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RTO MEETING PROCEEDINGS 36

Structural Aspects of Flexible Aircraft Control

(les Aspects structuraux du contrôle actif et flexible des aéronefs)

Papers presented at the Specialists' Meeting of the RTO Applied Vehicle Technology Panel (AVT) held in Ottawa, Canada, 18-20 October 1999.

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Structural Aspects of Flexible Aircraft Control

(RTO MP-36)

Executive Summary

The papers presented at this meeting dealt with the state-of-the-art, underlying theory of the influencing factors and characteristics, and existing capabilities of Nations to integrate various factors during the design stage while observing the effects on aircraft layout and behaviour.

Aircraft are inherently flexible and flexibility can be used to advantage as a design feature for improved performance. Flexible aircraft are subject to interaction between flight mechanics, structural dynamics, and flight control system dynamics. Aeroservoelastic instability can lead to disastrous failures in aircraft as was recently the case for several fighter aircraft. These problems are very similar to flutter accidents which occurred two decades ago. Limit cycle oscillations could restrict fighter aircraft performance particularly those with various store configurations. This problem is most relevant to air-to-ground attack and fighter aircraft.

Flight control systems increasing the stability, or the active control of low damped or unstable aircraft with rigid or flexible modes, have additional coupling effects on flight mechanics and structural responses. These interactions must be considered when designing the airframe structure, flight control systems, and elastic alleviation systems in order to avoid bad handling qualities and bad ride comfort.

An integral analysis of flight mechanics, flight control, static and dynamic loads, flutter and aeroservoelasticity has to be carried out. Therefore, a compatible mathematical model of the coupled dynamics of flight mechanics, flight control, and structural dynamics must be established. Such models (using the time and frequency domain descriptions) are available in the military aircraft industry to assist in the design and clearance of flight control systems. However, the design of flight control systems and structures is usually performed separately. As such, an integrated interdisciplinary design of flight control systems is generally not feasible due to its complexity. At present, it is only used to improve the control system and the structural capability of components in critical areas.

How to improve the design methods used in the development of military fighter aircraft, and its use in transport aircraft design applications was an outcome of this meeting.

les Aspects structuraux du contrôle actif et flexible des aéronefs

(RTO MP-36)

Synthèse

Les communications présentées lors de cette réunion ont examiné l'état actuel des connaissances dans ce domaine, les théories régissant les facteurs déterminants et les caractéristiques et les capacités actuelles des pays membres de l'OTAN à incorporer ces différents facteurs dans le processus de conception, ainsi que les effets sur la configuration et le comportement des aéronefs.

Les aéronefs sont intrinsèquement flexibles et cette flexibilité peut être mise à profit au stade de la conception pour améliorer leurs performances. Les aéronefs flexibles sont sujets à des interactions entre la mécanique du vol, la dynamique structurale et la dynamique des systèmes de pilotage. L'instabilité aéroservoélastique peut conduire à une défaillance catastrophique de l'avion, comme il a été démontré récemment pour plusieurs avions de combat. Ces problèmes ressemblent aux accidents dûs au flottement, survenus il y a deux décennies. Il se peut que le rayon d'action des avions de combat soit limité par les oscillations limites, et surtout dans le cas de certaines configurations d'emports. Ce problème affecte particulièrement les avions de combat d'attaque au sol.

Les systèmes de pilotage privilégiant l'augmentation de la stabilité, ou le contrôle actif d'aéronefs instables ou aux oscillations faiblement amorties ayant des modes rigides ou flexibles peuvent créer des effets de couplage supplémentaires affectant la mécanique du vol et les réponses structurales. Ces interactions doivent être prises en compte lors de la conception de la cellule, des systèmes de commande de vol et des systèmes d'allègement élastique afin d'éviter la détérioration des qualités de vol et du confort du pilote.

Il y a lieu de procéder à une analyse intégrale de la mécanique du vol, des systèmes de pilotage, des charges statiques et dynamiques, du flottement et de l'aéroservoélasticité. Il est, par conséquent, nécessaire d'établir un modèle mathématique compatible de la dynamique couplée de la mécanique du vol, des systèmes de pilotage et de la dynamique structurale. De tels modèles (qui intègrent la description du domaine du temps et du domaine de fréquence), sont à la disposition de l'industrie aéronautique militaire pour la conception et l'homologation des systèmes de pilotage. Cependant, les systèmes de commande de vol et les structures sont, en principe, conçus séparément. Par conséquent, la conception interdisciplinaire intégrée des systèmes de commande de vol n'est en général guère faisable en raison de sa complexité. A l'heure actuelle, cette approche est utilisée uniquement pour améliorer le système de commande et la capacité structurale de certains composants critiques.

Les conclusions de cette réunion permettent d'envisager l'amélioration des méthodes de conception mises en œuvre dans le développement des avions de combat et de les appliquer à la conception des avions de transport militaires.

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SESSION II: ACTIVE CONTROL OF FLEXIBLE STRUCTURE I

SESSION III: ACTIVE CONTROL OF FLEXIBLE STRUCTURE II

† Paper not available at time of printing.

Theme

Aircraft are inherently flexible and flexibility can be used to advantage as a design feature for improved performance. Aeroservoelastic instability can also lead to a catastrophic failure of the aircraft as was shown lately on a F117 stealth aircraft accident similar to flutter accidents two decades ago. Limit cycle oscillations may placard fighter airplanes especially with various store configurations. This is most true to military transport and fighter aircraft. Flexible aircraft are subject to interactions between flight mechanics, structural dynamics and flight control system dynamics. The Meeting will look into the state of the art treating as well the underlying theory of the influencing factors and characteristics as also the existing capabilities of Nations for integrating the various factors in the design stage and the effects on aircraft layout and behaviour.

Flight control systems for the augmentation of stability or for the active control of low damped or unstable aircraft with rigid or flexible modes have additional coupling effects on flight mechanics and structural responses. These interactions have to be taken into consideration for the design of the airframe structure, flight control system and elastic alleviation systems in order to avoid bad handling qualities as well as bad ride comfort.

An integral analysis of flight mechanics, flight control, static and dynamic loads, flutter and aero-servo-elasticity has to be carried out. Therefore, a compatible mathematical model of the coupled dynamics of flight mechanics, flight control, and structural dynamics must be established. Such models (using the time and frequency domain description) are available in the military aircraft industry to assist in the design and clearance of flight control systems. However, the design of flight control systems and structures is in principle performed separately and integrated interdisciplinary design of flight control systems is in general not yet feasible due to its complexity. At present, it is used only to improve the control system and the structural capability of components in critical areas.

How the design methods used in the development of military fighter aircraft can be improved, and applied to transport aircraft design applications will be an outcome of this meeting.

Thème

Les aéronefs sont par nature flexibles et cette flexibilité peut être mise à profit au stade de la conception pour améliorer les performances. L'instabilité aéroservoélastique peut également conduire à une défaillance catastrophique de l'avion, comme il a été démontré récemment par l'accident du bombardier furtif F117, qui ressemble aux accidents dûs au flottement, survenus il y a deux décennies. Il se peut que le rayon d'action des avions de combat soit limité par les oscillations limites, et surtout dans le cas de certaines configurations d'emports. Ces phénomènes affectent particulièrement les avions de combat et de transport militaires. En raison de leur flexibilité, ces aéronefs sont sujets à des interactions entre la mécanique du vol, la dynamique structurale et la dynamique des systèmes de commande de vol. La réunion examinera l'état actuel des connaissances dans ce domaine, et traitera également des théories régissant les facteurs déterminants et les caractéristiques. Elle étudiera également les capacités actuelles des pays membres de l'OTAN à incorporer ces différents facteurs dans le processus de conception, ainsi que les effets sur la configuration et le comportement des aéronefs.

Les systèmes de commande de vol privilégiant soit l'augmentation de la stabilité, soit le contrôle actif d'aéronefs instables ou aux oscillations faiblement amorties ayant des modes rigides ou flexibles, peuvent créer des effets de couplage supplémentaires affectant la mécanique du vol et les réponses structurales. Ces interactions doivent être prises en compte lors de la conception de la cellule, des systèmes de commande de vol et des systèmes d'allègement élastique afin d'éviter la détérioration des qualités de vol et du confort du pilote.

Il y a lieu de procéder à une analyse intégrale de la mécanique du vol, des systèmes de pilotage, des charges statiques et dynamiques, du flottement et de l'aéroservoélasticité. Il est, par conséquent, nécessaire d'établir un modèle mathématique compatible de la dynamique couplée de la mécanique du vol, des systèmes de commande de vol et de la dynamique structurale. De tels modèles (qui intègrent la description du domaine du temps et du domaine de fréquence), sont à la disposition de l'industrie aéronautique militaire pour la conception et l'homologation des systèmes de commande de vol. Cependant, les systèmes de commande de vol et les structures sont, en principe, conçus séparément, et la conception interdisciplinaire intégrée des systèmes de commande de vol n'est guère encore faisable en raison de sa complexité. A l'heure actuelle, cette approche est utilisée uniquement pour améliorer le système de commande et la capacité structurale de certains composants critiques.

Les conclusions de cette réunion devraient permettre d'améliorer les méthodes de conception mises en œuvre dans le développement des avions de combat et de les appliquer à la conception des avions de transport militaires.

Publications of the RTO Applied Vehicle Technology Panel

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MP-37, Spring 2000

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MP-36, May 2000

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Transport aircraft
Flexible structures

14. Abstract

The Specialists' Meeting dealt with Design Issues and more specifically Structural Aspects of Flexible Aircraft Control.

Twenty six papers and a Keynote address were presented with the following objective: How the design methods used in the development of military fighter aircraft can be improved, and applied to transport aircraft design applications.

There were three sessions covering the following topics:

– Aeroservoelasticity
– Active Control of Flexible Structure I
– Active Control of Flexible Structure II

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