Helicopter flight control design tool integrating handling qualities requirements

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Abstract

Helicopters are naturally very unstable systems. Pilots must make considerable efforts to stabilize their helicopters. That's why AP (autopilots) are used and the design of the associated flight control laws is important. These flight controls can then be evaluated via the Flight Qualities, which specify all the qualities a helicopter needs so that an average pilot can easily perform all tasks accurately and safely. Usually, many loops are necessary to correctly configure the AP in order to handle as much as possible the flight qualities requirements given – for example – by the ADS-33 [1]. In this PhD thesis, we want to establish a method that will permit engineers to directly and correctly configure the AP in order to handle at best the requirements of standards, deleting the previously necessary loops. Only NASA has led such studies in the past, which have permitted the development of CONDUIT (Control Designer's Unified Interface) [3].

During the first year of the thesis, some works have been made in that purpose. Two main tools have been developed to help the studies: CAST-HEL-AP (Computer Aided Setting and Tuning tool for HELicopters'AutoPilots) and an autopilot that had been implemented in two environments.

The first main tool, CAST-HEL-AP (Fig. 1), has been created in order to facilitate the study of gain tuning sensitivity to standards from ADS-33 requirements, via simultaneous pole placement, actuators need, attitude quickness and bandwidth / phase delay analysis. Thanks to it, we can simultaneously calculate all selected criteria depending on the configuration. At the date of the writing of this abstract, linear and non-linear models of helicopters are used with the ATT (attitude retention) control law (principle shown on Fig. 2), as well as linear models of actuators and delays. This tool could already be used by engineers to evaluate handling qualities performances of any helicopter with any value combination of the gains. A complete evaluation needs less than half a second, so that the user can rapidly "feel" the adjustment of his flight control laws. For the moment three criteria can be studied simultaneously on all axis of the helicopter. Thanks to this tool, a first manual design of the ATT control law can be led in good condition.

The second main tool (developed in Simulink) is an autopilot. This AP (with 3 flight control laws including their operational logics) has been integrated in 2 simulators: the first one is an offline simulator (using same linear models used by the first main tool) developed specifically to evaluate the AP (still on Simulink: see the structure of this tool on Fig. 3); the second one is PycsHEL, a prototyping and design bench of systems for helicopters of the future, that permits online simulations with state of the art non-linear models of helicopters (using HOST: Helicopter Overall Simulation Tool developed by Onera/Eurocopter/DLR): a photo is shown on Fig. 4.

Some improvements are in progress, such as the use of non-linear models of helicopters, actuators saturations, implementation of many control laws, taking into account others parts of the specifications of ADS-33, the use of optimization techniques, automatic identification of eigenstructures, and HMI improvements. Once this is done, a first complete design of flight control laws will be made. Thereafter, an application to studies of helicopters landing at sea is possible.

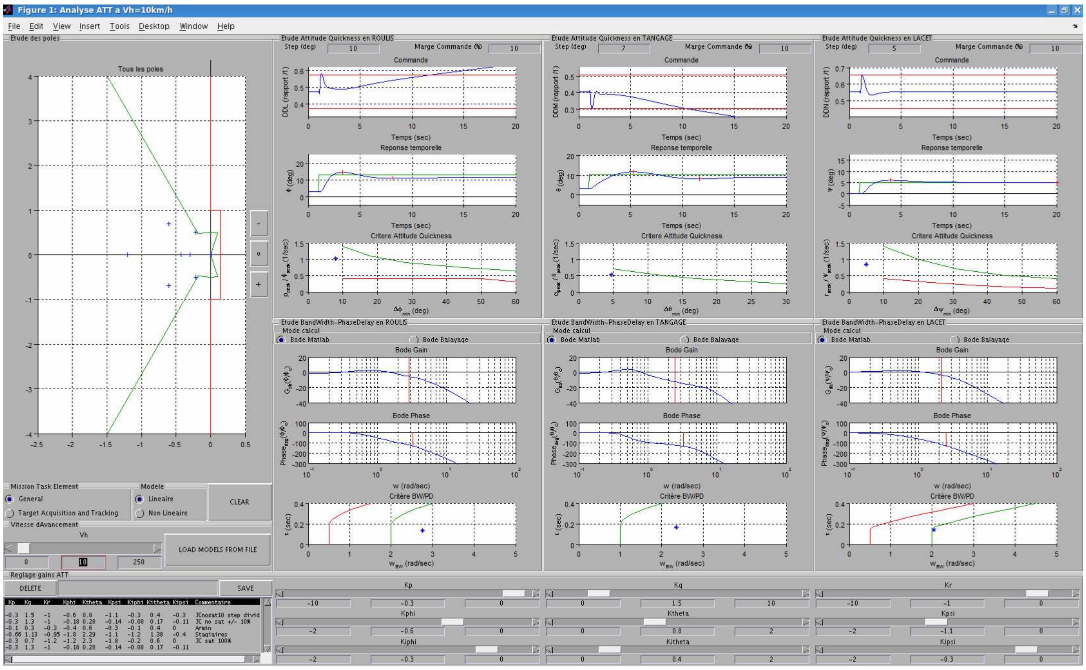
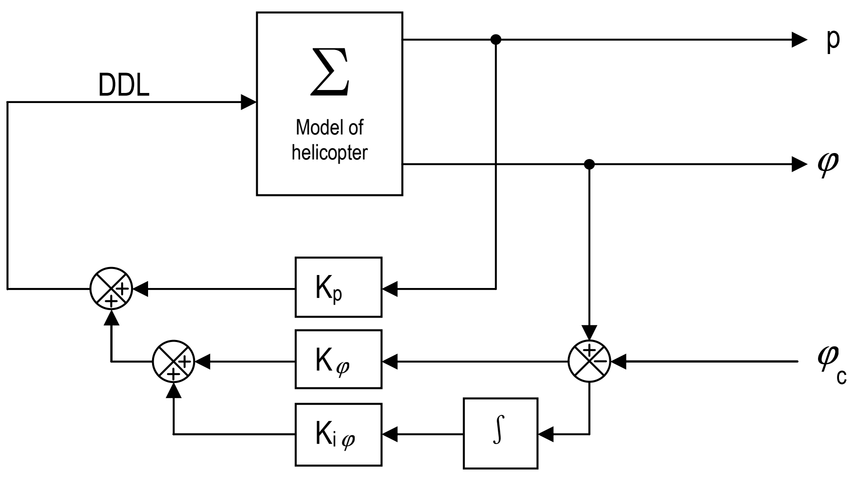


Fig. 1: screenshot of the first version of CAST-HEL-AP, Computer Aided Setting and Tuning tool for HELicopters'AutoPilots. Bottom: gain tuning area. Left figure: poles of closed loop linear model. Others figures, first column for roll study, second column for pitch study and last column for yaw study: actuators need, Attitude Quickness, and Bandwidth / Phase Delay analysis



Variables:

- DDL : lateral control of helicoper
- p : roll rate of helicopter
- φ : bank angle of helicopter
- φ_c: roll control
- Kp : derivative gain
- Kφ : proportional gain
- Kiφ: integral gain

Fig. 2: ATT – Attitude retention principle applied to roll axis

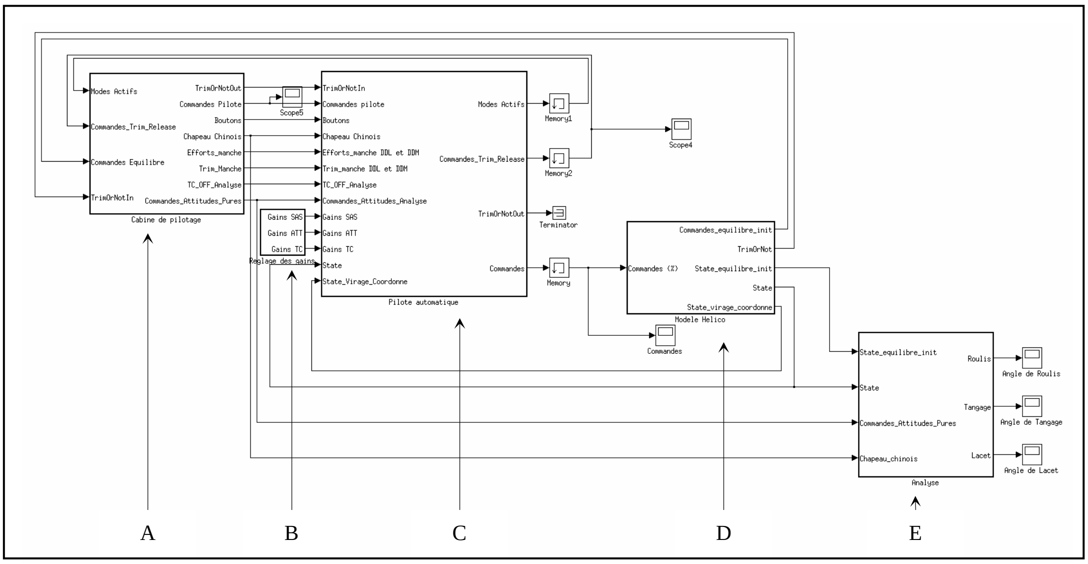


Fig. 3: Simulation tool for autopilots (on Simulink).
A: cockpit – B: gain tuning – C: autopilot – D: model of helicopter – E: Analysis

Fig. 4: PycsHEL (early stage of development) – prototyping
and design bench of systems for helicopters of the future.
The block C of Fig. 3 has been implemented here.

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