RTO-MP-079(I)
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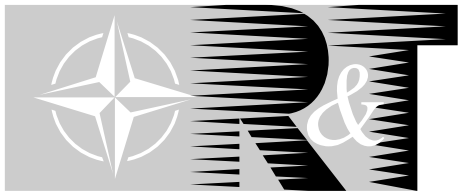
RTO-MP-079(I)

NORTH ATLANTIC TREATY ORGANISATION



RESEARCH AND TECHNOLOGY ORGANISATION

BP 25, 7 RUE ANCELLE, F-92201 NEUILLY-SUR-SEINE CEDEX, FRANCE

RTO MEETING PROCEEDINGS 79(I)

Ageing Mechanisms and Control

(Les mécanismes vieillissants et le contrôle)

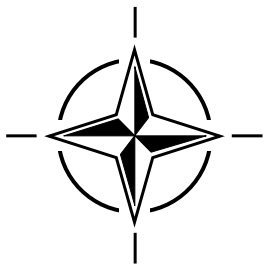
Symposium Part A – Developments in Computational Aero- and Hydro-Acoustics

(Symposium Partie A – Développements dans le domaine de l'aéroacoustique et l'hydroacoustique numériques)

Symposium Part B – Monitoring and Management of Gas Turbine Fleets for Extended Life and Reduced Costs

(Symposium Partie B – Le suivi et la gestion des turbomoteurs en vue du prolongement de leur durée de vie et de la diminution des coûts)

Papers presented at the RTO Applied Vehicle Technology Panel (AVT) Symposium held in Manchester, United Kingdom, 8-11 October 2001.



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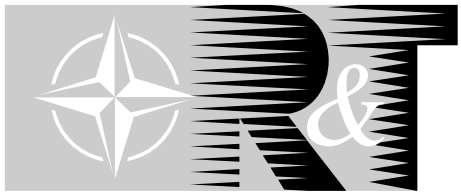

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The Research and Technology Organisation (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote cooperative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective coordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also coordinates RTO's cooperation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of initial cooperation.

The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS Studies, Analysis and Simulation Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier cooperation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

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Ageing Mechanisms and Control

Symposium Part A – Developments in Computational Aero- and Hydro-Acoustics

(RTO MP-079(I) / AVT-074)

Executive Summary

Computational aero- and hydro-acoustics is a relatively new and rapidly expanding technical discipline with a large potential for (more) accurate prediction of the acoustic characteristics of air and sea vehicles.

The acoustic characteristics of air and sea vehicles are of increasing importance for war-time as well as peace-time operations. Examples are:

– The acoustic signature of sea and air vehicles in military operations in war-time.

– Acoustic fatigue loads and their consequences for the structural integrity of air vehicles.

– Effects of inboard noise levels and the near-field acoustic environment on the effective and efficient operation of the vehicle and its systems (human factors).

– Community noise of air vehicles during peace-time operation.

The (accurate) modelling and prediction of the acoustic characteristics of (military) vehicles is therefore of increasing importance for the design as well as the operation of such vehicles and, hence, highly relevant for the NATO community.

The objective of the symposium was to create an opportunity for exchange of information on recent and current developments in computational acoustics between specialists in aero-acoustics and hydro-acoustics from the member states of NATO for the benefit of identifying the most successful and promising approaches for the prediction of noise characteristics of air and sea vehicles.

The intended program of the symposium was set-up for 32 ‘ordinary’ paper presentations and 3 invited speakers.

However, as a consequence of the events of the 11th of September in the USA, many authors and other intended attendees, from the US in particular, were not permitted or did not want to travel. This resulted in the situation that 11 out of the 32 ‘ordinary’ papers were not presented (requiring significant ad-hoc adaptation of the program) and that the average number of attendees (estimated about 40) was substantially smaller than expected.

Among the remaining 21 papers there were many good ones, in particular from France and Germany.

Excellent presentations were given by the invited speakers: Prof. Tam from Florida State University (US), Dr Blake from the USNavy and Dr Castelo Branco from Portugal. The presentation by the latter, on ‘Low Frequency Noise: A Major Risk Factor in Military Operations’ triggered a lot of discussion and it was suggested that the paper should be disseminated on a broad scale within the NATO community.

In the closing session of the symposium an extraordinary well prepared Technical Evaluation was presented by Dr Philip Morris of Pennsylvania State University. This was followed by a lively general discussion among the symposium attendees.

The general feeling among (most of) the attendees was that the objective of the symposium was well met; this in spite of the extraordinary circumstances resulting from the 11th of September.

Les mécanismes vieillissants et le contrôle

Symposium Partie A – Développements dans le domaine de l'aéroacoustique et l'hydroacoustique numériques

(RTO MP-079(I) / AVT-074)

Synthèse

L'aéroacoustique et l'hydroacoustique numériques sont des disciplines techniques relativement nouvelles, en plein essor, susceptibles de fournir des prévisions précises des caractéristiques acoustiques des véhicules aériens et maritimes. Celles ci sont d'une importance croissante pour les opérations de guerre comme pour les activités en temps de paix. Il s'agit par exemple :

– De la signature acoustique des véhicules aériens et maritimes lors d'opérations militaires de guerre.

– Des charges en fatigue acoustique et leurs conséquences pour l'intégrité structurale des véhicules aériens.

– Des effets des niveaux du bruit intérieur, ainsi que de ceux de l'environnement acoustique du champ proche sur l'exploitation effective et efficace du véhicule et de ses systèmes (facteurs humains).

– Du bruit provoqué en ville par des aéronefs lors d'opérations en temps de paix.

La modélisation et la prévision (précises) des caractéristiques des véhicules militaires sont par conséquent d'une importance croissante pour la conception et l'exploitation de tels véhicules. Ces activités présentent donc un grand intérêt pour les pays membres de l'OTAN.

L'objectif du symposium était de donner l'occasion aux spécialistes de l'aéroacoustique et de l'hydroacoustique des pays membres de l'OTAN d'échanger des informations sur les développements récents et actuels en acoustique numérique. Il devait permettre ainsi d'identifier les approches les plus prometteuses et les plus réussies de la prévision des caractéristiques acoustiques des véhicules aériens et maritimes.

Le programme initial du symposium avait été établi sur la base de 32 communications écrites « normales » et 3 conférenciers invités.

Cependant, en raison des événements du 11 septembre 2001 aux Etats-Unis, de nombreux auteurs et participants annoncés, en particulier des Etats-Unis, n'ont pas été autorisés à se déplacer ou n'ont pas souhaité participer. Sur les 32 communications normalement prévues 11 n'ont pas pu être présentées et la participation moyenne a été beaucoup moins forte que prévue. La majorité des 21 communications restantes a été cependant de bonne qualité, notamment les contributions de la France et de l'Allemagne.

D'excellentes présentations ont été faites par les conférenciers invités : Le Prof. Tam de Florida State University (US), le Dr. Blake de l'US Navy et le Dr. Castelo Branco du Portugal. La présentation de ce dernier, sur « Le bruit de fréquence basse : facteur de risque majeur » a provoqué de nombreuses discussions et il a été proposé de procéder à une diffusion plus large de cette communication au sein de l'OTAN.

Lors de la séance de clôture, le Dr. Philip Morris de la Pennsylvania State University a fait une excellente évaluation technique qui a donné lieu à une discussion animée.

La plupart des participants ont considéré que les objectifs du symposium avaient été atteints, malgré les circonstances extraordinaires résultant des événements du 11 septembre.

Ageing Mechanisms and Control

Symposium Part B – Monitoring and Management of Gas Turbine Fleets for Extended Life and Reduced Costs

(RTO MP-079(I) / AVT-075)

Executive Summary

Financial constraints on NATO nations have made it imperative to retain weapon systems for longer periods than originally planned and to operate those retained systems in ways not envisioned by the designers. Technologies that extend the useful lives of weapon systems and their components are of strong benefit to the NATO nations. Part B of the fall symposium clearly identified a number of methodologies in use and being developed to allow the safe extension of life for gas turbines used in weapon systems.

Two excellent keynotes on experience obtained from marine gas turbine operations of the UK Royal Navy and on the USAF experiences with aircraft gas turbines set the scene. They specifically addressed the reduction of turn round time without a companion reduction in the level of operational support and the use of RCM-based support plans, illustrated with benefits obtained on the C-5 fleet.

The twenty four papers from seven NATO nations including an invited paper from Australia were provided by Original Equipment Manufacturers (7), government Research and Technology Organisations (7), operators (6), independent Research and Technology Organisations (3), and independent manufacturers (1). Three of the originally planned papers were withdrawn but three additional papers were obtained in a timely manner to restore the stream to its planned level. The audience represented the spectrum of NATO.

The main categories were covered: maintenance and logistics practices, general design practices, usage data and mission analysis, and life determination methodologies. These categories provided material of interest to, respectively, the fleet manager, the equipment designer, the fleet operators, and the technical specialists responsible for fundamental technologies.

All sessions were well attended and produced much spirited attendee discussion with the presenters and with other attendees. A consensus view emerged that full fleet monitoring is optimal for understanding fleet life. Further, limitations in existing data bases with regard to both content and ability to support appropriate data manipulation were identified as a significant concern. The existence of design conservatism (demonstrated by aging systems which have exceeded their planned lives) illustrated the need for more research into the failure mechanisms such as crack growth in order to identify and safely use the remaining life in fielded systems.

This stream of the symposium originated in the work of the former PEP WG28, now AVT-017, documented in RTO-TR-28, “Recommended Practices for Monitoring Gas Turbine Engine Life Consumption”, April, 2000. It is recommended that significant research be continued/undertaken in crack propagation and that a symposium on life cycle cost modeling be considered. Further, a specialist’s meeting is recommended for the topic of non-destructive testing and residual stress determination. Finally, continued emphasis should be placed on methods whereby databases of materials and usage/damage can be developed and shared.

Les mécanismes vieillissants et le contrôle

Symposium Partie B – Le suivi et la gestion des turbomoteurs en vue du prolongement de leur durée de vie et de la diminution des coûts

(RTO MP-079(I) / AVT-075)

Synthèse

Les contraintes financières que subissent aujourd'hui les pays membres de l'OTAN entraînent un maintien en service de systèmes d'armes bien au-delà des délais initialement prévus et une exploitation de ces systèmes dans des conditions non envisagées par les concepteurs. Toutes les technologies ayant une incidence sur l'augmentation de la durée de vie utile des systèmes d'armes et de leurs composants présentent donc un intérêt certain pour les pays membres de l'OTAN. La partie B du symposium d'automne a clairement identifié un certain nombre de méthodologies qui permettent de prolonger, en toute sécurité, la durée de vie des turbomoteurs équipant les systèmes d'armes; certaines sont déjà en application et d'autres en cours de développement.

La réunion a commencé par deux excellents discours thématiques sur l'expérience acquise dans l'exploitation des turbomoteurs embarqués par la Royal Navy (GB), ainsi que sur l'expérience de l'USAF en matière de turbomoteurs avionnés. En particulier, ont été abordés la réduction des délais de mise en œuvre sans réduction associée du niveau du soutien opérationnel, ainsi que la mise en œuvre de plans d'entretien à coût réduit (RCM), avec des exemples de gains obtenus dans le cas de la flotte C-5.

Vingt-quatre communications ont été présentées par 7 pays membres de l'OTAN, et une communication a été présentée par l'Australie sur invitation. La répartition des conférenciers par secteur d'activité était la suivante : Fabricants de matériels de base (7); organisations gouvernementales de recherche et technologie (7); utilisateurs (6); organisations indépendantes de recherche et technologie (3) et fabricants indépendants (1). Trois communications initialement prévues ont dû être annulées mais trois communications supplémentaires ont été obtenues en temps utile rétablissant ainsi le programme à son niveau initial. L'assistance était représentative de l'ensemble des pays membres de l'OTAN.

Les principaux domaines couverts furent : les pratiques en matière de maintenance et de logistique; les processus généraux de conception; les relevés d'usure et l'analyse de la mission; ainsi que les méthodologies de détermination du cycle de vie. Ces sujets ont fourni des textes intéressants pour les gestionnaires de flottes aériennes, les concepteurs d'équipements, les exploitants et les spécialistes techniques responsables des technologies fondamentales.

Toutes les sessions ont accueilli de nombreux participants et ont vu des discussions animées entre l'assistance et les conférenciers. Il a été unanimement reconnu que la maîtrise du cycle de vie d'une flotte passe par le suivi de l'intégralité des appareils. En outre, les limitations des bases de données existantes en ce qui concerne aussi bien leur contenu que leur capacité à manipuler les données appropriées ont été identifiées comme un sujet de préoccupation majeur. L'existence d'une tendance conservatrice au niveau de la conception (attestée par la permanence de systèmes vieillissants qui ont dépassé leurs cycles de vie prévus) a fait ressortir le besoin d'entreprendre des travaux de recherche supplémentaires sur les mécanismes de défaillance, tels que la propagation des fissures, afin de pouvoir définir et exploiter en toute sécurité la durée de vie restante des systèmes en service.

Les communications présentées lors de cette partie du symposium ont pour origine les travaux de l'ancien groupe de travail PEP WG28, désormais connu sous le nom d'AVT-017, publiés sous la référence : RTO-TR-28 « Pratiques recommandées pour le contrôle du vieillissement des turbomoteurs » en avril 2000. Il y a lieu de poursuivre ou entreprendre des travaux de recherche d'envergure sur la propagation des fissures et d'envisager l'organisation d'un symposium sur la modélisation des coûts globaux de possession. De plus, une réunion de spécialistes pourrait être organisée sur le thème des essais non destructifs et sur la détermination des tensions résiduelles. Enfin, il faut continuer de privilégier les méthodes permettant le développement et le partage de bases de données sur les matériaux et sur la corrélation entre utilisation et détérioration.

Programme Committee

Symposium Part A – Developments in Computational Aero- and Hydro-Acoustics

Chairman
Prof. Ir. Joop Slooff
National Aerospace Laboratory/ NLR
Anthony Fokkerweg 2
1059 CM Amsterdam
The Netherlands
em: jwslooff@nlr.nl

BELGIUM
Prof. C. Hirsch
Vrije Universiteit Brussel
Dienst Stromingsmechanica
Pleinlaan, 2
B-1050 Brussel
em: hirsch@stro10.vub.ac.be

CANADA
Dr. D.G. Zimcik
National Research Council Canada
IAR
Ottawa, Ontario, K1A 0R6
em: david.zimcik@nrc.ca

FRANCE
Mr. G. Elias
ONERA
29, ave de la Division Leclerc
BP 72, 92322 Chatillon Cedex
em: elias@onera.fr

GERMANY
Dr. J. Delfs
Institute of Design Aerodynamics
DLR
Postfach 3267
18022 Braunschweig
em: jan.delfs@dlr.de

Dr. M. Hoenlinger
Krauss Maffei-Wegmann GmbH & Co. KG
Krauss Maffei Str. 11
80997 Muenchen
em: michael.hoenlinger@kmweg.de

GREECE
Prof. S. Tsangaris
National Technical University of Athens
Dept. of Mechanical Engineering
P.O. Box 64070
15710 Zografu, Athens
em:sgt@fluid.mech.ntua.gr

ITALY
Prof. M. Gennaretti
Dipartimento di Ingegneria Meccanica e Industriale
Universita Roma Tre
via della Vasca Navale 79
00146 Roma
em: m.genneretti@uniroma3.it

PORTUGAL
Prof. A. Suleman
Instituto Superior Technico
Departmento de Engenharia Mecanica
avenida Rovisco Pais
1096 Lisboa Codex
em: suleman@alfa.ist.utl.pt

SPAIN
Mr. J.M. Riola Rodriguez
El Pardo Model Basin
El Pardo
E-28048 Madrid
em: riola@cehipar.es

TURKEY
Prof. Dr. C. Ciray
Aeronautical Eng. Department
Middle East Technical University
Inonu Bulvari PK06531
Ankara
em: cciray@metu.edu.tr

UNITED KINGDOM
Mr. R. Cottington
Assistant Director, Air Transport
DERA Pyestock
Farnborough, Hants, GU14 0LS
em: rvcottington@qinetiQ.com

Mr. D. Lovell
Air Vehicle Studies
F9, 401 Building, DERA
Pyestock, Farnborough, Hants GU14 0LX
em: dalovell@qinetiQ.com

UNITED STATES
Dr. R. R. Antcliff
Aerospace Vehicle Systems Technology Program
Office, Mail Stop 113, 11 Langley Boulevard
NASA Langley Research Centre
Hampton, VA 23681-2199
em: r.r.antcliff@larc.nasa.gov

Dr. R. S. Christiansen
Associate Director for Plans, Code X
Dryden Flight Research Centre
Edwards, CA 93523
em: richard.christiansen@drfc.nasa.gov

Dr. D. Paul
Air Force Research Laboratory
2130 8th St. Suite
Wright Patterson AFB
OH 45433-7652
em: donald.paul@va.afrl.af.mil

Dr. L.P. Purtell
Mechanics and Energy Conversion Division
Code 333 - Office of Naval Research
800 North Quincy Street
Arlington, VA 22217-5660
em: purtelp@onr.navy.mil

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The conduct of this Meeting was marked by the "Events of 11 September 2001". A substantial number of authors were unable to present their paper at the meeting site, however these papers have been published in line with the schedule of the Meeting Announcement. Some replacement papers were submitted and are indicated after the "regular papers". The Specialists' Meeting on "Life Management Techniques for Ageing Air Vehicles" (MP-079(II)) greatly suffered and an entirely new schedule was organised at short notice. Both the original schedule and the actual schedule have been included in the Proceedings.

AVT Executive

SESSION I.2: PROPULSION & POWER NOISE: FANS

SESSION I.3: PROPULSION & POWER NOISE: POWER SYSTEMS

SESSION I.4: PROPULSION & POWER NOISE: JETS

SESSION II.1: FLUID FLOW NOISE: SHEAR LAYS AND VORTEX SHEDDING/INTERACTION

Programme Committee

Symposium Part B – Monitoring and Management of Gas Turbine Fleets for Extended Life and Reduced Costs

Chairman
Mr. G. Lazalier
Sverdrup Technology Inc.
AEDC Group, MS-9109
Arnold AFB, Tennessee 37389, USA
em: glen.lazalier@arnold.af.mil

BELGIUM
Prof. C. Hirsch
Vrije Unviersiteit Brussel
Dienst Stromingsmechanica
Pleinlaan, 2
B-1050 Brussels
em: hirsch@stro10.vub.ac.be

Prof. Dr. Vantomme
Royal Military Academy (RMA)
Department of Civil Engineering
avenue de la Renaissance, 30
B-1000 Brussels
em: jvt@cobo.rma.ac.be

CANADA
Mr. D. Rudnitski
Structures, Materials
and Propulsion Laboratory
Institute for Aerospace Research
1500 Montreal Road, Building M-7
National Research Council of Canada
Ottawa, Ontario K1A 0R6
em: don.rudnitski@nrc.ca

DENMARK
Mr. E. Dannenberg
Danish Defence Research Establishment
Ryvangs Alle 1, P.O. Box 2715
DK-2100 Copenhagen
em: ed@ddre.dk

FRANCE
Mr. P. Donguy
SNECMA
2, Boulevard General Martial Valin
75724 Paris Cedex 15
em: paul.donguy@snecma.fr

GERMANY
Dr. M. Albers
MTU Motoren- und Turbinen-Union (MTM)
Muenchen GmbH
Dachauer Strasse 665
80995 Muenchen
em: martin.albers@muc.mtu.de

Prof. Dr. D. Hennecke
Fachgebiet Gasturbinen und Flugantriebe
Darmstadt University of Technology
Petersenstrasse 30
64287 Darmstadt
em: hennecke@gfa.tu-darmstadt.de

GREECE
Prof. Dr. P. Kotsiopoulos
Hellenic Air Force Academy
Dekelia, Attiki
em: petkot@central.ntua.gr

Dr. K. Mathioudakis
Technical University of Athens
Dept. of Mechanical Engineering
P.O. Box 64069, 157 10 Athens
em: kmathiou@central.ntua.gr

Prof. S. Paipetis
School of Engineering
Dept. of Mechanical Engineering
University of Patras, 26100 Patras
em: paipetis@mech.upatras.gr

ITALY
Prof. L. DeLuca
Departimento di Energetica
Politecnico di Milano
Piazza Leonardo da Vinci 32
20133 Milano
em: fivbd@tin.it

THE NETHERLANDS
Mr. W.P.J. Visser
NLR
Anthony Fokkerweg 2
1059 Amsterdam
em: wvisser@nlr.nl

NORWAY
Mr. I. Sollien
Norwegian Defence Research Establishment
(FFI)
P.O. Box 25
NO-2027 Kjeller
em: ivar.sollien@ffi.no

POLAND
Dr. R. Szczepanik
Air Force Institute of Technology
01-494 Warsaw
M. Box 69
str.Ksiecia Boleslawa 6
em: ryszard@afit.polbox.pl

PORTUGAL
Maj. P. A. Costa
Laboratorio de Aeronautica
Academia da Forca Aerea
Granja do Marques
2710 Sintra
em: mop13967@mail.telepac.pt

Lt. Col. M. de Matos G. Chambel
CLAFA/DMA
avenida de Forca Aerea
2720 Alfragide
Fax: 351 121 4716361

TURKEY
Prof. O.C. Eralp
Middle East Technical University
Mechanical Engineering Dept.
Inonu Bulvari, 06531 Ankara
em: ceralp@metu.edu.tr

UNITED KINGDOM
Mr. R. Cottington
Assistant Director, Air Transport
DERA Pyestock
Farnborough, Hants, UK GU14 0LS
em rvcottington@QinetiQ.com

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SESSION VI: LIFE DETERMINATION METHODOLOGIES-1

SESSION VII: LIFE DETERMINATION METHODOLOGIES-2

SESSION VIII: LIFE DETERMINATION METHODOLOGIES-3

SESSION IX: LIFE DETERMINATION METHODOLOGIES-4

SESSION X: LIFE DETERMINATION METHODOLOGIES-5

Publications of the RTO
Applied Vehicle Technology Panel

MEETING PROCEEDINGS (MP)

Advanced Flow Management: Symposium Part A – Vortex Flows and High Angle of Attack for Military Vehicles / Part B – Heat Transfer and Cooling in Propulsion and Power Systems
MP-069(I), February 2003

Low Cost Composite Structures / Cost Effective Application of Titanium Alloys in Military Platforms
MP-069(II), February 2003

Ageing Mechanisms and Control: Symposium Part A – Developments in Computational Aero- and Hydro-Acoustics / Part B – Monitoring and Management of Gas Turbine Fleets for Extended Life and Reduced Costs
MP-079(I), February 2003

Ageing Mechanisms and Control: Specialists' Meeting on Life Management Techniques for Ageing Air Vehicles
MP-079(II), February 2003

Unmanned Vehicles (UV) for Aerial, Ground and Naval Military Operations
MP-052, January 2002

Active Control Technology for Enhanced Performance Operational Capabilities of Military Aircraft, Land Vehicles and Sea Vehicles
MP-051, June 2001

Design for Low Cost Operation and Support
MP-37, September 2000

Gas Turbine Operation and Technology for Land, Sea and Air Propulsion and Power Systems (Unclassified)
MP-34, September 2000

Aerodynamic Design and Optimization of Flight Vehicles in a Concurrent Multi-Disciplinary Environment
MP-35, June 2000

Structural Aspects of Flexible Aircraft Control
MP-36, May 2000

New Metallic Materials for the Structure of Aging Aircraft
MP-25, April 2000

Small Rocket Motors and Gas Generators for Land, Sea and Air Launched Weapons Systems
MP-23, April 2000

Application of Damage Tolerance Principles for Improved Airworthiness of Rotorcraft
MP-24, January 2000

Gas Turbine Engine Combustion, Emissions and Alternative Fuels
MP-14, June 1999

Fatigue in the Presence of Corrosion
MP-18, March 1999

Qualification of Life Extension Schemes for Engine Components
MP-17, March 1999

Fluid Dynamics Problems of Vehicles Operation Near or in the Air-Sea Interface
MP-15, February 1999

Design Principles and Methods for Aircraft Gas Turbine Engines
MP-8, February 1999

Airframe Inspection Reliability under Field/Depot Conditions
MP-10, November 1998

Intelligent Processing of High Performance Materials
MP-9, November 1998

Exploitation of Structural Loads/Health Data for Reduced Cycle Costs
MP-7, November 1998

EDUCATIONAL NOTES (EN)

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TR-044, April 2002

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NATO East-West Workshop on Magnetic Materials for Power Applications
TR-031, August 2001

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Recommended Practices for Monitoring Gas Turbine Engine Life Consumption
TR-28, April 2000

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TR-27, December 1999

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Ageing Mechanisms and Control
Symposium Part A – Developments in Computational Aero- and Hydro-Acoustics
Symposium Part B – Monitoring and Management of Gas Turbine Fleets for Extended Life and Reduced Costs

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Acoustic emission	Aging (metallurgy)	Gas turbine engines	Methodology
Acoustic impedance	Aircraft	Human factors engineering	Models
Acoustic properties	Computational acoustics	Hydroacoustics	Noise (sound)
Acoustic signatures	Fatigue (materials)	Life (durability)	Sound waves
Acoustics	Fatigue life	Life cycle savings	Structural analysis
Aeroacoustics	Fatigue tests	Mechanical properties	Structural design
Ageing tests (materials)	Fluid flow noise	Mechanical tests	

14. Abstract

Part A:
The acoustic characteristics of air and sea vehicles are of increasing importance for war-time as well as peace-time operations. The meeting treated the potential of and results obtained with computational aero- and hydro-acoustics. It is a relatively new and rapidly expanding technical discipline with a large potential for (more) accurate prediction of the acoustic characteristics of air and sea vehicles. Examples are:

- Acoustic signatures.
- Acoustic fatigue loads and their consequences for the structural integrity.
- Effects of inboard noise levels and the near-field acoustic environment including low frequency noise on the effective and efficient operation of the vehicle and its systems (human factors).
- Community noise of air vehicles during peace-time operation.

Papers were presented on the following topics.

- Propulsion & power noise: propellers, fans, jets, power systems.
- Fluid flow noise: shear layers and vortex shedding/interaction, cavities.
- Noise propagation.
- Structural response and acoustic loads suppression.

Part B:
Financial constraints make it imperative to retain weapon systems for longer periods than originally planned and to operate them in ways not envisioned by the designers. Therefore technologies that extend the useful lives of weapon systems and their components are needed.
Twenty four papers from seven NATO nations and one allied nation (Australia) were presented threating the Monitoring and Management of Gas Turbine Fleets for Extended Life and Reduced Costs. Papers were presented in four major categories:

- Maintenance and logistics practices,
- General design practices,
- Usage data and mission analysis, and
- Life determination methodologies.

These categories provided material of interest to, respectively, the fleet manager, the equipment designer, the fleet operators, and the technical specialists responsible for fundamental technologies.
A consensus view emerged that full fleet monitoring is optimal for understanding fleet life. Further, limitations in existing data bases with regard to both content and ability to support appropriate data manipulation were identified as a significant concern. There is need for more research into the failure mechanisms such as crack growth in order to identify and safely use the remaining life in fielded systems. This originated from the work of the former AGARD/PEP WG28.

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