OX1 3PJ

LIST OF PARTICIPANTS, CONT'D

R. J. Parker, Esq.,
Advanced Research Laboratory,
Rolls-Royce plc,
P.O. Box 31,
Derby.
DE2 8BJ

Dipl. -Ing. P. Pretzsch,
RWTH Aachen,
Institut für Strahlantriebe und Turboarbeitsmaschinen,
Templergraben 55,
D-4100 Aachen,
West Germany.

A. C. Reusch, Esq.,
Group Leader, Aerodynamics,
Development Department,
Ruston Gas Turbines Ltd.,
New Products Division,
Firth Road,
Lincoln.
LN6 7AA

Dipl. -Ing. N. Römer,
Universität der Bundeswehr München,
Institut für Strahlantriebe,
Werner-Heisenberg-Weg 39,
D-8014 Neubiberg,
West Germany.

Dipl. -Ing. G. Ruck,
Universität Stuttgart,
Institut für Thermische Strömungsmaschinen,
Pfaffenwaldring 6,
D-7000 Stuttgart 80,
West Germany.

Dipl. -Ing. H. -A. Schreiber,
DFVLR,
Institut für Antriebstechnik,
Linder Höhe,
5 Köln 90,
West Germany.

Dr. T. Schröder,
MTU,
Postfach 50 06 40,
D-8000 München 50,
West Germany.

LIST OF PARTICIPANTS, CONT'D

M. K. Schulz,
Laboratoire de Thermique Appliquée,
EBF-Lausanne,
CH-1015 Lausanne,
Switzerland.

Professor C. H. Sieverding,
V.K.I.,
Chausée de Waterloo 72,
1640 Rhode-St.-Genese,
Brussels,
Belgium

Dr. S. Skillings,
C.E.R.L.,
Kelvin Avenue,
Leatherhead,
Surrey.
KT22 7SE

P. J. Storey, Esq.,
GEC Engineering Research Centre,
Cambridge Road,
Whetstone,
Leicstershire.

J. Thomas, Esq.,
NEI Parsons Ltd.,
Heaton Qorks,
Newcastle-upon-Tyne.
NE6 2YL

Isabelle Trebinjac,
Laboratoire de Mchanique des Fluids,
Ecole Centrale de Lyon,
36 Avenue Guy de Collongue,
BP 163,
69131 Ecully Cedex,
France.

M. A. Voillarmet,
Laboratoire de Mechanique des Fluids,
Ecole Centrale de Lyon,
36 Avenue Guy de Collongue,
BP 163,
69131 Ecully Cedex,
France.

LIST OF PARTICIPANTS, CONT'D

R. M. Watt, Esq.,
University of Oxford,
Department of Engineering Science,
Parks Road,
Oxford.
OX1 3PJ

Dr. K. Ziddi,
GEC Engineering Research Centre,
Cambridge Road,
Whetstone,
Leicestershire.