THE MAINTENANCE STUDY OF COAL LOADING MACHINE FROM TURCENI POWER STATION'S COALYARD

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Abstract: This paper aims at studying the maintenance of machine type T2052 used for taking the coal in Turceni power station's coalyard. After a brief presentation of the machine construction is analysed its functionality, by highlighting the frequency of continuously failures, the sub-assemblies which go to accidental down-time through failure. Analysis shows that the superstructure's rotating system is most commonly exposed to damage. The maintenance study of this system shows that it is necessary to adopt preventive-maintenance strategy planned in order to avoid the occurrence of defects.
Cuvinte cheie: coalyard, loading machine, failure, rotating system, maintenance function, service intensity, preventive maintenance

1. Introduction

After unloading the railway wagons, inside the power station, the coal (lignite) is taken over by six loading machines with short arm, type T 2052, and delivered to the coalyards, either directly for use in thermal power station.

Figure 1 shows the overall solution of the T 2052 type loading machine, whence result the main parts of it.

The meaning of the numbers shown in the picture is: 1 - displacement gear from the railway ; 2 - rotation gear of the upper side with bucket wheel towards the groundwork; 3 - lever arm for rotor and conveyer; 4 - bucket wheel for loading the coal; 5 - belt conveyer from the arm where the bucket wheel put the coal on and which transport and discharge the coal on the high capacity belt from the discharging front; 6 - metallic tower 7 - arm lift mechanism made by pulley, cables and sheaves; 8 - reverse arm for balancing the ballast box; 9 - electrical equipment of force and command.

The loading machine has the processing capacity of 1200 t/h.

2. Action of loading machine during exploitation

Analyses of loading machine's action has been made by using the information recorded in an year by watching ten machines of this kind in operation to Turceni coalyards.

This information are shown in table 1 and 2, figures 2-9, where are highlighted the numbers of failures, their causes and time of parking, which is actually the time used for repair.

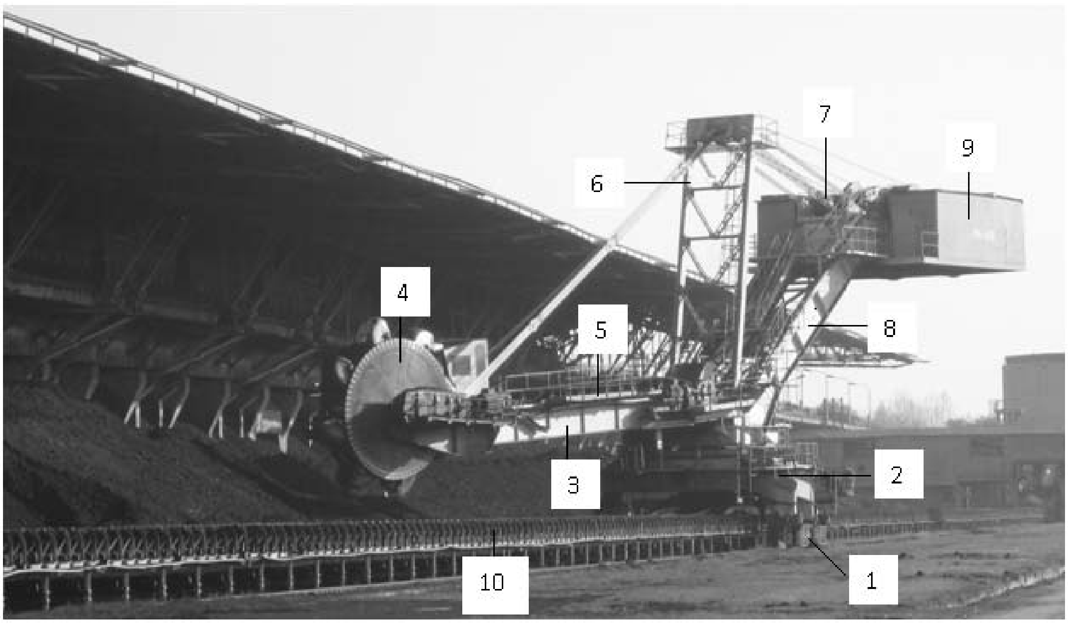

Fig. 1 *Overall view of loading machine T 2052 type used for loading the coal from power station's discharge front*

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Table 1. *Failures and time of parking for loading machines type T 2052*

No..	*Loading machine*	*Number of failures*		*Time or repair*	
		item	*% from total*	*hours*	*% from total*
1	Mp 1A	3	7,50	5	2,63
2	Mp 1B	6	15,00	35	18,42
3	Mp 2A	4	10,00	11	5,79
4	Mp 2B	9	22,50	46	24,21
5	Mp 4B	3	7,50	14	7,37
6	Mp 5A	6	15,00	47	24,74
7	Mp 10A	1	2,50	4	2,11
8	Mp 10B	2	5,00	7	3,68
9	Mp 26A	3	7,50	9	4,74
10	Mp 26 B	3	7,50	12	6,32
TOTAL		**40**		**190**	

Table 2. *Failures and time for repair ordered on subassembly*

No..	*Faulty subassembly*	*Number of failures*		*Time for repair*	
		item	*% from total*	*hours*	*% from total*
1	Rotating system (actuator set, mainly the conical-cylindric decelerator, crown gear, assembler clutches)	17	42,50	83	43,68
2	Belt conveyer (vulcanization, belt joint, mat replacement, idler, fluid coupling)	8	20,00	58	30,53
3	Displacement system on railway (electrical engine, bogie)	9	22,50	32	16,84
4	Bucket wheel (electrical engine, decelerator, fluid coupling)	3	7,50	14	7,37
5	Lighting	3	7,50	3	1,58
TOTAL		**40**		**190**	

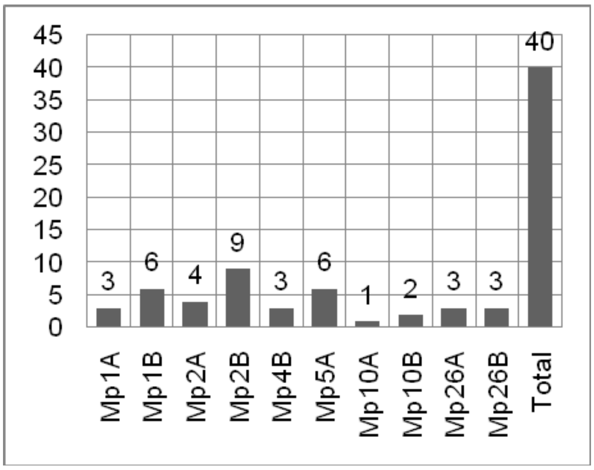

Fig. 2 *Order of failures for loading machines*

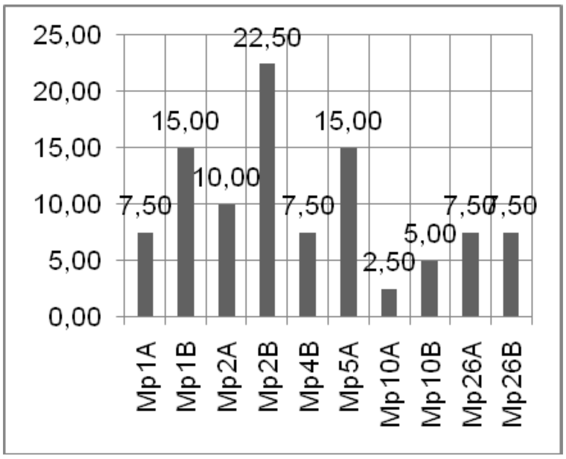

Fig. 3 *Order of percentage for loading machines*

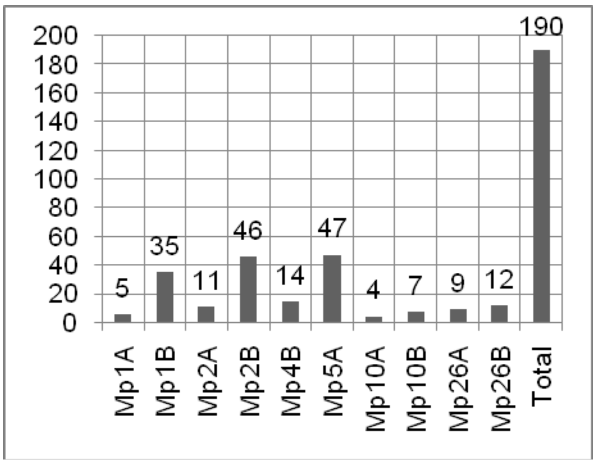

Fig. 4 *Order of repairing time for loading machines*

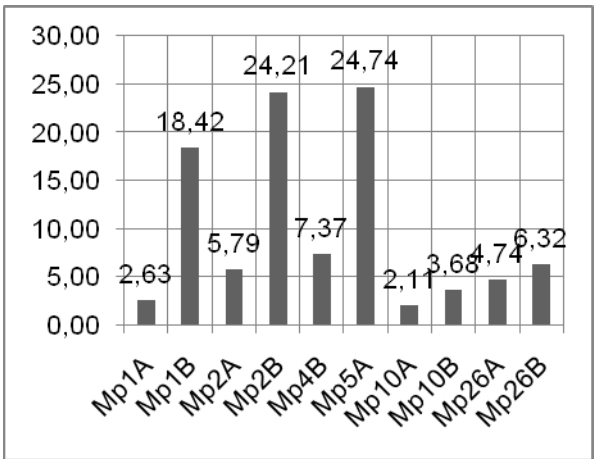

Fig. 5 *Order of percentage for repairing time needed for loading machines*

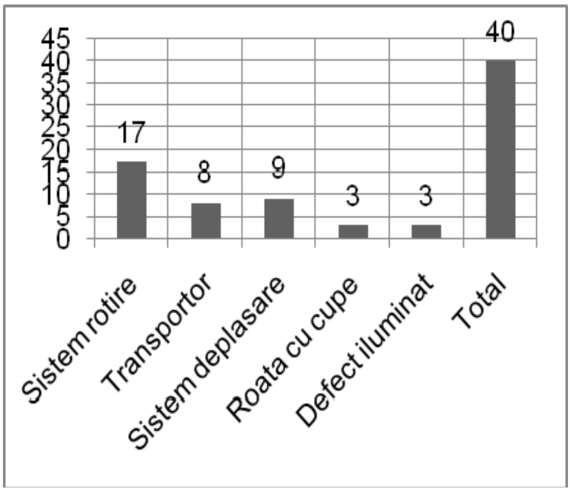

Fig. 6 *Order of failure for subassembly*

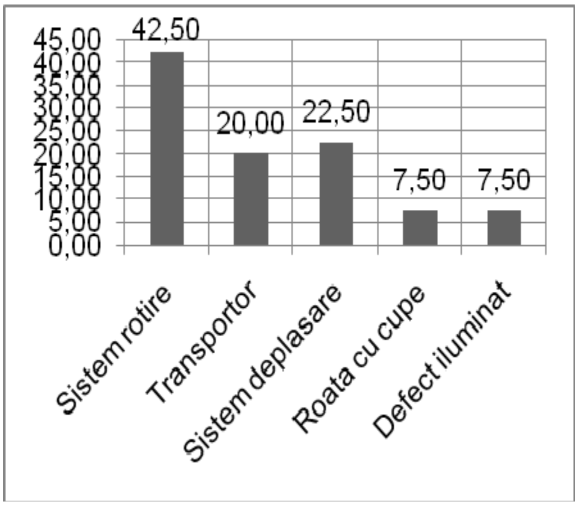

Fig. 7 *Order of percentage for failure for subassembly*

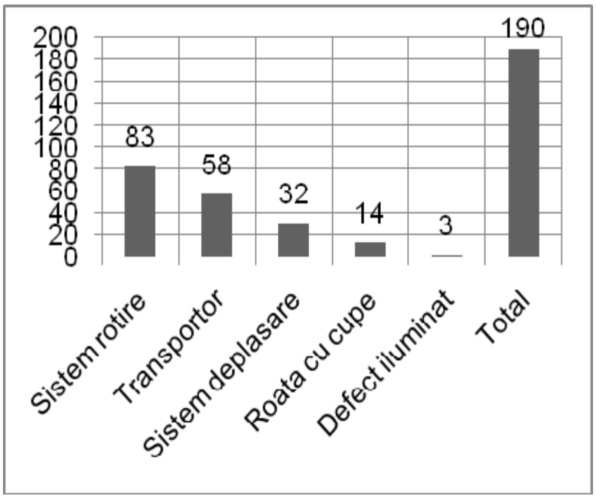

Fig. 8 *Order of repairing time for subassembly*

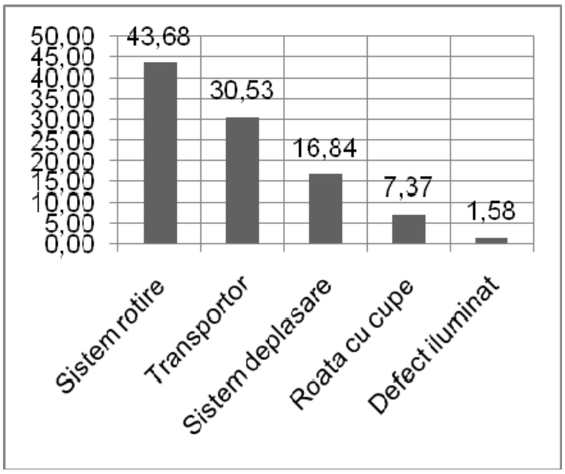

Fig. 9 *Order of percentage for repairing*

One observation is that the loading machines type Mp1B, Mp2B and Mp5A have the most often failures, getting to a number of over 52% from the totally failures and about 67% for repairing time.

The presented histograms shown that the rotating system is the most affected subassembly by failure, as a number of failures, 42,5% from totally, and as a number of time repairing, 44%, that's why this item will be studied more careful.

After this, there is a number of failures to the displacement system; the main failure is on electrical engine, 22,5 % and belt conveyers from the loading arm, 20%. The repairing time is very long and has a very high percentage, 30,5%. For the displacement system, the percentage is 17%, because of the time needed for vulcanization.

3. The maintenance study of rotating system

The maintenance study of rotating system has as a cornerstone the statistical series made by n=17 values which represent the time, in *hours*, of repairing the rotating system, after the accidental failure. The statistical series is made by the following values: 2; 2; 3; 3; 3; 4; 4; 4; 4; 4; 4; 4; 4; 6; 8; 8; 16, being a (S2) serial type, where a part of values are being repeated.

The probability distribution of this serial, which represent the empirical maintenance function which characterize the functionality of rotating system, results from the reckoning shown in table 3.

The literature shows that maintainability of electromechanical systems is best characterized, generally, by the laws of a negative exponential distribution, normal, lognormal or Weibull.

The choice of the distribution law is made on the basis of a test between empirical (experimental) distribution and the theoretical one, from which, the Kolmogorov-Smirnov and χ^2 (square hi) are the most used. The specific maintenance parameters for distribution laws are determined by punctually estimation methods, from which, the most used are: maximum likelihood method, method of least squares, method of moments and linearization method.

By applying these specific reliable techniques of statistical series which characterize the rotation system's maintainability has come to the conclusion that the dual parametric distribution law of Weibull is the best, for which parameters were calculated by the method of least squares; validating the model with the Kolmogorov-Smirnov general test.

Table 3. *The reckon of empirical maintenance function*

No.	*Values of repairing time,* t_r *, h*	*Absolute abundance,* n_i	*Relative abundance,* f_i	*The empirical maintenance function (order),* $\hat{M}(t_r)$
1	2	2	0,117647	0,117647
2	3	3	0,176471	0,294118
3	4	8	0,470588	0,764706
4	6	1	0,058824	0,823529
5	8	2	0,117647	0,941176
6	16	1	0,058824	1,000000

The values of Weibull's dual parametric distribution parameters are calculated with:
- the shape parameter, β,

$$\beta = \frac{n\left[\sum_{i=1}^{n} ln\ ln \frac{1}{1-\hat{M}(t_i)} ln\ t_{ri}\right] - \left[\sum_{i=1}^{n} ln\ ln \frac{1}{1-\hat{M}(t_{ri})}\right]\left(\sum_{i=1}^{n} ln\ t_{ri}\right)}{n\left[\sum_{i=1}^{n}(ln\ t_{ri})^2\right] - \left(\sum_{i=1}^{n} ln\ t_{ri}\right)^2}, \quad (1)$$

- the λ parameter,

$$\lambda = exp\left\{\frac{\left[\sum_{i=1}^{n} ln\ ln \frac{1}{1-\hat{M}(t_{ri})}\right]\left[\sum_{i=1}^{n}(ln\ t_{ri})^2\right] - \left(\sum_{i=1}^{n} ln\ t_{ri}\right)\left[\sum_{i=1}^{n} ln\ ln \frac{1}{1-\hat{M}(t_i)} ln\ t_i\right]}{n\left[\sum_{i=1}^{n}(ln\ t_{ri})^2\right] - \left(\sum_{i=1}^{n} ln\ t_{ri}\right)^2}\right\}. \quad (2)$$

- the real scale parameter, η,

$$\eta = \frac{1}{\lambda^{\frac{1}{\beta}}}. \quad (3)$$

The results of this method application are shown in table 4.

Table 4. *The calculation elements specific for rated Weibull dual parametric distribution parameter using the method of least squares and checking its accuracy*

i	t_{ri}, h	$ln\ t_{ri}$	$(ln\, t_{ri})^2$	$ln\, ln \frac{1}{1-\hat{M}(t_{ri})} \cdot ln\, t_{ri}$	$ln\, ln \frac{1}{1-\hat{M}(t_{ri})}$	$M(t_{ri})$	$\lvert M(t_{ri}) - \hat{M}(t_{ri})\rvert$	$\lvert M(t_{ri}) - \hat{M}(t_{i-1})\rvert$
1	2	0,693147	0,480453	-1,440455	-2,078137	0,256122	0,138475	0,256122
2	3	1,098612	1,206949	-1,158675	-1,054672	0,368145	0,074027	0,250498
3	4	1,386294	1,921812	0,512148	0,369436	0,465810	0,298896	0,171693
4	6	1,791759	3,210402	0,986861	0,550777	0,622008	0,201521	0,142698
5	8	2,079442	4,324077	2,165554	1,041412	0,735180	0,205996	0,088349
6	16	2,772589	7,687248	0,000000	0,000000	0,940137	0,059863	0,001039
		$\sum_{i=1}^{6} ln\, t_{ri} =$ =9,821844	$\sum_{i=1}^{6}(ln\, t_{ri})^2 =$ =18,830941	$\sum_{i=1}^{6} ln\, ln \frac{1}{1-\hat{M}(t_{ri})} \cdot ln\, t_{ri} = 1,065432$	$\sum_{i=1}^{6} lnln \frac{1}{1-\hat{M}(t_{ri})}$ =-1,171184		D_{max}= **0,298896**	0,256122
		$\left(\sum_{i=1}^{6} ln\, t_{ri}\right)^2 =$ =96,468611						
$\boldsymbol{D_{max}}$ **= 0,298896 <** $\boldsymbol{D_{0,05\,,\,17}}$ **= 0,317963** Kolmogorov-Smirnov test								
Shape parameter, $\boldsymbol{\beta}$ **= 1,083474** Relația (1)								
$\boldsymbol{\lambda}$ **parameter = 0,139622** Relația (2)								
Real scale parameter, $\boldsymbol{\eta}$ **= 6,154187** ***h*** Relația (3)								

The main maintenance indicators expressed by Weibull's dual parametric distribution law are shown in table 5.

Table 5. *Calculation formula of indicators expressed by rated Weibull's dual parametric distribution law*

Nr. crt.	*Parameter*	*Symbol*	*Formula*	*Observation*	*M.U.*
1	Maintenance function	$M(t_r)$	$M(t_r)=1-e^{-\left(\frac{t_r}{\eta}\right)^{\beta}}$, (4)	t_r – fluctuation of repairing time, *h*; β – shape parameter; η – real scale parameter, *h*	%
2	Function of probability density of repairing time	$f(t_r)$	$f(t_r)=\frac{\beta}{\eta}\left(\frac{t_r}{\eta}\right)^{\beta-1} e^{-\left(\frac{t_r}{\eta}\right)^{\beta}}$, (5)		1/*h*
3	Function of intensity or repairing rate	$z(t_r)$	$z(t_r)=\frac{\beta}{\eta}\left(\frac{t_r}{\eta}\right)^{\beta-1}$, (6)		1/*h*
4	Average of repairing time	*MTR*	$MTR=\eta\,\Gamma\left(\frac{1}{\beta}+1\right)$, (7)	Γ - Gamma function or Euler's integral, type two, $\Gamma(p)=\int_0^{\infty} x^{p-1} e^{-x} dx$, $p>0$,	*h*
5	Median time of corrective maintenance	*TMMC*	$TMMC=\eta\left(-\ln 0{,}5\right)^{1/\beta}$, (8)		*h*
6	Maximum time of corrective maintenance for a 90% probability	$T_{max}90$	$T_{max}90=\eta\left(-\ln 0{,}1\right)^{1/\beta}$, (9)		*h*
7	Maximum time of corrective maintenance for a 95% probability	$T_{max}95$	$T_{max}95=\eta\left(-\ln 0{,}05\right)^{1/\beta}$, (10)		*h*

In figures 10, 11 and 12 there are shown the main indicators which characterized the maintenance of rotating system of loading machines from Turceni power station coalyards.

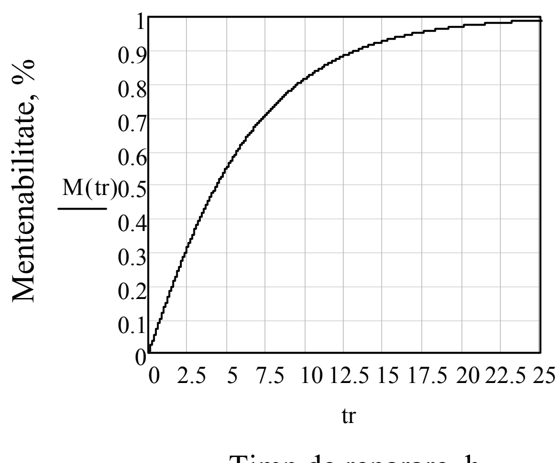

Fig. 10 *Maintenance function curve*

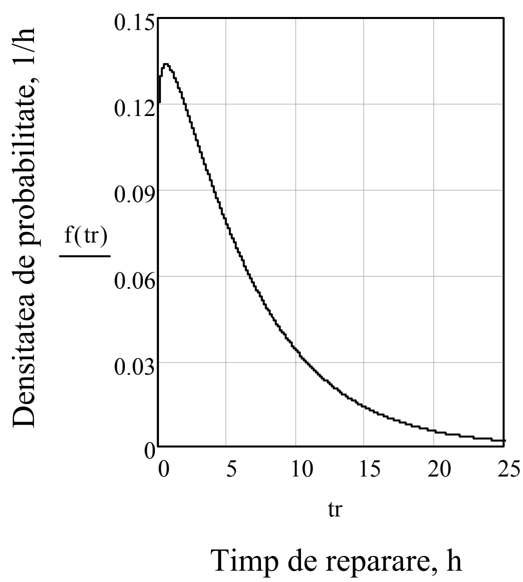

Fig. 11 *Time repairing probability density curve*

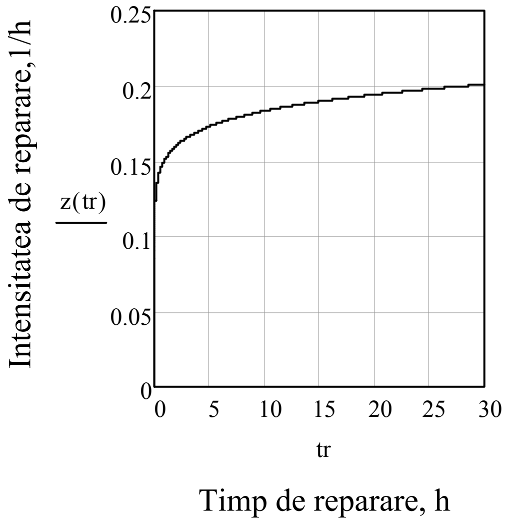

Fig. 12 *Intensity curve or repairing rate*

Average time for repair *MTR* = 6 *hours*, and median time of corrective maintenance *TMMC* = 4,4 *hours.* Maximum time of corrective maintenance, for a 90% probability is $T_{max}90 = 13$ *hours*, and for 95% probability, $T_{max}95 = 17$ *hours.* From the figures shown above, the probability for rotation system of getting back to work in 4,4 *hours* is only 50%. For a 80% probability, the repairing time goes up to 10 *hours*, big values, considering the machinery's construction.

It can also be seen a very low fluctuation of repairing intensity, (0,15...0,20) *repair*/*hours*, the values of this parameter is very low as well, but its relative constancy is explained by the uniformity of operating teams, in terms of promptness action, facility with tools and spare parts, with action machineries and not at last their experience.

The higher values of corrective maintenance time owe to the ineffectual management of maintaining activity. This statement is based on the argument that the adopted maintenance strategy for the rotation system, and for the whole machinery is for the corrective maintenance, based on repairing actions for unexpected failures, for getting back the product to its best quality. For this action, the main goal is to get off the unexpected failures.

Obviously, such corrective maintenance actions have:
- insurance of the specialized personnel, when the failure appear;
- failure diagnosis, finding the nature and the cause of the failure;
- locating the failure;
- ensuring the spares, tools, consumables and other things for repair;
- repairing the failure by complete or partially replacing of a part or many elements or subassembly which were the cause of failure;
- checking the maintenance operations.

Each of these elements represent a substantial time of inefficiency.

There is one way to reduce the time used for repairing the failures, respectively the time for parking, by embracement a preventive-scheduled maintenance strategy, used for having checked the vulnerable elements and operate to the weak observed points, which mean to reconsider or embracement a new maintenance strategy.

4. Conclusions

The study on the loading machine from coalyards show a long list of failures, mainly to the rotation system, which confirm the low reliability of this machinery and impose to reconsider the functional and design solutions.

The corrective maintenance system applied is totally impropriate, being necessary to embracement the preventive-scheduled system for maintenance and repair.

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3. *** * ***
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