ASSESSING THE RELIABILITY OF MECHANICAL SYSTEMS AFET ANTIAIRCRAFT CANNON AUTOMATIC

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***Abstract**: The reliability calculus is made taking into consideration the specific and the particularities of each system or use of it concrete. For solving this problem it is necessary to know the relations between system and element parameters. It was made the logical diagram of the method of system reliability using decomposition. The reliability function for the time duration is pre-established resulting from execution of a sufficient number of Monte Carlo simulation technique simulations trough considered for the system, made it to get higher confidence levels of estimated output parameters.*

***Keywords**: reliability of mechanical systems, antiaircraft cannon, Monte-Carlo simulation technique.*

1. PRELIMINARY

To determine the reliability of forecasting antiaircraft gun carriage mechanisms automatically, can be used analytical methods are used when computing analytical relations, custom cases in which resistance and distribution applications are specific laws reviewed equipment components, or method of using existing data in the literature regarding the intensity of failure of machine parts in the composition of the mechanical system analyzed. To achieve the numerical evaluation of forecast reliability function antiaircraft gun carriage mechanisms studied, considered as a complex system, using Monte-Carlo simulation technique. This method is related to problems with random data, random variables modeling in order to assess their reliability. Generate random numbers based on the values of a selection on a random variable X, which has a given interval [0, k], $k \in N$ a uniform distribution. Achieving a certain way random numbers uniformly distributed on the whole [0, k], k is sufficiently large, u can get uniform random numbers in the interval [0,1] by the transformation: $u = x / k$, $0 \le x \le k$. Establishing the number of simulations required result by Kolmogorov-Smirnov-test. Be n-number of simulations, L - the maximum difference between the empirical distribution function Fn (xi) and distribution function F theoretical (xi), obtained by simulation for a level of significance α. Values for the α and L, with n > 35 are presented in Table 1.

Table 1 Relations for determining the maximum difference between the empirical function and the theoretical distribution, the level of significance

α	0,20	0,15	0,10	0,05	0,01
L	$1{,}07/\sqrt{n-1}$	$1{,}14/\sqrt{n-1}$	$1{,}22/\sqrt{n-1}$	$1{,}36/\sqrt{n-1}$	$1{,}63/\sqrt{n-1}$

It is considered that the building blocks of machine mechanisms analyzed individual reliability functions that have exponential type with different failure rates.

2. DEVELOPMENT RELIABILITY BLOCK DIAGRAM

Reliability block diagram was developed based on the interconnections between antiaircraft gun carriage constructive elements (MKOMAAG, 1998), as shown in Figure 1. Are also presented and connections with other gun systems analyzed complex components.

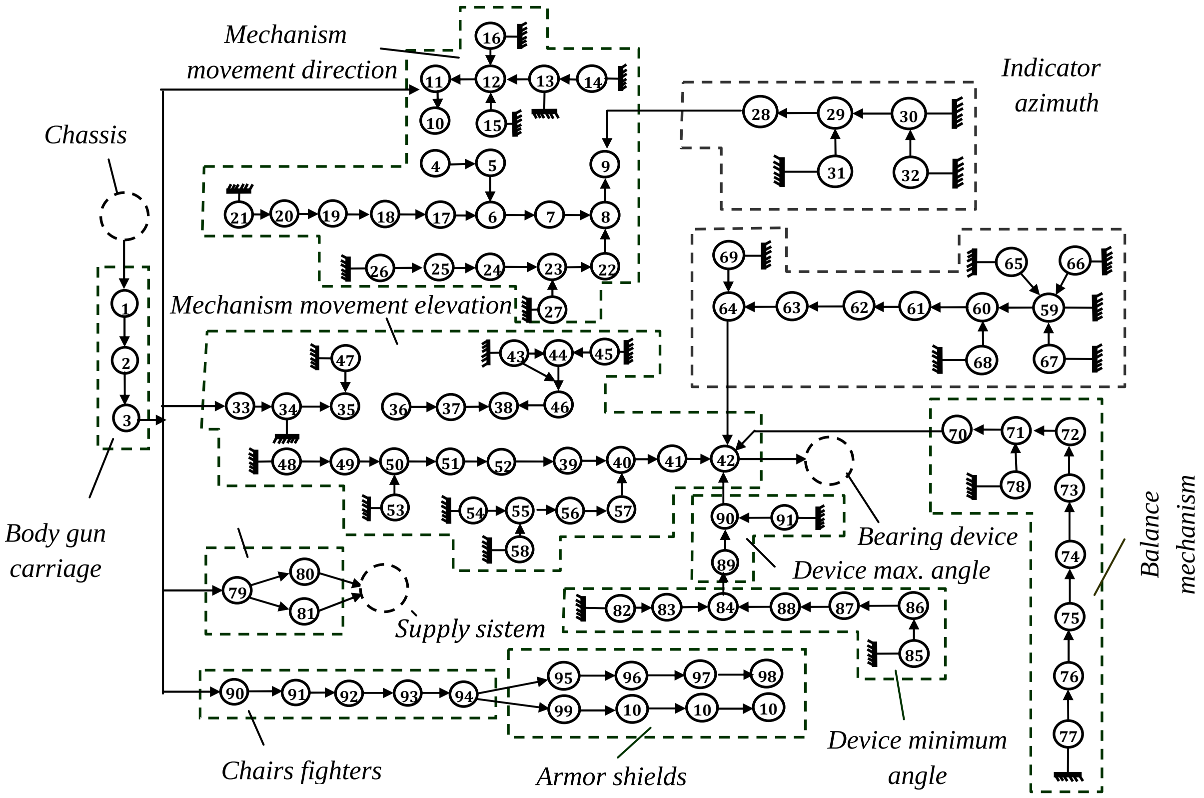

Fig. 1 Reliability block diagram antiaircraft gun carriage mechanisms

3. DETERMINATION OF RELIABILITY MECHANISMS AFET CANNON

For the simulation technique Monte-Carlo method, were originally established a total of 1000 simulations (nrs: = 1000) and the length of time [a, t] for which system reliability analysis is determined t: = 1000 hours.

3.1 Determination of body gun carriage forecast reliability.

- The structure function of the subsystem:

SA(e1, e2, e3) := e1·e2 ·e3 (1)

- The number of constructive elements of the subsystem: n := 3

- Calculation of reliability of structural elements that compose the analyzed subsystem:

$k := 1..3,\ j := 1..nrs,\ R_k := \exp(-\lambda_k \cdot t)$ (2)

- Perform simulation state vector is given by:

$RND_{i,j} := rnd(1),\ x_{i,j} := if(RND_{i,j} < R_i,1,0)$,

$$\lambda_k = \begin{bmatrix} 0.015\cdot10^{-6} \\ 3.530\cdot10^{-6} \\ 0.180\cdot10^{-6} \end{bmatrix},\ R_k = \begin{bmatrix} 0.999950 \\ 0.996476 \\ 0.998182 \end{bmatrix} \quad (3)$$

- Subsystem reliability resulting from the simulation is given by:

$Sistem_j := SA\ [x_{1,j}, x_{2,j}, x_{3,j}]$,

$$R := \frac{\sum_{j=1}^{nrs} Sistem_j}{nrs};\ R := 0.994614 \quad (4)$$

3.2 Determination of reliability forecasting mechanism direction of movement direction.

- The structure function of the subsystem:

SA(e4, e5, e6, e7, e8, e9, e10, e11, e12, e13, e14, e15, e16, e17, e18, e19, e20, e21, e22, e23, e24, e25, e26,e27) := [1 – (1 – e10·e11·e12·e13·e14·e15·e16·e17·e18·e19·e20· e21·e22 ·e23·e24·e25·e26·e27)] (5)

- The number of constructive elements of the subsystem: n := 24;

- Calculation of reliability of structural elements that compose the analyzed subsystem:

$k := 1\ \ 24$, $j := 1..nrs$, $R_k := \exp(-\lambda_k \cdot t)$

$$\lambda_k = \begin{bmatrix} 0.280\cdot10^{-6} \\ 0.025\cdot10^{-6} \\ 0.200\cdot10^{-6} \\ 0.025\cdot10^{-6} \\ 0.300\cdot10^{-6} \\ 0.980\cdot10^{-6} \\ 0.135\cdot10^{-6} \\ 0.025\cdot10^{-6} \\ 0.100\cdot10^{-6} \\ 0.002\cdot10^{-6} \\ 0.050\cdot10^{-6} \\ 0.220\cdot10^{-6} \\ 0.420\cdot10^{-6} \\ 0.090\cdot10^{-6} \\ 1.150\cdot10^{-6} \\ 0.025\cdot10^{-6} \\ 0.300\cdot10^{-6} \\ 0.002\cdot10^{-6} \\ 0.001\cdot10^{-6} \\ 0.300\cdot10^{-6} \\ 0.010\cdot10^{-6} \\ 0.050\cdot10^{-6} \\ 0.025\cdot10^{-6} \\ 0.030\cdot10^{-6} \end{bmatrix}, \quad R_k = \begin{bmatrix} 0.999720 \\ 0.999975 \\ 0.999800 \\ 0.999975 \\ 0.999700 \\ 0.999020 \\ 0.999865 \\ 0.999975 \\ 0.999900 \\ 0.999998 \\ 0.999950 \\ 0.999780 \\ 0.999580 \\ 0.999910 \\ 0.998850 \\ 0.999975 \\ 0.999700 \\ 0.999998 \\ 0.999999 \\ 0.999700 \\ 0.999970 \\ 0.999950 \\ 0.999975 \\ 0.999970 \end{bmatrix}$$

- Perform simulation state vector is given by: $RND_{i,j} := rnd(1)$, $x_{i,j} := if(RND_{i,j} < R_i, 1, 0)$

- Subsystem reliability resulting from the simulation is given by:

$Sistem_j := SA[x_{1,j},x_{2,j},x_{3,j},x_{4,j},x_{5,j},x_{6,j},x_{7,j},x_{8,j}, x_{9,j},x_{10,j},x_{11,j},x_{12,j},x_{13,j},x_{14,j},x_{15,j},x_{16,j},x_{17,j},x_{18,j},x_{19,j}\ x_{20,j},x_{21,j},x_{22,j},x_{23,j},x_{24,j}]$

$$R := \frac{\sum_{j=1}^{nrs} Sistem_j}{nrs}, \quad R := 0.995244$$

3.3 Determination of reliability forecasting mechanism elevation motion.

- The structure function of the subsystem:

SA(e33,e34,e35,e36,e37,e38,e39,e40,e41,e42 e43,e44,e45,e46,e47,e48,e49,e50,e51,e52,e53, e54,e55,e56,e57,e58):=e33·e34·e35·e36·e37· e38·e39·e40·e41·e42·e43e44·e45·e46·e47·e48· e49·e50·e51·e52·e53·e54·e55·e56·e57·e58 (6)

- The number of constructive elements of the subsystem: n:= 26;

- Calculation of reliability of structural elements that compose the analyzed subsystem:

$k := 1..26$, $j := 1..nrs$, $R_k := \exp(-\lambda_k \cdot t)$

$$\lambda_k = \begin{bmatrix} 0.030\cdot10^{-6} \\ 0.001\cdot10^{-6} \\ 0.150\cdot10^{-6} \\ 0.030\cdot10^{-6} \\ 0.025\cdot10^{-6} \\ 0.050\cdot10^{-6} \\ 0.025\cdot10^{-6} \\ 0.300\cdot10^{-6} \\ 0.020\cdot10^{-6} \\ 0.010\cdot10^{-6} \\ 0.020\cdot10^{-6} \\ 0.025\cdot10^{-6} \\ 0.025\cdot10^{-6} \\ 0.030\cdot10^{-6} \\ 0.001\cdot10^{-6} \\ 0.025\cdot10^{-6} \\ 0.001\cdot10^{-6} \\ 0.020\cdot10^{-6} \\ 0.020\cdot10^{-6} \\ 0.030\cdot10^{-6} \\ 0.022\cdot10^{-6} \\ 0.040\cdot10^{-6} \\ 0.200\cdot10^{-6} \\ 0.025\cdot10^{-6} \\ 0.002\cdot10^{-6} \\ 0.025\cdot10^{-6} \end{bmatrix}, \quad R_k = \begin{bmatrix} 0.999970 \\ 0.999999 \\ 0.999850 \\ 0.999970 \\ 0.999975 \\ 0.999950 \\ 0.999975 \\ 0.999700 \\ 0.999980 \\ 0.999990 \\ 0.999980 \\ 0.999975 \\ 0.999975 \\ 0.999970 \\ 0.999999 \\ 0.999975 \\ 0.999999 \\ 0.999980 \\ 0.999980 \\ 0.999970 \\ 0.999978 \\ 0.999960 \\ 0.999800 \\ 0.999975 \\ 0.999998 \\ 0.999975 \end{bmatrix}$$

- Perform simulation state vector is given by: $RND_{i,j} := rnd(1)$, $x_{i,j} := if(RND_{i,j} < R_i, 1, 0)$

- Subsystem reliability resulting from the simulation is given by:

$Sistem_j := SA[x_{1,j},x_{2,j},x_{3,j},x_{4,j},x_{5,j},x_{6,j},x_{7,j},x_{8,j}, x_{9,j},x_{10,j},x_{11,j},x_{12,j},x_{13,j},x_{14,j},x_{15,j},x_{16,j},x_{17,j},x_{18,j},x_{19,j}\ ,x_{20,j},x_{21,j},x_{22,j},x_{23,j},x_{24,j},x_{25,j},x_{26,j}]$

$$R := \frac{\sum_{j=1}^{nrs} Sistem_j}{nrs}, \quad R := 0.997672$$

3.4 Determination of reliability forecast balance mechanism.

- The structure function of the subsystem:

SA(e59,e60,e61,e62,e63,e64,e65,e66,e67,e68 e69):=e59·e60·e61·e62·e63·e64·e65·e66·e67· e68·e69 (7)

- The number of constructive elements of the subsystem: n:= 11;
- Calculation of reliability of structural elements that compose the analyzed subsystem:

$k := 1..11,\ j := 1..nrs,\ R_k := \exp(-\lambda_k \cdot t)$

$$\lambda_k = \begin{bmatrix} 0.010\cdot10^{-6} \\ 0.220\cdot10^{-6} \\ 0.040\cdot10^{-6} \\ 0.020\cdot10^{-6} \\ 0.130\cdot10^{-6} \\ 0.010\cdot10^{-6} \\ 0.020\cdot10^{-6} \\ 0.025\cdot10^{-6} \\ 0.010\cdot10^{-6} \\ 0.018\cdot10^{-6} \\ 0.012\cdot10^{-6} \end{bmatrix},\quad R_k = \begin{bmatrix} 0.999990 \\ 0.999960 \\ 0.999980 \\ 0.999870 \\ 0.999988 \\ 0.999990 \\ 0.999980 \\ 0.999975 \\ 0.999990 \\ 0.999982 \\ 0.999780 \end{bmatrix}$$

- Perform simulation state vector is given by:

$RND_{i,j} := rnd(1),\ x_{i,j} := if(RND_{i,j} < R_i, 1, 0)$

- Subsystem reliability resulting from the simulation is given by:

$Sistem_j := SA[x_{1,j}, x_{2,j}, x_{3,j}, x_{4,j}, x_{5,j}, x_{6,j}, x_{7,j}, x_{8,j}, x_{9,j}, x_{10,j}, x_{11,j}]$

$$R := \frac{\sum_{j=1}^{nrs} Sistem_j}{nrs};\ R := 0.999485.$$

3.5 Determination of forecast reliability of the locking mechanism in the elevation.

- The structure function of the subsystem:

$$SA(e70,e71,e72,e73,e74,e75,e76,e77,e78) := e77\cdot e76\cdot e75\cdot e74\cdot e73\cdot e72\cdot e78\cdot e71\cdot e70 \quad (8)$$

- The number of constructive elements of the subsystem: n:= 9;
- Calculation of reliability of structural elements that compose the analyzed subsystem:

$k := 1..9,\ j := 1..nrs,\ R_k := \exp(-\lambda_k \cdot t)$

- Perform simulation state vector is given by:

$RND_{i,j} := rnd(1),\ x_{i,j} := if(RND_{i,j} < R_i, 1, 0)$

- Subsystem reliability resulting from the simulation is given by:

$Sistem_j := SA[x_{1,j}, x_{2,j}, x_{3,j}, x_{4,j}, x_{5,j}, x_{6,j}, x_{7,j}, x_{8,j}, x_{9,j}]$

$$R := \frac{\sum_{j=1}^{nrs} Sistem_j}{nrs};\ R := 0.999414.$$

$$\lambda_k = \begin{bmatrix} 0.220\cdot10^{-6} \\ 0.015\cdot10^{-6} \\ 0.010\cdot10^{-6} \\ 0.020\cdot10^{-6} \\ 0.040\cdot10^{-6} \\ 0.018\cdot10^{-6} \\ 0.120\cdot10^{-6} \\ 0.042\cdot10^{-6} \\ 0.001\cdot10^{-6} \end{bmatrix},\quad R_k = \begin{bmatrix} 0.999780 \\ 0.999985 \\ 0.999990 \\ 0.999980 \\ 0.999960 \\ 0.999882 \\ 0.999880 \\ 0.999958 \\ 0.999999 \end{bmatrix}$$

3.6 Determination of forecast reliability tray discharge tubes and links.

- The structure function of the subsystem:

$$SA(e79, e80, e81) = e79\cdot e80\cdot e81 \quad (9)$$

- The number of constructive elements of the subsystem: n := 3;
- Calculation of reliability of structural element that compose the analyzed subsystem:

$k := 1..3,\ j := 1..nrs,\ R_k := \exp(-\lambda_k \cdot t)$

$$\lambda_k = \begin{bmatrix} 0.020\cdot10^{-6} \\ 0.040\cdot10^{-6} \\ 0.001\cdot10^{-6} \end{bmatrix},\quad R_k = \begin{bmatrix} 0.999960 \\ 0.999882 \\ 0.999880 \end{bmatrix}$$

- Perform simulation state vector is given by:

$RND_{i,j} := rnd(1),\ x_{i,j} := if(RND_{i,j} < R_i, 1, 0)$

- Subsystem reliability resulting from the simulation is given by:

$Sistem_j := SA[x_{1,j}, x_{2,j}, x_{3,j}]$

$$R := \frac{\sum_{j=1}^{nrs} Sistem_j}{nrs};\ R := 0.999974.$$

3.7 Determination of forecast reliability of the device to limit maximum elevation angle.

- The structure function of the subsystem:

$$SA(e89, e90, e91) = e89\cdot e90\cdot e91 \quad (10)$$

- The number of constructive elements of the subsystem: n := 3;

- Calculation of reliability of structural elements that compose the analyzed subsystem:

$k := 1..3,\ j := 1..nrs,\ R_k := \exp(-\lambda_k \cdot t)$

$$\lambda_k = \begin{bmatrix} 0.025\cdot10^{-6} \\ 0.080\cdot10^{-6} \\ 0.100\cdot10^{-6} \end{bmatrix},\ R_k = \begin{bmatrix} 0.999975 \\ 0.999920 \\ 0.999900 \end{bmatrix}$$

- Perform simulation state vector is given by:

$RND_{i,j} := rnd(1),\ x_{i,j} := if(RND_{i,j} < R_i, 1, 0)$

- Subsystem reliability resulting from the simulation is given by:

$Sistem_j := SA[x_{1,j}, x_{2,j}, x_{3,j}]$

$$R := \frac{\sum_{j=1}^{nrs} Sistem_j}{nrs};\ R := 0.999790.$$

3.8 Determination of forecast reliability of the device to limit minimum elevation angle.

- The structure function of the subsystem:

$$SA(e82,e83,e84,e85,e86,e87,e88) := e82\cdot e83\cdot e84\cdot e85\cdot e86\cdot e87\cdot e88 \quad (11)$$

- The number of constructive elements of the subsystem: n := 7;

- Calculation of reliability of structural elements that compose the analyzed subsystem:

$k := 1..7,\ j := 1..nrs,\ R_k := \exp(-\lambda_k \cdot t)$

$$\lambda_k = \begin{bmatrix} 0.045\cdot10^{-6} \\ 0.030\cdot10^{-6} \\ 0.020\cdot10^{-6} \\ 0.025\cdot10^{-6} \\ 0.080\cdot10^{-6} \\ 0.100\cdot10^{-6} \\ 0.040\cdot10^{-6} \end{bmatrix},\ R_k = \begin{bmatrix} 0.999955 \\ 0.999970 \\ 0.999980 \\ 0.999975 \\ 0.999920 \\ 0.999900 \\ 0.999960 \end{bmatrix}$$

- Perform simulation state vector is given by:

$RND_{ij} := rnd(1)\ x_{i,j} := if(RND_{i,j} < R_i, 1, 0)$

- Subsystem reliability resulting from the simulation is given by:

$Sistem_j := SA[x_{1,j}, x_{2,j}, x_{3,j}, x_{4,j}, x_{5,j}, x_{6,j}, x_{7,j}]$

$$R := \frac{\sum_{j=1}^{nrs} Sistem_j}{nrs};\ R := 0.999660.$$

3.9 Determination of reliability forecasting mechanism azimuth indicator.

- The structure function of the subsystem:

$$SA(e28, e29, e30, e31, e32) := e28\cdot e29\cdot e30\cdot 31\cdot e32 \quad (12)$$

- The number of constructive elements of the subsystem: n := 5;

- Calculation of reliability of structural elements that compose the analyzed subsystem:

$k := 1..5,\ j := 1..nrs,\ R_k := \exp(-\lambda_k \cdot t)$

$$\lambda_k = \begin{bmatrix} 0.010\cdot10^{-6} \\ 0.005\cdot10^{-6} \\ 0.005\cdot10^{-6} \\ 0.150\cdot10^{-6} \\ 0.025\cdot10^{-6} \end{bmatrix},\ R_k = \begin{bmatrix} 0.999990 \\ 0.999995 \\ 0.999995 \\ 0.999850 \\ 0.999975 \end{bmatrix}$$

- Perform simulation state vector is given by:

$RND_{i,j} := rnd(1),\ x_{i,j} := if(RND_{i,j} < R_i, 1, 0)$

- Subsystem reliability resulting from the simulation is given by:

$Sistem_j := SA[x_{1,j}, x_{2,j}, x_{3,j}, x_{4,j}, x_{5,j}]$

$$R := \frac{\sum_{j=1}^{nrs} Sistem_j}{nrs};\ R := 0.999805$$

3.10 Determination of the protective shield of forecast reliability.

- The structure function of the subsystem:

$$SA(e95,e96,e97,e98,e99,e100,e101,e102) := (1-(1-e95\cdot e96\cdot e97\cdot e98)\cdot(1e99\cdot e100\cdot e101\cdot e102)) \quad (13)$$

- The number of constructive elements of the subsystem: n := 8;

- Calculation of reliability of structural elements that compose the analyzed subsystem:

$k := 1..8,\ j := 1..nrs,\ R_k := \exp(-\lambda_k \cdot t)$

- Perform simulation state vector is given by:

$RND_{i,j} := rnd(1),\ x_{i,j} := if(RND_{i,j} < R_i, 1, 0)$

- Subsystem reliability resulting from the simulation is given by:

$Sistem_j := SA[x_{1,j}, x_{2,j}, x_{3,j}, x_{4,j}, x_{5,j}, x_{6,j}, x_{7,j}, x_{8,j},]$

$$R := \frac{\sum_{j=1}^{nrs} Sistem_j}{nrs};\ R := 0.9999999977.$$

3.11 Determination of forecast reliability seat fighters.

- The structure function of the subsystem:

$$SA(e90, e91, e92, e93, e94) := e90 \cdot e91 \cdot e92 \cdot e93 \cdot e94 \quad (14)$$

- The number of constructive elements of the subsystem: n := 5;
- Calculation of reliability of structural elements that compose the analyzed subsystem:

$k := 1 \,..5$, $j := 1 \,..nrs$, $R_k := \exp(-\lambda_k \cdot t)$

$$\lambda_k = \begin{bmatrix} 0.030 \cdot 10^{-6} \\ 0.130 \cdot 10^{-6} \\ 0.050 \cdot 10^{-6} \\ 0.040 \cdot 10^{-6} \\ 0.025 \cdot 10^{-6} \end{bmatrix}, \; R_k = \begin{bmatrix} 0.999970 \\ 0.999870 \\ 0.999951 \\ 0.999960 \\ 0.999975 \end{bmatrix}$$

- Perform simulation state vector is given by:

$RND_{i,j} := rnd(1)$, $x_{i,j} := if(RND_{i,j} < R_i, 1, 0)$

- Subsystem reliability resulting from the simulation is given by:

$Sistem_j := SA[x_{1,j}, x_{2,j}, x_{3,j}, x_{4,j}, x_{5,j}]$

$$R := \frac{\sum_{j=1}^{nrs} Sistem_j}{nrs} \quad ; \quad R := 0.999726$$

The reliability of mechanical systems afet antiaircraft cannon automatic is determined by following the same steps to calculate the Monte Carlo simulation method, according to its own structure.

The structure function of the system:

$$SA(s1,s2,s3,s4,s5,s6,s7,s8,s9,s10,s11) := s1 \cdot s2 \cdot s3 \cdot s4 \cdot s5 \cdot s6 \cdot s7 \cdot s8 \cdot s9 \cdot s10 \cdot s11 \quad (15)$$

- The number of subsystems of the system:n := 11;
- Calculation of reliability of structural system that compose the analyzed system:

$k := 1 \,..11$

$j := 1 \,..nrs$

- Perform simulation state vector is given by:

$RND_{i,j} := rnd(1)$, $x_{i,j} := if(RND_{i,j} < R_i, 1, 0)$

- System reliability resulting from the simulation is given by:

$Sistem_j := SA[x_{1,j}, x_{2,j}, x_{3,j}, x_{4,j}, x_{5,j}, x_{6,j}, x_{7,j}, x_{8,j}, x_{9,j}, x_{10,j}, x_{11,j}]$

$$R := \frac{\sum_{j=1}^{nrs} Sistem_j}{nrs} \; ; \; R := 0.985460$$

$$R_k = \begin{bmatrix} 0.994614 \\ 0.995244 \\ 0.999485 \\ 0.997672 \\ 0.999414 \\ 0.999974 \\ 0.999790 \\ 0.999660 \\ 0.999805 \\ 0.999999 \\ 0.999726 \end{bmatrix}$$

4. CONCLUSIONS

Research findings developed during the development work have revealed the following conclusions: In the study of mechanical systems afet antiaircraft cannon automatic, developing functional connections graphs and use Monte Carlo simulation technique of possible values of parameters, the result that there is a very large number of elements connected in series, this leading to a decrease in system reliability. It requires a redesign of the logical schemes of reliability in order to reduce the number of elements in series. Proposals are made in this regard (Luculescu, 2000), to reduce the number of elements in series constructive mechanisms of movement direction and elevation of anti-aircraft gun automatic. The proposed constructive alternatives analyzed will increase the operability of equipment, possibly with other similar equipment interconnection, all these in turn being driven by a modern fire control unit.

BIBLIOGRAPHY

1. Carter, A.D. (1986). *Mechanical Reliability*. London: Mac Millan Education Ltd.
2. Constantin, G., Nuțu, V. (1998). *Fundamentals of weapon systems reliability*. Bucharest: Military Technical Academy.

3. Gertsbanskh, I.B. (1989). *Statistical Reliability Theory*. New York: Marcel Decker.
4. Luculescu, D. (1993). *Design of mechanical transmissions used in artillery and air defense missiles*. Brasov: Military Institute of Artillery and Air Defense Missile "General Bungescu".
5. Luculescu, D. (2000). *Research on the reliability of the equipment TAA*. PhD Thesis. Brasov: University "Transilvania".
6. Scheiber, E., Lixăndroiu, D. (1994). *Mathcad. Introduction and Problem*s. Bucharest: Technical Publishing.
7. *** (1998). *Manual of knowledge, operation and maintenance of automatic antiaircraft guns* (MKOMAAG). Bucharest: MND, CAAT.