Experimental Characterization of Nonlinear Pilot Induced Oscillations using a flight simulator

Giuseppe Avon*, Luigi Fortuna*,** and Arturo Buscarino*,**

**Dipartimento di Ingegneria Elettrica Elettronica e Informatica, University of Catania, Italy*

***IASI, Consiglio Nazionale delle Ricerche (CNR), Roma, Italy*

Abstract. Pilot controlling action depends, in part, on the motions of the airplane in response to imposed commands. Aircraft and pilot form a closed-loop feedback control system where the pilot operates in the loop. Nonlinear oscillations which result in this human-machine coupling can be identified as closed-loop instabilities of the described feedback control system. Although the aircraft, left without command input may be stable, the human pilot parameters related to its intrinsic delays and non-linearities feed detrimental oscillations to the system driving it to instability. Starting from a FlightGear simulation environment, which offers input and output connection facilities, PIO are stimulated and aircraft response is studied as a function of several parameters which are strictly related to their onset.

Introduction

Pilot induced oscillation are the result of a detrimental collaboration between human and machine. PIOs onset conditions are usually related to high gain tasks, which intuitively could be associated to abrupt and abnormal changes in flight envelope but also, counterintuitively, are part of standard and well-defined flight operations. While high gain tasks are normal part of the pilot routine, the onset of severe PIO is an extraordinary event. This implies the need of a precursory trigger, which can be embodied in an unexpected event from the external environment [1, 2]

Interesting results may be observed by feeding waveforms to pilot inputs and studying the response of the aircraft flying inside a simulator, which has several different physics model working together to calculate the overall vehicle dynamics. For the purpose of the work, pilot contribution is reduced to a simplified model which includes parameterizable delays, dead bands, gains and saturations.

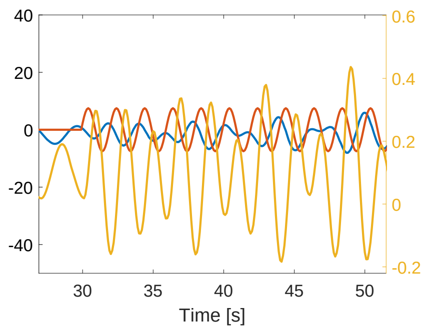

Figure 1: Example of aircraft excitation-response model. In red: roll angle setpoint; in yellow: normalized stick input; in blue: aircraft roll oscillation modes arising from specific deadband, pilot gain, delay and saturation.

Results and discussion

The study of PIOs as a result of oscillatory perturbation on flight sticks while observing the aircraft response is generally carried out as part of the aircrafts testing routine to asses their resilience, while PIO handling and suppression are part of the pilot knowledge base. The examination of the PIO phenomena as scenarios of non-linear dynamics can give possible further explainations to their occurrence.

Through the use of FlightGear simulator, which offers reasonably good flight dynamic models and superb integration possibilities, a simulation routine is established. The routine consists mainly on the setup of consistent conditions over all the experiments conducted, including weather, flight level, aircraft weights and other major flight-influencing aspect. Aircraft data is flowed out the simulator as a stream, which feeds the custom developed aircraft stimulation model. First of all, a fixed amount of time pursuing the straight-and-level flight is given to allow decay of residual oscillations arising from the switch between manual and automated modes. After that, a setpoint variation waveform is fed into the pilot model, which translates into the related stick movement and, consequentially, into aircraft angles. The pilot model, which has configurable delays, setpoints, saturations and gains, flyes the aircraft into pursuing the desired pitch and bank angles.

The onset of oscillations is then studied, relating the frequency of occurence, the amplitude and the oscillatory mode to the pilot model parameters. Results suggest relationships between deadband width, rate limitation and delay on pilot intervention which could, in turn, suggest mitigation and suppression strategies.

References

[1] McRuer Duane T, Pilot-Induced Oscillations and Human Dynamic Behaviour. NASA Contractor Report 4683.

[2] Choe R. et al, L1 Adaptive Control under Anomaly: Flying Qualities and Adverse Pilot Interaction