THE BEHAVIOR ANALYSIS RESULTS IN OPERATING THE SCRAPER CONVEYORS TR-3

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Abstract: The rapid development of science and technology, but also the restructuring of the mining extractive industry determines profound changes in the structure and complexity of the technological equipment used in the field of exploitation of useful mineral resources. In the present paper, for the analysis of the behavior of the scrape conveyor TR 3 in operation at a mining exploitation in the Jiu Valley, the SR EN ISO 9001:2001 regulations were followed which provide for the determination of defects, the opportunity to introduce corrective actions, analysis of causes, which led to defects and the need to undertake actions to prevent their recurrence. In this context, based on the pursuit register card of the functioning of the TR 3 scraper conveyor, an analysis of the defects was made, determining the absolute frequency of occurrence of each type of defect and operating times until the occurrence of failures. The purpose of this analysis was to determine the problems that must be treated with priority by tracing the frequency-cause diagram (Pareto), which classifies the causes of failures according to their importance. In order to optimize the quality of the TR 3 conveyor subassemblies, the Ishikawa diagram was designed, which is based on a graphic-logical, causal and suggestive method. For the subassemblies that presented the highest weight of the defects, a statistical processing of the experimental data was made, using a distribution law, for example Weibull.

Keywords: failures, maintenance, reliability, Pareto chart, Ishikawa diagram, Weibull distribution

1. INTRODUCTION

The study of the quality of mining equipment has become a major issue of interest both for the manufacturer of mining equipment and for their beneficiary. The aim is to reduce the effort and the negative impact on the environment by continuously improving technologies and by improving the quality of equipment and the efficiency of technological processes. In this context, the need for theoretical and applied treatment

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of issues regarding the increase in reliability independently of the construction of mining technological equipment is influenced by their increasingly intensive working regimes. Looking at the problem of reliability probabilistically, it can be stated that the moment of occurrence of a failure cannot be established with certainty, but only in the form of a probability to which a confidence interval is attached. The concept of reliability has, in addition to the probabilistic character, also the statistical one. This aspect is explained by the fact that the determination of reliability characteristics can only be done on the basis of data obtained by monitoring the operation of the product, when data are obtained regarding the failures found on a certain statistical population (sample). Mining units must be equipped with machines, equipment and of high installation, which provide an advanced degree of mechanization and automation, to ensure increased productivity. At present, mining equipment companies and mining units must to make agree special attention to the analysis of changes in technical and functional parameters, in the exploitation process, the discovery of the causes that lead to their reduction, the detection subassemblies that often falls and causes failures accidental. ISO 9000 standards establish the basic rules for quality management systems, from principles to implementation, without the take in consideration of the product or service offered and are applicable regardless of the technical characteristics of the final product, which must be implemented in the mining field.

2. CALCULATION OF RELIABILITY INDICATORS OF THE TR-3 SCRAPER CONVEYOR USED IN THE JIU VALLEY EXPLOITATIONS

The reliability analysis of the TR-3 scraper conveyor required its monitoring, in operation, using the operation sheet (fig. 1) over a period of 18 months.

RECORD SHEET

Name/Title:
Company:
Place of operation:
Symbol:

Year of manufacture	Date of commissioning	Date of failure occurrence	Cause of failure	Conditions under which the failure occurred	Number of operating days between failures	Date of last repair	Type of repair	Duration of repair [hours]	Remarks
1	2	3	4	5	6	7	8	9	10

Fig. 1. TR-3 conveyor failure tracking sheet in operation

The causes of the occurrence of failures of the component elements of the scraper conveyor were determined by calculating: the absolute frequency of occurrence of each type of failure; the operating times until the occurrence of failures and the Pareto diagram (fig. 2) of the share of failures depending on their cause was constructed.

Analyzing the Pareto diagram, it is observed that the highest percentages of failures are: conveyor chain breakage 35% and electrical installation failure 18.5%.

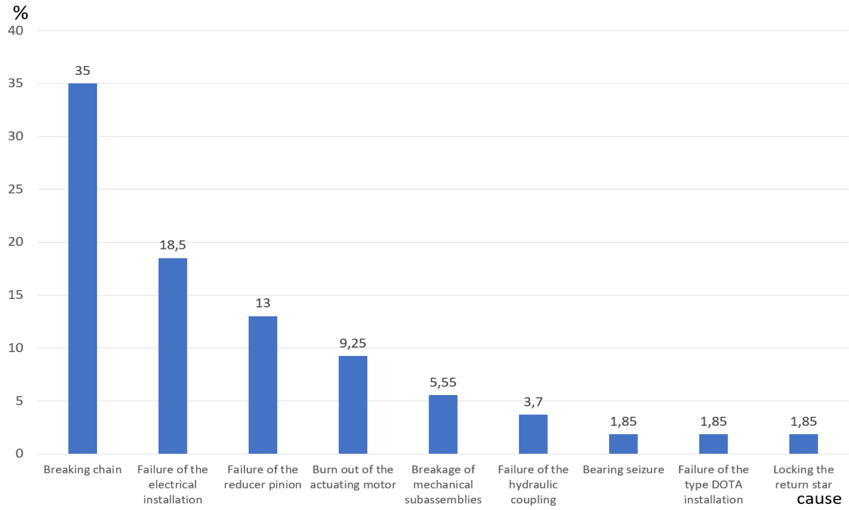

Fig. 2. Frequency-cause diagram for the TR-3 scraper conveyor

The determination of the reliability of the subassemblies that presented failures was obtained through statistical processing of experimental data using the Weibull distribution law.

For the conveyor chain, following observations in operation, it was found that the conveyor chain broke at the following time intervals (in hours): 2; 5; 12; 15; 23; 38; 40; 46; 49; 54; 72; 93; 101; 105; 134; 243; 297; 298; 820 (n=19). For statistical processing of the data, they are grouped into equal time intervals, Δt, using the Sturges method:

$$\Delta t = \frac{t_{max} - t_{min}}{1+3.322 \cdot \lg n} = \frac{820-2}{1+3.322 \cdot \lg 19} = 78 \quad (1)$$

The results of the calculations regarding the relative frequency and cumulative frequency of defects are presented in Table 1.

Using the Alain Plait probabilistic network (fig. 3), the results are: γ =0; η=65; β=0.6; MTBF=97.79 hours. Based on the data obtained, the variation of reliability over time can be plotted (fig. 4).

The Weibull model was used to determine the reliability of the conveyor subassemblies with faults. The calculation of the Weibull model parameters was done graphically using Alain-Plait diagrams, their values being presented in Table 2.

The reliability values R(t) over time of the component elements of the TR-3 type scraper conveyor are presented in Table 3.

Knowing the reliability values of the component elements and taking into account their connection within the assembly, with the exception of the conveyor chain, it is found that for an operating time interval between 100 and 1300 hours, the system reliability variation is between 0.7 and 0.02.

Table 1. **Relative frequency and cumulative frequency for the conveyor chain**

Operating interval, hours	Average operating duration, hours	Number of failures	Relative frequency	Cumulative frequency F(t) %
0-78	39	11	0.5789	57.89
78-156	117	4	0.2105	78.94
156-234	195	-	-	-
234–312	273	3	0.1578	94.72
312-390	351	-	-	-
390-468	429	-	-	-
468-546	507	-	-	-
546-624	585	-	-	-
624-702	663	-	-	-
702-780	741	-	-	-
780-858	819	1	0.0526	99.98
TOTAL		19	1.00	100

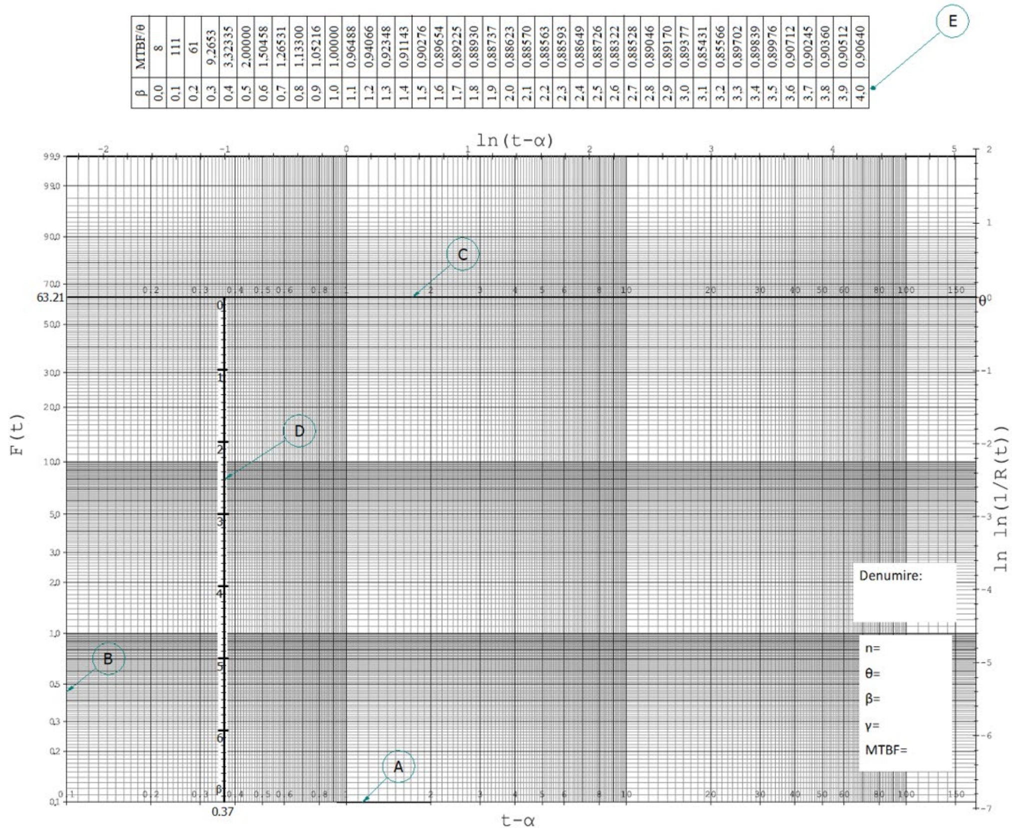

Fig. 3. Model for the Allan Plait network

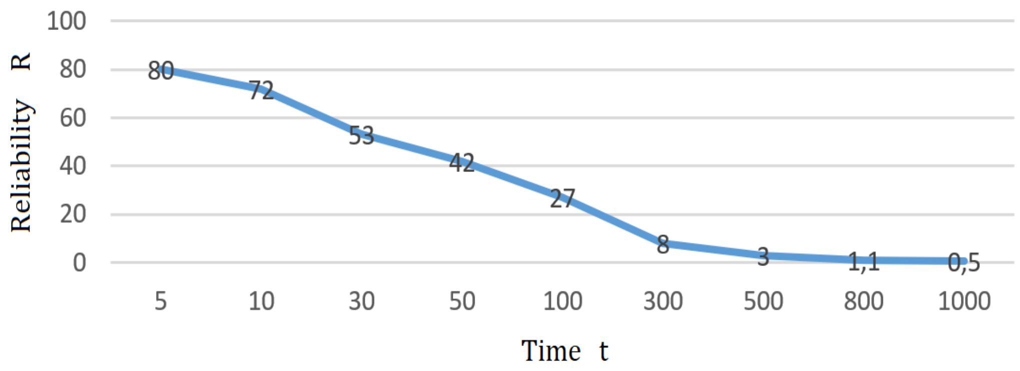

Fig. 4. Variation in conveyor chain reliability

Table 2. **Reliability parameters for the scraper conveyor**

No	Name of the element	Shape parameter β	Scale parameter η	Failure rate λ, [h^{-1}]x10^{-3}	Location parameter γ	MTBF [h]
1	Conveyor chain	0.6	65	10	0	97.8
2	Electrical installation	0.9	440	2.16	0	462.9
3	Reducer input pinion	2.2	880	1.246	-300	802
4	Electric drive motor	1.3	470	2.304	0	434
5	Mechanical equipment	1.4	950	1.156	0	865
6	Conveyor reducer	1.2	1250	1.481	0	675

Table 3. **Variation of the reliability of the TR-3 scraper conveyor components**

No	Name of the element	Operating time [hour]	Reliability
1	Conveyor chain	5÷500	0.8÷0.03
2	Electrical installation	178÷2000	0.64÷0.02
3	Reducer input pinion	200÷1300	0.74÷0.024
4	Electric drive motor	100÷1300	0.87÷0.023
5	Mechanical equipment	100÷3500	0.82÷0.039
6	Conveyor reducer	300÷4000	0.75÷0.023

3. ISHIKAWA DIAGRAM FOR TR-3 CONVEYOR CHAIN BREAKAGE

Ishikawa diagrams represent a type of analysis that uses a graphic-logical, causal and suggestive method in order to optimize the quality of a product, allowing efficient and economical action on the technological parameters of the process because it expresses the link between causes and effects. The construction of the Ishikawa diagram (fig. 5) for the TR-3 conveyor chain highlights the causes that lead to its failure.

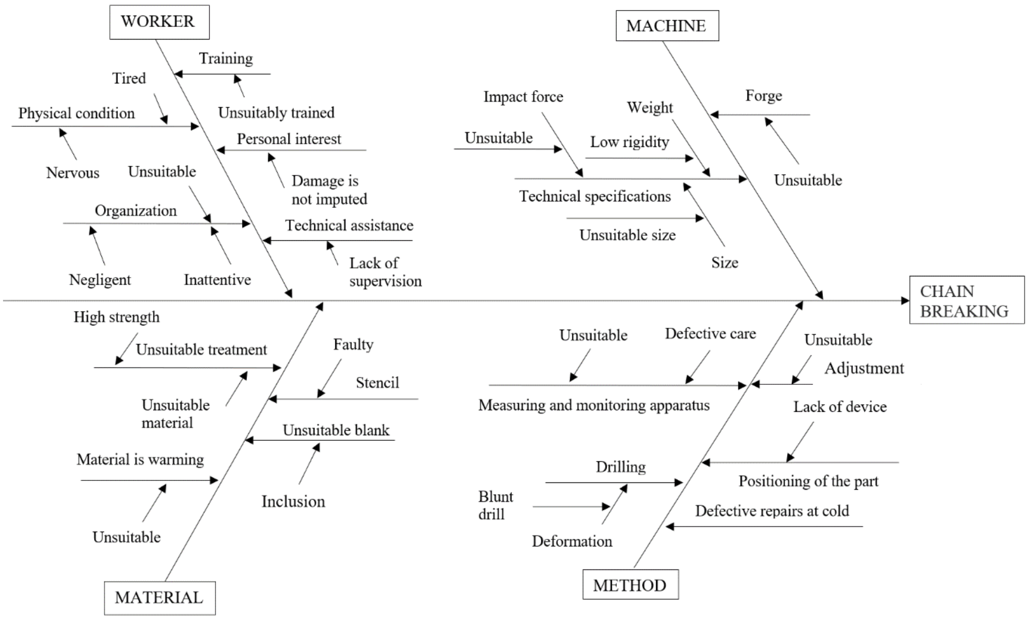

Fig. 5. Ishikawa diagram for broken chain failure

The time standards for repairs to scraper conveyors are presented in Table 4.

Table 4. **Time standards provided for repairs of to scraper conveyors**

Type of repair	Operating period [hours]	Time required for repair [days]	Number of interventions per cycle	Cost, % of the maximum replacement value
Technical revision R_t	150	1	80	2.2
Current first grade repair RC1	900	3	14	11
Current second grade repair RC2	7200	10	1	18
Capital repair RK	14400	30	1	55

The service life of scraper conveyors is 7 years, and the operating cycle diagram is shown in Figure 6.

The technical inspection, R_t at the beginning of each shift includes maintenance and repair of the scraper conveyors and will be carried out only by well-trained personnel with the instructions in force. The technical inspection is carried out daily, weekly and monthly.

The daily technical inspection consists of:

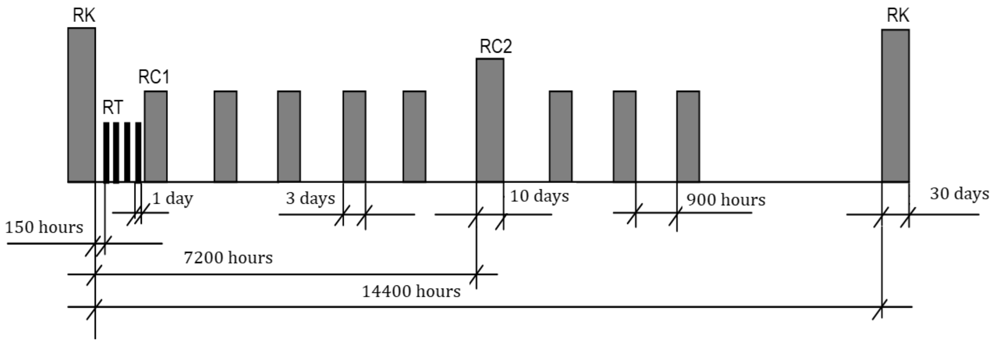

Fig. 6. Operating cycle diagram and repair downtime for scraper conveyors

- visual inspection of the conveyor;
- checking the chain tension;
- lubrication of the chain with used oil;
- checking the condition and fastening of the scrapers;
- visually inspecting all conveyor chutes for wear, connecting bolts and stiffening screws;
- checking the drive and turning station;
- removing small material (coal, rock) from the reducers, hydraulic couplings and electric motors;
- checking the integrity of the power cable of the electric motors, control blocks and the entire control and signaling device.

The weekly technical inspection consists of the following checks:

- condition of the scraper chain;
- tightening of the scraper fixing nuts;
- condition of the drive and turning drums;
- tightening of the fixing screws of the reducer, motor and drive drum;
- condition of the drive stations and turning head anchorage;
- the condition of the intermediate chute and in particular the scraper insertion blades on the lower side;
- the lubrication condition;
- the condition of the seal of the reducer and the hydraulic coupling:
- the condition of the turning head and in particular the condition of the scraper insertion blades on the lower side.

The monthly technical inspection will include, in addition to the activities provided for in the weekly technical inspection, the following:

- checking the oil level in the reducers and hydraulic couplings, topping them up;
- checking the lubrication condition of the bearings on the drive and turning head;
- checking the anchoring method of the drive and turning station;
- checking the assembly of the drive and turning stations and the drive drums.

The current first-degree repair RC1 is carried out after 900 hours of operation and consists of checking the following:

- the wear condition of the drive and turning crowns;
- the wear status of the chain hoists;
- the oil level in the reducer and the hydraulic coupling;
- the wear status of the scrapers, eyelets and chain;
- the condition of the side risers;
- the condition of the base and connecting troughs;
- the condition of the anchoring system.

The permissible wear of the scrapers in the guide area is 10 mm, the permissible wear of the chain lifter is also 10 mm, and the permissible wear of the drive crown is 5 mm. Parts that exceed the permissible wear level will be replaced with new parts or reconditioned.

The current second-degree repair RC2 is carried out after 14400 operating hours, correlated with the operating limit of the respective cutting and with the removal of the cutting. When dismantling the scraper conveyors, special attention will be paid to dismantling the drive station, which will be carried out in the following order:

- disconnect the electric motor from the power source;
- remove the electric cable from the motor;
- remove the electric motor with the coupling housing;
- remove the reducer;
- disconnect the scraper chain above the drive station;
- remove the drive drum guards;
- dismantle the chain lifter claws;
- dismantle the drive drum bearings.

The RK major repair of the scraper conveyor is carried out at specialized companies.

4. CONCLUSIONS

Chain breakage has the highest failure rate (35%) and this makes the average uptime only 97.8 hours. As for the other defects, it is found that they have a failure rate with quite similar values.

To increase the reliability of TR-3 type scraper conveyors, the following measures can be taken:

- improving the chain manufacturing technology;
- using another, more reliable drive motor;
- checking the conveyor mechanics and improving the parts that fail most often during operation.

Ways to increase reliability in design are achieved through: intervention methods in the block diagrams of the systems and constructive methods.

Intervention methods in the block diagrams of the systems include four directions:

- simplification of the diagrams without reducing the reliability characteristics;
- development of diagrams with limiting the consequences of failures, in order to limit the failures (development of diagrams with univocal failure response);
- use of protection (safety) devices in order to allow a failure of previously established elements, which can be easily replaced and whose cost is low;
- use of redundant elements or subsystems, respectively of reserve elements or subsystems.

Construction methods include four directions for increasing reliability:

- increasing the reliability of certain elements, subassemblies, and safe subsystems, based on which the operating regime and constructive solutions are established;
- correct choice of elements and subsystems from the point of view of reliability;
- unification of elements by designing schemes with standardized, typical safe elements that are found in current production and are approved;
- accessibility of elements for both maintenance and overhaul activities and for repair activities.

In execution (manufacturing and assembly), the following directions are distinguished, which aim to increase the reliability of equipment:

- improvement of manufacturing and assembly technology (machine adjustment operations, use of modern processing and assembly methods);
- mechanization and automation of technological processes, with the advantages of increasing labor productivity and increasing processing precision;
- running-in of parts, subassemblies, with the aim of improving quality by increasing the quality of surfaces, improving superficial layers;
- static control of the quality of products and work in order to have an information system necessary for functional analysis and to establish measures for the future increase in product reliability.

In operation, the following directions for increasing reliability are distinguished:

- establishing operating methods that contain precise instructions regarding the operation of the system;
- collecting and processing operating information in order to know how different products behave and what parameters influence product quality;
- appropriate organization of maintenance and repair activities;
- staff qualification;
- organization of experimental operation of new products in real conditions.

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