Pilot-in-the-loop aeroelastic stability analysis in tiltrotors

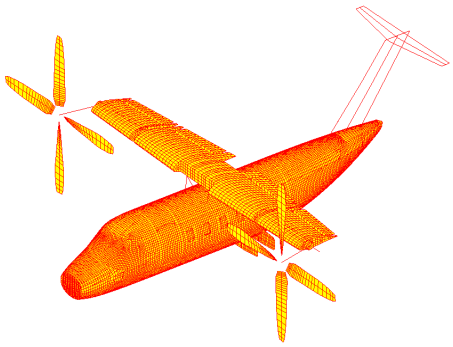
In tiltrotors, as well as in helicopters, the unintentional pilot's body response can be triggered by the structural vibrations of the vehicle, possibly creating an unstable feedback path. These phenomena go under the name of Pilot-Assisted Oscillations (PAOs). Several PAOs phenomena have been encountered, for example, during the V-22 experimental flight tests (ref. [1]).

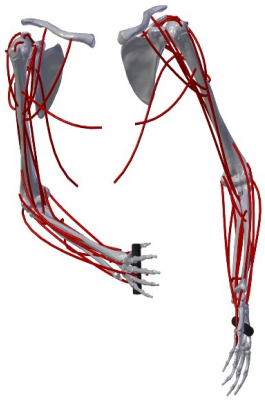
The main target of this thesis will be centered on the development of an aeroelastic tiltrotor model, representative of the Bell-Boeing XV-15, coupled with several pilot-control device biomechanical models in order to investigate the PAOs phenomena and to provide means of prevention.

The aeroelastic tiltrotor model will be built by the student using the simulation software MASST (Modern Aeroservoelastic State Space Tools, see refs. [2]), developed at the Aerospace Science and Technology Department, and actually used by a leader industry in helicopter manufacturing.
Linearized pilot-control-device biomechanical models will be identified starting from a multibody model of the pilot upper limbs built in the open source general purpose simulation code MBDyn (www.mbdyn.org, ref. [3]).

Key points are:

- The development of the elastic airframe model in NASTRAN, able to capture the low-frequency wing modes, that mainly participate at the pilot-in-the-loop aeroelastic phenomena;
- The generation of a database of pilot's biomechanical models, considering sensitivities to the pilot's anthropometric characteristics, muscular activation dynamics and control device dynamics and their correlation with the pilot's transfer functions presented in literature;
- Aeroelastic stability analyses, with the pilot's biomechanics in feedback loop, on the tiltrotor conversion corridor;
- The design of active and/or passive devices to avoid instabilities (notch filters, vibration absorbers, new control devices, etc...).





Example of tiltrotor model in MASST and pilot-control-device biomechanical model inMBDyn

References:

[1] T. Parham, Jr., David Popelka, David G. Miller, and Arnold T. Froebel. “V-22 pilot-in-the-loop aeroelastic stability analysis.” In American Helicopter Society 47th Annual Forum, Phoenix, Arizona (USA), May 6–8 1991

[2] P. Masarati, V. Muscarello, G. Quaranta, A. Locatelli, D. Mangone, L. Riviello, and L. Viganò. “An integrated environment for helicopter aeroservoelastic analysis: the ground resonance case.” In 37th European Rotorcraft Forum, pages 177.1–12, Gallarate, Italy, September 13–15 2011.

[3] P. Masarati, G. Quaranta, and A. Zanoni “A Detailed Biomechanical Pilot Model For Multi-Axis Involuntary Rotorcraft-Pilot Couplings”. In 41st European Rotorcraft Forum, Munich, Germany, September 1-4 2015

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