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COMPUTING THE STATICS AND DYNAMICS OF AIRPLANE AILERON POSITION CONTROL USING THE NUT LANGUAGE

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Abstract. This paper discusses a program package based on the object-oriented programming language NUT and its environment. It is used for computing static and stationary characteristics as well as transient responses of the electro-hydraulic position control system (EHPCS) of an airplane aileron. The program package contains a knowledge base in the form of classes of functional elements (FE), subsystems, parameters, disturbances, computing procedures, and graphical output. The multi-port models of FEs and subsystems were used. FE mathematical models were composed by oriented graphs. A two-level method was used for calculating the characteristics. The NUT system ensures an automatic synthesis of computing programs. The computing procedure was implemented in a Sun SPARCstation.

Key words: computer modelling, airplane aileron, electro-hydraulic position control system, object-oriented programming language NUT, multi-port model, oriented graph, two-level computing method, automatic computing program synthesis.

NOMENCLATURE

*A*1, *A*2	Active areas of a piston
d	Servo valve diameter
ea	Torsion elasticity of an aileron
ec	Torsion elasticity of a crank
er	Elasticity of a piston rod
fi	Position angle of an aileron, considering the deformations and backlash
*fi*0	Minimal cinematic position angle of an aileron
fibl	Rotation angle of an aileron, caused by the crank mechanism backlash
fic	Position angle of a crank, considering the deformations

fie	Anchor angle of an electromechanical transducer at the neutral position
fik	Cinematic position angle of a crank
fim	Maximal cinematic position angle of an aileron
Ffpi	Friction force of a piston sealing
Ffr	Friction force of a piston rod sealing
Fhd	Hydrodynamic force of a liquid jet to a flapper
Fpir	Force from a piston to a piston rod
Fr	Output force of piston rod
*Fz*1...*Fz*4	Hydrodynamic forces of jets of servo valve slits
*Fz*13, *Fz*24	Summarized hydrodynamic forces of jets of servo valve slit pairs
Fz	Total hydrodynamic force of jets of servo valve four slits
*GQ*5	Conductivity of an orifice in a piston
h	Flapper shift from central position; damping factor
Ie	Input current of an electromechanical transducer
Iin	Control input current
I	Polar moment of inertia of an aileron and a crank mechanism
kFr, *kvr*, *kxr*	Transmission factors of a crank mechanism
k	Coefficient of servo valve slit length
l	Piston stroke distance
mpi	Mass of a piston with a rod
om	Angular velocity of an aileron, considering deformations and backlash
omc	Angular velocity of a crank, considering deformations
ome	Angular velocity of an anchor of an electromechanical transducer
*p*1...*p*10	Pressures of a flapper-and-nozzle valve (Fig. 5)
*p*1, *p*2	Pressures before and after a servo valve slit (Fig. 8)
*p*1*ch*, *p*2*ch*	Pressures in the left and right chambers of a cylinder
pp	Feeding pressure of a hydraulic amplifier
pt	Exit pressure of a hydraulic amplifier
*Q*1...*Q*8	Volumetric flow rates in a flapper-and-nozzle valve (Fig. 5)
*Q*1...*Q*4	Volumetric flow rates through servo valve slits
*Q*1*ch*, *Q*2*ch*	Volumetric flow rates at the left and right end of a cylinder
*Q*1*nf*, *Q*8*nf*	Volumetric flow rates at the entering and leaving of a flapper-and-nozzle valve (Fig. 16)
*Q*1*pf*, *Q*2*pf*	Volumetric flow rates at the left and right end of a piston
*Q*5	Volumetric flow rate through a piston orifice (Fig. 12)
Qfl	Volumetric flow rate depending on the cylinder flange shift
Qli	Volumetric flow rate depending on the cylinder lid shift
Qp	Feeding volumetric flow rate of a hydraulic amplifier
Qt	Exit volumetric flow rate of a hydraulic amplifier

S	Laplace operator
T	Shaft input or output torque of an aileron
Ta	Total shaft torque of an aileron, except inertia and damping torque
Tf	Friction torque of the crank mechanism reduced on the aileron shaft
Tm	Dead weight torque of an aileron
Tp	Aerodynamic position torque of an aileron
TFr	Crank torque caused by the piston rod force
Ue	Input voltage of an electromechanical transducer
Uin	Control input voltage
vpi	Piston velocity
vr	Piston rod velocity
xpi	Piston displacement
xr	Piston rod displacement
z	Servo valve shift from the starting position in relation to the body
*z*1...*z*4	Initial values of servo valve slit width (overlaps signed "-")
zsp	Servo valve shift in relation to the body from the position, where $vr = 0$, $Fr = 0$, $Ffpi = 0$, $Ffr = 0$
μ	Discharge coefficient
ρ	Liquid density

Notation supplements for variables:

S	static
St	steady-state motion
01	on the previous time step

1. INTRODUCTION

The main type of position control drive of an airplane aileron is the electro-hydraulic servo drive. Because of extremely high requirements set for the static, steady-state, and dynamic characteristics of such drives, a detailed computer modelling is reasonable. This task involves a multitude of nonlinear and changing structured relations with many loops. The paper presents a modelling method and an effective application of computer facilities. The computer modelling of an electro-hydraulic position control system of an airplane consists of the following phases:

- functional element (FE) and subsystem selection on the circuit drawing;
- FE and subsystem multi-port model selection;
- block scheme development of multi-port models, as separate for statics, the steady-state motion, and the transient response;
- giving the parameters, the input variables, and disturbances, and indicating the output variables;
- liquid selection;
- automatic program synthesis;
- computation and organization of the graphic output.

2. AN ELECTRO-HYDRAULIC POSITION CONTROL SYSTEM OF AN AILERON

The electro-hydraulic position control system (EHPCS) of an aileron converts signals transmitted by the (auto)pilot into the position angle of an aileron. The control system (Fig. 1) consists of a driving device, i.e. a joystick or autopilot, a flight control computer, an electro-hydraulic amplifier, a hydraulic cylinder with position feedback from the piston rod and the crank mechanism with a rotatory aileron.

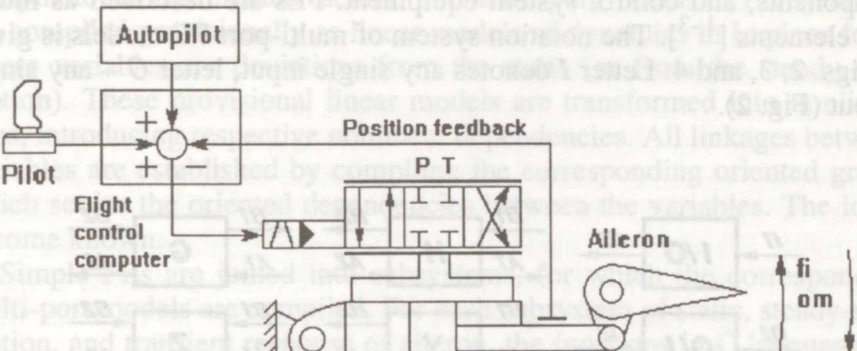

Fig. 1. Fly-by-wire type aileron position control system.

Such a system has the following external variables: control input voltage from the (auto)pilot ***Uin*** and the corresponding control input current ***Iin***; aileron position angle ***fi*** and angular velocity ***om***, and shaft torque *T*; feeding and exit pressures ***pp***, ***pt*** and feeding and exit volumetric flow rates ***Qp***, ***Qt*** of a hydraulic amplifier. Processes in EHPCS of an aileron, their input and output variables are presented in Table 1.

Table 1

Processes in EHPCS of an aileron

Process nomination	Input variables	Output variables
Static	*fiS, UinS, ppS, ptS*	*TS, IinS, QpS, QtS*
Steady-state	*omSt, UinSt, ppSt, ptSt*	*TSt, IinSt, QpSt, QtSt*
Transient response of aileron position angle	*T, Uin, pp, pt*	*fi, Iin, Qp, Qt*
Transient response of aileron angle velocity	*T, Uin, pp, pt*	*om, Iin, Qp, Qt*
Transient response of aileron torque	*fi* or *om, Uin, pp, pt*	*T, Iin, Qp, Qt*

Table 1 shows that static and steady-state motions exist only for aileron torque as an output variable. Frequency responses cannot be calculated instantly because of switching between mathematical models of overlapping servo valve slit resistors.

3. PRINCIPLES OF MATHEMATICAL MODEL COMPILATION

The mathematical models used in the program package are based on the following principles. According to the functional or assembling scheme, the hydraulic system is divided into FEs. Such FEs can be simple or complicated links, tubes, hydraulic pumps and motors, various hydraulic components, and control system equipment. FEs are described as multi-port elements [1–3]. The notation system of multi-port FE models is given in Figs. 2, 3, and 4. Letter ***I*** denotes any single input, letter ***O*** – any single output (Fig. 2).

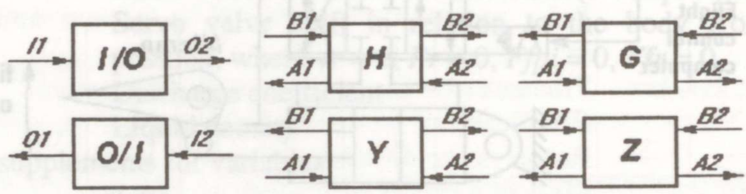

Fig. 2. Notation of two- and four-port FE models depending on the input and output variables.

Left ports are denoted by odd numbers and right ports – by even numbers. Letter ***A*** denotes potential variables (for instance, pressure, force, torque, and voltage) and letter ***B*** – flow rate variables (for instance, volumetric flow rate, displacement, velocity, acceleration, angle, angular velocity, angular acceleration, and current) which occur in pairs. Letters ***C*** and ***D*** denote the pairs of variables (Fig. 3). As in electrical engineering, depending on the existence of input and output variables, four-port models are denoted by the letters ***H***, ***G***, ***Y***, and ***Z*** (Fig. 2). If a multi-port model has a four-port part, it is denoted by the corresponding sign (Figs. 3 and 4). The rest of the ports are denoted by the corresponding letters, while the left and right ports are separated by a sloping line.

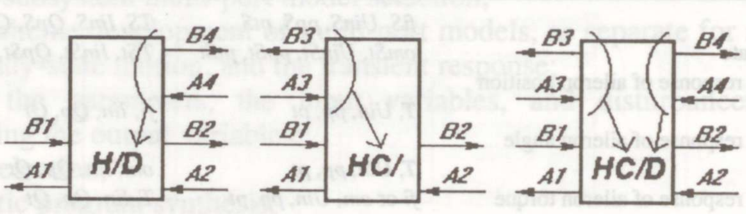

Fig. 3. Notation of six- and eight-port FE models according to the scheme of variable pairs.

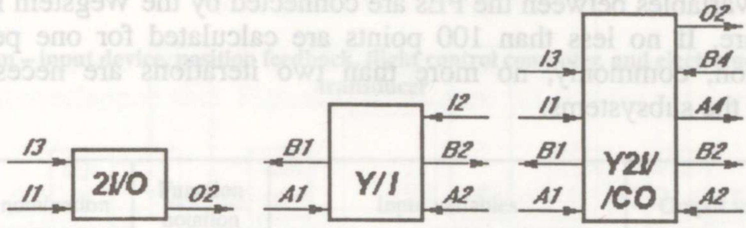

Fig. 4. Notation of singular input-output of the multi-port FEs.

Every FE may have several mathematical models differing in compilation and estimated factors. The multi-port models of FE dynamics are compiled provisionally as linear models of dynamics in Laplace form, where variables are deviations from the static (or from the steady-state motion). These provisional linear models are transformed into nonlinear ones, introducing respective nonlinear dependencies. All linkages between variables are established by compiling the corresponding oriented graph, which settles the oriented dependencies between the variables. The loops become known.

Simple FEs are joined into subsystems, for which the corresponding multi-port models are compiled. For each subsystem of static, steady-state motion, and transient response of aileron, the functions in **C** language are compiled. The programs are very detailed and take into account all essential nonlinear and changeable dependencies.

To solve the task, first, using the multi-port FEs, a block scheme is built [1, 3], based on the following:

• given input and output variables;
• table of multi-port models of the FEs used;
• recommendations for multi-port model forms selection;
• possible variants of connecting multi-port models;
• block schemes of typical hydraulic systems.

4. CALCULATION

To calculate the characteristics of hydraulic systems, the two-level method was used. For the first, FE level, characteristics of isolated FEs were calculated. Any method of calculation may be used. The transient responses on the FE level for numerical non-stiff continuous functions were calculated by the standard Runge–Kutta method. Numerical stiffness problems may be avoided using mathematical models with the differentiation procedure. Then, to compute FE transient responses, the Newton's iteration method was used. Discontinuities should be transferred to continuous functions in short time intervals. In the case of loop dependencies, iteration procedures were widely used.

The variables between the FEs are connected by the Wegstein iteration procedure. If no less than 100 points are calculated for one period of oscillation, commonly, no more than two iterations are necessary to connect the subsystems.

5. THE NUT LANGUAGE AND ENVIRONMENT

The NUT language was developed at the Institute of Cybernetics of the Estonian Academy of Sciences and completed in cooperation with the Department of Telecommunications and Computer Systems of Stockholm Royal Institute of Technology [4–6].

NUT is a high-level object-oriented programming language with automatic program synthesis tools, where the problem settings or computational models are specified as classes. A class can be user-defined or predefined. An explicit description of a class is used for specifying components, methods, initial values, and some other properties of the objects of that class. The relations in a class are methods, methods as constraints, subtasks, and parameters. In the NUT language, the classes are described in special windows. The objects' reference to classes contains additionally the values of parameters, the values of the constant input variables, and other properties.

A program in the NUT language is a sequence of statements for manipulating objects. The problem to be solved may be specified in the form of a scheme composed of computational elements. The current states (next states, initial states, and final states) of the computational elements will be collected into global current states of the process by aliasing. Such a model base of knowledge enables us any calculations by inquiry. In the NUT language, the task description changes into the description of task conditions.

6. SUBSYSTEMS OF EHPCS OF AN AILERON

6.1. Input device, position feedback, flight control computer, and electromechanical transducer

The main input of the EHPCS of an aileron is the control input voltage ***Uin***, given by pilot's joystick or autopilot. The flight control computer calculates the input voltage of an electromechanical transducer on the basis of control input voltage, position feedback voltage, and damper voltage. Process nominations, function notations, and input/output variables are shown in Table 2.

Table 2

Subsystem – input device, position feedback, flight control computer, and electromechanical transducer

Process nomination	Function notation	Input variables	Output variables
Static	**fbetS**	*UinS, xrS, zspS, FhdS*	*hS, IinS, fieS*
Steady-state	**fbetSt**	*UinSt, vrSt, zspSt, FhdSt*	*hSt, IinSt, fieSt*
Transient	**fbetDyn**	*Uin, xr, vr, zsp, Fhd, fie*01*, ome*01	*h, Iin, fie, ome*

6. 2. Nozzle-and-flapper valve and servo valve

A functional scheme of a nozzle-and-flapper valve with an electromechanical transducer and a servo valve is shown in Fig. 5. Based on the scheme, a block scheme of multi-port FEs is compiled (Fig. 6). By replacing every block with the corresponding oriented graph, we obtain an oriented graph of the nozzle-and-flapper valve (Fig. 7). Table 3 illustrates process nominations, function notations, and input/output variables of this subsystem.

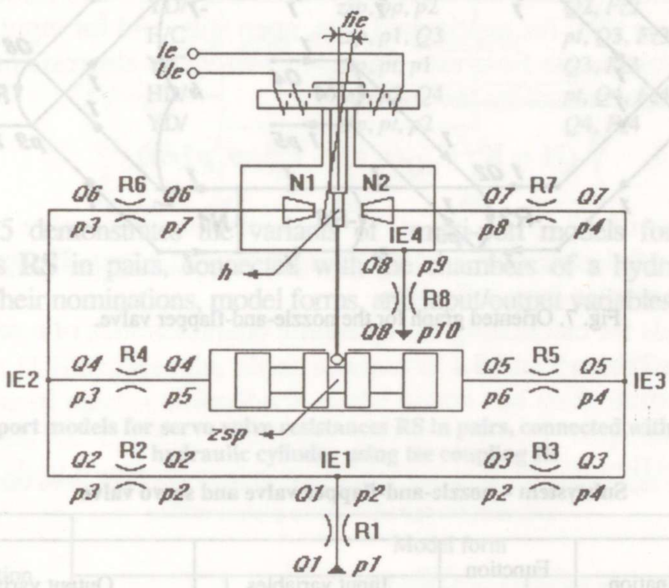

Fig. 5. Functional scheme of two cascade electro-hydraulic amplifier, where R1–R8 – hydraulic resistances, N1, N2 – nozzle-and-flapper valve resistances, and IE1–IE4 – tee couplings.

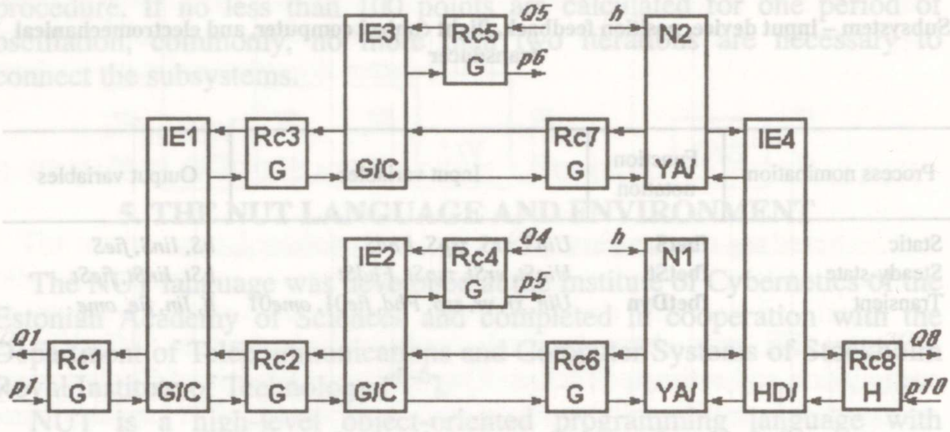

Fig. 6. Block scheme of multi-port elements for the nozzle-and-flapper valve.

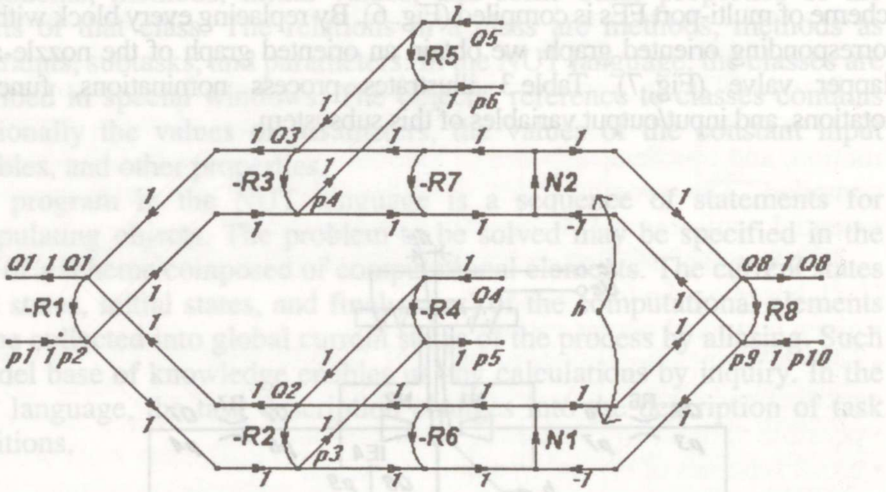

Fig. 7. Oriented graph for the nozzle-and-flapper valve.

Table 3

Subsystem – nozzle-and-flapper valve and servo valve

Process nomination	Function notation	Input variables	Output variables
Static	**nfspS**	*hS*, *p*1*S*, *p*10*S*, *FzS*	*zspS*, *Q*1*nfS*, *Q*8*nfS*, *FhdS*
Steady-state	**nfspSt**	*hSt*, *p*1*St*, *p*10*St*, *FzSt*	*zspSt*, *Q*1*nfSt*, *Q*8*nfSt*, *FhdSt*
Transient	**nfspDyn**	*h*, *p*1, *p*10, *Fz*	*zsp*, *Q*1*nf*, *Q*8*nf*, *Fhd*

6. 3. Servo valve resistors

The servo valve of an electro-hydraulic amplifier has four middle-position overlapped slits. Figure 8 shows each slit scheme separately.

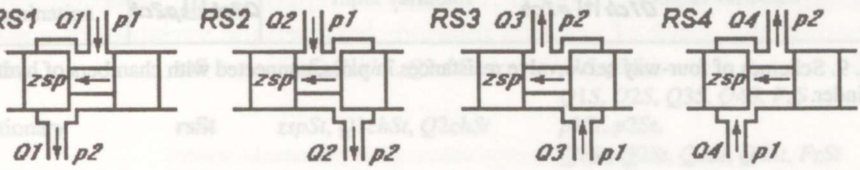

Fig. 8. Schemes of four-way servo valve slits.

Variants of multi-port models for servo valve resistances **RS** are illustrated in Table 4.

Table 4

The models for servo valve resistances RS

Nomination	Model form	Input variables	Output variables
RS1	G/C	*zsp*, *pp*, *Q*1	*p*1, *Q*1, *Fz*1
	Y/C	*zsp*, *pp*, *p*1	*Q*1, *Fz*1
RS2	GD/	*zsp*, *pp*, *Q*2	*p*2, *Q*2, *Fz*2
	YD/	*zsp*, *pp*, *p*2	*Q*2, *Fz*2
RS3	H/C	*zsp*, *p*1, *Q*3	*pt*, *Q*3, *Fz*3
	Y/C	*zsp*, *pt*, *p*1	*Q*3, *Fz*3
RS4	HD/	*zsp*, *p*2, *Q*4	*pt*, *Q*4, *Fz*4
	YD/	*zsp*, *pt*, *p*2	*Q*4, *Fz*4

Table 5 demonstrates the variants of multi-port models for servo valve resistances **RS** in pairs, connected with the chambers of a hydraulic cylinder (Fig. 9). Their nominations, model forms, and input/output variables are shown in Table 6.

Table 5

The multi-port models for servo valve resistances RS in pairs, connected with chambers of a hydraulic cylinder using tee coupling IE

Nomination	Model form				
	RS1	RS2	RS3	RS4	IE
RS13PQ	G/C		YC/		G/C
RS13QQ	Y/C		H/C		Z/D
RS24PQ	Y/C		Y/C		H/C
RS13QP		GD/		YD/	ZC/
RS24QP		YD/		HD/	HD/
RS24QQ		YD/		YD/	GD/

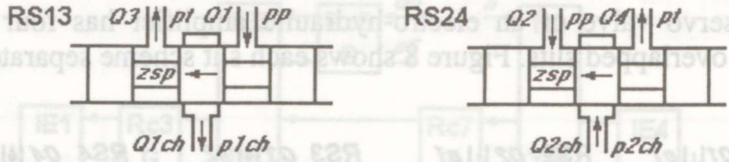

Fig. 9. Schemes of four-way servo valve resistances in pairs, connected with chambers of hydraulic cylinder.

Table 6

The multi-port models for servo valve resistances RS in pairs, connected with chambers of a hydraulic cylinder

Nomination	Model form	Input variable	Output variable
RS13PQ, RS13QP	G/DC	*zsp, pp, Q1ch, pt*	*p1ch, Q1, Q3, Fz13*
RS13QQ	Y/DC	*zsp, pp, p1ch, pt*	*Q1ch, Q1, Q3, Fz13*
RS24PQ, RS24QP	HCD/	*zsp, pt, Q2ch, pp*	*p2ch, Q2, Q4, Fz24*
RS24QQ	YCD/	*zsp, pp, p2ch, pt*	*Q2ch, Q2, Q4, Fz24*

Mathematical models are used for volumetric flow rates through servo valve throttling slits: for overlapped slits, open slits, and for input flow rate saturation. Volumetric flow rate through servo valve slit resistor **RS1** for open slits is determined by the expression:

$$Q1 = \mathbf{K} \cdot \mathbf{F_{zQ}}(z, z1) \cdot \mathbf{F_p}(pp, p1ch),$$

where $\mathbf{K} = \mu\pi \mathbf{dk}\sqrt{2/\rho}$; $\mathbf{F_{zQ}}(z, z1)$ – accounts for servo valve position z, overlap $z1$, radial clearance, and rounding radius of edges, $\mathbf{F_p}(pp, p1ch)$ – determines pressure drop influence.

The models for calculating the hydraulic characteristics of a servo valve are shown in Tables 7 and 8.

Table 7

Models for calculating the static and steady-state characteristics of servo valve with a hydraulic cylinder and a piston orifice

Process nomination	Function notation	Input variables	Output variables
Static	**rsvFS**	*vrS* = 0, *FrS* = 0, *FfpiS* = 0, *FfrS* = 0	*zspS, p1S, p2S, Q1S, Q2S, Q3S, Q4S*
Steady-state	**rsvFSt**	*vrSt, FrSt, FfiSt, FfrSt*	*zspSt, p1St, p2St, Q1St, Q2St, Q3St, Q4St*

Table 8

Models of servo valve for calculating the complete control system

Process nomination	Function notation	Input variables	Output variables
Static	rsS	*zspS, Q1chS, Q2chS*	*p1S, p2S, Q1S, Q2S, Q3S, Q4S, FzS*
Stationary	rsSt	*zspSt, Q1chSt, Q2chSt*	*p1St, p2St, Q1St, Q2St, Q3St, Q4St, FzSt*
Transient	rsDyn	*zsp, p1ch, p2ch, Q101, Q201, Q301, Q401*	*Q1ch, Q2ch, Q1, Q2, Q3, Q4, Fz*

6.4. Cylinder without a piston, a piston rod, a flow through the piston, sealing friction, and deformation

A scheme of a cylinder with a piston, a rod, and a flow through the piston is shown in Fig. 10. The subsystem consists of the following FEs: fixing **FI**, fixing backlash **BL**, flange **FL**, bush **BU**, lid **LI** (forms the cylinder without piston **CY**), piston **PI**, rod **R**, and flow through piston **Q5**.

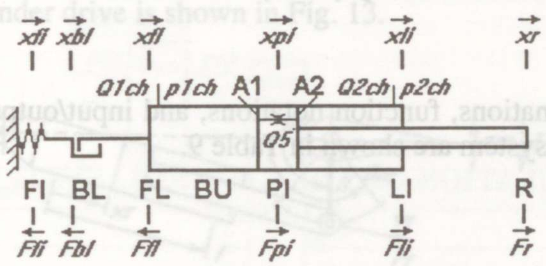

Fig. 10. Scheme of hydraulic cylinder CY with piston PI, rod R, and a flow through piston Q5.

Figure 11 illustrates the block scheme of a cylinder without piston **CY**. In the case of electrical feedback of the piston rod shift, deformations and dispositions of cylinder elements affect transient response only. The corresponding transient response function is denoted by **cylDyn**.

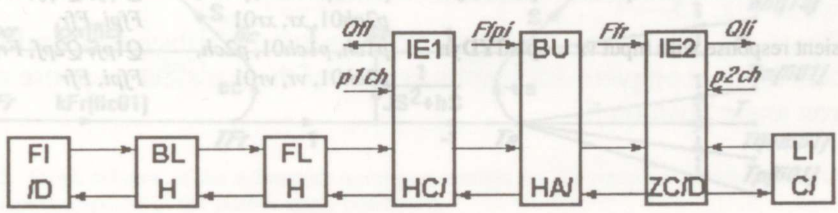

Fig. 11. Block scheme of multi-port elements of a cylinder without piston CY.

Piston **PI** with rod **R** and a flow through piston **Q5** are regarded as separate subsystem **PIS**. Here, an eight-port model in the form of **Y/C20** is used. The input variables at the piston rod may be shift *xr* or velocity *vr*. The flow through piston **Q5** is presented as the **Y** form four-port model. O-ring rubber sealings are used for sealing and their friction forces are calculated using the models based on experimental data. Figure 12 illustrates the graph of oriented relations between the variables of a piston with a rod, a flow through the piston and the friction forces.

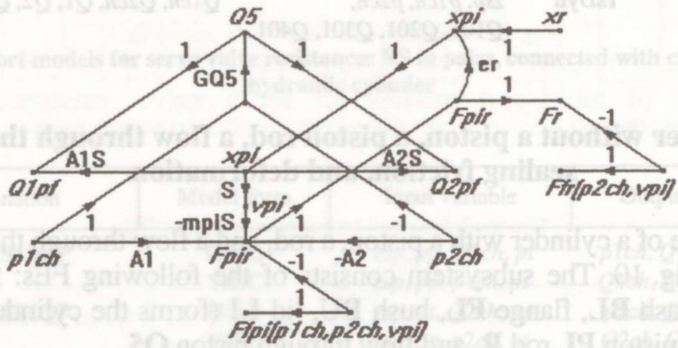

Fig. 12. Eight-port form **Y/C20** oriented graph of a piston with a rod, a flow through the piston, and the friction forces.

Process nominations, function notations, and input/output variables of the observed subsystem are shown in Table 9.

Table 9

Subsystem – a piston with a rod, a flow through the piston, sealing friction and deformation

Process nomination	Function notation	Input variables	Output variables
Static	**piscYS**	*p1chS, p2chS, xrS*	*FrS, FfpiS, FfrS*
Steady-state	**pisdYSt**	*p1chSt, p2chSt, xrSt*	*Q1pfSt, Q2pfSt, FrSt, FfpiSt, FfrSt*
Transient response with input *xr*	**piscYDyn**	*p1ch, p1ch01, p2ch, p2ch01, xr, xr01*	*Q1pf, Q2pf, Fr, Ffpi, Ffr*
Transient response with input *vr*	**pisdYDyn**	*p1ch, p1ch01, p2ch, p2ch01, vr, vr01*	*Q1pf, Q2pf, Fr, Ffpi, Ffr*

6.5. Volume elastances of hydraulic cylinder chambers

Volume elastances of hydraulic cylinder chambers affect dynamic processes only. In this case, volume elastances of hydraulic cylinder chambers are presented by four-port **Z** form models. The corresponding process nominations, function notations, and input/output variables are shown in Table 10.

Table 10

Volume elastances of hydraulic cylinder chambers

Process nomination	Function notation	Input variables	Output variables
Transient response, left chamber	**velZDyn**	*Q*1, *Qfl*, *Q*1*pf*, *xr*, *p*1*ch*01	*p*1*ch*
Transient response, right chamber	**verZDyn**	*Q*2, *Qli*, *Q*2*pf*, *xr*, *p*2*ch*01	*p*2*ch*

6.6. Crank mechanism with an aileron

A scheme of a crank mechanism to control the position of an aileron by a hydraulic cylinder drive is shown in Fig. 13.

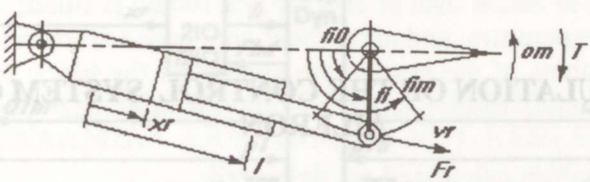

Fig. 13. Scheme of a crank mechanism for the control of the position of an aileron.

Figure 14 illustrates an oriented graph of relations between dynamic variables of a crank mechanism with an aileron, form **YO/O**.

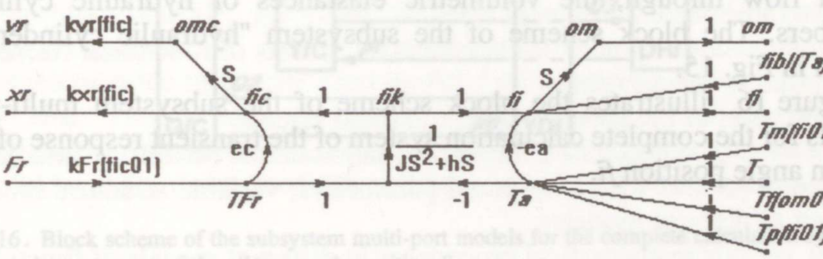

Fig. 14. Oriented graph of a crank mechanism with an aileron, form YO/O.

Cinematic relations kFr(*fic*01), kxr(*fic*), and kvr(*fic*) and variables *Tp*(*fi*01),*Tf*(*om*01), and *fibl*(*Ta*) depend on *fic*01, *fic*, *fi*01, *om*01, and *Ta*, correspondingly (Fig. 14). Process nominations, function notations, and input/output variables of a crank mechanism with an aileron are shown in Table 11.

Table 11

Crank mechanism with an aileron

Process nomination	Function notation	Input variables	Output variables
Static	**cmGS**	*fiS, FrS*	*TS, xrS, fikS*
Steady-state	**cmGSt**	*omSt, FrS*	*TSt, vrSt, fikSt*
Transient response of aileron position angle	**cmYDynfi**	*T, Fr, fi*01, *fic*01, *om*01	*fi, fic, xr, vr, om*
Transient response of aileron angular velocity	**cmYDynom**	*T, Fr, fi*01, *fic*01, *om*01	*om, fic, xr, vr*
Transient response of aileron shaft torque by input *fi*	**cmYZDynT**	*fi, Fr, fic*01, *omc*01	*T, xr, vr, fic, omc*
Transient response of aileron shaft torque by input *om*	**cmYZDynT**	*om, Fr, om*01, *fi*01, *fic*01, *omc*01	*T, xr, vr, fi, fic, omc*

7. CALCULATION OF THE CONTROL SYSTEM OF AN AILERON

The calculation scheme of the complete control system of the aileron position is compiled of the subsystems discussed above. To describe the task, block schemes are built. Five block schemes are required as shown in Table 1. Let us look how a block scheme for the calculation of the transient response of aileron position angle is developed. First, we build a block scheme for the subsystem "hydraulic cylinder", other partial subsystems included are: a cylinder without a piston, a piston with a rod and a flow through, the volumetric elastances of hydraulic cylinder chambers. The block scheme of the subsystem "hydraulic cylinder" is shown in Fig. 15.

Figure 16 illustrates the block scheme of the subsystem multi-port models for the complete calculation system of the transient response of the aileron angle position *fi*.

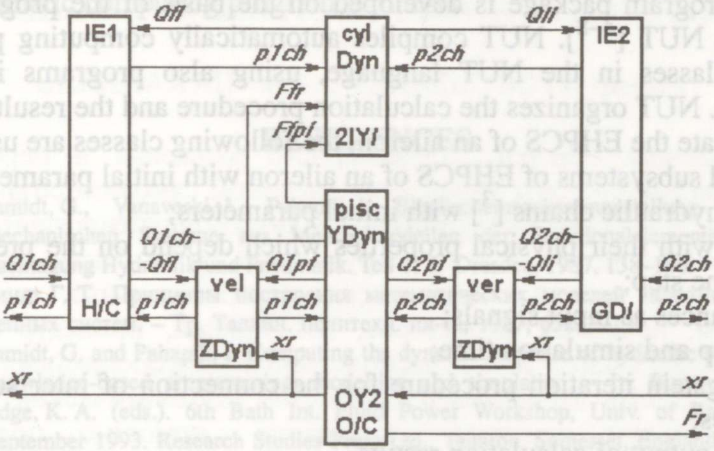

Fig. 15. Block scheme of the subsystem "hydraulic cylinder" **chDyn** form **ZO/C**, where the models: **cylDyn** – cylinder without a piston, **piscYDyn** – piston with a rod and a flow through, **vel** and **ver** – volumetric elastances of hydraulic cylinder chambers, **IE1** and **IE2** – tee couplings.

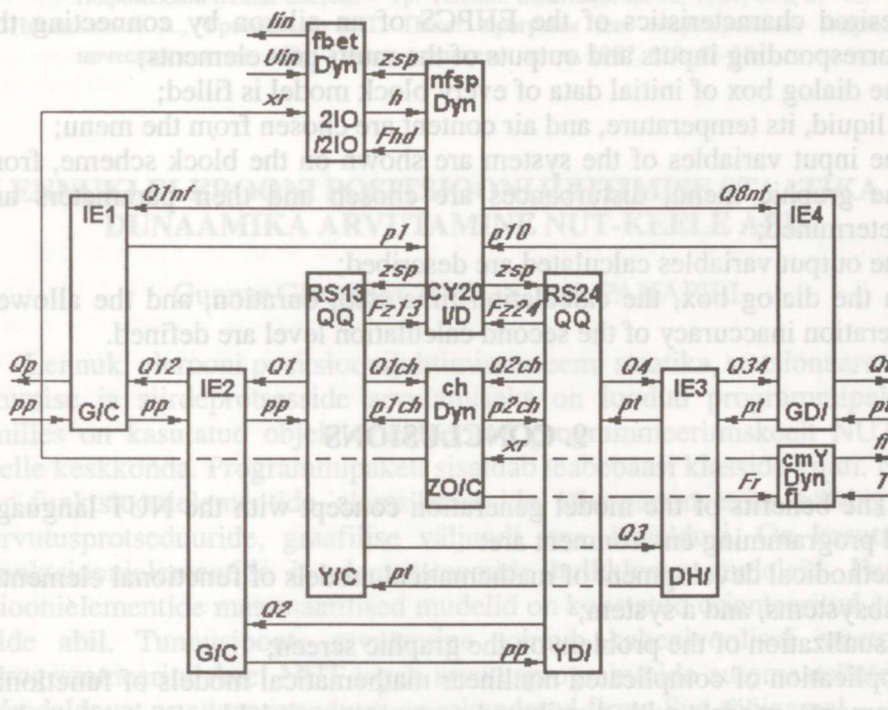

Fig. 16. Block scheme of the subsystem multi-port models for the complete calculation system of the transient response of the aileron angle position *fi*.

8. PROGRAM PACKAGE

The program package is developed on the basis of the programming language NUT [4–8]. NUT compiles automatically computing programs out of classes in the NUT language, using also programs in the C language. NUT organizes the calculation procedure and the results output. To calculate the EHPCS of an aileron, the following classes are used:

- FEs and subsystems of EHPCS of an aileron with initial parameters;
- FEs of hydraulic chains [3] with initial parameters;
- liquids with their physical properties which depend on the pressure on each time step;
- disturbances as input signals;
- time step and simulation time;
- the Wegstein iteration procedure for the connection of inter subsystem variables;
- graphic output of calculation results.

The calculation task of characteristics of the EHPCS of an aileron is described as follows:

- based on the principal scheme, the FEs and subsystems are chosen and notated;
- from the graphic menu, suitable variants of blocks of multi-port elements of FEs and subsystems are chosen;
- a block scheme of multi-port elements is compiled to calculate the desired characteristics of the EHPCS of an aileron by connecting the corresponding inputs and outputs of the multi-port elements;
- the dialog box of initial data of every block model is filled;
- a liquid, its temperature, and air content are chosen from the menu;
- the input variables of the system are shown on the block scheme, from the graphic menu, disturbances are chosen and their parameters are determined;
- the output variables calculated are described;
- in the dialog box, the calculation time step, duration, and the allowed iteration inaccuracy of the second calculation level are defined.

9. CONCLUSIONS

The benefits of the model generation concept with the NUT language and programming environment are:

- methodical development of mathematical models of functional elements, subsystems, and a system;
- visualization of the problem on the graphic screen;
- application of complicated nonlinear mathematical models of functional elements, models with distributed parameters, variable structure models as well as discrete models;
- use of various mathematical procedures in different models of functional elements and subsystems;

• possibility of calculating any kind of characteristics for any kind of variables at all operating points;
• an automatic computing program synthesis.

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LENNUKI ELEROONI POSITSIOONIJUHTIMISE STAATIKA JA DÜNAAMIKA ARVUTAMINE NUT-KEELE ABIL

Gunnar GROSSSCHMIDT, Jaak PAHAPILL

Lennuki elerooni positsioonijuhtimissüsteemi staatika, statsionaarse liikumise ja siirdeprotsesside arvutamiseks on loodud programmipakett, milles on kasutatud objekt-orienteeritud programmeerimiskeelt NUT ja selle keskkonda. Programmipakett sisaldab teabebaasi klasside kujul. Neis on funktsioonielementide, alamsüsteemide, lähteparameetrite, häiringute, arvutusprotseduuride, graafilise väljundi jms. kirjeldusi. On kasutatud funktsioonielementide ja alamsüsteemide hulkklemm-mudeleid. Funktsioonielementide matemaatilised mudelid on koostatud orienteeritud graafide abil. Tunnusjoonte arvutamine toimub kahenivoolisel meetodil. Programmeerimiskeel NUT tagab arvutusprogrammide automaatsünteesi. Vaadeldavat arvutusprotseduuri on rakendatud firma Sun tööjaamal.

РАСЧЕТ НА ЭВМ СТАТИКИ И ДИНАМИКИ СИСТЕМЫ УПРАВЛЕНИЯ ПОЗИЦИЕЙ ЭЛЕРОНА САМОЛЕТА С ПРИМЕНЕНИЕМ ЯЗЫКА ПРОГРАММИРОВАНИЯ NUT

Гуннар ГРОССШМИДТ , Яак ПАХАПИЛЛЬ

Для расчета статики, стационарного движения и переходных характеристик системы управления элероном самолета создан пакет программ, в котором использован объектно-ориентированный язык программирования NUT и его окружающая среда. Пакет программ содержит базу знаний в виде классов функциональных элементов, подсистем, исходных параметров, возмущений, процедур расчета, графического вывода и т. д. Используются многополюсные модели функциональных элементов и подсистем. Математические модели функциональных элементов составляются с помощью построения ориентированных графов. Расчет характеристик осуществляется двухуровневым методом. Язык программирования NUT обеспечивает автоматический синтез расчетных программ. Рассмотренная расчетная процедура применялась на рабочей станции фирмы "Sun".