The Ministry of Education and Science of Russia
Samara State Aerospace University
(National Reserch University)

Examples of performance of laboratory works on the subject "Reliability and Operation of Airplanes"

Electronic Methodic Instructions

SAMARA
2011

The development programme for 2009-2018 of Samara State Aerospace University named after Academician S. P. Korolyov (National Research University)

Compiler and translator: Mrykin Sergey V.

Mrykin, S. V. Examples of performance of laboratory works on the subject “Reliability and Operation of Airplanes”. = Примеры выполнения лабораторных работ по дисциплине “Надёжность и эксплуатация самолётов”. [Electronic resource]: Electronic Methodic Instructions/ S. V. Mrykin; The Ministry of Education and Science of Russia, Samara State Aerospace University. — Electronic text and graphic data (264KB). — Samara, 2011. — 1 CD-ROM.

Examples are intended for tutors and used for training masters on the subject “Reliability and operation of airplanes”.

The examples is a part of postgraduate programmes which were developed based on using new educational technologies, resources and distance-learning systems for the Masters programme “Designing, construction and CALS-technologies in aircraft engineering” for educational direction 160100.68 “Aeronautical Engineering”.

Prepared by the Department of Aeronautical Engineering SSAU.

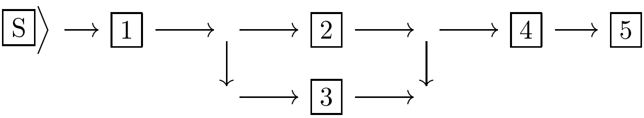
1 Method of block diagrams

The task on a source is given [1, variant 1].

1.1 Task formulation

1. For certain block diagram (var. 1) and time of working cycle ($\tau =$ 1 hour) find reliability function $P_\tau(S)$ and operating time to failure $T_f(S)$.

   Block diagram:



   Failure rate for elemets:

NN element	Failure rate $\lambda_i(t)$, h^{-1}
1	0,04
2	0,05
3	0,06
4	0,07
5	0,08
6	0,09

2. Write answers on following questions:
   - May operating time to failure for system is increased twice by changing failure rate for element number 1? Calculate reliability function.
   - Calculate reliability function for system if element number 1 is failure-free absolutly?

1.2 Performance

1. Failure rate for system:

$$\lambda_S = \lambda_1 + \tau\lambda_2\lambda_3 + \lambda_4 + \lambda_5.$$

Substitute the set numerical values:

$$\lambda_S = 0,04 + 1 \times 0,05 \times 0,06 + 0,07 + 0,08 = 0,193 \text{ h}^{-1}.$$

Failure function:

$$P_\tau(S) = 1 - \tau\lambda_S = 1 - 1 \times 0,193 = 0,807$$

Operating time to failure:

$$T_f(S) = \frac{1}{\lambda_S} = \frac{1}{0,193} = 5,18 \text{ h.}$$

2. Second part task includes two questions. We'll to begun with second question.

2.2. In limit element number 1 failure-free absolutly, that is $\lambda_1 = 0$. Then:

$$\lambda_S = 1 \times 0,05 \times 0,06 + 0,07 + 0,08 = 0,153 \text{ h}^{-1}.$$

Failure function:

$$P_\tau(S) = 1 - \tau\lambda_S = 1 - 1 \times 0,153 = 0,847$$

Operating time to failure:

$$T_f(S) = \frac{1}{\lambda_S} = \frac{1}{0,153} = 6,54 \text{ h.}$$

2.1. Reliability function and operating time to failure have increased, but not twice, hence, to increase operating time to failure twice due to element number 1 it's impossible.

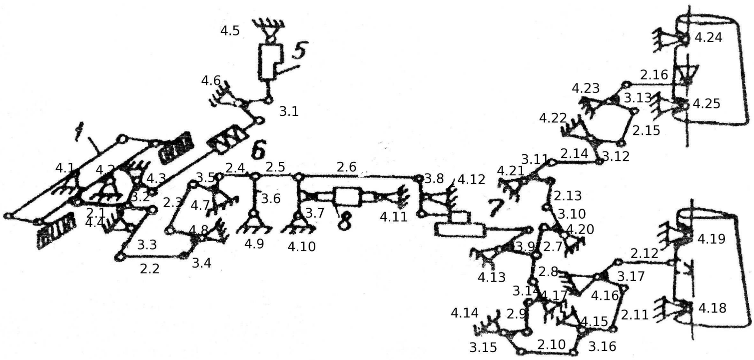
2 Reliability analysis system

The task on a source is given [2, figure 4].

2.1 Studying system

2.1.1 Analysis and addition of initial data

Yaw control system is shown on (figure 1).



1 — rudder pedal unit; 2 — rod; 3 — crank; 4 — bracket; 5 — trimming effect mechanism; 6 — artificial spring feel unit; 7 — booster; 8 — autopilot steering machine.

Figure 1— Control channel of rudders

In yaw control system hinge brakets 4 — 25, bell cranks 3 — 17, control rods 2 — 16.

Purpose system [3]: necessary efficiency of lateral control.

Functional failures [3]:

— decrease efficiency;

— increase efficiency;

— self-turn one or both rudders;

— change control efforts;

— fluctuations one or both rudders.

We receive type airplane FULCRUM.

Flight mission: training flight by close route, flying figure "flank"on one of sites route.

Expected conditions of operation: flight above deserted district in simple meteo conditions in afternoon. Flight altitude 5 km, length of route 600 km, time of flight $\tau = 1$ hour.

2.1.2 Elements failures analysis

N	Element name	$\omega \times 10^6, h^{-1}$	Failure element	Failure system
1	2	3	4	5
1	Rudder pedal unit	0,3	Jam in swivels	Increase efforts
2	Control rod	0,05	Jam in swivel	Increase efforts
3	Bell crank	0,05	Jam in swivel	Increase efforts
4	Bracket	0,04	Jam in swivel	Increase efforts
5	Trim effect mechanism	1,0	Move operating rod DC motor in extreme position	Increase efforts
6	Feel mechanism	0,5	Jam in swivel	Increase efforts
7	Booster	5,0	Hydrofeed opening	Increase efforts
8	Servo unit	3,0	Circuit opening	Failure servo unit

At the failures analysis for elements control system following assumptions are received:

1. Wedging and disconnect in hinges, for the received system of maintenance and repair, event practically incredible.

2. Servo unit 8 is electrohydraulic mechanism, connecting to bell crank 3.7. At failure servo unit control system is blocked.

3. Hydraulic actuator 7 (booster) has reversible connecting.

4. Increase control efforts is estimated by following criterion:

$$[P_p]_l < P_p \leq [P_p]_s,$$

where P_p — pilot efforts to pedals; $[P_p]_l = 9,0\ daN$ — long time maximal efforts to pedals; $[P_p]_s = 70,0\ daN$ — short time maximal efforts to pedals.

5. The effort to pedals cannot be removed simultaneous turning other control surfaces.

6. Yaw control has to good state for execute flight mission.

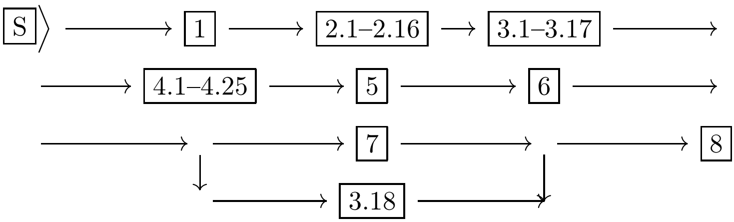
For the received assumptions extreme limitations are upset, hence special situation can be classified as emergency.

2.1.3 Normative level for operating time to failure

In accordance with [2, table 1] normative operating time to failure for emergency is:

$$[T_f] = 0,3 \cdot 10^7 \text{ h.}$$

2.2 Block diagram



Failure intensity for system:
$\omega_S = \omega_1 + 16\omega_2 + 17\omega_3 + 25\omega_4 + \omega_5 + \omega_6 + \tau\omega_7\omega_{3.18} + \omega_8 =$
$= 10^{-6} \cdot (0,3 + 16 \cdot 0,05 + 17 \cdot 0,05 + 25 \cdot 0,04 + 1,0 + 0,5+$
$+1,0 \cdot 5,0 \cdot 0,05 \cdot 10^{-6} + 3,0) = 6,45 \cdot 10^{-6},\ 1/\text{h}.$

Operating time to failure:

$$T_f = \frac{1}{\omega_S} = \frac{1}{6,45 \cdot 10^{-6}} = 0,155 \cdot 10^6 \text{ h.}$$

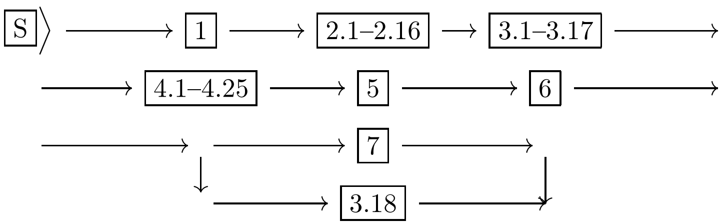
2.3 Analysis result discussion

Reliability criterion:

$$T_f(= 0,0155 \cdot 10^7 \text{ h}) \geq [T_f](= 0,3 \cdot 10^7 \text{ h}),$$

is not executed, hence system redesign is needed.

1. Bell crank 3.7 construction is changed from supported to summarizing, then failure servo unit is not blocked control system. Block diagram will be shown:



Failure intensity for system:
$\omega_S = \omega_1 + 16\omega_2 + 17\omega_3 + 25\omega_4 + \omega_5 + \omega_6 + \tau\omega_7\omega_{3.18} =$
$= 10^{-6} \cdot (0,3 + 16 \cdot 0,05 + 17 \cdot 0,05 + 25 \cdot 0,04 + 1,0 + 0,5+$
$+1,0 \cdot 5,0 \cdot 0,05 \cdot 10^{-6}) = 3,45 \cdot 10^{-6},\ 1/\text{h}.$

Operating time to failure:

$$T_f = \frac{1}{\omega_S} = \frac{1}{3,45 \cdot 10^{-6}} = 0,29 \cdot 10^6 \text{ h}.$$

2. Change trim effect mechanism such, that $\omega_5 = 0,2 \cdot 10^{-6}$ 1/h, then $\omega_S = 3,15 \cdot 10^{-6}$ 1/h, and operating time to failure for yaw control system $T_f = 0,32 \cdot 10^6$ h, reliability criterion is executed.

Bibliography

[1] Vilchek, M.I. Reliability, fail-safe, operating. Method of block diagrams and estimate reliability system [Text]: methodic instructions/ compilers M. I. Vilchek. — Kuibyshev: KuAI, preprint, 1981. — 27 p. (in Russian).

[2] Napadov, K.A. Reliability analysis airplane system at design [Text]: methodic instructions. — Samara: Publishing SSAU, 2010. — 17 p. (in Russian).

[3] Mrykin, S.V. Functional failure effects airplane systems [Text]: manual. — Samara: Publishing SSAU, 2009. — 49 p. (in Russian).