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MODEL-BASED DESIGN OF AUTOMATIC FLIGHT CONTROL SYSTEMS

The article deals with the model-based approach to the design of automatic control systems which used for safety critical systems. Advantages of this approach by illustrative example and opportunity of practical use and its manufacturing application are showed.

Design technology of AFCS (automatic control systems) for aircraft is mostly formed so far. There are three major developments in technology design:

1) The creation of mathematical software for modeling the dynamics of controlled movement of aircraft;

2) Software development (on-board programs);

3) Design bench set for semi-natural simulation.

This paper shows the opportunity of using model-based approach for the first development. The model- based design – is an efficient and cost-effective way for control system design. Instead of physical prototypes and text specifications in model- design model is applied. This model is used in all stages of development. This approach to design allows to carry out simulation of whole system entirely as well as its components, in addition to select and justify the structure of the AFCS, to analyze the stability of the system and show compliance of specification requirements for this control system with a given probability. There is a possibility of automatic code generation, testing in continuous mode and verification. Development of mathematical algorithms of synthesis ends in full mathematical model of a closed loop control, including in particular statistical modeling [1].

At the present stage of development of technology product design of aerospace vehicles, including AFCS (automatic flight control systems) for civil aircraft, we can see the trend of carrying the main volume of work on the stage of ground testing, which includes mathematical modeling and semi-natural bench modeling. This is due to primarily economic reasons, since the cost of identifying and eliminating defects at the stages of mathematical modeling, practicing bench and flight tests are in the ratio 1:10:100 [2]. It turns out that the volume of flight tests required for removal of previously unrevealed defects close to zero, and it is only to demonstrate the results achieved, because nearly 80% of all problems that arise when developing appropriate systems shall be decided on the ground. With the development of complex technical systems role of modeling in assessing the parameters of these processes increased considerably. This is explained by characteristics of research objects that are lying in the complexity of functional relationships between system parameters, environmental changing conditions and the estimated parameters.

Model-based approach can be used not only in preparing technical proposals and the formation of technical requirements for new objects but also on the stages of conceptual and technical design, and the debugging samples in closed systems and also on the stage of different kind full-scale tests that determine the characteristics of objects their debugging and possible to move from this stage to further testing or serve as justification for transfer objects to the serial production [3]. Model-based approach provides solving of the next tasks:

justification of tactical technical requirements for AFCS;

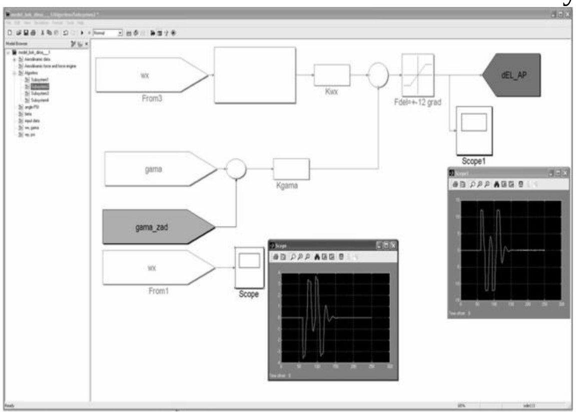
implementation of a preliminary analysis of the developed modes and laws of AFCS at the aircraft design stage (see Figure 1, Figure 2);

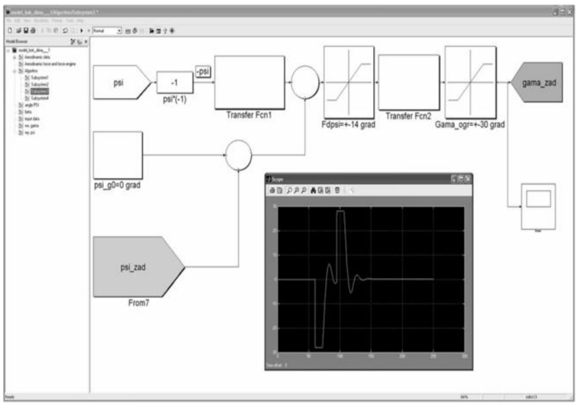
Maintenance of semi-natural simulation AFCS;

statistical analysis of approach mode with savings of material costs during flight test;

development of recommendations setting paths automatic control during flight test AFCS that reduce time and material costs of full-scale test, certification and more.

As an example, consider the automatic control lateral movement of the main plane which implements through the rudder channel and ailerons. Rudder channel provides short-damping oscillations around the normal axis and eliminates slip angle. Purposive roll and course control provides by ailerons in coordinated turn mode. Testing of the given angle and roll rate providing by simultaneous operation of ailerons and rudder. Development of automatic control laws of lateral movement is based on the principle of decomposition (separation) of ailerons and rudder channel. For this purpose, the original object of the lateral movement divides into two subobjects which are implement flat coordinated turn mode. The following software implementation of the above laws and an example of AFCS research in "Approach mode" with following conditions of research results made in the block simulation system of dynamic systems Simulink / Matlab:

(a) 

(b) 

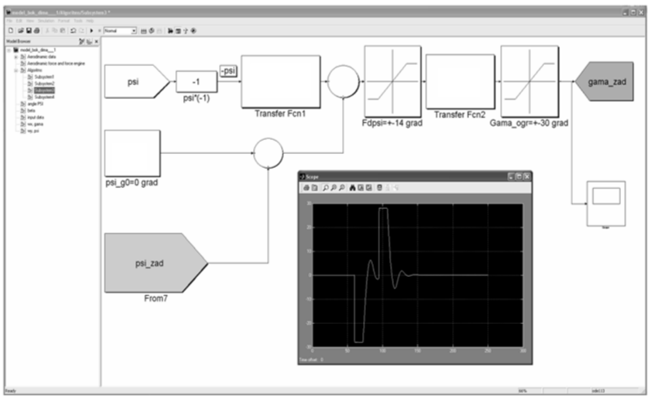
(c) 

Fig. 1. Control law in ailerons channel (a) in rudder channel (b), roll angle set.

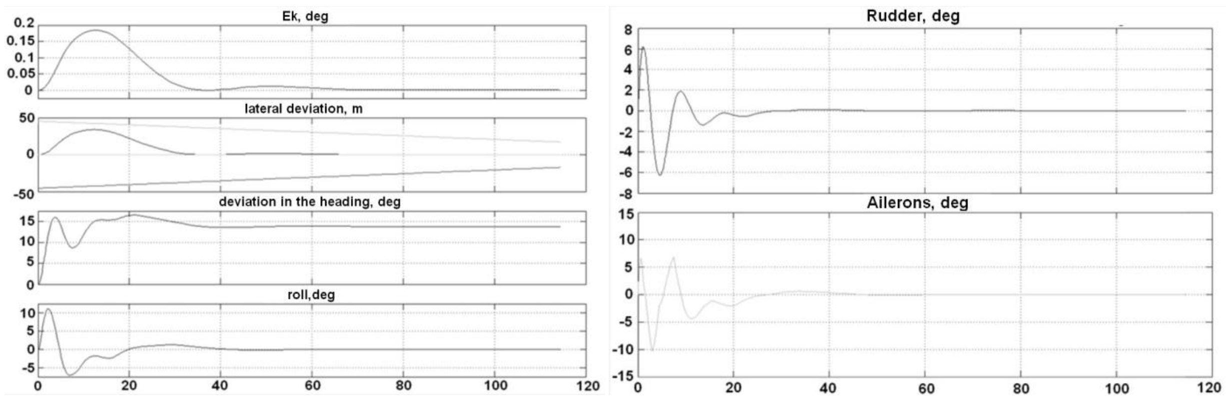


Fig. 2. Research of the AFCS operation in "Approach mode" (with wind disturbance Wz = - 15m / s).

Figure 3-6 presents a brief analysis of the stability of lateral movement. It shows that the aircraft has a itinerary and transversal stability with small value of damping decrement.

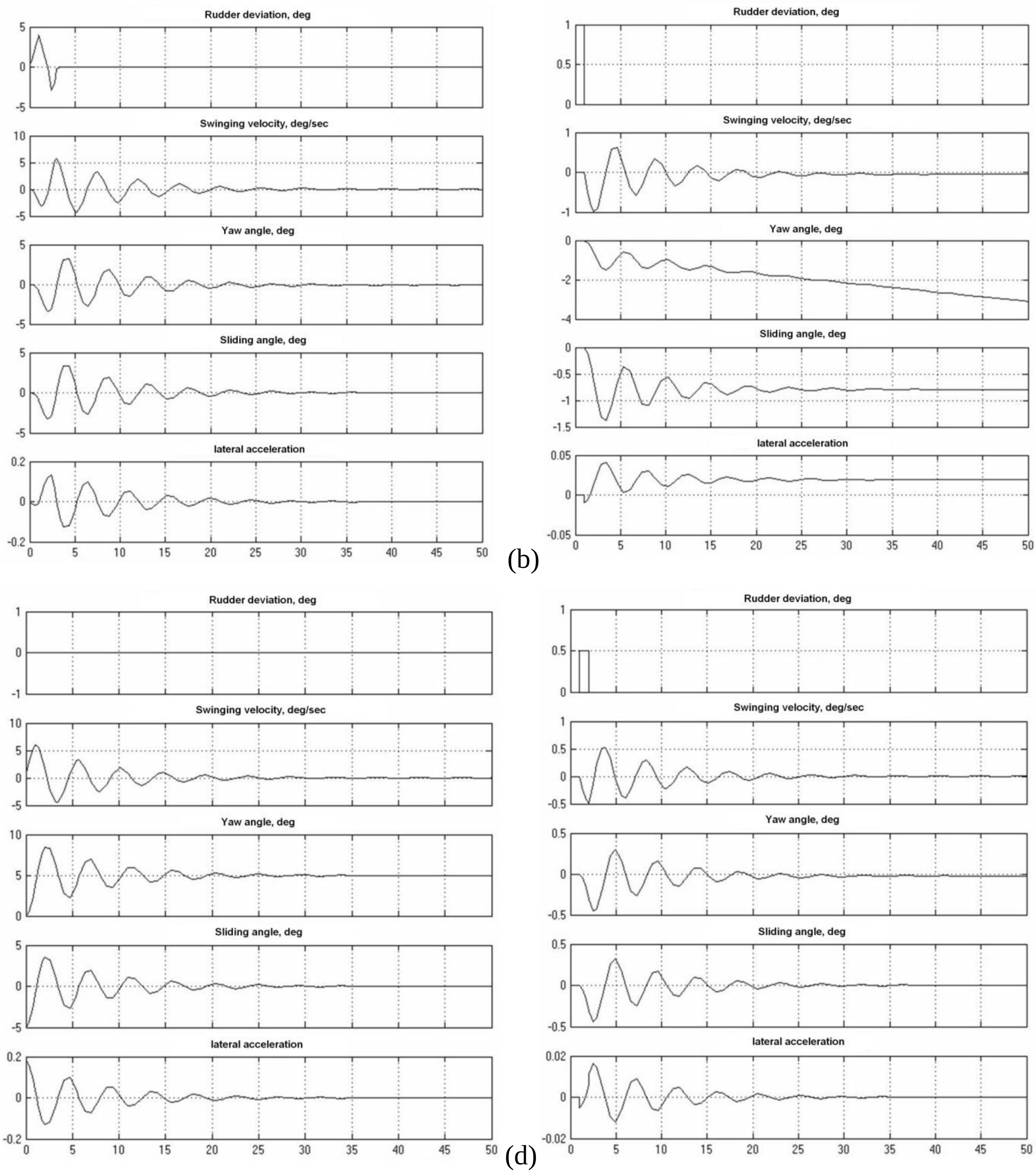


Fig. 3. Step-function gust response PSIwind = 5 deg at Vnp =430km/h, H = 11600m; m = 36000kg; alfao = 5 deg (a), rudder impulse response (b), double rudder impulse response (c), Step-function rudder deviation response

For a visual representation of simulation results FLIGHTGEAR as a tool for visualization is proposed (Fig. 4, 5) [4]. Choice of this flight simulator due to the possibility of free access to its source, and therefore more features unlike its commercial counterparts. In addition Matlab allows to combine Matlab model created in Simulink with virtual reality models of FLIGHTGEAR, created using 3D editors - VRML (Virtual Reality Markup Language) 3ds Max, AC3D, blender and more.

Conclusions

In many cases not possible to assess the qualitative properties of control systems by direct method - full-scale test- through objectively existing limited conditions of their test operation. This and the relative duration, the necessity to spend real resources of funds and engineering tools, significant economic costs of full-scale tests forced to seek more efficient ways of organizational management for the control systems performance assess. A number of quite obvious advantages of model-based approach can promote it to first place among the methods of safety critical systems planning and research. However, it should be given and the main difficulties of this method - the results require a specific reliability qualification and comparison with the results of full-scale tests.

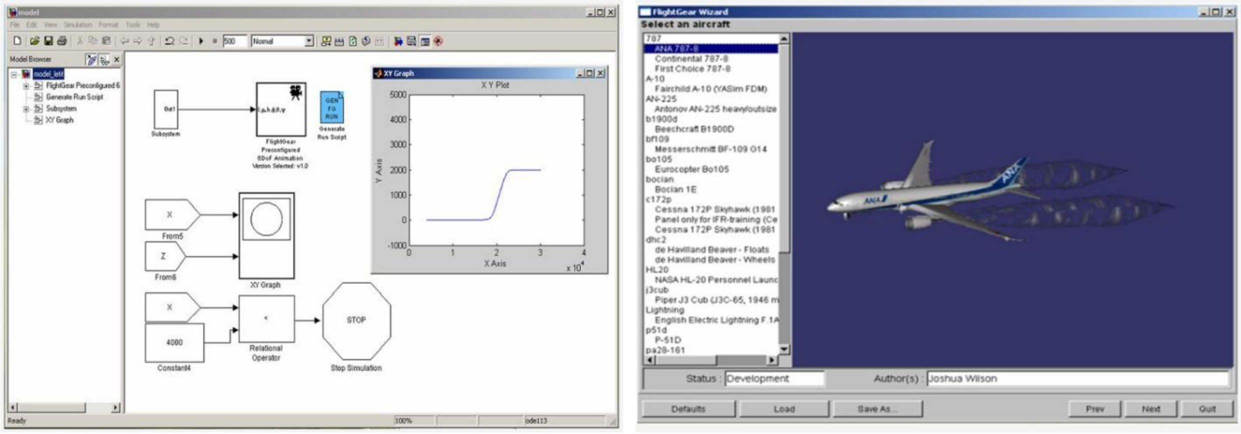


Fig. 4. Aerospace Blockset blocks providing interface to FlightGear.

Fig. 5. FlightGear visualization.

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