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MODELING THE DECISION FOR MENTENANCE EXECUTION ABOUT PARTIALLY WORN EQUIPMENT STILL IN OPERATIONAL SERVICE

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Abstract: This paper refers at power equipment with a high degree of wear. Analyzing how this facility has developed an operational period of 18 years, decision makers may propose maintaining or decommissioning of its operation. The case study, based on the Elmaghraby model, recommended for systems in final state operating and other statistical techniques, define the optimal solution.

1. Introduction

There are times when the operation of power equipment is the actual assembly or manufacturing inaccuracies and wear it does not match expected. In this case the decision should be made before reaching the replacement of life. This may affect the proper conduct of the machinery is involved because once served conducting facility maintenance interruptions, the duration of which may increase of weight or importance of that element in the system part. In this case, the decision on the application maintenance of a technical unit must be well substantiated and the results should lead to the maintenance facility functionality, cost and minimum risk.

2. Presentation of the mathematical model

Case study analysis is a cylinder subjected equipment belonging to the district heating system and currently is the 16th year of operation. Table 1 refers to the temporal evolution of the equipment outages occurred in the analyzed year while Table 2 presents the number of falls and their corresponding frequencies.

Tab.1 The evolution of outages

an	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI
r_i	0	1	0	0	1	2	1	1	3	1	2	1	2	3	4	2

Tab.2 Number of falls and their corresponding frequencies

k	1	2	3	4	5
r_k	0	1	2	3	≥ 4
f_k	3	6	4	2	1

In table 2 the notations used, have the following meanings:
r_k - the number of falls which correspond to the same frequency
f_k - often a number of falls

Referring to the fault-failure states, it is necessary to determine the number and frequency of emergency state, the nature of their distribution: once specified distribution function f = φ (r) can determine the probabilities of occurrence of states of unavailability. In this sense we will test the hypothesis of Poisson distribution of couples (r_k, f_k), such a distribution is characteristic of rare events. To check the nature of the job poissanieneevenimantelor distribution function will be used Pearson χ2 test. The calculation for the verification is shown in Table 3.

Tab. 3 Measures calculated for the applied model

k	r_k	f_k	$\bar{r}$	$r_k-\bar{r}$	$(r_k-\bar{r})^2$	$f_k(r_k-\bar{r})^2$	σ	Z_k	$\Phi(Z_k)$	p_k	n	$n\cdot p_k$	$(f_k-np_k)^2$	$\frac{(fk-np_k)^2}{n\cdot p_k}$
1	0	3	1,5	-1,5	2,25	6,75	1,12	-1,40	0,0810	0.0810	16	1,296	2,9036	2,2404
2	1	6		-0,5	0,25	1,50		-0,45	0,3265	0,2455		3,928	4,2932	1,0930
3	2	8		+0,5	0,25	1,00		+0,45	0,6735	0,3470		5,552	2,4087	0,4338
4	3	6		+1,5	2,25	4,50		+1,40	0,9190	0,2455		3,928	3,7172	0,9463
5	≥4	4		+2,5	6,25	6,25		+2,23	0,8875	0,0810		1,296	0,0876	0,0676
$\sum_i k$	*	16	*	*	*	20,00	*	*	*	1,0000	*	*	*	4,7811

The measures of this table have the following meanings:
r_k - falling number;
f_k - frequency falls - the average number of falls

The average number of falls could be calculated with relation:

$$\bar{r} = \frac{\sum_k r_k \cdot f_k}{\sum_k f_k}, \ k = \overline{1;5} \tag{1}$$

Figure 1 shows the frequency dependency graph according to their number falls.

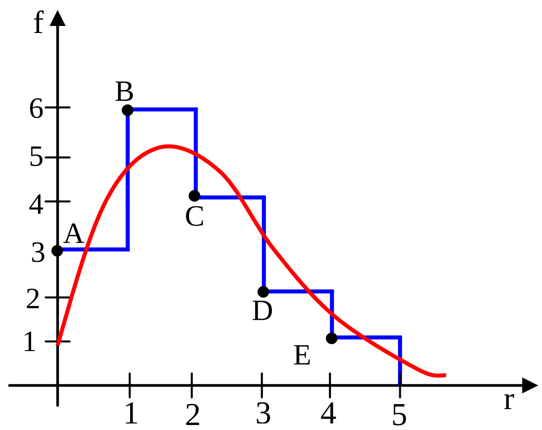

Figure 1. Dependency graph function of frequency dependence by their number falls. Points scored are couples (r_k-f_k) is defining the discrete grafcului function dependence with respect only those points (A, B, C, D, E).

σ - standard deviation is:

$$\sigma = \sqrt{\frac{\sum_k \left(r_k - \bar{r}\right)^2 f^k}{\sum_k f_k}} \tag{2}$$

Z_k - Laplace variable size:

$$Z_k = \frac{r_k - \bar{r}}{\sigma} \tag{3}$$

Φ (z) - Laplace function:

$$\varphi(z)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{+\infty} e^{\frac{z}{2}}dz \tag{4}$$

The values of this function are shown in Table 4.
p_k - r_k drop probability
Calculation of these probabilities are calculated as follows:

$$p_k = \Phi(Z_k) - \Phi(Z_{k-1}) \tag{5}$$

This relationship is not valid for the last chance to retain it is inferred by the difference between figure 1 and sum of the other. Other elements of calculation in the table are: n is the sum of the frequencies, the last column defines the amount of calculation quintile χ2c
For valodarea Poisson distribution assumption should be provided:

$$\chi_c^2 < \chi_{n;P}^2 \tag{6}$$

Where $\chi_{n;P}^2$ is quintile of the test.

Table 5 is based on the values of this quantum number n and the threshold frequency required plausibility, P.

$$P = 1 - \alpha \tag{6}$$

Where α is the coefficient of risk.

Follows: $\chi_c^2 = 4{,}7811 < \chi_{n=16;P=0{,}95}^2 = 7{,}96$

which means that the Poisson model assumption is confirmed.

Foundation for maintaining optimal strategy or disposal of tank based on the criterion of minimum total costs and the decision is defined by the inequality:

$$\Delta C(r^* - 1) \leq 0 \tag{7}$$

where: ΔC - expresses the amount of the costs - *financial units

$$\Delta C(r^* - 1) = A_1 - A_2 + A_3 \tag{8}$$

and r* is the optimal number of corrective interventions in which:

$$A_1 = (c_o + hT)[1 - p(r_k,\lambda T)] \tag{9}$$

$$A_2 = \frac{N(h+\pi)}{\lambda} p(N,\lambda T) \tag{10}$$

$$A_3 = \left[\frac{N(h+\pi)}{\lambda} - \pi T\right] \sum_k p(r_k, \lambda T) \qquad (11)$$

Tab. 4 Values of Laplace probability function Φ (z)

Nr ordine	P(x)0	(x)	P(x)	x	P(x)	x	P(x)	x	P(x)
-3,00	0,001	-1,18	0,119	-0,38	0,352	0,42	0,663	1,22	0,888
-2,90	0,002	-1,16	0,123	-0,36	0,359	0,44	0,670	1,24	0,892
-2,80	0,003	-1,14	0,127	-0,34	0,367	0,46	0,677	1,26	0,896
-2,70	0,004	-1,12	0,131	-0,32	0,374	0,48	0,684	1,28	0,900
-2,60	0,005	-1,10	0,136	-0,30	0,382	0,50	0,691	1,30	0,903
-2,50	0.006	-1,08	0,140	-0,28	0,390	0,52	0,698	1,32	0,907
-2,40	0,008	-1,06	0,145	-0,26	0,397	0,54	0,705	1,34	0,910
-2,30	0,011	-1,04	0,149	-0,24	0,405	0,56	0,712	1,36	0,913
-2,25	0,012	-1,02	0,154	-0,22	0,413	0,58	0,719	1,38	0,916
-2,20	0,014	-1,00	0,159	-0,20	0,421	0,60	0,726	1,40	0,919
-2,15	0,016	-0,98	0,164	-0,18	0,429	0,62	0,732	1,42	0,922
-2,10	0,018	-0,96	0,169	-0,16	0,436	0,64	0,739	1,44	0,925
-2,05	0,020	-0,94	0,174	-0,14	0,444	0,66	0,745	1,46	0,928
-2,00	0,023	-0,92	0,179	-0,12	0,452	0,68	0,752	1,48	0,930
-1,95	0,026	-0,90	0,184	-0,10	0,460	0,70	0,758	1,50	0,933
-1,90	0,029	-0,88	0,189	-0,08	0,468	0,72	0,764	1,54	0,938
-1,85	0,032	-0,86	0,195	-0,06	0,476	0,74	0,770	1,58	0,943
-1,80	0,036	-0,84	0,200	-0,04	0,484	0,76	0,776	1,62	0,947
-1,75	0,040	-0,82	0,206	-0,02	0,492	0,78	0,782	1,66	0,952
-1,70	0,045	-0,80	0,212	**0**	**0,500**	0,80	0,788	1,70	0,955
-1,66	0,048	-0,78	0,218	0,02	0,508	0,82	0,794	1,75	0,960
-1,62	0,053	-0,76	0,224	0,04	0,516	0,84	0,800	1,80	0,964
-1,58	0,057	-0,74	0,230	0,06	0,524	0,86	0,805	1,85	0,968
-1,54	0,062	-0,72	0,236	0,08	0,532	0,88	0,811	1,90	0,971
-1,50	0,067	-0,70	0,242	0,10	0,540	0,90	0,816	1,95	0,974
-1,48	0,069	-0,68	0,248	0,12	0,548	0,92	0,821	2,00	0,977
-1,46	0,072	-0,66	0,255	0,14	0,556	0,94	0,826	2,05	0,980
-1,44	0,075	-0,64	0,261	0,16	0,564	0,96	0,831	2,10	0,982
-1,42	0,078	-0,62	0,268	0,18	0,571	0,98	0,836	2,15	0,984
-1,40	0,081	-0,60	0,274	0,20	0,579	1,00	0,841	2,20	0,986
-1,38	0,084	-0,58	0,281	0,22	0,587	1,02	0,846	2,25	0,988
-1,36	0,087	-0,56	0,288	0,24	0,595	1,04	0,851	2,30	0,989
-1,34	0,109	-0,54	0,295	0,26	0,603	1,06	0,855	2,40	0,992
-1,32	0,093	-0,52	0,302	0,28	0,610	1,08	0,860	2,50	0,994
-1,30	0,097	-0,50	0,309	0,30	0,618	1,10	0,864	2,60	0,995
-1,28	0,100	-0,48	0,316	0,32	0,626	1,12	0,869	2,70	0,997
-1,26	0,104	-0,46	0,323	0,34	0,633	1,44	0,873	2,80	0,997
-1,24	0,107	-0,44	0,330	0,36	0,641	1,16	0,877	2,90	0,998
-1,22	0,111	-0,42	0,337	0,38	0,648	1,18	0,881	3,00	0,999
-1,20	0,115	-0,40	0,345	0,40	0,655	1,20	0,885		

In the previous relations for calculating the significance of quantities is as follows:
c_0 - the cost of storage equipment. In this case, is considered null.
h - the amount of amortization, potential investment to replace worn equipment;

π - λ boiler damage due to malfunction - the average number of failures, $\lambda = \bar{r}$
T - time-keeping operation likely, T = 1 year
N - number of possible failures during period T
p (r_k) - the probability of occurrence of a particularnumber of failures in time T; calculating the quantities according to the Poisson model is expressed by:

$$p(r_k) = \frac{\lambda^{r_k} \cdot e^{-\lambda}}{r_k!} \tag{12}$$

And the recurrence relation is:

$$p(r_k+1) = \frac{\lambda}{k+1} p(r_k) \tag{13}$$

Tab.5 Quintile values considered in relation to the number of frequencies N and required threshold of plausibility, P

n \ p	P = 0,99	P = 0,95	P = 0,90	P = 0,10	P = 0,05	P = 0,01
1	≈ 0	≈ 0	0,01	2,70	3,84	6,63
2	0,02	0,10	0,21	4,60	5,99	9,21
3	0,11	0,35	0,58	6,25	7,81	11,3
4	0,29	0,71	1,06	7,77	9,48	13,2
5	0,55	1,14	1,61	9,23	11,0	15,0
6	0,87	1,63	2,20	10,6	12,5	16,8
7	1,23	2,16	2,83	12,0	14,0	18,4
8	1,64	2,73	3,49	13,3	15,5	20,0
9	2,08	3,32	4,16	14,6	16,9	21,6
10	2,55	3,94	4,86	15,9	18,3	23,2
11	3,05	4,57	5,57	17,2	19,6	24,7
12	3,57	5,22	6,30	18,5	21,0	26,2
13	4,1	5,89	7,04	19,8	22,3	27,6
14	4,66	6,57	7,79	21,0	23,6	29,1
15	5,22	7,26	8,54	22,3	24,9	30,5
16	5,81	7,96	9,31	23,5	26,2	32,0
17	6,4	8,67	10,0	24,7	27,5	33,4
18	7,01	9,39	10,8	25,9	28,8	34,8
19	7,63	10,1	11,6	27,2	30,1	36,1
20	8,26	10,8	12,4	28,4	31,4	37,5
21	8,89	11,5	13,2	29,6	32,6	38,9
22	9,54	12,3	14,0	30,8	33,9	40,2
23	10,1	13,0	14,8	32,0	35,1	41,6
24	10,8	13,8	15,6	33,1	36,4	42,9
25	11,5	14,6	16,4	34,3	37,6	44,3
26	12,1	15,3	17,2	35,5	38,8	45,6
27	12,8	16,1	18,1	36,7	40,1	46,9
28	13,5	16,9	18,9	37,9	41,3	48,2
29	14,2	17,7	19,7	39,0	42,5	49,5
30	14,9	18,4	20,5	40,2	43,7	50,8

It considers the following calculation:
h = 200q and 100q;
π = 500q
T = 1 an;

$\lambda \bar{r} \Rightarrow \lambda=1,5$

Probability values p (r_k) is determined according to relation (12) and presented in Table 6 and the optimal solution is given by equation (7) is inferred iteratively in the same table.

It finds that:

a). In variant purchase costs, h = 200q should be retained for another year running the heater, if this time occurs later than a fall. When the machine crashes twice in this case momunetul last fall to coincide with the decommissioning.

b). In variant purchase costs, h = 100q, will keep running if the equipment within a year was not damaged, or if the number falls is r ≤ 2. Otherwise, the next damage, Bolier will be out of service.

Tab. 6 Probability values calculated in two ways

i	A_i	r_k	A_{ik}	h	
				Varianta a)	Varianta b)
				200q	100q
1	A_1	0	A_{10}	0	0q
		1	A_{11}	45q	22q
		2	A_{12}	112q	56q
		3	A_{13}	162q	81q
		≥ 4	A_{14}	200q	100q
2	A_2	0	A_{20}	0q	0q
		1	A_{21}	156q	134q
		2	A_{22}	234q	201q
		3	A_{23}	176q	151q
		≥ 4	A_{24}	123q	105q
3	A_3	0	A_{30}	-500q	-500q
		1	A_{31}	-269q	-78q
		2	A_{32}	+192q	+133q
		3	A_{33}	+172q	+134q
		≥ 4	A_{34}	+90q	+72q
ΔC(r*-1)		0	ΔC(0-1)	- 500q	- 500q
		1	ΔC(1-1)	- 137q	- 190q
		2	ΔC(2-1)	+ 70q	-12q
		3	ΔC(3-1)	+ 158q	+ 64q
		≥ 4	ΔC(4-1)	+ 167q	+ 67q

3. Conclusions

Maintaining the service of power equipment that has a high attrition level is required only if based on a justifiable economic support. Operation of heating structure having a single heat exchanger and it having a poor operational potential, is a major problem for the decider. So the best strategy approach becomes obvious. This problem required in such cases need redundancy present in such large utility installations.

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