RESEARCHES ON WEAR AND RELIABILITY OF SOME SUBASSEMBLIES AND SPARE PARTS OF TECHNOLOGICAL EQUIPMENT

VLAD ALEXANDRU FLOREA[1]

Abstract: Any source of light from an airport area which is situated above the level of the runway must have a breaking section, which should give in the case of a collision with an airplane or any other vehicle. This breaking section is assured by a frangible coupling, which is an replacable part in the construction of the support. In this paper, we present the constructive solution of a frangible aluminum coupling, which must offer a breaking section at a height of maximum 38 millimeters above the level of the runway, for a height of the signal light of maximum 360 mm. The breaking section of the frangible coupling must resist at the air speeds behind a large plane, speeds that can go up to 480 km/h, and give in at a bending moment which is between 204 and 678 J. This frangible coupling was made by the firm ElectroMax Petroșani and was tested in the Strength of materials laboratory from the University of Petroșani.

Key words: frangible support, signal light, panel, airport.

1. INTRODUCTION

The complex friction-wear phenomenon of the technological equipment subassemblies is a research objective for determining wear capacity of other materials on them, such as the dislocated, transported or processed sterile rocks as well as determining their reliability. Mining shearers, coal screens in preparation, excavators and loaders in quarries, operate under sterile rocks, coal etc. conditions is subject to abrasive wear and change in reliability

Vibrating screens type SCC III from preparations, which take up the coal to achieve removal of material particles less than 0.8 mm, have a number of subassemblies, such as screening surfaces (fig. 1), the troughs, the loading funnel and the basic support of the screen, subjected to excessive wear.

---

[1] *Lecturer, Eng. Ph.D., University of Petroşani, VladFlorea@upet.ro*

The difference in behavior between different subassemblies of the same machine can be appreciated only after a reliability analysis, because if you take example of the screen, it found that while screening surface has a reliability of 4.8 %, after 100 hours, the trough has a reliability of 31.3 %, for the same useful life.

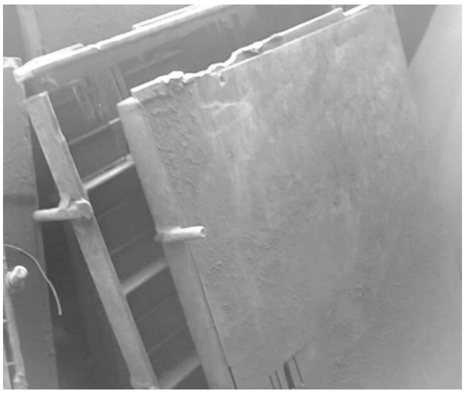

Fig.1. Worn screening surface

Fig. 2. Worn shearer tools CMR 4

Rocks cutting and dislocation tools (fig. 2) are reinforced with hard alloy inserts which ensure hardness, modulus of elasticity and thermal heat transfer.

The variation of the specific wear Ψ_A of the tools, depending on rocks abrasion (fig. 3) experimentally established, can determine the degree of wear of the tools, over time, depending on this property. This is important because it has been found that the value of the tools for cutting and dislocation the rocks sometimes represents 14 % of the production costs. Alongside the shearer tools, the excavator teeth can be exemplified (fig. 4) that supporting significant wear and cause, the same measure and for the same reasons, the negative economic effects.

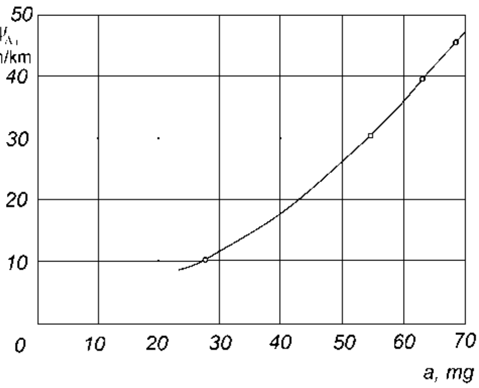

Fig. 3. Variation of the specific wear of the shearer tools depending on rocks abrasion

Fig. 4. Worn excavator teeth

Knowing reliability and practical aspects of these problems refers to the establishment of the theoretical distribution laws that can shape the mechanical phenomena of failure, including wear, and to the ways to improve the behaviour in time of different subassemblies of the technological equipment.

2. RELIABILITY ANALYSIS OF SUBASSEMBLIES „TROUGH” OF THE SCREEN TYPE SCC III

Experimental data used in the analysis:

- T_f, time between failures (table 1) for n=26 events (in increasing order);
- T_{rem}, time to repair of trough (also in increasing order).

Based on data from table 1, the mean value of operation times, calculated between failures is:

$$M\left[t\right]=\sum_{i=1}^{k}t_i\cdot f\left(t_i\right)=59,53+49,61+33,06+36,33=178,53\quad\text{[hours]}\qquad(1)$$

And the value of mean time to repair is:

$$MTR=\frac{\sum_{i=1}^{26}T_{rem}}{n}=\frac{1730}{26}=66,54\quad\text{[min]}\qquad(2)$$

Table 1 **Values of time between failures and time to repair of trough**

T_f [hours]	7	7	14	14	21	49	56	56	56	63
	63	70	91	112	112	133	154	154	175	203
	224	231	287	462	511	987				
T_{rem} [minute]	20	30	45	50	50	50	50	50	60	60
	70	70	70	70	70	70	70	80	80	80
	80	80	90	90	90	105				

The time interval Δt needed to determine the relative frequency $f(t_i)$ is calculated with the Sturges relationship:

$$\Delta t=\frac{t_{\max}-t_{\min}}{1+3,322\cdot\lg n}=\frac{987-7}{1+3,322\cdot\lg 26}=171,9\ \text{[hours]}\qquad(3)$$

where, t_{max} and t_{min} are the maximum and minimum limits of operating times and n represents the number of events

Is chosen Δt =172 [hours], resulting K=6 time intervals.

For the exponential distribution law the failures rate is

$$\lambda=\frac{1}{M\left[t\right]}=\frac{1}{178,53}=0,005601\ \text{[hours]}\qquad(4)$$

Using the obtained data, the relative frequencies $f(t_i)$, cumulative frequencies $F_c(t_i)$ and functions $F(t_i)$ can be determined (table2).

Table 2 **Exponential distribution function and the distance "d" for trough**

Nr. int.	Interval size Δt	Average value t_i	Number of failures n_i	Relative frequency $f(t_i)$	Cumulative Frequency $F_c(t_i)$	Distribution Function $F(t_i)$	d
1	0÷172	86	18	0,6923	0,6923	0,3822	0,31
2	172÷344	258	5	0,1923	0,8846	0,7643	0,12
3	344÷516	430	2	0,0769	0,9615	0,91	0,052
4	516÷688	602	-	-	0,9615	0,9657	0,004
5	688÷860	774	-	-	0,9615	0,9869	0,025
6	860÷1032	946	1	0,0384	0,9999	0,995	0,005
			n=26				

The validity of the exponential distribution law is tested:

$$F\left(t_i\right) = 1 - e^{-\lambda C t_i} \tag{5}$$

The value of the distribution function obtained (table 2) allows the calculation of the distance "*d*" between the theoretical and experimental distribution function. It is found that this law does not validate, according to the Kolmogorov concordance test, because:

$$d_{\max} = 0{,}31 > \frac{1{,}36}{\sqrt{n}} = \frac{1{,}36}{\sqrt{26}} = 0{,}2667 \tag{6}$$

It is necessary to choose another law, for example the Weibull distribution law. The values of the Weibull distribution function, presented in table 3, correspond to the parameters calculated using the relations:

$$\begin{aligned} a_1 &= \frac{\sum_{i=1}^{k} \ln t_i \cdot \sum_{i=1}^{k} Y_i \cdot \ln t_i - \sum_{i=1}^{k} Y_i \cdot \sum_{i=1}^{k} \ln^2 t_i}{\sum_{i=1}^{k} \ln t_i^2 - k \cdot \sum_{i=1}^{k} \ln^2 t_i} = \\ &= \frac{35{,}972 \cdot 42{,}764 - 6{,}693 \cdot 219{,}604}{35{,}972^2 - 6 \cdot 219{,}604} = -2{,}8976 \end{aligned} \tag{7}$$

where:

$$Y_i = \ln \ln \frac{1}{1 - F_c\left(t_i\right)} \tag{8}$$

Result:

$$\lambda = e^{a_1} = e^{-2{,}8976} = 0{,}05557 \tag{9}$$

$$a_2 = \frac{\sum_{i=1}^{k} \ln t_i \cdot \sum_{i=1}^{k} Y_i - k \cdot \sum_{i=1}^{k} Y_i \cdot \ln t_i}{\sum_{i=1}^{k} \ln t_i^2 - k \cdot \sum_{i=1}^{k} \ln^2 t_i} = \\ = \frac{35,972 \cdot 6,693 - 6 \cdot 42,764}{35,972^2 - 6 \cdot 219,604} = 0,6694 \quad (10)$$

$$\beta = a_2 = 0,6694 \quad (11)$$

The mean time between failures (MTBF) result from the relation:

$$MTBF = \frac{\Gamma(1/\beta + 1)}{\lambda^{1/\beta}} = \frac{1,344}{0,05557^{1/0,6694}} = 107,2 \text{ [hours]} \quad (12)$$

It is found that the Weibull distribution law is validated according to the Kolmogorov concordance test because:

$$d_{\max} = 0,11 < \frac{1,36}{\sqrt{n}} = \frac{1,36}{\sqrt{26}} = 0,2667 \quad (13)$$

In the case of Weibull biparametric model the expression of reliability is:

$$\mathrm{R}\left(\mathrm{t_i}\right) = \mathrm{e}^{-\lambda \cdot \mathrm{t_i^\beta}} \quad (14)$$

Table 3 **Values of the Weibull distribution function and the distance "d" for trough**

Nr. int.	Average value t_i	Cumulative frequency $F_c(t_i)$	Y_i	$\ln t_i$	$\ln^2 t_i$	$Y_i \ln t_i$	Distribution function $F(t_i)$	d
1.	86	0,6923	0,164	4,454	19,841	0,730	0,650	0,08
2.	258	0,8846	0,769	5,552	30,835	4,269	0,885	0,11
3.	430	0,9615	1,180	6,063	36,769	7,154	0,952	0,009
4.	602	0,9615	1,180	6,400	40,963	7,552	0,977	0,016
5.	774	0,9615	1,180	6,651	44,243	7,848	0,988	0,027
6.	946	0,9999	2,220	6,852	46,953	15,211	0,994	0,059
$\sum$			6,693	35,972	219,604	42,764		

The reliability values for the Weibull distribution, for different operating times, of the trough subassembly are shown in table 4 and represented in figure 5.

Table 4 **Reliability variation depending on the time for trough subassembly**

***t* [hours]**	50	100	150	200	250	300	350
***R(t)* [%]**	0,479	0,313	0,219	0,159	0,119	0,090	0,070
***t* [hours]**	400	500	600	700	800	900	1000
***R(t)* [%]**	0,055	0,034	0,022	0,015	0,010	0,007	0,004

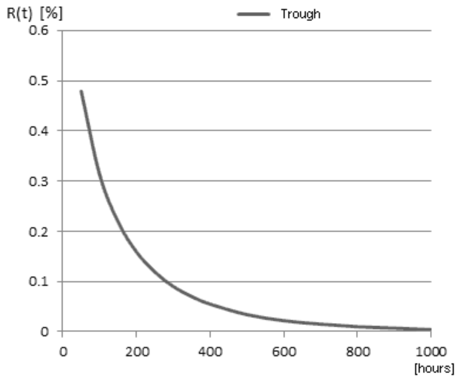

Fig. 5. Reliability variation of trough of the vibrating screens

3. EVOLUTION WEAR TO CUP TEETH OF THE FRONTAL LOADERS AND SOLUTIONS TO INCREASE THEIR LIFETIME

Equipping basalt quarries with dislocation and frontal loading machine on tires type Volvo L 220 E allows for the following operations

- loading crushed stone in trucks for delivery;
- transportation of crushed stone to the temporary deposit;
- feeding with broken stone of the crushing the secondary flow;
- cleaning and arranging the access ways both on the crushing platform and on the working front.

The analysis of the behaviour of subassemblies that are subject to excessive wear on Volvo L 220 E machines to point out the need for frequently replacement of some of them, especially the cup teeth (fig. 6 a). The abrasive wear of the loader teeth in the production of aggregates from basalt rocks, is mainly, determined by the dimensional changes and the weight loss at the active surfaces (fig. 6 b).

Fig. 6. Cup tooth for the Volvo equipment: a-new teeth; b-worn teeth

Determining how cup teeth wear evolve (fig. 7) have led to the necessity of finding solutions to increase their lifetime.

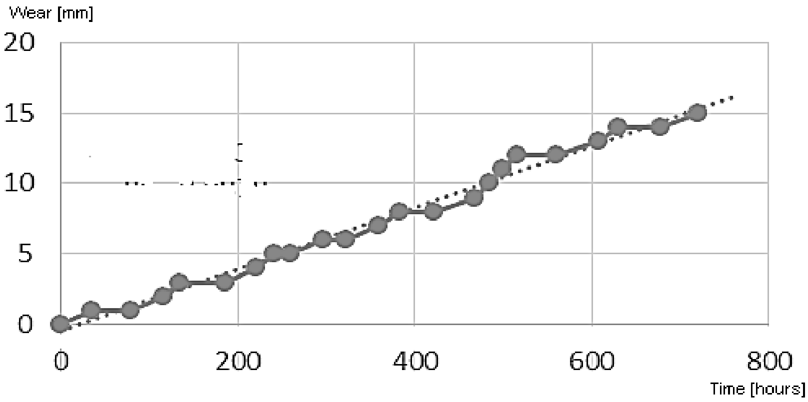

Fig. 7. Evolutions of cup teeth wear

The methodology for improving the technical-economic characteristics of the cup teeth has as a its starting point the precise setting of their chemical composition (table 5) and hardness. The chemical composition of the cast tooth, determined experimentally, is within the mark of alloy steel G45CrNiMo4, in accordance with SR EN 1027-1.

Table 5 **Chemical composition of the cup cast tooth**

Cup tooth material	**Chemical composition [%]**							
	C	**Si**	**Mn**	**P**	**S**	**Cr**	**Ni**	**Mo**
Alloy steel G45CrNiMo4	0,45	0,26	0,80	0,007	0,06	1,00	0,50	0,15

Sclerometric investigations to be effected on the two teeth, in transverse section in five zones randomly selected (table 6), and conversion HRC=f (HV 10) has achieved in accordance with DIN 50-150.

Table 6 **Cup teeth hardness**

Number of tooth	**Hardness**									
	HV10	**HRC**	**HV10**	**HRC**	**HV10**	**HRC**	**HV10**	**HRC**	**HV10**	**HRC**
1	425	43	437	44	464	46	458	46	466	47
2	421	42	442	45	473	46,5	462	47	459	46

Elaboration of self-protection system against tooth wear (fig. 8) can be done in different mode, depending on active zone position namely:

- the active tooth edge, protects with compact layer;
- the active surfaces, protects with rhomboidal systems.

Manual electrically welded load with electrodes coated containing the alloys of the type Cr25%-4%W-1%Ti-V can provide good abrasion resistance and allows reconditioning of used teeth, without demounting them from equipment, by using the existing equip in quarries.

Fig. 8. Wear self-protection system

4. CONCLUSIONS

Operating conditions of the technological equipment, in general and due to mining in particular, influences their useful life especially the negative effects of abrasive wear. In this context it is necessary to create the experimental data base regarding the wear and the useful times achieved in the practice as well as the elaboration of the reliability analyses. Evaluation of reliability indicators can lead to the development of specific methodologies for rehabilitation of technological equipment which in turn can lead to savings and increased profitability in production processes.

REFERENCES

[1]. **Binchiciu, H., Surgean, I., s.a.,** *Încărcarea prin sudare cu arcul electric*, Editura Tehnică, Bucuresti, (1992);

[2]. **Florea, V.A.,** *Fiabilitatea și mentenanța produselor – îndrumător de laborator*, Editura Universitas, Petroșani, (2011);

[3]. **Iovanas, R., Iovanas, D.M.,** *Recondiționarea și remanierea produselor sudate*, Editura Universității Transilvania din Brașov, (2006);

[4]. **Lazăr, M., Andraș, I., Faur, F., Andraș, A.,** *Influence Of Physical, Mechanical And Technological Characteristics Of Coal And Overburden Rocks On The Excavation Process*, SGEM2017 Conference Proceedings, ISBN 978-619-7105-00-1 / ISSN 1314-2704, 29 June - 5 July, 2017, Vol. 17, Issue 13, 445-452 pp, DOI: 10.5593/sgem2017/13/S03.057

[5]. **Todorescu, A.,** *Proprietăţile rocilor*, Editura Tehnică, Bucureşti, (1984).