# STUDY ABOUT THE RELIABILITY OF BELT CONVEYORS USED IN THE UNDERGROUND COAL MINES IN JIUL VALLEY

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**Abstract:** The paper analyses the reliability of the belt conveyors used for the transport of coal in the underground mines from the Jiu Valley, based on the information about faults, recorded between June 2012 and March 2013. The analysis was performed for each main part of the belt conveyor system, in order to highlight the type of defect, the damaged part and the occurrence of defects for each sub-assembly.

**Keywords:** conveyor, analysis, reliability, defects, Vulcan.

## 1. 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 2 and 3.

*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 |

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The table above shows that the most frequent is the belt sections coupling staples, 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.

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.

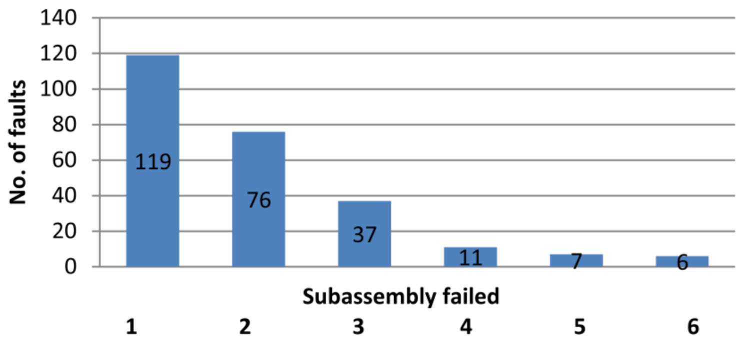


**Fig. 1.** Absolute frequency of faults

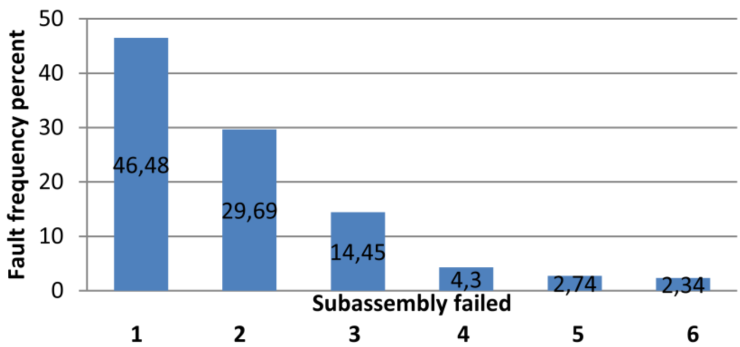


**Fig. 2.** Absolute frequency of faults in percent

Analyzing the occurrence of stapled joints failures, we selected from the overall 9 conveyors 3 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.

From the available data, we inferred the running hours until the failure, obtaining the time series as follows: 50; 50; 50; 50; 50; 50; 50; 50; 50; 58; 58; 58; 58; 58; 58; 58; 58; 60; 60; 60; 60; 60; 60; 60; 60; 60; 60; 60; 60; 60; 60; 60; 60; 60; 60; 60;

60; 60; 88; 88; 88; 88; 88; 88; 88; 88; 100; 100; 100; 100; 110; 110; 110; 135; 135; 147; 147; 147; 147; 147; 147; 150; 150; 150; 150; 154; 154; 154; 170; 170; 200; 200; 200; 200; 200; 200; 200; 200; 210; 210; 210; 210; 210; 220; 220; 220; 220; 220; 220; 220; 230; 250; 340; 400; 420; 460; 620; 760; 760; 1100

This statistical series have 92 values and it is a statistical series of type S2 with redundant values.

For this series of running hours between two faults, the calculated empirical repartition function, $\hat{F}(t_i)$ are presented in table 2.

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

| $i$ | $t_i$, ore | Frecvența absolută, $n_i$ | Frecvența relativă, $f_i$ | Funcția empirică de repartiție $\hat{F}(t_i)$ |
|---|---|---|---|---|
| 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 |
| 18 | 420 | 1 | 0,010870 | 0,945652 |
| 19 | 460 | 1 | 0,010870 | 0,956522 |
| 20 | 620 | 1 | 0,010870 | 0,967391 |
| 21 | 760 | 2 | 0,021739 | 0,989130 |
| 22 | 1100 | 1 | 0,010870 | 1,000000 |
| | | $\sum_{i=1}^{22} n_i = 92$ | $\sum_{i=1}^{22} f_i = 1{,}000000$ | |

The values of the Empirical repartition function are calculated with the formula:

$$\hat{F}(t_i) = \sum_{j=1}^{i-1} f_j \text{ , for } i = 2, 3, \ldots, 22, \tag{1}$$

Considering the nature of the subassembly in the study, it is assumed that the times of failure, considered between two consecutive failures are distributed following a Weibull distribution law, as this will be confirmed or infirmed using concordance tests.

The probability density of failures for tri-parametric Weibull distribution is expressed by the relation:

$$f\left(t;\eta,\beta,\gamma\right)=\frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} exp\left[-\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right] \tag{2}$$

where β is the shape parameter, η is real scale parameter and γ is the initializing parameter.

The parameters of a tri-parametric Weibull distribution can be calculated using the method of moments. The shape parameter β is obtained by solving the equation

$$CV=\frac{\sqrt{\Gamma\left(\frac{2}{\beta}+1\right)-\left[\Gamma\left(\frac{1}{\beta}+1\right)\right]^{2}}}{\Gamma\left(\frac{1}{\beta}+1\right)} \tag{3}$$

where CV is the coefficient of variation, which is obtained using the relation

$$CV=\frac{s}{m} \tag{4}$$

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

The scale parameter η is calculated with

$$\eta=s/C_{\beta} \tag{5}$$

and initializing parameter γ with the relation

$$\gamma=m-\eta\,K_{\beta} \tag{6}$$

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

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

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

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; $\gamma$ = -9,0421×10-5; $K\beta$ = 0,959754; $C_\beta$ = 0,859552. By calculating the elements needed to define the distribution and verification of the Weibullian character of the analyzed product behavior using the Kolmogorov-Smirnov concordance test, we obtain the maximum distance, *Dmax* = 0,367631 ≈ *Dα, n* = *D99,5*, 22 = 0,357818, *D*99,5, 22 0,085254 < *Dα, 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:

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

- The non-reliability function:

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

- Intensity or rate of failure:

$$z(t;\eta,\beta,\gamma) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} \text{ , } def/h; \qquad (11)$$

- average uptime:

$$m = \gamma + \eta\,\Gamma\left(1+\frac{1}{\beta}\right) \text{, } h; \qquad (12)$$

- median of uptimes:

$$t_{med} = \gamma + \eta(-ln\,0{,}5)^{1/\beta} \text{ , } h. \qquad (13)$$

In figures 3, 4, 5, 6 these reliability parameters variation is presented.

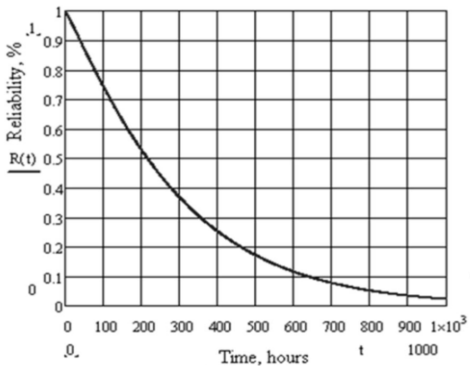


**Fig. 3.** Variation of the reliability function

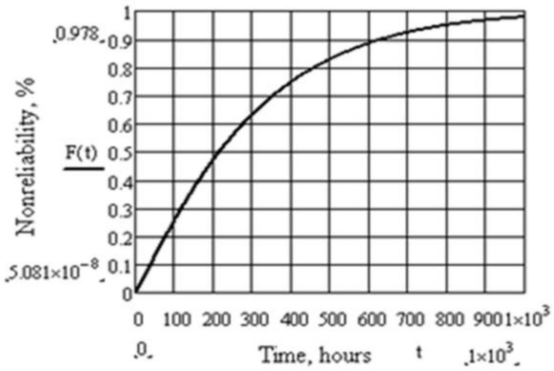


**Fig. 4.** Variation of the non- reliability function

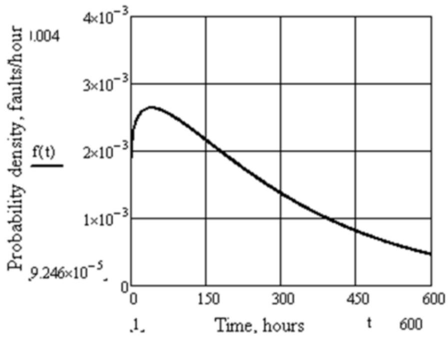


**Fig. 5.** Probability density of failure occurrence

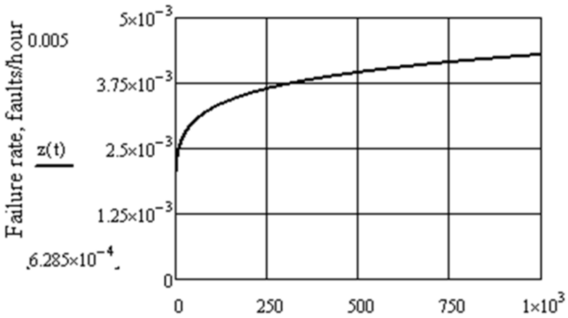


**Fig. 6.** Failure rate

## 4. CONCLUSIONS

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%.

So, in order to reduce the downtimes it is necessary to improve the quality of belt joining, e.g. by replacing stapled joints with vulcanized joints.

### REFERENCES

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