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Influence of the pilot on the modal parameters of the control system lightweight aircraft

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This paper is focused on creation of experiment and experimental determination of pilot influence on the modal parameters of the longitudinal mechanical control system of lightweight aircraft. There are some publications which describes pilot response and traffic delay in relation to flight dynamics. Several studies on the description of the pilot's muscular activity have been published. The paper [1] deals with the recent studies of the human controller. At first describes linear models of human controllers, discus results of linear model studies, next describes nonlinear models like "bang bang" model for high-order system. The paper [2] deals with the lumbar muscular activity during real flight conditions, using surface electromyography sensors. With focus on type and duration of flight, type of helicopter, pilot dimensions. The paper [3] deals with vibration of helicopters during flight at very low frequencies 0.315-5 Hz. The paper [4] discusses mathematical models of human pilot behaviour at low frequencies till 1.6 Hz. Publication [5] describes influence of muscle responses in higher frequency up to 300Hz in relation to heavy tools such as drilling machine, drilling hammer, jackhammer. Main aim is description of influence of pilot arm on dynamical characteristics mechanical control route in the frequency range 1-70Hz. Determining where pilot´s properties are among the test boundary conditions of free and blocked control.

Test setup: During experiment pilot was sitting on the chair and hold the control stick. On the scheme are control stick, wrist, elbow and shoulder moving parts, other are without moving. On the pilot arm was placed seven sensors for measuring muscle activity. Measured muscles were brachialis, brachioradialis, biceps long head, biceps short head, triceps medial, triceps long head and triceps lateral. This measuring of the muscle activity called Electromyography (EMG) and usually is used for medicine purposes. On the control stick was placed three one-directional piezoelectric accelerometers from Bruel and Kjaer company with 14g range (position 2) on the frame and 71g range on the moving control stick (position 1,3). Point 4 wasn´t measured, dimensions are in millimeters. On the shaker was placed forcemeter from Bruel and Kjaer company.

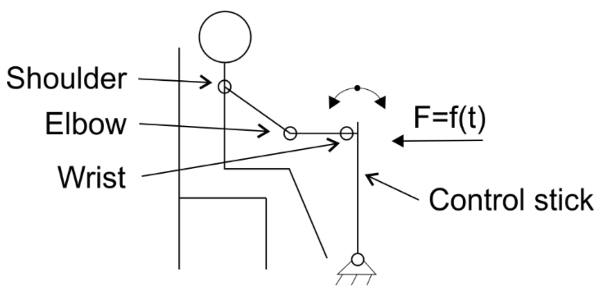

Fig. 1. Experiment layout

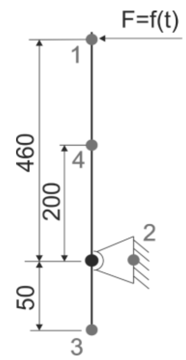

Fig. 2. Control stick scheme

Few boundary conditions were defined for this experiment. First one is a standard holding of control stick by a pilot. This boundary condition attempts to simulate the standard holding during balanced steady state flight with minimal or zero forces in control.

The second boundary condition is a state in which pilot tries to supress or minimize the movement of control stick within the range of vibration. Next boundary condition is a level of amplitude of excitation signal 1V, 2V, 3V.

The experiment was done with few types of excitation signals exactly sinesweep with linear and logarithm distribution and random burst. Excitation signal has frequency range 0.5-75 Hz. Sampling frequency was 1024 Hz, duration of one sample was 32s. Useful bandwidth was 400 Hz and has 32768 spectral lines.Measuring was done few times, first block was measured without averaging and it was done 3 times with the same boundary conditions. From this type of measuring we obtain EMG data. For calculating transfer function (further TF) from accelerometers and forcemeter we used data from averaged measurement. The setup of averaging was 66.6% of overlap with 12 averaging which consist of 5 full samples length.

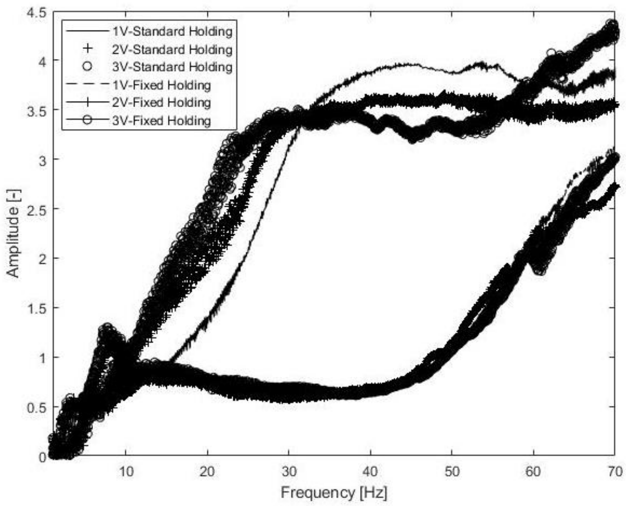

Fig. 3. Measured frequency response functions

Fig. 3 shows that there is some change in the measured TF when changing the amplitude of the excitation signal of “standard holding”. This change is not so clear on the second boundary condition “fixed holding”. A major change in the TF occurs in the case of a change of the handle type of the control stick. At higher frequencies, it is obvious, that the pilot is unable to suppress the movement and the TF is closer to the TF of the “standard holding”.

Measured data was postprocessed. The obtained postprocessed data was used for creation of a state-space model of description human pilot operator. State space model was created by using subspace method without disturbance matrix.

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