

Study on the reliability of the underground conveyor belt system installed at Vulcan Mine, the Jiu Valley Basin in Romania

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Abstract. The paper deals with a comprehensive reliability analysis of the conveyor belts belonging to an underground coal mine in the Jiu Valley, Romania. As resulted from the mine management reports, the transportation system is responsible for many downtimes and is a real bottleneck in the constant and adequate production, and the suspicion is the weak state of belt conveyers, which are the spinal column of the extraction process. For this reason, a comprehensive reliability analysis has been decided, in order to deliver a maintenance-upgrading plan.

1 Introduction

Vulcan mine plant is one of the oldest underground hard coal mines in the Jiu Valley coalfield. Jiu Valley hard coal is mined out since 1850, actually in 4 plants, other 3 being in downsizing and closure process. Vulcan is one of active mines, belonging to the Hunedoara Energetic Complex, with an output of about 2 M. tons/year, with a foreseen lifespan until the year 2022. The location of Vulcan mining field in the layout of Jiu Valley coalfield can be seen in figure 1 [1].

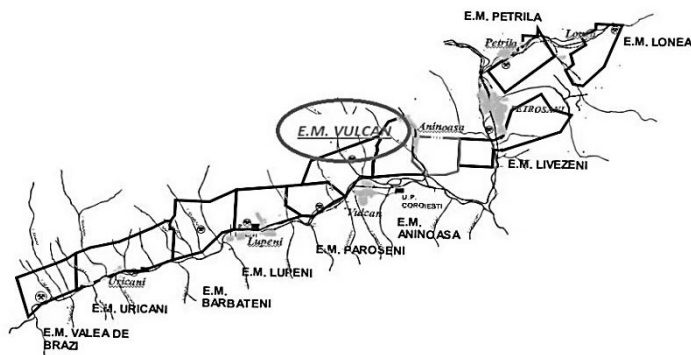


Fig. 1. The location of Vulcan mining field in the layout of Jiu Valley coalfield.

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The mine plant, due to its age and the tectonics of the coal seams, has been developed on horizontal and vertical directions in a way which led to a very large extension. In plus, the used technology, specific to thick inclined seams in horizontal slices, with top coal caving, in the past 20 years, has as result a very complex and irregular structure of the conveying system, as can be seen in figure 2 [2].

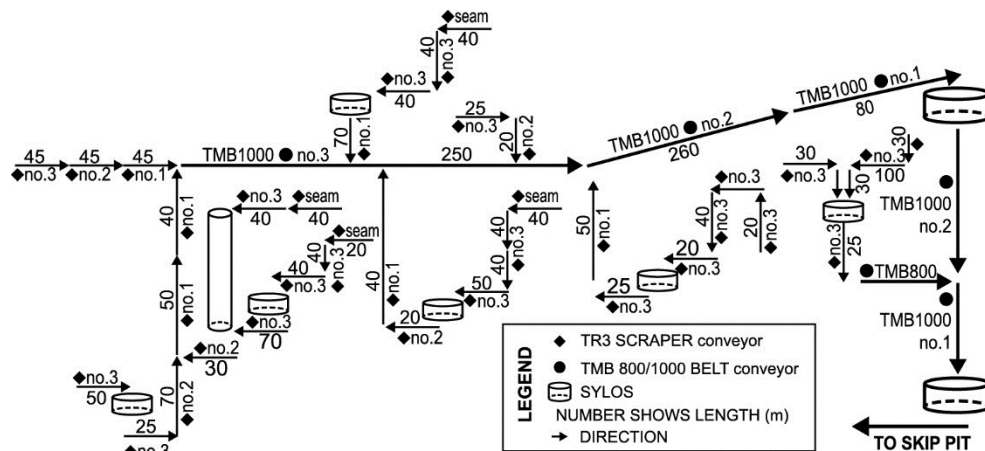


Fig. 2. Structure of the conveying system.

The main conveying system consist in belt conveyors TMB 800 and TMB 1000 (the figure indicating the width of the belt) on main gates at the levels 250, 315 and 360 (elevation related to the sea level) until the intermediary silos and finally to the main hoisting shaft [5].

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2 Reliability analysis of main belt conveyors

The reliability study of the main belt conveyors at Vulcan mine plant, has been performed using the data from the conveyor system monitoring books taking into accounts the records in the period June 2012 – March 2013.

The structure and occurrence frequency of faults of the conveyors in the period are presented in table 1 and in figures 3 and 4.

Table 1. Structure of faults occurred at belt conveyors.

No.	Subassembly failed	Absolute frequency of faults	
		No. of faults	%
1	Belt - staples	119	46.48
2	Upper and lower idlers	76	29.69
3	Belt tensioning system	37	14.45
4	Belt – requiring replacement	11	4.30
5	Mechanical drive system	7	2.74
6	Line supports	6	2.34
Total		256	100.00

The table above shows that the most frequent is the belt sections coupling staples , at about 47%.

This kind of fault is more relevant because they are 9 conveyers, each with one, two or three joints, remediation of a failure paralyzing for about two-three hours all the haulage system, which dramatically influence the operation cycle in all working faces [4].

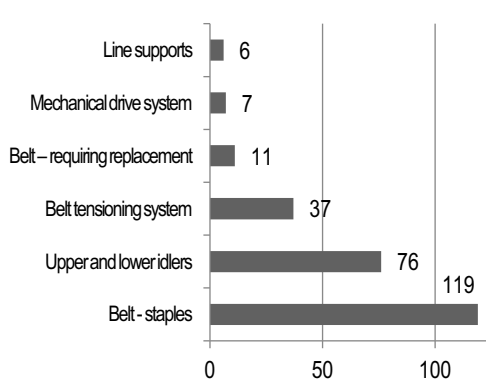


Fig. 3. Absolute frequency of faults.

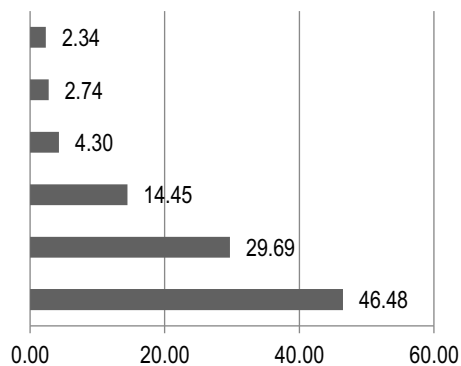


Fig. 4. Relative frequency of faults in %.

The idlers fault and replacement has a less impact on overall mining plant availability, despite their large amount, and its large share in total of faults - about 30% because of reduced time consumption for their replacement. The large share of staple joint faults in one year of operation was the main concern leading to the necessity of the present reliability analysis [2].

Analysing the occurrence of stapled joints failures, we selected from the overall 9 conveyors 3 ones which are similar length, working conditions and width of belt.

A factor which is more difficult to be quantified is the degree of ageing of belt's material, the three conveyors having, at the beginning of the study different operating hours.

Table 2. Empirical repartition function $\hat{F}(t_i)$ calculation.

i	t_i , hours	Absolute frequency, n_i	Relative frequency, f_i	Empirical repartition function, $\hat{F}(t_i)$
1	50	9	0.097826	0.097826
2	58	8	0.086957	0.184783
3	60	21	0.228261	0.413043
4	100	4	0.043478	0.456522
5	110	3	0.032609	0.489130
6	135	2	0.021739	0.510870
7	147	6	0.065217	0.576087
8	150	4	0.043478	0.619565
9	154	3	0.032609	0.652174
10	170	2	0.021739	0.673913
11	200	8	0.086957	0.760870
12	210	5	0.054348	0.815217
13	220	7	0.076087	0.891304
14	230	1	0.010870	0.902174
15	250	1	0.010870	0.913043
16	340	1	0.010870	0.923913
17	400	1	0.010870	0.934783

where s is the standard deviation and m is the mean value of the string.

The scale parameter η is calculated with

$$\eta = s / C_{\beta} \quad (5)$$

and initializing parameter γ with the relation

$$\gamma = m - \eta K_{\beta} \quad (6)$$

In these relations K_{β} and C_{β} are coefficients dependent on the shape parameter β , which are calculated from the relations:

$$K_{\beta} = \Gamma\left(\frac{1}{\beta} + 1\right) \quad (7)$$

$$C_{\beta} = \sqrt{\Gamma\left(\frac{2}{\beta} + 1\right) - \left[\Gamma\left(\frac{1}{\beta} + 1\right)\right]^2} \quad (8)$$

For the data above, with the mean value $m = 288.363636$, standard deviation $s = 258.257447$ and $CV = 0.895596$ the parameters of the Weibull distribution are obtained are: $\beta = 1,118460$; $\eta = 300.455874$ ore; $\gamma = -9,0421 \times 10^{-5}$; $K_{\beta} = 0.959754$; $C_{\beta} = 0.859552$.

By calculating the elements needed to define the distribution and verification of the Weibullian character of the analysed product behaviour using the Kolmogorov-Smirnov concordance test, we obtain the maximum distance, $D_{max} = 0.367631 \approx D_{\alpha, n} = D_{99,5, 22} = 0.357818$, $D_{99,5, 22} 0.085254 < D_{\alpha, n} = D_{80, 71} = 0.124985$, $D_{80, 71}$ being the Kolmogorov-Smirnov test feature for a confidence level of 99,5% and $n = 22$ values, so that the Weibullian character of failure times distribution is validated.

The tri-parametric Weibull distribution parameters characteristics are calculated with the equations:

- Reliability function:

$$R(t; \eta, \beta, \gamma) = \exp\left[-\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right], \% \quad (9)$$

- The non-reliability function:

$$F(t; \eta, \beta, \gamma) = 1 - \exp\left[-\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right] \quad (10)$$

- Intensity or rate of failure:

$$z(t; \eta, \beta, \gamma) = \frac{\beta}{\eta} \left(\frac{t-\gamma}{\eta}\right)^{\beta-1} \quad (11)$$

- Average uptime:

$$m = \gamma + \eta \Gamma \left(1 + \frac{1}{\beta} \right) \tag{12}$$

- Median of uptimes:

$$t_{med} = \gamma + \eta (-\ln 0,5)^{\frac{1}{\beta}} \tag{13}$$

In figures 5, 6, 7, 8 these reliability parameters variation are presented.

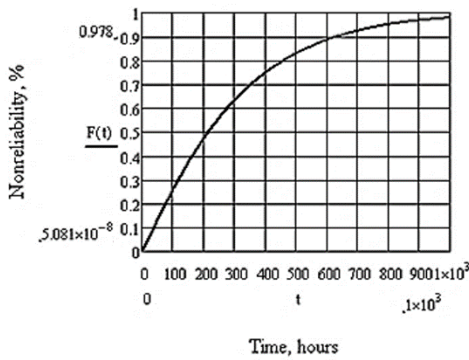


Fig. 5. Variation of the non-reliability function.

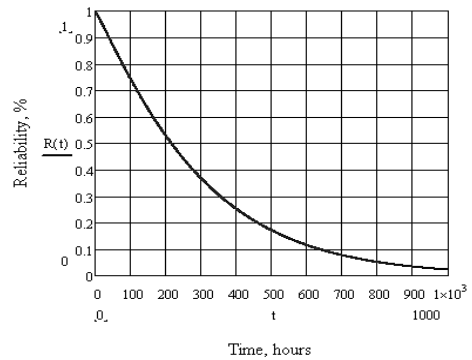


Fig. 6. Variation of the reliability function.

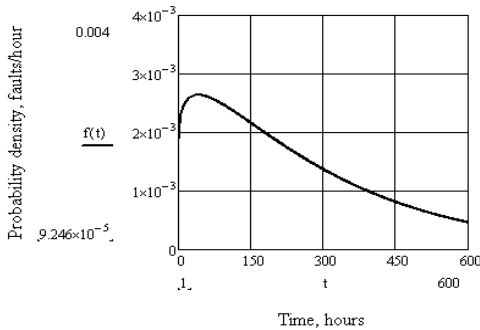


Fig. 6. Probability density of failure occurrence.

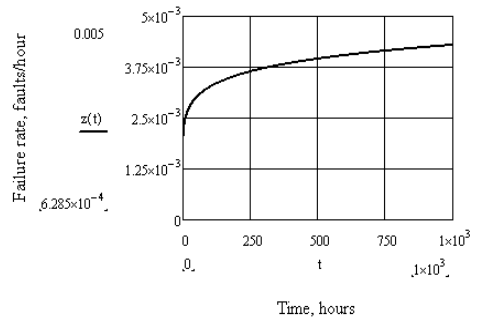


Fig. 7. Failure rate.

3 Conclusion

The analysis performed shows that:

The mean time to failure of belt joint is 288 hours, and the median is 216 hours. Considering that the running time is about 20 hours per day, it is expected to have a fault of joint each 14 days. This low reliability is shown by the diagrams above, the probability to not fail after 100 hours, i.e. one week is about 75%. In order to reduce downtimes, the quality of belt joining must be improved, by replacing stapled joints with vulcanized joints.

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