TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, and Mechanics, and Engineering
Vol. 58, Issue II, June, 2015

DETERMINATION OF RELIABILITY PARAMETERS IN COMPLEX TECHNICAL SYSTEMS

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Abstract: Optimal and efficient planning of preventive maintenance actions on the technical systems repairable requires knowledge of the real or accurate anticipation of parameters of reliability of these systems. Based on a virtual model of a complex technical system, considered as a case study, the present theoretical assumptions and develop the methodology for the determination of the function: reliability and non reliability, based on the data obtained from monitoring of parameters of reliability of real systems.

Key words: *Reliability, Maintenance, Maintainability, Weibull function.*

1. Introduction

Reliability Centered Maintenance (RCM), belongs to the Group of Preventive Maintenance based on the time that comprises all works that runs periodically in order to ensure the continuity of the operation of technical systems through inspections, adjustments, measurements, tests, replacement of parts and sub-assemblies, other ancillary works *etc."*

The frequency of preventive interventions is determined by the category and the technical condition of the system, suppliers of equipment, recommendations for safety standards, for deficiencies in the checks on a regular basis and the results of modern methods of diagnosis and/or interpretation of technical data obtained previously [7].

2. Content

Reliability Centered Maintenance, base its planning future operations (T) on the technical condition of the system, the state evaluated on the basis of the estimated reliability of the system at the time of planning (T_0), which in turn are mathematically estimated based on "historic events" — namely, on the basis of a priori information available related to the behavior of the system at the time (T_0), i.e. during the period (T^-) as shown in Figure 1.

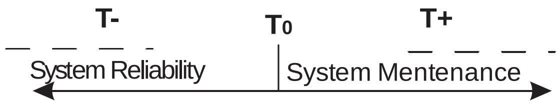

Fig. 1. The times appraisal and planning of the MTBF

Availability is the most complex form of manifestation of the quality of a system in the process of exploitation, since it includes both the reliability and maintainability of. Accepting as an expression of relationship readiness:

$$A(t) = R(t) + [1 - R(t)]*M(t') \quad (1)$$

where: A(t) - availability

R(t) - reliability

M(t') - mentainability

It can be inferred that the availability of a technical system is determined by two probabilities:

a.) The probability that the product will work without failure over a period of time (t) - *reliability;*

b.) The probability that the product, which occurs in the range (t), to be brought back into service in time (the) -maintainability*;*

Maintenance based on reliability analysis can be applied only to systems repairable, which technical after identifying malfunctions, replace components and eliminate possible causes, they can resume and hold further technical tasks with function parameters at least at the level of dominant of the production of a failure [6].

2.1 Estimation of reliability of technical system

It aims to analyze the hypothetical of a technical system, believed to be a technological system, established as a flexible manufacturing robotic system, consisting of 3 machine tools NC, 2 robots handling and transfer system, a total of 6 functional technical units, viewed as repairable subsystems.

This will further develop such a comprehensive analysis, within which you must take several steps, as follows:

In the hypothesis that the operation of each of the six functional units is absolutely vital for the production of making technological system, means that any of the damaged units will lead to termination of the functioning of the system and shutting down production. In this idea all 6 subsystems will be considered to be of the same rank as the main units [BIL90].

It accepts that the system repairable is composed of simple elements repairable, what are dependent on fiabilistic (the failure of an element influencing the functioning of the whole system) with negligible recovery time, or: Tri →0. | i = 1, n. In this case the availability will depend only on the overall reliability of the system, by this system.

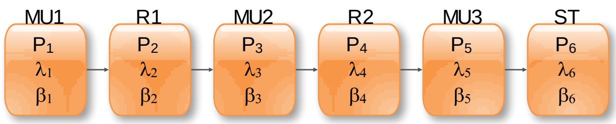

Fig. 2. Fiabilistical system technology scheme

In this context, it will study the technical system repairable the availability of a given lifetime T_v, which is a sequence of:

- Periods of uninterrupted operation, denoted t_{fi}, alternating with:
- A final period of repair, denoted by train

$$Tv = \Sigma\, t_{fi} + \Sigma\, t_{ri} \mid i = 1, n \qquad (2)$$

Such a specific system, accept the fact that the process of restoration-repair in this case, is actually a process of immediate replacement (immediate restitution) defective items, so the length $t_{fi} >> t_{ri}$.

Random variables used in reliability theory are: the number of faults that occur within an operating system, running time without damage to an item, the technological parameters of a system etc.

Knowledge of the availability of a system at any one time-required knowledge by means of mathematical statistics of the analytical procedure (type) distribution function of known by the numerical values of the parameters [1].

Estimation of reliability based on the statistical data processed during the period running from (0 ÷ T_0) - is based on the reaction system modeling using random processes, the following sequence of calculation:

a. Selection and processing of the data resulting from the operation of the system up to the moment (T_0), i.e. random variables*;*

b. Determining the type of distribution function that shapes the best random variables;

c. Calculation of the parameters of the distribution function;

d. Estimative checking, on the basis of statistical verification tests.

Although in all numerical analysis can be used a number of mathematical processing of data, the software package MATLAB, numerical calculation and dedicated graphics in the field of engineering and ştinţei, provides the greatest satisfaction [5].

2.2 Presentation of data obtained from technical system monitoring

Monitoring fiabilistic data for the proposed system are shown in table 1, the following marking shortlist:

- *Time moments*, $\mathbf{z_i}$ (expressed in days), that was interrupted for technical operation of the system, considering only those switches that were followed by corrective actions aimed at restoring the operation of the system;

- *Duration of the corrective actions*, $\mathbf{T_{ri}}$ (expressed in minutes), for reinstatement in the operation of the system;
- In those functional units, 6 duration of corrective actions can be found under the following notations: TrM1j – Tool machine 1 (MU1); TrR1j – Robot R1; TrM2j - Tool machine 2 (MU2); TrR2j - Robot R2; TrM3j - Tool machine 3 (MU3); TrSTj – Transfer system (ST).
- With j has noted the current number of registrations.
- Within the framework of the follow-up of 8 years were taken into account in working days only, approximately 2400 echivlalent days.

Based on these variables, discrete random variables and real primary (simple), can be calculated and other secondary variables, as well as the generation and processing of data and statistical functions:

- Operating time intervals between outages 't_f' [days] $t_{fi} = z_i - z_{i-1} \mid i = 0,n$ / for: $t_{f1} = z_1$ represented in figure 3-a.
- Repair time for each malfunction 't_r' [days] represented in figure 3-b.

The file MATLAB calculation for determining the distribution of run time and repair time on each intervention

```
tj=[155 210 350 385 420 505 610 702 775 802 825 850
910 992 1020 1104 1170 1240 1265 1295 1310 1365 1390
1475 1510 1590 1620 1685 1710 1765 1795 1812 1868
1905 1930 1970 1990 2010 2065 2095 2140 2165 2198
2214 2245 2275 2305 2332 2380 2436];
Trj=[15 22 124 420 520 12 42 75 540 60 15 22 480 68 60
48 12 15 220 320 110 480 60 480 32 48 12 30 45 120 360
480 24 30 115 30 120 15 45 25 240 30 45 90 90 36 48 60
120 360];
n=50;
w=(1/60)*(1/24);
for k=1:n
tr(k)=w*Trj(k);
end
tf=1:1:n;
tf(1)=tj(1);
for k=2:n
tf(k)=tj(k)-tj(k-1);
end
Tf=sum(tf)
Tr=sum(tr)
subplot(2,1,1),bar(tf,'b');
grid;
legend("Operating System Technology time/8 years")
subplot(2,1,2),bar(tr,'r');
grid;
legend(' Time of the technological System repairs /8 years')
Tf = 2436
Tr =  4.7708
```

The file MATLAB calculation for determining histograms for run time and time of interruption

```
tj=[155 210 350 385 420 505 610 702 775 802 825 850 910 992 1020
1104 1170 1240 1265 1295 1310 1365 1390 1475 1510 1590 1620
1685 1710 1765 1795 1812 1868 1905 1930 1970 1990 2010 2065
2095 2140 2165 2198 2214 2245 2275 2305 2332 2380 2436];
Trj=[15 22 124 420 520 12 42 75 540 60 15 22 480 68 60 48 12 15
220 320 110 480 60  480 32 48 12 30 45 120 360 480 24 30 115 30
120 15 45 25 240 30 45 90 90 36 48 60 120 360];
n=50;
w=(1/60)*(1/24);
for k=1:n
tr(k)=w * Trj(k);
end
tf=1:1:n;
tf(1)=tj(1);
↓  ↓
for k=2:n
tf(k)=tj(k)-tj(k-1);
end
tf
subplot(2,1,1), hist(tf)
grid
legend(' The histogram function tf times ')
subplot(2,1,2), hist(tr)
grid
legend("Histogram of repair times tr")
```

To determine the distribution of run time and repair time for each intervention, as well as for drawing the corresponding histograms of two variables [3], has been developed by computer program MATLAB presented below, following the running of which resulted in graphic elements presented in figures 3 and 4.

2.3 Technical system reliability modeling based on Weibull report function

Let T be the random variable that represents the running time without system failures and R (t) function of reliability [4] representing the probability function without failure of the system on the time interval (0, t), in which case:

$$R(t) = P(T > t) \tag{3}$$

Reliability function R (t) is a decreasing function, positive and continues throughout the time interval (0, ∞).

When: $t = 0, \; R(0) = 1$

And when; $t \to \infty, \quad R(t) \to 0 \qquad (4)$

Data recorded by monitoring the functioning of the technological system, Over a period of 8 years (2400 days)

Table 1

		j	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.
		z_j	155	210	350	385	420	505	610	702	775	802	825	850	910	992	1020	1104	1170	1240	1265	1295	1310	1365	1390	1475	1510
FUNCTIONAL UNITS	Mu1	$TRm1_j$	15						42							24		48					110				
	R1	$TrR1_j$					520			32											220				60		
	Mu2	$TrM2_j$						12			540			22		44			12								32
	R2	$TrR2_j$		22								60					60					320					
	Mu3	$TrM3_j$				420				75					480											480	
	St	$TrST_j$			124								15							15				480			
		$Trtot_j$	15	22	124	420	520	12	42	75	540	60	15	22	480	68	60	48	12	15	220	320	110	480	60	480	32

		j	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.	38.	39.	40.	41.	42.	43.	44.	45.	46.	47.	48.	49.	50.
		z_j	1590	1620	1685	1710	1765	1795	1812	1868	1905	1930	1970	1990	2010	2065	2095	2140	2165	2198	2214	2245	2275	2305	2332	2380	2436
FUNCTIONAL UNITS	Mu 1	$TRm1_j$							480			45											36			120	
	R1	$TrR1_j$	48					480											30								
	Mu 2	$TrM2_j$								24				120				240						48			
	R2	$TrR2_j$		12	30						30				15					45		30					
	Mu 3	$TrM3_j$				45						70									90				60		
	St	$TrST_j$					120						30			45	25					90					360
		$Trtot_j$	48	12	30	45	120	360	480	24	30	115	30	120	15	45	25	240	30	45	90	90	36	48	60	120	360

The correct setting for the type of reliability that would shape how accurately the probability of failure of the system, it requires knowledge of:

- The structure and the characteristics of the elements;
- The variation in time of the intensity of damage, within the area of operation (running-in, adulthood, old age);
- Influence of wear on system components, etc.

Because the system chosen for technical analysis is a complex technical system that contains subassemblies of mechanical, electrical and electronic, and their operation is directly influenced by the operating conditions, it can be asserted that the damage is due to slow aging and physical wear and tear over time.

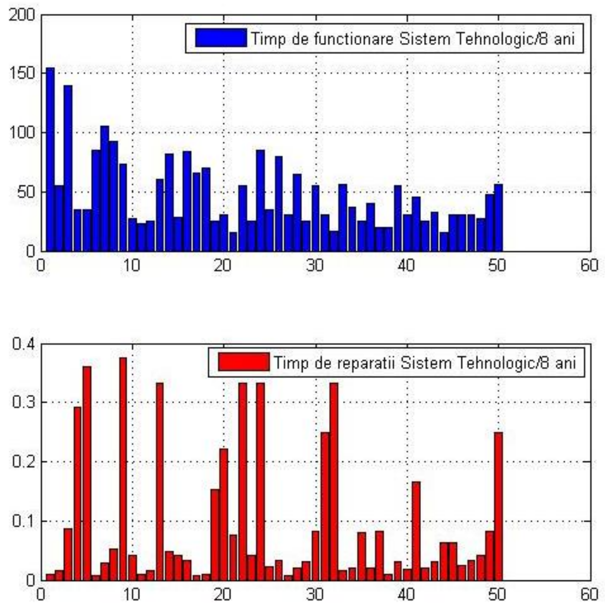

Fig. 3 The distribution of run time (case a) and time of repair on each intervention (case b)

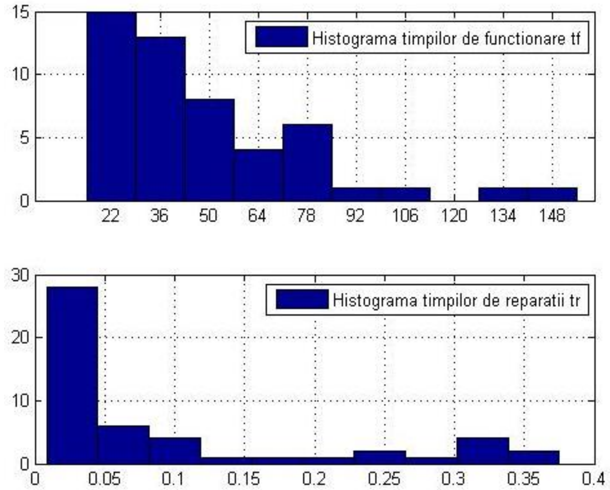

Fig. 4 Running time histogram (case a) and times of failure (case b)

Given these findings, for modeling such processes of survival, is using the Weibull distribution law [4].

Of the known forms of Weibull distribution Law (biparametrică and triparametrică, normal) reliability modeling is accepted with two shape parameters, given mathematical expression:

$$R(t;\beta,\lambda_w)=e^{-\lambda_w\cdot t^{\beta}} \quad (5)$$

Where:

- $\lambda_w > 0$ - represents a parameter of scale-corresponding to the units of measurement of the variable time 't ' in [days/hours/minutes.]
- $\beta > 0$ - is a parameter of the form, causing the shape of Weibull distribution; for $\beta = 1$ corresponds to exponentială distribution function;
- t – time variable.

Relation (5) It expresses the probability of the event occurring in the time interval (0, t) or the probability of failure-free functioning by the time 't'.

2.4 Estimation of parameters of Weibull function, through the ' BARON ' model

Based on the i = 1... n random variables and using the method of least squares are calculated from the values of the relative frequency of events 'I':

$$R_N(t_i)=e_w^{-\lambda_w\cdot(t_i)^{\beta}} \quad (6)$$

which by logaritmation leads to the:

$$lgR_N(t_i)=-\lambda_w\cdot t_i^{\beta}\cdot lge \quad \text{or}$$

$$lg[1/R_N(t_i)]=-\lambda_w\cdot t_i^{\beta}\cdot lge \quad (7)$$

repeating the operation logaritmare results:

$$lg\{\{lg[1/R_N(t_i)]\}=lg(lge)+lg\lambda_w+\beta\cdot lgt_i \quad (8)$$

Adopting notations:

$$a=lg(lge)+lg\lambda_w; \quad b_i=lg\{lg[1/R_N(t_i)]\} \quad (9)$$

to obtain the equation of a line:

$$b_i=a+\beta\cdot lgt_i \quad (10)$$

the application of the method of least squares produces the system:

$$\sum_{i=1}^{n}b_i=n\cdot a+\beta\cdot\sum_{i=1}^{n}lgt_i$$

$$\sum_{i=1}^{n}b_i\,lgt_i=a\cdot\sum_{i=1}^{n}lgt_i+\beta\cdot\sum_{i=1}^{n}(lgt_i)^2 \quad (11)$$

By introducing the simplifying notation, the system reduces to the form:

$$A=n\cdot a+\beta\cdot B$$

$$C=a\cdot B+\beta\cdot D \quad (12)$$

that solved in relation to unknowns a si β, and leads to the;

$$a = \frac{C \cdot B - A \cdot D}{B^2 - n \cdot D} \quad \text{şi}$$

$$\beta = \frac{n \cdot C - A \cdot B}{n \cdot D - B^2} \qquad (13)$$

and, from the relation (9) is calculated : λ_w

$$\lambda_w = 10^{[a - lg(lge)]} \qquad (14)$$

Calculation of the parameters file λ_w si β

```
tj=[155 210 350 385 420 505 610 702 775 802 825 850 910
992 1020 1104 1170 1240 1265 1295 1310 1365 1390 1475
1510 1590 1620 1685 1710 1765 1795 1812 1868 1905
1930 1970 1990 2010 2065 2095 2140 2165 2198 2214
2245 2275 2305 2332 2380 2436];
Trj=[15 22 124 420 520 12 42 75 540 60 15 22 480 68 60
48 12 15 220 320 110 480 60  480 32 48 12 30 45 120 360
480 24 30 115 30 120 15 45 25 240 30 45 90 90 36 48 60
120 360];
n=50; m=49; tz=2400;
Ri=1:1:m; Ai=1:1:m; Bi=1:1:m; Ci=1:1:m; Di=1:1:m;
for k=1:m;
Rj(k)=1-(tj(k)/tz);
Aj(k)=log10(log10(1/Rj(k)));
Bj(k)=log10(tj(k));
Cj(k)=Aj(k)*log10(tj(k));
Dj(k)=(log10(tj(k)))^2;
End
A=0; B=0; C=0; D=0;
for k=1:m;
A=A+Aj(k);
B=B+Bj(k);
C=C+Cj(k);
D=D+Dj(k);
end
Beta=(m*C-A*B)/(m*D-B^2);
Beta
a=(C*B-A*D)/(B^2-m*D);
y=log10(log10(2.7182818));
logLANDA=a-y;
LAMDA=10^(a-log10(log10(exp(1))));
```

After running the program MATLAB, shown above, were obtained the following numerical values of parameters of reliability:

$$\lambda_w = 2.6270\text{e-}005; \quad \beta = 1.4631 \qquad (15)$$

The function expression of reliability of the system, with these values becomes:

$$R_N(t_i) = e^{-2.6270\text{e}005\,(t_i)^{1.4631}} \qquad (16)$$

2.5 Estimation of parameters of Weibull function through the model 'MATLAB´

Another procedure of estimation of parameters of reliability funţiei the Weibull-law model is given by the environment MATLab programming through the Statistics Toolbox statement "weibfit" [4]. This instruction allows the estimation of parameters ' a ' and ' b ' in the standard form of the Weibull model for random values string ' x ', given in the form:

$$R_w = f(x \mid a, b) = a \cdot b \cdot x^{b-1} \cdot e^{-a \cdot x^b} \qquad (17)$$

with instructions:

phat = weibfit (x)

resulting vector ' phat ' with the corresponding coefficients of two dimensions ' a ' and ' b '.

phat (1) = a

phat (2) = b

Application case study, based on data contained in table 1, shall be determined ' a ' and ' b ' of the (17) on the basis of the calculations shown below.

The calculation to determine the coefficients a and b

```
tj=[155 210 350 385 420 505 610 702 775 802 825 850 910 992 1020
1104 1170 1240 1265 1295 1310 1365 1390 1475 1510 1590 1620
1685 1710 1765 1795 1812 1868 1905 1930 1970 1990 2010 2065
2095 2140 2165 2198 2214 2245 2275 2305 2332 2380 2436];
[phat,pci]=weibfit(tj);
a = phat(1)
b = phat(2)
```

2.6 Validation of the consistency of the law of distribution Weibull model

After identifying the theoretical law that would shape the best probability of running/wear and tear of the phenomenon under study, it is necessary to check the consistency between the data obtained through monitoring and analytical model chosen [4].

Reworded: under what conditions can a function be approximated empirically ‘F_1’, by an analytic function ‘F’?

In the case studydiat:

$F_1 \equiv t_1/t_{max}$ experimental values, (tabelul 1)

$F \equiv R_N$ the analytical model, according to the relationship (16)

For consistency use the analytical method: ζ_t^2 (“chi^2”) the consistency of the experimental values and the Weibull distribution, experimental model [BARON].

The calculation of the values of the parameters ζ_t^2 and X^2

```
tj=[155 210 350 385 420 505 610 702 775 802 825 850 910
992 1020 1104 1170 1240 1265 1295 1310 1365 1390 1475
1510 1590 1620 1685 1710 1765 1795 1812 1868 1905
1930 1970 1990 2010 2065 2095 2140 2165 2198 2214
2245 2275 2305 2332 2380 2436];s=32; r=2;
s=50; r=2;
tm=max(tj);
Beta=1.4631;
LAMDA=2.6270e-005;
for k=1:s
Rt(k)=tj(k)/tm;
RN(k)=1-exp(-LAMDA*(tj(k)^Beta));
end
f=[Rt;RN];
fip=sum(f');
fpj=sum(f);
sfip=sum(fip);
x2=0;
for i=1:r
for j=1:s
t=fip(i)*fpj(j)/sfip;
X2=x2+(f(i,j)-t)^2/t;
end
end
Hi2=chi2inv(0.99,49)
```

Following the implementation of the programme above, results were obtained:

$$\zeta_t^2=74.9195 \text{ and } X^2= 0.0041$$

Because $\zeta_t^2=74.9195 > X^2=0.0041$

It follows confirmation that the two attributes are consistent, and in consequence of the hypothesis according to which the law of technical system is wear a Weibull-type law.

Further it was switched to determining and drawing the graphics functions: reliability and technical system Nonfiabilitatea, computer file as shown below.

The calculation for the reliability function $R_N(t_i)$ and nonreability function $Q_s(t_i)$

```
tj=[155 210 350 385 420 505 610 702 775 802 825 850 910
992 1020 1104 1170 1240 1265 1295 1310 1365 1390 1475
1510 1590 1620 1685 1710 1765 1795 1812 1868 1905
1930 1970 1990 2010 2065 2095 2140 2165 2198 2214
2245 2275 2305 2332 2380 2436];
Trj=[15 22 124 420 520 12 42 75 540 60 15 22 480 68 60
48 12 15 220 320 110 480 60  480 32 48 12 30 45 120 360
480 24 30 115 30 120 15 45 25 240 30 45 90 90 36 48 60
120 360];
n=50; m=49; tz=2400;
Ri=1:1:m; Ai=1:1:m; Bi=1:1:m; Ci=1:1:m; Di=1:1:m;
for k=1:m;
Rj(k)=1-(tj(k)/tz);
Aj(k)=log10(log10(1/Rj(k)));
Bj(k)=log10(tj(k));
Cj(k)=Aj(k)*log10(tj(k));
Dj(k)=(log10(tj(k)))^2;
end
A=0; B=0; C=0; D=0;
for k=1:m;
A=A+Aj(k);
B=B+Bj(k);
C=C+Cj(k);
D=D+Dj(k);
End
Beta=(m*C-A*B)/(m*D-B^2);
Beta
a=(C*B-A*D)/(B^2-m*D);
y=log10(log10(2.7182818));
logLANDA=a-y;
LAMDA=10^(a-log10(log10(exp(1))));
LAMDA
Lo=LAMDA;
Rs=1:1:n; Qs=1:1:m;
for i=1:n
Rs(i)=exp(-Lo*(tj(i)^Beta));
Qs(i)=1-Rs(i);
end
plot(tj,Rs,'b',tj,Qs,'r-')
grid
axis([0 1750 0. 1.])
legend(' Reliability Function ' RS, ' Qs nonfiability function
' )
gtext('Rs;Qs')
gtext('T[zile]')
```

Figure 5 shows the graph of the function of reliability $R_N(t_i)$ and nonreability function $Q_s(t_i)$.

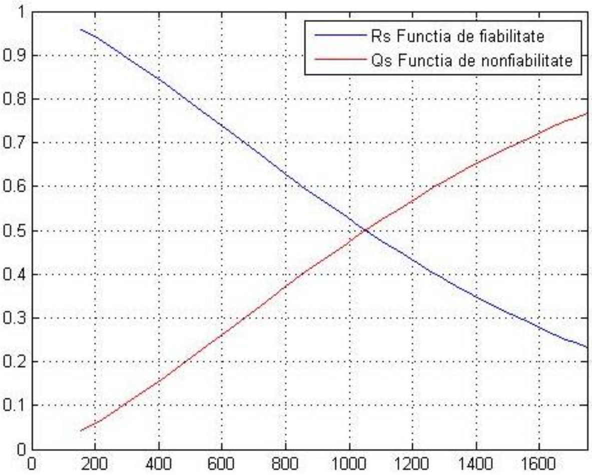

Fig. 5. The variance functions: reliability and nonreability for the technical system

3. CONCLUSION

Analysis of parameters of reliability of a technical virtual system, initially in the system as a whole and on the basis of the reliability of its functional units, aimed at developing a coherent and effective model of analysis for any technical/technological system, a model which can be made available to professionals working in the field of reliability.

By entering numerical data obtained through monitoring, real or virtual, preliminary data were calculated as Baron λw and β parameters of a Weibull reliability function using MATLAB programming environment.

Through the validation of the consistency between the experimental values and the Weibull distribution, experimental model [BARON], it can be concluded that the relationship (16) shapes with a good precision, reliability function of the system so you can use the maintenance based on reliability studies of it. For random variables listed in table 1, I get the graph of the function of reliability $R_N(t_i)$ and nonreability function $Q_s(t_i)$.

This stage is preliminary necessary step in applying the principles of Reliability Centered Maintenance (RCM) and ensemble works planning which runs periodically and prevention in order to ensure the continuity of the operation of technical systems through inspections, adjustments, measurements, tests, replacement of parts and sub-assemblies, other auxiliary papers etc.”

ACKNOWLEDGMEND This paper is supported by the Sectoral Operational Programme Human Resources Development POSDRU /159/1.5/S/ 137516 financed from the European Social Fund and by the Romanian Government.

4.REFERENCES

[1] Baron, T. ş.a. Calitate şi fiabilitate, Manual practic. Volumul 1 şi 2. Bucureşti, Editura Tehnică, 1988.

[2] Billinton R., Allan R. N. Reliability Evaluation of Engineering Systems. PLENUM PRESS, New York and London, 1990.

[3] Burlacu Eugen şi col. Introducere în studiul fiabilităţii sistemelor. Editura Ştiinţifică, Bucureşti, 1995.

[4] Isaic-Maniu Ah. Metoda WeibuiL, Aplicaţii. Editura Academiei RSR Bucureşti, 1983.

[5] Knezevic, J. Systems Maintainability Analysis, Engineering and Management. London: Chapman and Hall, 1997.

[6] Martinescu, I., Popescu, I. Analiza fiabilităţii şi securităţii sistemelor. Editura Universităţii „Transilvania” din Braşov, 2002.

[7] Ţîţu, M. Fiabilitate şi mentenanţă. Editura AGIR, 2008.

DETERMINAREA PRACTICĂ A PARAMETRILOR DE FIABILITATE ÎN CAZUL SISTEMELOR TEHNICE COMPLEXE

Rezumat: Determinarea şi analiza unor parametrii de fiabilitate în cazul unui sistem tehnic complex, format din mai multe unităţi funcţionale, privind iniţial sistemul ca un tot unitar şi în continuare pe baza fiabilităţii subsistemelor sale, are ca scop elaborarea unui model coerent şi eficient de analiză pentru orice sistem tehnic, model ce poate fi pus la dispoziţia specialiştilor ce activează în domeniul fiabilităţii, în ideea adoptării celei mai adecvate strategii de planificare şi acţiune. Pe baza unui model virtual al unui sistem tehnic complex, considerat ca şi un studiu de caz, lucrarea prezentă premisele teoretice şi dezvoltă metodologia pentru determinarea funcţiilor: fiabilitate şi non fiabilitate, având la baza datele obţinute în urma monitorizării sau anticipării parametrilor de fiabilitate a unor sisteme reale.

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