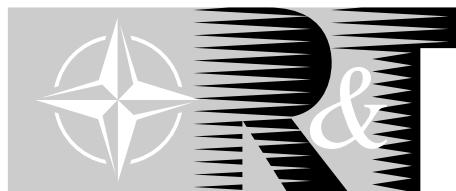


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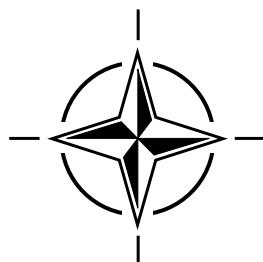
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RTO MEETING PROCEEDINGS 25

**New Metallic Materials for the Structure
of Aging Aircraft**

(les Nouveaux Matériaux métalliques pour les structures des
aéronefs d'ancienne génération)

*Papers presented at the Applied Vehicle Technology Panel (AVT) Workshop, held in Corfu,
Greece, 19-20 April 1999.*



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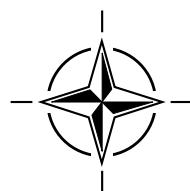
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RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote cooperative research and information exchange. The objective is to support the development and effective use of national defence research 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.

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- SCI Systems Concepts and Integration
- SET Sensors and Electronics Technology
- IST Information Systems Technology
- AVT Applied Vehicle Technology
- HFM Human Factors and Medicine
- MSG Modelling and Simulation

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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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New Metallic Materials for the Structure of Aging Aircraft

(RTO MP-25)

Executive Summary

Military hardware is very demanding on structural performance. Advanced materials and processing methods are providing new options for materials selection and component design. The papers presented showed how new metallic alloys and composite materials can improve the performance and life of airframe structures. Larger units can be manufactured by improved processes such as investment casting, welding, creep-age forming and high-speed machining. This reduces the parts count and reduces assembly costs. Life can be extended by new corrosion resistant coatings, but these must be environmentally friendly.

The round table discussion closing the meeting focussed on three main issues requiring further work: integrating sub-structures into larger structures, cost-benefit issues of applying new materials and cost reduction through “Qualification by Analysis”.

Larger structures were discussed under the aspects of inspectability and damage tolerance. They may be easier to inspect since they have less fasteners, less holes etc. However, large unit constructions do not contain the crack stoppers inherent in smaller riveted components. This must be considered carefully in design. Also the load path during failure will be different in these new units so substitution needs careful stress analysis and full understanding of the failure modes.

However, these large parts will undoubtedly require coatings to protect them from corrosion and care should be taken to ensure that this does not impair inspectability. Discussion raised the point that civil aircraft experience more corrosion damage, although they are usually manufactured from similar materials. For example, Dassault Aviation see more corrosion problems in business jets than in the Mirage, but business jets fly about twice as many hours per year. British and Canadian experience has shown a high incidence of corrosion in transports and maritime patrol aircraft, although this is often linked to poor design and coating technology which reflects the age of the systems.

The balance of cost against benefit is an important issue. With the small fleet sizes of European airforces it is difficult to introduce new materials to overcome ageing problems. The cost of re-certification testing is too high for the potential benefit. Substitution only becomes an option when there is a serious problem which would require part replacement several times through the life cycle of the aircraft. Since this represents a significant barrier to the application of new materials, the options for removing this barrier were discussed.

A change to a system of “Qualification by Analysis” would provide the step change necessary for materials substitution. This topic has already been raised as a potential AVT Technical Team activity under ageing systems. Certifying authorities insist on full structural tests for new flight-critical components. However there is already some shift away from testing since new versions of aircraft can be approved if they are extrapolations of existing designs and have appropriate laboratory and analytical data to support the new design. Numerical stress analysis of designs is now relatively easy and accurate. However there is still poor quantitative understanding of the effects of ageing and the definition of failure. Qualification by analysis will need a full identification of all the possible failure modes and a risk assessment which quantifies the most important areas of concern. These may change with time as the aircraft role is changed and if damage, such as corrosion or inelastic strains start to affect the load paths in the structure. These are issues which should be addressed in the life cycle management of the system.

les Nouveaux Matériaux métalliques pour les structures des aéronefs d'ancienne génération

(RTO MP-25)

Synthèse

Les performances structurales du matériel militaire doivent être exceptionnelles. Or, les nouvelles méthodes de traitement et les matériaux avancés offrent de nouvelles opportunités pour le choix des matériaux et la conception des composants. Les communications présentées ont montré les possibilités des nouveaux alliages métalliques et des matériaux composites pour l'amélioration des performances et du cycle de vie des cellules. Des éléments plus grands peuvent désormais être fabriqués par le biais de procédés avancés tels que le moulage de précision, le soudage, le formage qui anticipe les effets du fluage et du vieillissement, et l'usinage ultra-rapide. Ces procédés permettent de réduire le nombre de pièces et de diminuer les coûts de montage. Les nouveaux revêtements résistant à la corrosion permettent de prolonger la durée de vie, mais doivent être sans danger pour l'environnement.

La table ronde qui a clôturé la réunion a porté essentiellement sur trois grands domaines pour lesquels il y a lieu d'entreprendre des travaux supplémentaires, à savoir : l'intégration des sous-structures dans des structures plus grandes, la comparaison coûts-avantages de la mise en oeuvre de nouveaux matériaux et la réduction des coûts par « la qualification par l'analyse ».

Les éléments de grande dimension ont été examinés du point de vue de leur contrôlabilité et leur tolérance à l'endommagement. S'ils sont plus faciles à contrôler (absence de fixations, moins d'ouvertures etc...), les grands éléments n'ont pas les arrêts de crique habituellement intégrés aux composants rivés plus petits. Il faut en tenir compte lors de la conception. De même, les voies de contrainte en cas de défaillance seront différentes pour les nouveaux ensembles ; par conséquent tout remplacement doit être précédé d'une analyse poussée des contraintes et les modes de défaillance doivent être bien appréciées.

Cependant, ces grands ensembles devront certainement être revêtus d'une protection afin de les protéger contre la corrosion, et cela ne doit pas compromettre leur contrôlabilité. Il est ressorti des discussions que les aéronefs civils subissent plus d'endommagements dûs à la corrosion que les avions militaires, bien qu'en général, ils soient fabriqués à partir de matériaux analogues. A titre d'exemple, la compagnie Dassault Aviation a relevé plus de cas de corrosion sur les avions d'affaires à réaction que sur les Mirages, même si les avions d'affaires effectuent deux fois plus d'heures de vol par an que les Mirages. L'expérience des britanniques et des canadiens montre que la corrosion se produit fréquemment sur les aéronefs de transport et de patrouille maritime, même si ce phénomène est souvent lié à des défauts de conception et à des technologies de revêtement qui témoignent de l'âge des systèmes.

Le compromis entre coûts et avantages demeure une question importante. Etant donné les flottes relativement réduites des armées de l'air européennes, il est difficile, pour résoudre les problèmes de vieillissement, de mettre en place des nouveaux matériaux. En effet, les coûts des essais en vue d'une nouvelle certification sont trop élevés par rapport aux avantages possibles. Le remplacement ne peut être proposé qu'en cas de problèmes importants, nécessitant le remplacement de pièces plusieurs fois pendant le cycle de vie d'un aéronef. Etant donné que celà représente un obstacle sérieux à la mise en oeuvre des nouveaux matériaux, les différentes possibilités d'élimination de cet obstacle ont été abordées.

L'adoption d'un système de « Qualification par l'analyse » serait un premier pas vers le nécessaire remplacement des matériaux. Ce sujet a déjà été proposé pour une éventuelle activité d'une équipe technique AVT dans le cadre des systèmes vieillissants. Les autorités de certification imposent des essais structuraux complets pour tout nouveau composant indispensable à la sécurité. Cependant, les fabricants font de moins en moins appel aux essais, puisque de nouvelles configurations peuvent être approuvées dans la mesure où il s'agit d'extrapolations d'études déjà réalisées et que la nouvelle conception soit étayée par des données analytiques et des résultats d'essais en laboratoire. L'analyse numérique des contraintes est aujourd'hui précise et simple à réaliser. Cependant, il n'existe que peu de données quantitatives sur les effets du vieillissement et la définition de la défaillance. La mise en oeuvre généralisée de la qualification par analyse passe par l'identification détaillée de toutes les modes de défaillance possibles et une évaluation des risques qui quantifie les domaines les plus préoccupants. Ces domaines risquent de changer avec le temps, au fur et à mesure que le rôle de l'aéronef évolue, et en particulier si l'endommagement, par la corrosion ou les contraintes inélastiques, commence à modifier les voies de contrainte dans la structure. Toutes ces questions sont à aborder dans le cadre de l'examen de la gestion du cycle de vie d'un système.

Contents

	Page
Executive Summary	iii
Synthèse	iv
Theme/Thème	vii
Publications of the RTO Applied Vehicle Technology Panel	viii
Workshop Programme Committee	x

	Reference
Technical Evaluation Report by M. Winstone	T
General Keynote by P. Santini	K

SESSION I: OVERVIEW

The Need for New Materials in Aging Aircraft Structures by R.J. Bucci, C.J. Warren and E.A. Starke, Jr.	1*
Implementation of New Materials on Aging Aircraft Structure by L.K. Austin, M. van den Bergh, A. Cho and M. Niedzinski	2*
Technology Trends for Future Business Jet Airframe by A. Rouquet and D. Chaumette	3

SESSION II: ALUMINUM ALLOYS AND COMPOSITES

Future Aluminium Technologies and their Application to Aircraft Structures by J.B. Borradaille	4
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Paper 5 withdrawn

Paper 6 withdrawn

RRA Heat Treatment of Large Al 7075-T6 Components by R.T. Holt, M.D. Raizenne, W. Wallace and D.L. DuQuesnay	7
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Paper 8 withdrawn

SESSION III: PROCESSING, FATIGUE AND DURABILITY

Paper 9 withdrawn

* Paper was prepared in time for the meeting but was not presented.

Improved Durability Aluminium Alloys for Airframe Structures	10*
by T. Warner, R. Dif, J.C. Ehrstrom and P. Lassince	
Studies on Long Term Durability of Aluminum Airframe Structure Made by Affordable Process	11
by H. Hirohito and Y. Yasuaki	
Plastic Envelope in Propagating Crack Wake on Al-Li Alloys Subjected to Fatigue Cycles and to Different Heat Treatments	12
by S. Corradi, M. Marchetti and W. Stellino	
Paper 13 withdrawn	
A Framework for Corrosion Prediction and Management	14*
by T.E. Steyer	
Advances in Protective Coatings and their Application to Ageing Aircraft	15
by C.J.E. Smith, M.S. Higgs and K.R. Baldwin	

* Paper was available at the time of the meeting but not presented.

Theme

Structural components of aging aircraft can be replaced with components manufactured from materials with specifications of a higher qualification, thus enhancing various parameters including overall life cycle cost (LCC). Recent research has led to development of several new materials, heat treatments and processing technology which can be used for the replacement of components prone to corrosion, stress corrosion and fatigue. Specific examples include: a new T77 heat treatment for 7150 alloy; a new alloy 7055, and new processing to control composition and microstructure, e.g. 2524. New alloys have been developed, e.g.: high strength aluminium lithium alloy 2195; fatigue resistant aluminium lithium alloy 2097; laminated hybrids of aluminium and titanium alloys; Timetal 1100 for up to 1100-F; Ti62222 alloy; lower oxygen versions of Ti-6Al-4V; new beta titanium alloys; improved metal matrix composites; high strength, high corrosion resistant steels; improved Ni-Co alloys and low carbon steels.

These new materials and processes may add significant life to aging aircraft that form the backbone of the NATO operational force structure: the KC-135, introduced more than 40 years ago; e.g. the F-15 air superiority fighter, operational 20 to 25 years ago; the F-16 KC-10 became operational at least 15 years ago. Many are expected to remain in service an additional 25 years or more. Maintaining them is based on economic and safety considerations. Retrofitting damaged components with new advanced materials can considerably reduce life cycle cost. NATO must consider the use of these new materials and the proposed workshop provides a unique forum to discuss and further promote common approaches necessary for keeping international fleets.

Thème

Les composants structuraux des aéronefs en service depuis longtemps peuvent être remplacés par des composants fabriqués à partir de matériaux avec de meilleures spécifications, en vue d'améliorer certains paramètres tels que les coûts globaux de possession (LCC). Les travaux de recherche récents ont conduit au développement de matériaux, de traitements thermiques et de technologies de transformation, dont la mise en oeuvre permettrait de remplacer les composants sujets à la corrosion, à la corrosion sous contrainte, et à la fatigue. Parmi d'autres exemples il faut citer : un nouveau traitement thermique pour l'alliage 7150, un nouvel alliage 7055, et de nouveaux traitements pour le contrôle de la composition et de la microstructure, par exemple le 2524. Des nouveaux alliages ont été développés, par exemple l'alliage aluminium-lithium à haute résistance 2195 ; l'alliage aluminium-lithium 2097 résistant à la fatigue ; des hybrides stratifiés d'alliages d'aluminium et de titane ; le Timetal 1100 pour des températures allant jusqu'à 1100 °F ; l'alliage Ti62222 ; des versions de Ti-6Al-4V à teneur en oxygène réduite ; de nouveaux alliages bêta titane ; des matériaux composites à matrice métallique améliorés ; des aciers anticorrosion à haute résistance ; des alliages Ni-Co améliorés et des aciers à bas carbone.

Ces nouveaux matériaux et traitements devraient permettre de prolonger de façon appréciable la durée de vie des aéronefs en service depuis longtemps qui composent l'essentiel des forces opérationnelles de l'OTAN. Le KC-135, dont l'entrée en service date de plus de 40 ans, le F-15, avion de supériorité aérienne, opérationnel depuis 20 à 25 ans ; et le F-16, et le KC-10 entré en service il y a au moins 15 ans. Bon nombre de ces appareils devront rester en service pendant encore 25 ans au moins. Leur maintenance est tributaire de considérations de sécurité et d'ordre économique. Le remplacement de composants endommagés par des matériaux avancés permettrait de diminuer les coûts globaux de possession de façon considérable. L'OTAN doit réfléchir à l'utilisation de ces nouveaux matériaux et l'atelier proposé représente un forum unique pour la discussion et la promotion continue d'approches communes du problème de la conservation des flottes aériennes internationales.

Publications of the RTO Applied Vehicle Technology Panel

MEETING PROCEEDINGS (MP)

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

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

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

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

Missile Aerodynamics
MP-5, November 1998

EDUCATIONAL NOTES

Measurement Techniques for High Enthalpy and Plasma Flows
EN-8, April 2000

Development and Operation of UAVs for Military and Civil Applications
EN-9, April 2000

Planar Optical Measurements Methods for Gas Turbine Engine Life
EN-6, September 1999

High Order Methods for Computational Physics (published jointly with Springer-Verlag, Germany)
EN-5, March 1999

Fluid Dynamics Research on Supersonic Aircraft
EN-4, November 1998

Integrated Multidisciplinary Design of High Pressure Multistage Compressor Systems
EN-1, September 1998

TECHNICAL REPORTS

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

Verification and Validation Data for Computational Unsteady Aerodynamics
TR-26, Spring 2000

A Feasibility Study of Collaborative Multi-facility Windtunnel Testing for CFD Validation
TR-27, December 1999

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14. Abstract	<p>This workshop dealt with the replacement of Structural components of aging aircraft with components manufactured from materials with specifications of a high qualification, thus enhancing various parameters including overall life cycle cost technology (LCC).</p> <p>The following topics were treated:</p> <ul style="list-style-type: none"> - An Overview - Aluminium Alloys and Composites - Processing, Fatigue and Durability 																								



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