Mathematical modelling of tilt-rotor aircraft configurations. A comprehensive model for flight control system development and real-time piloted simulation.

Abstract

This thesis aims to describe the development and validation of TRoReS (Tilt Rotor Reseach Simulator), a comprehensive tilt-rotor mathematical model implemented in MATLAB/Simulink®, for real-time flight simulation and flight control laws design. The development of TRoReS started with the review of the work performed by NASA and Bell Helicopters and reported by Samuel W. Ferguson in 1988, in the NASA report CR-166536, *A mathematical model for real time flight simulation of a generic tilt-rotor aircraft*. The report describes the mathematical model implemented in Fortran environment, in the GTRS/Sigma 8 flight simulator. A first implementation of the reference model was attempted by the author at the beginning of the project, but a fully successful replication of it in the simulink environment was never achieved, and doubts were raised regarding the correctness of some of the equations reported. In fact, while a working model was achieved and several simulations were carried, unexpected instabilities were encountered during piloted simulations in several flight conditions for both helicotper and airplane modes. As this thesis will describe, the author performed several modifications to the reference mathematical model, including the replacement of the rotor models with a novel gimballed proprotor model, and a revised aerodynamics formulation. As a result, the new mathematical model was implemented in MATLAB/Simulink® environment and submitted to several validation and simulation activities, both off-line and real-time on the Research and Didactics simulator of the Zurich University of Applied Sciences, with the help of a licenced helicopter pilot. The TRoReS development was coordinated by the author between mid 2018 and end 2020, in a joint research project between Polytechnic University of Turin (PoliTo) and Zurich University of Applied Sciences (ZHAW). During the project, the author developed his knowledge of the tilt-rotor aeromechanics and aerodynamics, improved his model based design skills with the use of MATLAB/Simulink®, and coordinated the activities of several engineering students which joined the team in different parts of the project to complete their master thesis projects. This thesis will provide description of the most relevant aspects of the project in terms of simulation model software impelmentation, mathematical model development and validation activities.