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EFFICIENCY OF THE TRANSPORT SYSTEM OPERATION IN SEPARATION AT THE OPEN PIT "DIMNJAČE"

Abstract

This paper sets out the methodology and presents the results of calculation the efficiency of transport system in separation of the OP "Dimnjače", based on the data of monitoring the operating time and downtime/failure. Properly determined state of operation of the transport system, allows preventive measures and selection of maintenance strategy. Data collection lasted a year, and the data were analyzed, and thus the results are given by month for the transport system as a whole.

Keywords: *efficiency, belt transport, time, downtime, failure, open pit, reliability, availability, functional suitability, separation, maintenance*

1 INTRODUCTION

The coal mine “Gračanica” D.O.O. is engaged in the production and preparation of lignite coal. It started operating in 1938 as a mine with the underground exploitation until 1975, when it began with the surface exploitation at the OP "Gračanica", which was located in the municipality of Bugojno, as well as the separation facilities.

Currently, the mine has the coal exploitation at the OP "Dimnjače". The open pit "Dimnjače" as well as the coal separation facilities, and accompanying facilities, mechanical workshop and administrative building are located on the territory of the municipality of Gornji Vakuf - Uskoplje.

Exploitation at the open pit "Dimnjače" began in 1986, and the coal separation was performed with separation whose capacity was approximately 50 t/h and mostly coal fraction (0-60 mm) was obtained.

Since the placement of coal was increased, and the open pit "Gračanica" was in the final phase of exploitation, the construction of a new separation at the open pit "Dimnjača" began. In a very short period, the construction of separation facilities was completed by 1987.

The coal separation capacity of the OP "Dimnjače" is approximately 200 t/h, and the annual approximately 700,000 t/ear. Figure 1 shows the technological scheme of separation of ZD Coal Mine "Gračanica" D.O.O. Gornji Vakuf - Uskoplje.

Coal mining at the OP ”Dimnjače”- Coal mine “Gračanica” is carried out by the bucket excavators. The excavated coal is loaded directly into trucks, which are transported to the primary crusher. The crusher grinds coal with a granulation of up to 400 mm. The rakes transport coal to the T1A belt conveyor, which is B = 1000 mm wide and 210 m long.

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The transport system in separation has thirteen belt conveyors (T1A, T1, T3, T4, T6, T8, T11, T12, T13, T14, T15 T16 and T17), three rakes, caliber sieve 80x80 mm, caliber sieve 120x120 mm, single-level sieve and control panel [4,5,6,7].

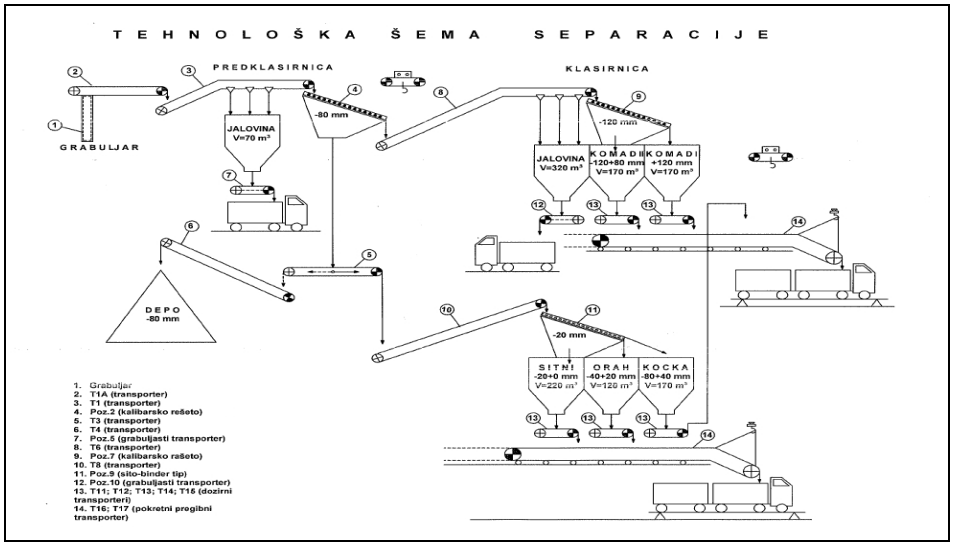


Figure 1 *Transport system in separation [7]*

2 METHODOLOGY OF DETERMINING THE EFFICIENCY OF THE TRANSPORT SYSTEM OPERATION

Data on operating conditions and failure/downtime of individual elements of the separation transport system were used to determine the distribution law and calculation of reliability indicators.

Effectiveness of the complex is expressed by the basic formula [9]:

$$E(t) = A(t) \cdot R(t) \cdot FP$$

E (t) - efficiency as a function of operation time; expressed as probability

A (t) - availability of the complex as a function of time; expressed as probability

R (t) - reliability of the complex as a function of time; expressed as probability

FP - functional similarity. It does not depend on time; it is a measure of meeting the required performances or degree of adaptation to the working conditions

Efficiency of the complex, expressed as the probability of successful start of operation, maintenance of the function within the framework defined by the function criteria, and adaptation to the changes in external working conditions is in the range: $0 \leq E \leq 1$ [9].

Component of the total effectiveness of availability the complex A(t) and reliability R(t) are functions of time (t), and their value ranges from 0.0 to 1.0, and therefore the

total effectiveness is also limited to the interval 0.0 to 1.0. The value of FP, in common efficiency calculations is equal to one. During development of the complex, the value of functional suitability is analyzed in the range: 0 < FP < 1 [9].

The availability is defined as the probability that the complex will be able to take effect at the time of need. This component is especially important for the transport complexes that have been out of operation for some time. In principle, the availability depends on reliability, but also on the maintenance system, i.e. the speed of returning the complex from the state of failure to the state of operation. The availability can be calculated via the appropriate ratio of time of the correct state of complex and time of the state of complex in failure [1]:

$$A(t) = \frac{T_{er}}{T_{kal}} = \frac{T_{er}}{T_{er} + T_{ot}} = \frac{\sum_{i=1}^{n} t_{er}}{\sum_{i=1}^{n} t_{er} + \sum_{i=1}^{n} t_{er}}$$

$T_{er} = \Sigma_{ter}$ - total time that the complex spends in operation

T_{kal} – calendar operation time

$T_{ot} = \sum_{i=1}^{n} t_{ot}$ - total time that the complex spends in failure

$$A(t) = \frac{1}{1 + \frac{T_{ot}}{T_{er}}}$$

The effect of complex availability on the system effectiveness is reflected in realization the maximum time in operation, and minimum time in failure.

Reliability characteristics are determined on the basis of failure time data. These data are obtained by monitoring the elements of transport complexes in real operation and performing the special tests. Data processing is performed by the statistical methods and methods of probability theory. The choice of distribution law implies a way of determining the type of distribution that best corresponds to the data being processed. The normal or Gaussian distribution and the Weibull distribution have the greatest application. In both distributions (t) is a random variable, i.e. the operating time until failure occurs. The two-parameter Weibull distribution is the most acceptable in the reliability analyzes of the elements of transport complexes. The two-parameter form of the Weibull distribution is given by the formula [1]:

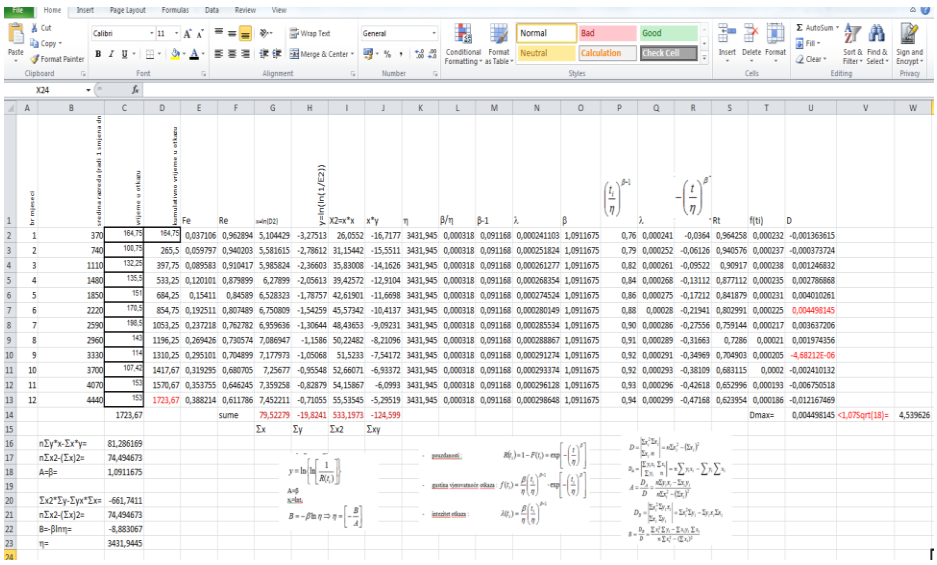
$$R(ti) = 1 - F(ti) = \exp\left[-\left(\frac{t}{\eta}\right)^{\beta}\right]$$

The parameters of this distribution are: β-shape parameter and η-scale parameter. The shape parameter directly determines the shape of density function. For β = 1, the Weibull distribution is identical to the exponential distribution. For β <1, the spans of randomly variable magnitudes are larger than for the exponential distribution. For β = (2.5-3.5), the Weibull distribution coincides with the Gaussian distribution. The scale parameter of the Weibull distribution represents a quantity proportional to the mean value of distribution, i.e.:

$$m = \eta\Gamma\left(1 + \frac{1}{\beta}\right)$$

Value (Γ) of the gamma function Γ(1+1/β) for different values of the shape parameter (β) is shown in tabular form in literature [1].

Based on the previous analytical expressions in Microsoft Excel, a program was created to facilitate the calculation of individual reliability functions and check the distribution law (Figures 2 and 3).

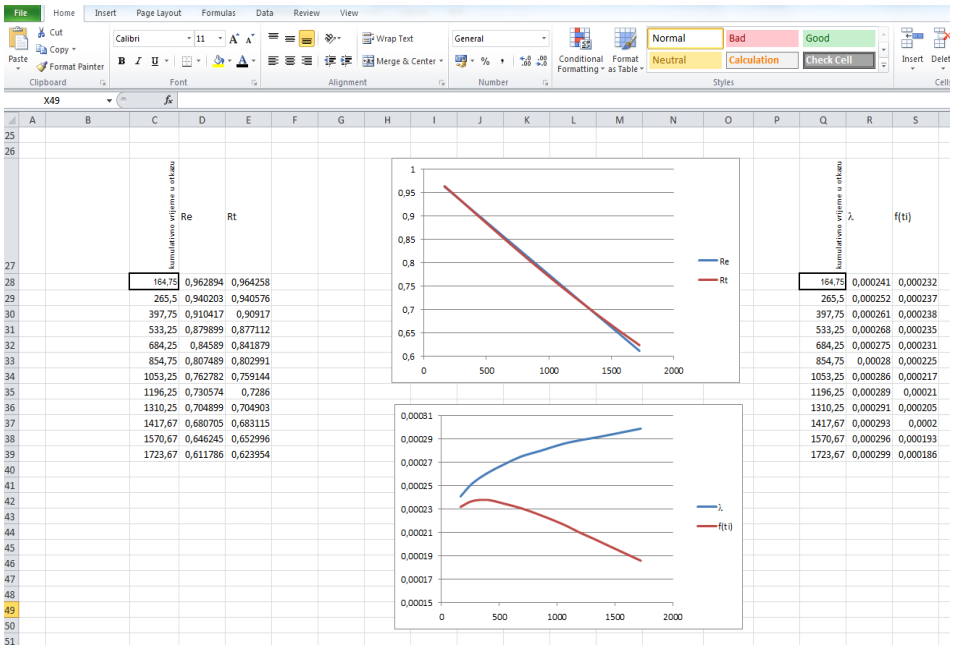


br. rejecesi	sredina razreda (sati 1 sirjeme di	vrijeme u otkazu	kumulativno vrijeme u otkazu	Fe	Re	i=ln(D2)	y=ln(ln(1/(E2))	X2=x*x	x*y	η	β/η	β-1	λ	β	$\left(\frac{t_i}{\eta}\right)^{\beta-1}$	λ	$-\left(\frac{t}{\eta}\right)^{\beta}$	Rt	f(ti)	D
1	370	164,75	164,75	0,037106	0,962894	5,104429	-3,27513	26,0552	-16,7177	3431,945	0,000318	0,091168	0,000241103	1,0911675	0,76	0,000241	-0,0364	0,964258	0,000232	-0,001363615
2	740	100,75	265,5	0,059797	0,940203	5,581615	-2,78612	31,15442	-15,5511	3431,945	0,000318	0,091168	0,000251824	1,0911675	0,79	0,000252	-0,06126	0,940576	0,000237	-0,000373724
3	1110	132,25	397,75	0,089583	0,910417	5,985824	-2,36603	35,83008	-14,1626	3431,945	0,000318	0,091168	0,000261277	1,0911675	0,82	0,000261	-0,09522	0,90917	0,000238	0,001246832
4	1480	135,5	533,25	0,120101	0,879899	6,27899	-2,05613	39,42572	-12,9104	3431,945	0,000318	0,091168	0,000268354	1,0911675	0,84	0,000268	-0,13112	0,877112	0,000235	0,002786868
5	1850	151	684,25	0,15411	0,84589	6,528323	-1,78757	42,61901	-11,6698	3431,945	0,000318	0,091168	0,000274524	1,0911675	0,86	0,000275	-0,17212	0,841879	0,000231	0,004010261
6	2220	170,5	854,75	0,192511	0,807489	6,750809	-1,54259	45,57342	-10,4137	3431,945	0,000318	0,091168	0,000280149	1,0911675	0,88	0,00028	-0,21941	0,802991	0,000225	0,004498145
7	2590	198,5	1053,25	0,237218	0,762782	6,959636	-1,30644	48,43653	-9,09231	3431,945	0,000318	0,091168	0,000285534	1,0911675	0,90	0,000286	-0,27556	0,759144	0,000217	0,003637206
8	2960	143	1196,25	0,269426	0,730574	7,086947	-1,1586	50,22482	-8,21096	3431,945	0,000318	0,091168	0,000288867	1,0911675	0,91	0,000289	-0,31663	0,7286	0,00021	0,001974356
9	3330	114	1310,25	0,295101	0,704899	7,177973	-1,05068	51,5233	-7,54172	3431,945	0,000318	0,091168	0,000291274	1,0911675	0,92	0,000291	-0,34969	0,704903	0,000205	-4,68212E-06
10	3700	107,42	1417,67	0,319295	0,680705	7,25677	-0,95548	52,66071	-6,93372	3431,945	0,000318	0,091168	0,000293374	1,0911675	0,92	0,000293	-0,38109	0,683115	0,0002	-0,002410132
11	4070	153	1570,67	0,353755	0,646245	7,359258	-0,82879	54,15867	-6,0993	3431,945	0,000318	0,091168	0,000296128	1,0911675	0,93	0,000296	-0,42618	0,652996	0,000193	-0,006750518
12	4440	153	1723,67	0,388214	0,611786	7,452211	-0,71055	55,53545	-5,29519	3431,945	0,000318	0,091168	0,000298648	1,0911675	0,94	0,000299	-0,47168	0,623954	0,000186	-0,012167469
		1723,67			sume	79,52279	-19,8241	533,1973	-124,599										Dmax=	0,004498145 <1,075qrt(18)= 4,539626

Σx	Σy	Σx2	Σxy

nΣy*x-Σx*y=	81,286169
nΣx2-(Σx)2=	74,494673
A=β=	1,0911675
Σx2*Σy-Σyx*Σx=	-661,7411
nΣx2-(Σx)2=	74,494673
B=-βlnη=	-8,883067
η=	3431,9445

Figure 2 *Calculating the reliability of transport system in Microsoft Excel*



kumulativno vrijeme u otkazu	Re	Rt
164,75	0,962894	0,964258
265,5	0,940203	0,940576
397,75	0,910417	0,90917
533,25	0,879899	0,877112
684,25	0,84589	0,841879
854,75	0,807489	0,802991
1053,25	0,762782	0,759144
1196,25	0,730574	0,7286
1310,25	0,704899	0,704903
1417,67	0,680705	0,683115
1570,67	0,646245	0,652996
1723,67	0,611786	0,623954

kumulativno vrijeme u otkazu	λ	f(ti)
164,75	0,000241	0,000232
265,5	0,000252	0,000237
397,75	0,000261	0,000238
533,25	0,000268	0,000235
684,25	0,000275	0,000231
854,75	0,00028	0,000225
1053,25	0,000286	0,000217
1196,25	0,000289	0,00021
1310,25	0,000291	0,000205
1417,67	0,000293	0,0002
1570,67	0,000296	0,000193
1723,67	0,000299	0,000186

Figure 3 *Graphic representation of the reliability of transport system in Microsoft Excel*

3 EFFICIENCY OF THE TRANSPORT SYSTEM OPERATION IN SEPARATION

Data on the state of operation and failure/downtime of transporter were used to determine the distribution law and calculation of reliability indicators. Based on the data on electrical, mechanical, technological and total failures/downtimes, the law of distribution of reliability indicators has been determined. Based on the above, the following were determined: reliability, failure intensity function and failure density function. Based on the time in operation and failure/downtime, the values of operational readiness and functional suitability of all considered trucks were also calculated.

Table 1 and Figure 4 show the efficiency of transport system in the separation of the OP "Dimnjače" D.O.O. Gornji Vakuf-Uskoplje.

Based on the obtained parameters of reliability, operational readiness and functional suitability, the efficiency of operation was calculated.

Table 1 *Efficiency of the transport system in separation of the OP "Dimnjače" DOO Gornji Vakuf-Uskoplje*

Transport system of separation				
Month/2013	**Efficiency based on electrical down-time / failure E(e)**	**Efficiency based on machine downtime / failure E(m)**	**Efficiency based on technological downtime / failure E(t)**	**Efficiency based on the total downtime / failure E(u)**
January	0.930342	0.952068	0.537412	0.501271
February	0.95686	0.959926	0.670057	0.629226
March	0.983467	0.964304	0.584552	0.562317
April	0.987346	0.962068	0.550532	0.529722
May	0.99414	0.966666	0.477851	0.46325
June	0.924534	0.978227	0.446081	0.417078
July	0.977827	0.982375	0.362167	0.349964
August	0.958514	0.963655	0.450868	0.422935
September	0.971996	0.970446	0.490038	0.463107
October	0.959136	0.93563	0.504492	0.457153
November	0.975736	0.934607	0.424473	0.388909
December	0.970037	0.954668	0.42099	0.387004

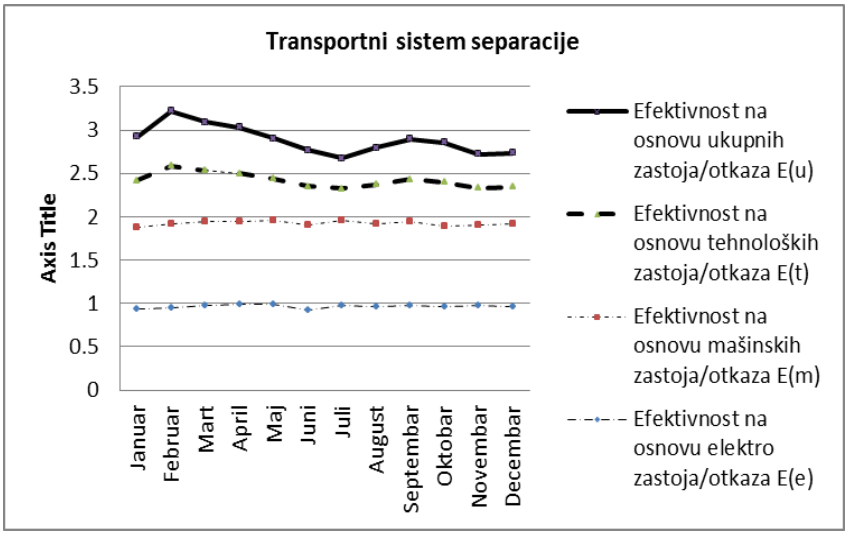


Figure 4 *Efficiency of the transport system in separation of the OP "Dimnjače" DOO Gornji Vakuf-Uskoplje*

The minimum efficiency based on the total failures/downtimes was achieved in the seventh month of monitoring and amounts to 35.00%. The maximum efficiency based on the total failures/downtimes was achieved in the second month of monitoring and amounts to 62.92%.

4 PREVENTIVE MEASURES AND SELECTION OF MAINTENANCE STRATEGY

The obtained values of efficiency of the transport system operation in separation for the monitored transporters as a whole were low during the entire monitoring period of transporter operation. Based on the conducted research, it can be concluded that most of the time the transport system did not work due to the following registered technological downtimes:

- human factor,
- waiting for a loader,
- frequent downtimes on the T6 belt due to waste separation,
- empty bins,
- cleaning and washing of a dispenser,
- separation is not included in separation.

Proposed activities to reduce these downtimes to a tolerable level:

- ✓ human factor downtimes amounted to 246 hours due to delays at work place. With a strict supervision by the technical and supervisory staff, these downtimes can be reduced to a tolerable level;
- ✓ in production, it is necessary to have at least 2 loaders, but in order to reduce a downtime in waiting for separation of the transport system due to a loader, there is a need for a third one;
- ✓ transporter T6 is a transporter from which the waste is separated. The

content of waste that does not separate from it is crucial for the quality of coal in the bins. Therefore, in the period when there is a high content of waste in material that occurs on the conveyor belt T6, that transporter is often stopped, which leads to the stopping of the other transporters. For less downtime of a transporter, it is necessary to ensure better quality of run-of-mine coal and increase number of labors on waste separation from T6 transporter;

- ✓ empty bins are connected to the dosing conveyors and they are in standby mode. In order to improve the production system and flow of material on belts, it is necessary to evenly distribute material on belts, and this is achieved only with two loaders that transfer the material from a landfill to a rake which transports it further to the separation. In this way, the bins would be filled more evenly and faster, and the dosing conveyors would have less technological downtime;
- ✓ due to a need to clean and wash the separation, the separation work must be stopped. By turning off the electricity, the separation does not work, but during that time, the old separation works, which crushes the material that is transported to the landfill so that the production is not endangered.

5 CONCLUSION

The presented methodology of processing, analysis and extraction of important information on operating parameters and downtimes/failures of the transport system in the separation in this way and in our area was done for the first time and can be repeated for a continuous transport system in other separations. The contribution of this paper to the professional literature is that for the first time the efficiency of transport system on separation was determined on the basis of collected data on working hours and failures based on the set methodology. Operational efficiency based on electrical, mechanical, technological and total failures/downtime is used to determine the preventive measures and maintenance strategies of the transport system in order to increase the effective operating time.

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