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WING DESIGN FOR A CIVIL TILTROTOR TRANSPORT AIRCRAFT: A PRELIMINARY STUDY

by

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Abstract

A preliminary study was conducted on the design of the wing-box structure for a civil tiltrotor transport aircraft. The wing structural weight is to be minimized subject to structural and aeroelastic constraints. The composite wing-box structure is composed of skin, stringers, ribs and spars. The design variables include skin ply thicknesses and orientations, and spar cap and stringer cross-sectional areas. With the total task defined, an initial study was conducted to learn more about the intricate dynamic and aeroelastic characteristics of the tiltrotor aircraft and their roles in the wing design. Also, some work was done on the wing finite-element modeling (via PATRAN) which would be used in structural analysis and optimization. Initial studies indicate that in order to limit the wing/rotor aeroelastic and dynamic interactions in the preliminary design, the cruise speed, rotor system and wing geometric attributes must all be held fixed.

Introduction

The tiltrotor aircraft is a flight vehicle which combines the efficient take-off, landing, hover and low speed characteristics of a helicopter with the efficient high-speed cruise characteristics of an airplane.[1] With the success of Bell XV-15 program and its derivative the Bell-Boeing V-22, the tiltrotor concept has been seriously considered for civilian applications.[2] The civil tiltrotor transport aircraft is required to carry 40 passengers (8,000 lb) and cruise at 375 Knots with a range of 600 N. Miles. The tiltrotor aircraft is among many V/STOL configurations (e.g., tiltwing, variable-diameter rotor, etc.) that have been considered for civil transport application in the past few years; however, in terms of rapid payload delivery and fuel consumption versus the disk loading and in terms of manufacturability, the tiltrotor is judged as being the most efficient design.[3]

The preliminary efforts in this study have been focused on two tasks: (1) To perform a literature review to learn more about the unique dynamic and aeroelastic characteristics of the tiltrotor configuration and the procedures to analyze them; and (2) To work on the structural modeling and analysis techniques necessary in the tiltrotor wing design optimization. This abstract highlights the important aspects of each task performed.

Wing Design Problem

The design objective is to determine the optimum set of structural parameters that minimize the wing structural weight while satisfying all structural and aeroelastic constraints. The wing geometry is to be the same as that defined in a recent Bell Helicopter Textron study.[4] The wing box structural components (i.e., skin, stringers, spars, and ribs) are all made of graphite-epoxy composites. The wing design variables include skin ply thicknesses and orientations, and stringer and spar cap areas. These design variables would allow the tailoring of the composite materials to meet the design requirements most efficiently.

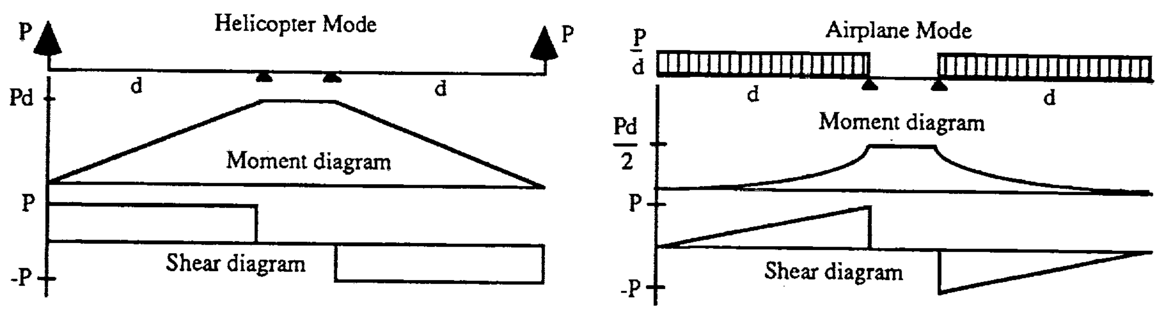
Since the civil tiltrotor aircraft must fly much faster than its military counterpart (i.e., V-22), total drag in general and compressibility drag in particular become important design drivers. The wing airfoil section on V-22 has a thickness to chord ratio of 23%. The structural design requirements on the civil tiltrotor are less stringent than those for the V-22; hence, a thinner airfoil would satisfy the structural design requirements while reducing the compressibility drag. The goal is to use an 18% thick supercritical airfoil for the civil tiltrotor wing to increase the drag-divergence Mach number and lower the compressibility drag. The wing structural design is based on the limit load factors in helicopter and airplane modes stated in FAR: Part XX (Interim Airworthiness Criteria: Powered Lift Transport Category Aircraft). The 2.0-g vertical jump take-off loads create the highest wing root bending moments as shown in the figure below—setting the requirements for wing strength in the form of maximum stress constraints on the stringers and the spar caps, and maximum strain constraints on the skin plies.

The large proprotor at each wing tip, resembling more like a helicopter rotor than an airplane propeller, produces high dynamic and aerodynamic loads. Furthermore, rotor hub and blade motions along with wing flexibility produce dynamic and aeroelastic couplings that may lead to several instabilities. The instabilities associated with the tiltrotor configuration may be classified as: (1) Mechanical instabilities; and (2) Aeroelastic instabilities. The heavy masses placed at the wing tips reduce the wing bending and torsion frequencies. The wing motions in bending and torsion (symmetric or antisymmetric) set off motions in the rotor hub. The rotor hub motions can cause the blades to depattern which cause further vibration of the rotor hub leading to mechanical instability and an eventual destructive failure. To eliminate this form of instability, the blade natural frequencies in the plane of rotation must be greater than rotor speed.[3] In the airplane mode, the oscillatory aerodynamic and dynamic forces generated by the rotors combined with the flexibility of the wing may tilt the axis of rotation causing the rotor to whirl. This whirling motion changes the fixed-wing aeroelastic flutter to what is known as whirl flutter. To eliminate this form of instability, the wing natural frequencies (mainly torsion) must be kept away from the rotor natural frequencies. Also, more importantly, the wing beamwise bending and torsional frequencies must be kept separated.[5] In this study, in order to limit the wing/rotor dynamic and aeroelastic interactions, the cruise speed, rotor system and wing geometry are all held fixed. Hence, the wing box stiffness is dictated by the aeroelastic instability boundary. The guidelines established in Ref. 4 will be used to create proper design constraints for aeroelastic stability and natural frequency placements.

Some work has also been done on the generation of the finite-element model of the wing/pylon using PATRAN. This model along with material property information will be used in MSC/NASTRAN for the static and dynamic structural analyses of the wing model. Following the completion of this task, and the proper formulation of aeroelastic and structural constraints, the design optimization will proceed.

References

1. Mark, H. and Lynn R.R., "Aircraft Without Airports-Changing the Way Men Fly," VERTIFLITE, Vol. 34, No. 3, 1988.
2. "Civil Tiltrotor Missions and Applications: A Research Study," Boeing Commercial Aircraft Company, Renton, WA, NASA-CR-177452, Summary Final Report, July 1987.
3. Loewy, R.G., "Aeroelasticity and the Tiltrotor VTOL Aircraft," VERTIFLITE, Vol. 38, No. 3, 1992.
4. Rogers, C. and Reisdorfer, D., "Advanced Material and Structural Concepts, Civil Tiltrotor Point Design-Model 940A," NASA-CR-191446, 1992.
5. Nixon, M.W., "Parametric Studies for Tiltrotor Aeroelastic Stability in High-Speed Flight," Proceedings of the 33rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference, Dallas, Texas, April 13-15, 1992, Part 4, pp. 2027-2037.



Shear and Moment Variations for the Same Total Lift