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MODELING A PILOT ERROR FROM UNCOORDINATED COMMANDS WHILE PERFORMING A TURN

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Keywords: *flight safety, modeling, control system, flight dynamics*

Abstract: *The study looked at the behavior of the "* pilot-aircraft *" system in the execution of a turn. The coordination of movements with the two-channel control lever is modeled with correct and improper operation.*

МОДЕЛИРАНЕ ГРЕШКА НА ПИЛОТА ОТ НЕКООРДИНИРАНИ КОМАНДИ ПРИ ИЗПЪЛНЕНИЕ НА ВИРАЖ

***Ключови думи*:** *безопасност на полетите, моделиране, контур за управление, динамика на полета.*

Резюме: *В изследването е разгледано поведението на системата "пилот-самолет" при изпълнение на вираж. Моделирана е координацията на движенията с лоста за управление по два канала при правилно и неправилно управление.*

Studied problem - receiving data for correct and incorrect coordination of movements with the control lever in the performance of a turn.

Users of the survey results - educators and instructors who train pilots of airplanes, aviation safety specialists.

Method of investigation - modeling and investigation of the pilot-plane system in "Matlab-Simulink" environment.

1. **Introduction** - setting the modeling task

Correct execution of the turn requires several parameters to be tracked: pitch and vertical speed, overload, air speed, height.

Except transition processes, when entering and exiting the figure the pitch angle remains constant during any slope - it is equal to the pitch in a horizontal rectilinear flight at the same a speed and height.

The average vertical speed in the turn is about zero, which is a sign of satisfactory coordination between the commands in the longitudinal and lateral motion when entering a turn.

Overloading meets the condition $n_y = \frac{1}{\cos\gamma}$;

It is assumed that the engine regime, speed and height prior to entering the turn are in line with the pilot's task.

Movement of the control lever when entering a turn is learned by the pilot and is acquired as a manner after training. In modeling, this can be reflected by using the simpler, but sufficiently accurate pilot models and a fast-running control loop.

Pilot mistakes when performing acrobatics flying include incorrect, disproportionate (coarse), uncoordinated and untimely displacements of control levers. All of them lead to deviation of the plane. For the turn, the cause of the error may be so "separate buckling and overloading" (initially, a slope is created, and then the overload to the need is increased). In such operations, the vertical velocity can be assumed to reach significant negative values in the turn process. If the vertical velocity V_y is negative and with absolute values greater than 20 m/s, entry into turn is considered to be a crude pilot error and the execution of the figure is terminated. With lower absolute vertical speeds, the error can only be corrected by decreasing the slope. Another rough mistake (especially on small heights and maximum overload forced turns) is to use the pedals for lifting the nose - by pressing on the pedal outer for the turn [2 - page 179-183]. With such a command the plane noticeably raises the nose (10-15^0) and creates an illusion eliminating of error, but the plane continues to move in a downward trajectory. At extreme forced turns the aircraft is at great angles of attack, and putting such a pedal command can complicate the situation.

The task of modeling is to fix and visualize graphically the cause of error in the coordination of commands through Simulink's tools.

2. A method for modeling a pilot error of a co-ordinate violation in lever movements in dual channel control

The research task includes:

• Creating a model to simulate the operation of the "Pilot-aircraft".

• Obtaining data on the handle trajectory from the control lever (general appearance) with correct and incorrect hand movements coordination.

• Analysis of the results of the pilot actions under different co-ordination.

Fig. 1 shows a general appearance of the model in "Simulink". The pilot models on the two control channels are shown in Fig. 2 and 3. The behavior of the airplane is modeled with transmission functions for varying the overload (longitudinal movement) and isolated slope movement (lateral movement).

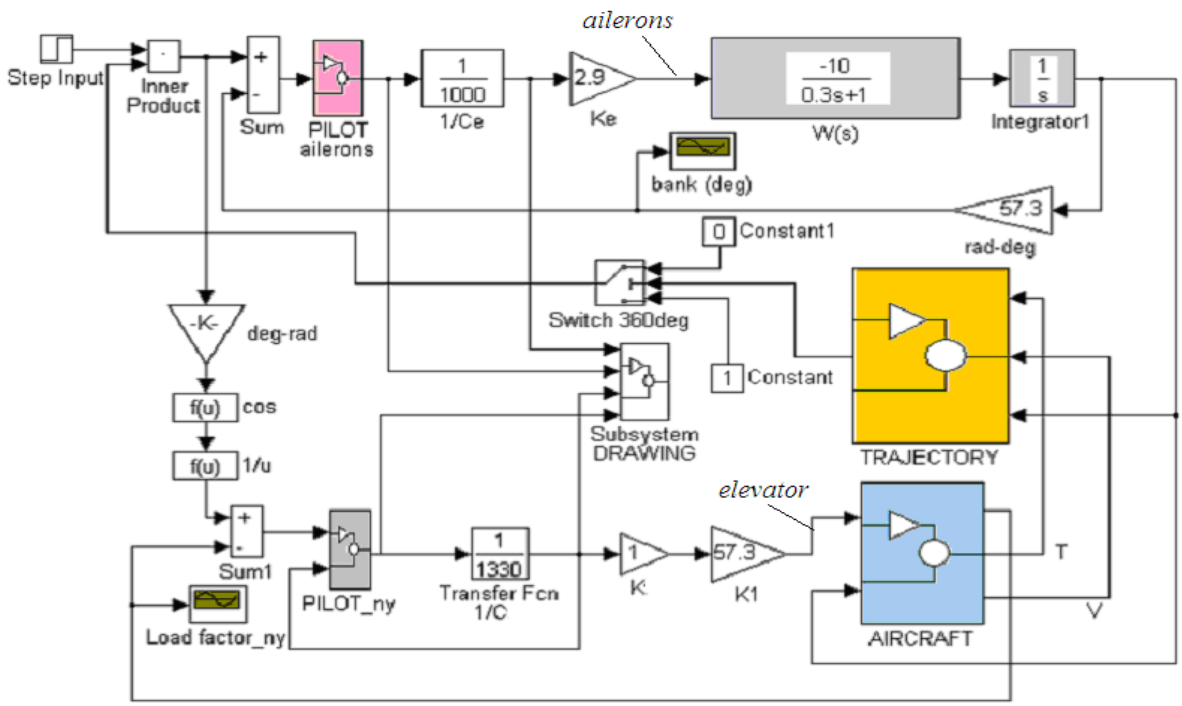


Fig. 1. General appearance of the model with two coordinate control loops.
Block "AIRCRAFT" - model of the airplane in longitudinal movement - overload transmission function;
Block "W (s)" - airplane model for angular velocity around the longitudinal axis;
Blocks "Transfer Fcn 1 / C" and "1 / Ce" - models of loading mechanisms with stiffness c = 1330N / m and se = 1000N / m, in modeling make the pilot effort to move the steering gear);
Blocks "k" and "k_e" - transmission coefficients k = 1rad / N and ke = 2.9rad / N;
Block "PILOT_ny" - pilot model for overload control;
Block "PILOT_ailerons" - pilot model for slope management;
"TRAJECTORY" block - a trajectory visualization;
Subsystem "DRAWING" - visualization of the results of the model's actions of the pilot (movement of the handle) with the capabilities of the "SINKS" library from "SIMULINK".

The management is hydro-mechanical and the forces are artificially formed by loading mechanisms.

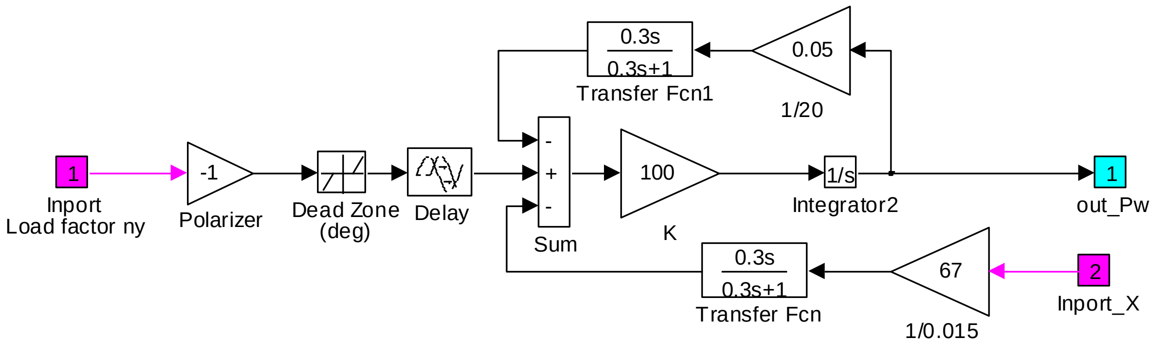


Fig. 2. Astatic pilot model for control over normal overload in the channel of the controllable horizontal stabilizer

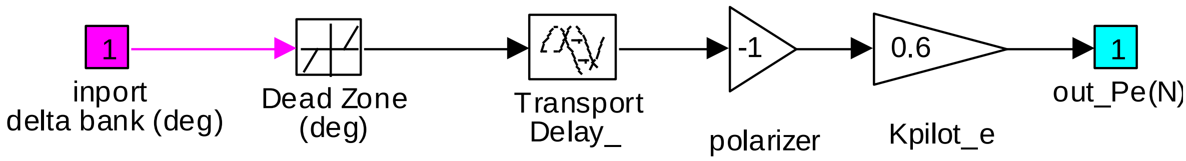
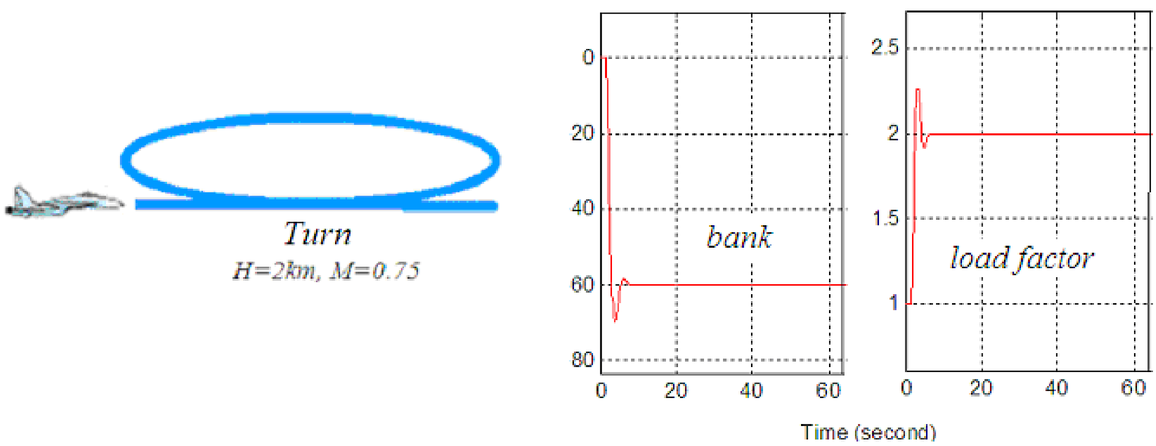


Fig. 3. Pilot Control Model in the Aerial Channel

Exit from the pilot model are the efforts on the control lever P and P_e in Newtons. Index "e" is the ailerons control channel. Lever shift results – the dependence $x = f(x_e)$ is obtained in the DRAWING subsystem (Figure 1). Inputs data after the "Transfer Fcn 1 / C" and "1 / Ce" blocks with loading mechanisms with relevant stiffness attached to the control lever. The standard tools in Simulink, the fourth version, are used to visualize the results. All modeling is done in GOST standard.

3. Results and conclusions

Figures 4, 5, 6 show the modeling results of correct and coordinated control over the two channels.



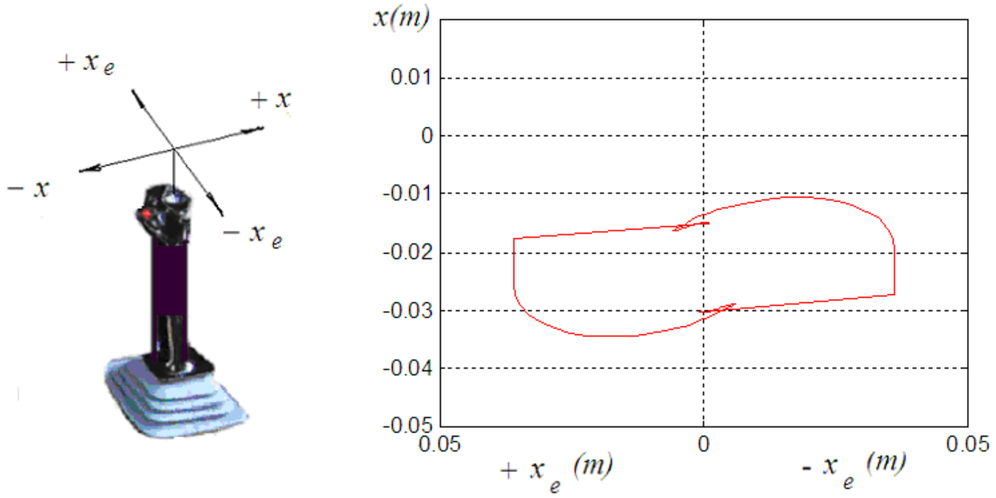


Fig. 4. Pilot arm movement with the control lever to create a left slope of 60 degrees and overload 2 with proper motion coordination

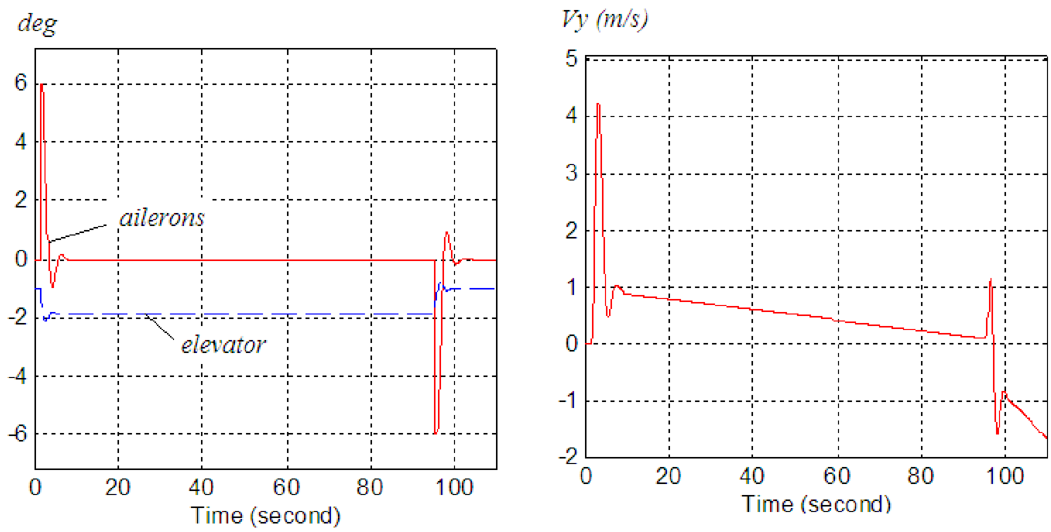


Fig. 5. Deviation of controls and vertical speed for coordinated control of the airplane

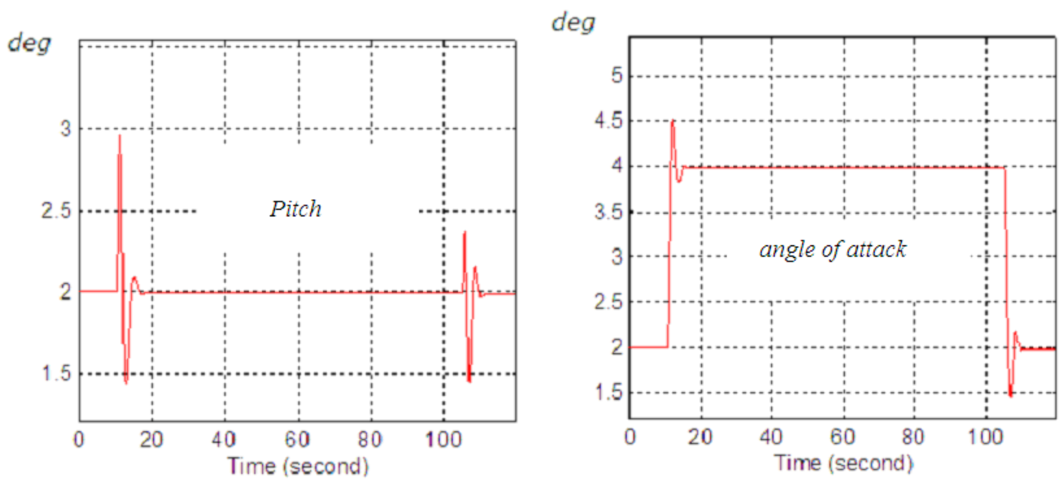


Fig. 6. Angles of pitching and attack when performing a correct coordinated turn

The results demonstrate the performance of the model as required in the introduction of the research task in the introduction (p. 1).

Incorrect motion coordination can be modeled by delaying movements in the longitudinal channel, etc. "Separate channel management". This is done by adjusting the block K of Fig. 2 from 100 to 10. The results after such adjustment show clearly how the movement delay in the longitudinal channel is reflected on the airplane trajectory. The turn degenerates into a downward spiral, and the vertical velocity of introduction reaches – 8 m/s; on exit - significant negative values -16 m/s. In this case, the execution of the turn is usually terminated at the beginning of its execution, but it is possible to correct the ailerons to reduce the slope and maintain the vertical velocity around zero.

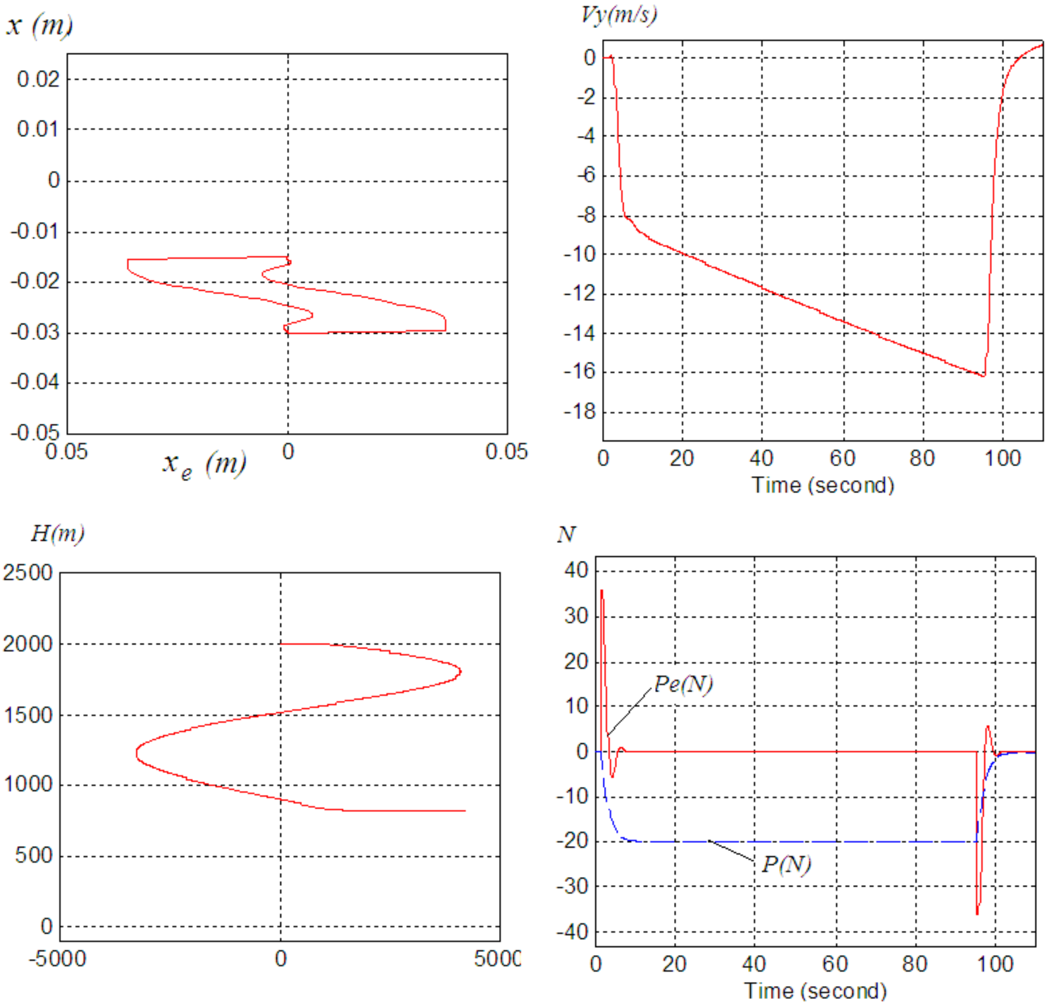


Fig. 7. Non-coordinated execution of the turn

Simulation with vertical speed correction (Fig. 9) can be obtained with another model of the pilot controlling the aelerons. Such a model is shown in Fig. 8.

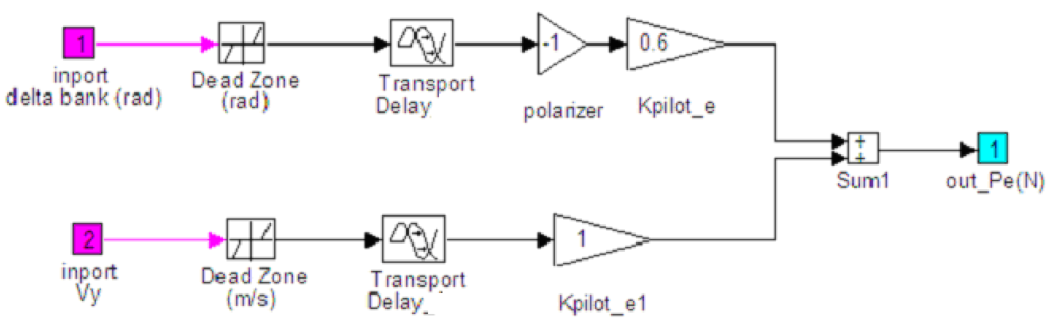


Fig. 8. Pilot model to control ailerons when reading the vertical speed; the accuracy of the control is – at a vertical velocity ΔVy = ± 0.1 m / s, and at a slope angle Δγ = ± 0.10 (Dead zone)

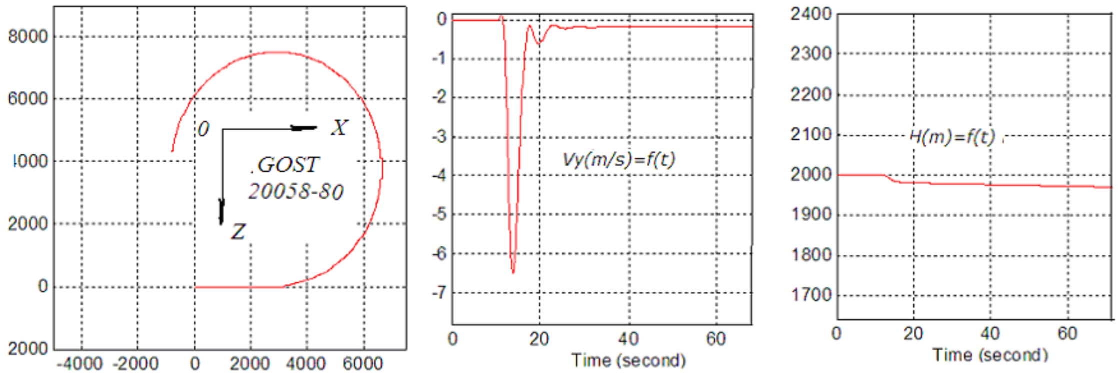


Fig. 9. Curve modeling results at 270 degrees with uncoordinated entry into the turn, but corrected by the pilot model by slope adjustments

Conclusions

- The proposed model, based on elementary contours for longitudinal and isolated slope movement, can demonstrate a significant portion of the pilot's actions when executing a or turn with correct commands or uncoordinated movements of the control lever.
- Modeling confirms the importance of vertically controlling the initiation and execution of the turn.
- The model is fast enough and works practically in real time. It can be used in the training of pilots and aviation safety specialists.

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