Biodynamic Pilot Modelling for Aero-Elastic Aircraft

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Abstract

In the paper, the models of biodynamic pilot are identified to describe biodynamic pilot-aircraft interaction under high-frequency lateral accelerations. The results presented are received in the course of project ARISTOTEL performed within the 7th European Framework Program, and are further development of that shown in [1]. In perspective, the results will be used to develop criteria to assess the effect of structural elasticity on aircraft handling qualities.

As it is shown in Figure 1, depending on the piloting task, one or more acceleration feedbacks can arise in addition to the visual feedback. As it was shown in [2], the effect of the accelerations, beneficial or negative, depends on the piloting task, acceleration intensity and aircraft characteristics. The accelerations due to structural elasticity are of high frequency and play negative role in piloting. Such accelerations can cause involuntary body and limb-manipulator displacements (biodynamic interaction), which, in turn, can intensify the high-frequency oscillations and lead to handling quality pilot rating degradation.

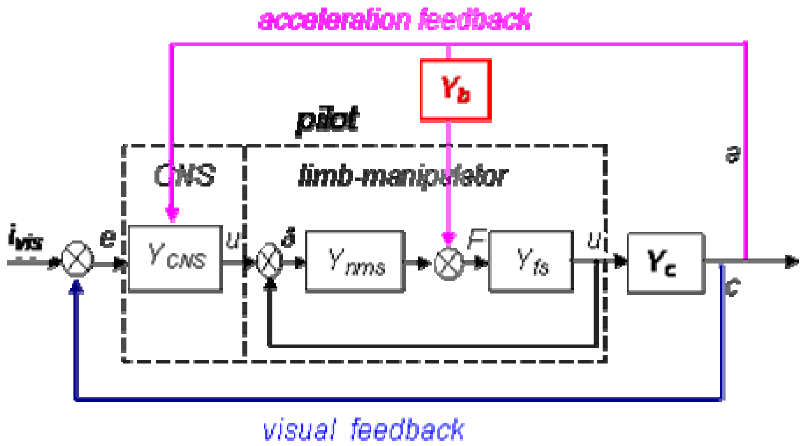

Figure 1. Block-diagram of pilot-aircraft interaction feedbacks.

To determine the effect of different factors on the biodynamic interaction, experiments were conducted on flight simulators of TsAGI (Russia) and NLR (The Netherlands). In the course of experiments the following research questions were considered:

1. Effect of the manipulator type (traditional wheel, center stick and side stick).
2. Effects of manipulator feel system characteristics (spring gradient, damping, breakout force).

In the experiments, the human pilots were exposed to lateral accelerations produced by flight simulator motion system. The paper describes experimental procedure (simulators, motion input signals, test matrices, piloting tasks, etc.), as well as experimentally identified describing functions. An example of the experimental data received for a sidestick is shown in Figure 2.

The results received in the course of the work can be summarized as follows:

1. The limb-manipulator characteristics are the most decisive factor for pilot-aircraft biodynamic interaction.

2. The limb-manipulator system with the traditional wheel is less prone to biodynamic interaction than the systems with center and side sticks.
3. In kind, the effects of feel system characteristics on biodynamic interaction (biodynamic describing function) are the same for all types of manipulators considered; in degree, the effects are different being the smallest for the wheel.
4. Manipulator damping is the most effective method to reduce biodynamic interaction at high frequencies (2 Hz and above).
5. The force gradient is an effective method to reduce amplitude of biodynamic interaction at small and middle frequencies (below 1 Hz).
6. Effect of breakout force on BDI is somewhat similar to the effect of force gradient within a limited range of breakout variation; the effect of friction is similar to the effect damping.
7. The biodynamic pilot transfer functions are identified; their parameters are determined as functions of manipulator feel system characteristics.

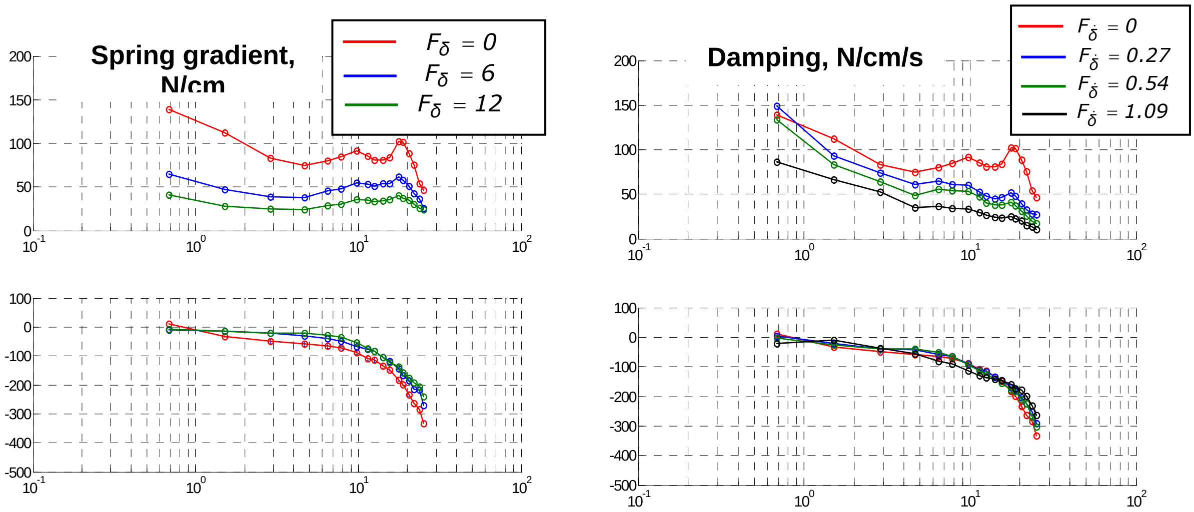

Figure 2. Effect of manipulator spring gradient and damping on biodynamic pilot describing functions.

References

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2. Rodchenko V.V., Zaichik L.E., Yashin Y.P., Lee B.P., “Simulation – To – Flight Correlation”, AIAA-5823-2003, Austin TX, 2003.