RELIABILITY OF TECHNOLOGICAL FLOWS. A CASE STUDY

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Abstract: The analysis of the operating behavior of equipment allows us to know the technical condition of the equipment in a technological flow, the influence of each equipment on the flow, as well as taking technical and organizational measures regarding, in particular, preventive and corrective maintenance activity, identifying and eliminating blockages in the process, reducing downtime and increasing the overall productivity of the technological flow.

Keywords: reliability, technological flow, Pareto diagram, distribution law

1. INTRODUCTION

During the period 02.02-30.08.2021 at the Lonea Mining Exploitation, the behavior of a technological flow consisting of the KWB 3 RDU felling shearer, the TR-7A scraper conveyor, two TR-5 scraper conveyors and seven TMB–1000 belt conveyors was monitored. The technological flow diagram during the commissioning of Panel 3, layer 3, block IV is presented in figure 1.

2. TECHNOLOGICAL FLOW RELIABILITY ANALYSIS

Based on the data resulting from monitoring the behavior of the equipment in the technological flow, it was possible to determine the number of falls, the causes of the falls and the times for fixing the faults that occurred.

The number of falls n and the times spent fixing the failures t_s for the equipment monitored over the seven-month period are presented in table 1.

Analyzing the data in table 1, the following findings emerge:

- the total number of failures recorded is 615, most of which were in July (146 falls, i.e. 23.7% of the total number);

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- the total duration of the time spent fixing the faults was 47190 minutes, the longest duration also being in July (10040 minutes, i.e. 21.2% of the total duration).

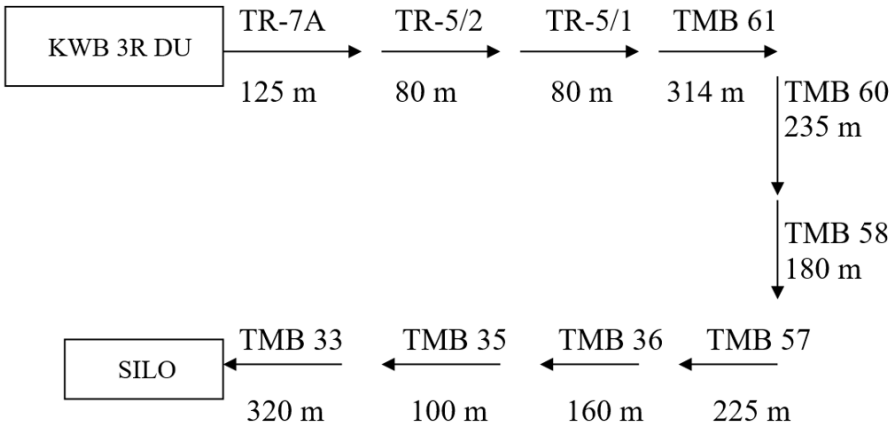

Fig. 1. Technological flow diagram

Table 1. **Number of failures *n* and repairs time t_s, in minute**

Name	Month														Total	
	02		03		04		05		06		07		08			
	n	t_s	n	t_s	n	t_s	n	t_s	n	t_s	n	t_s	n	t_s	n	t_s
KWB 3 RDU	9	1650	10	1300	9	890	16	2055	16	1700	22	1620	12	3320	94	12535
TR-7A	7	565	14	2265	4	105	44	3150	38	2215	29	2635	27	3145	163	14080
TR-5/1	3	135	3	285	6	255	4	115	10	505	14	1945	6	430	46	3670
TR-5/2	8	427	3	355	7	465	5	90	7	410	19	1510	5	405	54	3662
TMB 61	1	55	1	15	4	210	7	290	6	295	10	380	6	420	35	1665
TMB 60	2	65	5	320	3	95	9	170	5	135	11	340	13	345	48	1470
TMB 58	2	68	7	245	8	245	10	1175	6	270	17	450	11	420	61	2873
TMB 57	5	460	3	205	5	285	11	395	8	440	15	675	9	455	56	2915
TMB 36	5	200	2	60	2	155	3	255	-	-	2	140	-	-	14	810
TMB 35	3	120	2	35	5	130	4	220	8	255	1	60	5	110	28	930
TMB 33	1	50	-	-	1	120	2	160	4	240	6	285	2	125	16	980

Based on the data contained in Table 1, the values of the frequency of falls and the share of downtime due to failures for the equipment in the technological flow can be determined, which are presented in Table 2 and in the form of Pareto diagrams, in Figures 2 and 3.

3. CALCULATION OF THE RELIABILITY OF TECHNOLOGICAL FLOWS

Analyzing the data contained in table 2 and the Pareto diagrams in figures 2 and 3, the following can be found:

- the highest value of the frequency of falls and the share of the downtime for troubleshooting is found in the TR–7A scraper conveyor (26.50%, respectively 30.88%);

Table 2. **Failure frequency and repair time share due to failures**

Name	Failure frequency f_c, %	Repair time share p_s, %
KBW 3 RDU shearer	15.28	27.50
TR–7A conveyor	26.50	30.88
TR–5/1 conveyor	7.48	8.05
TR–5/2 conveyor	8.78	8.03
TMB 61 belt conveyor	5.69	3.65
TMB 60 belt conveyor	7.81	3.22
TMB 58 belt conveyor	9.92	6.30
TMB 57 belt conveyor	9.11	6.39
TMB 36 belt conveyor	2.28	1.79
TMB 35 belt conveyor	4.55	2.04
TMB 33 belt conveyor	2.60	2.15

- high values of the frequency of falls and the share of the time spent troubleshooting are also found in the KWB 3 RDU shearer (15.28%, respectively 27.50%);

- there is a correlation between the frequency of failures and the share of remediation time, as an order of causes with small exceptions, such as, for example the TR–5 conveyors, which in terms of share of remediation times are ranked 3rd and 4th; however, in terms of frequency of failures they are ranked 5th and 7th.

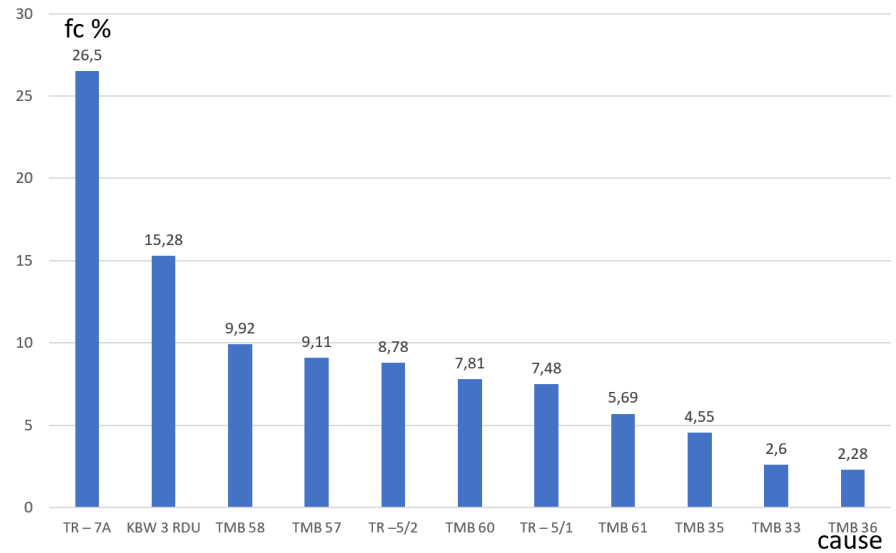

Fig. 2. Pareto diagram of the frequency of failures of equipment in the technological flow

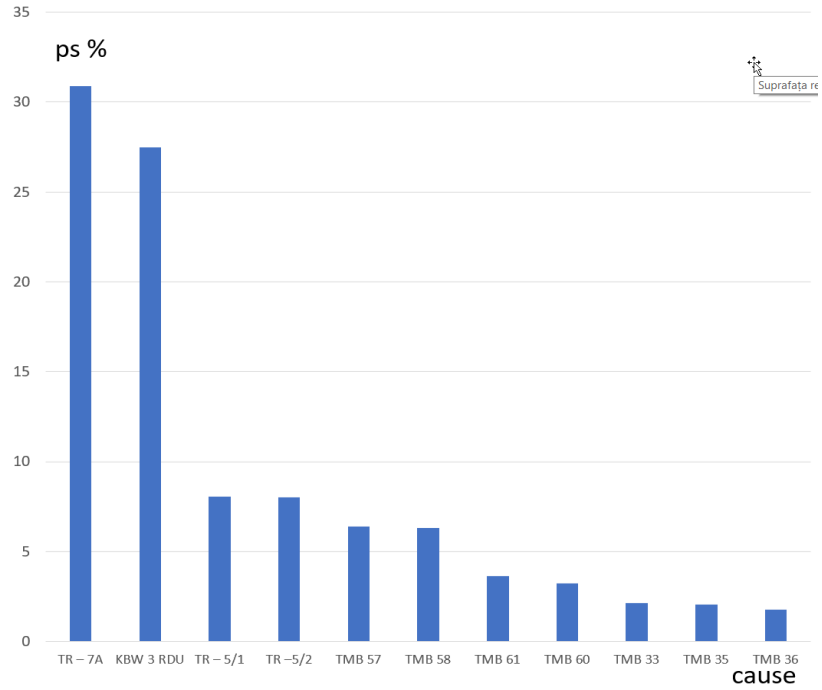

Fig. 3. Pareto diagram of the share of downtime due to failures for machines in the technological flow

Grouping the causes of failures according to their nature into failures: mechanical, electrical, hydraulic and other causes, table 3 presents the values of the frequency of failures and the share of downtime for troubleshooting.

Table 3. **Causes of failures depending on their nature**

Nature of the failure	KWB 3 RDU		TR–7A		TR -5		TMB	
	f_c %	p_s %	f_c %	p_s %	f_c %	p_s %	f_c %	p_s %
Mechanical	61.25	50.85	58.58	46.67	90.22	91.50	60.42	65.64
Electrical	17.25	22.56	7.69	11.07	7.78	8.50	21.67	21.21
Hydraulic	16.25	12.07	20.71	16.56	-	-	-	-
Other causes	5.25	14.52	13.02	25.07	-	-	17.09	13.15

Analyzing the data contained in table 3 and the Pareto diagrams in figures 4-7, the following can be found:

- the highest values of the frequency of failures and the share of time spent fixing faults, for all equipment, are due to mechanical faults;
- in the case of the KWB 3 RDU shearer, the main faults with a high frequency of failures and long durations for fault repair are:

a) mechanical:

- chain breakage (29 falls and 29.6 hours for remediation);

- shearer arm defects (7 falls and 58 hours for remediation);

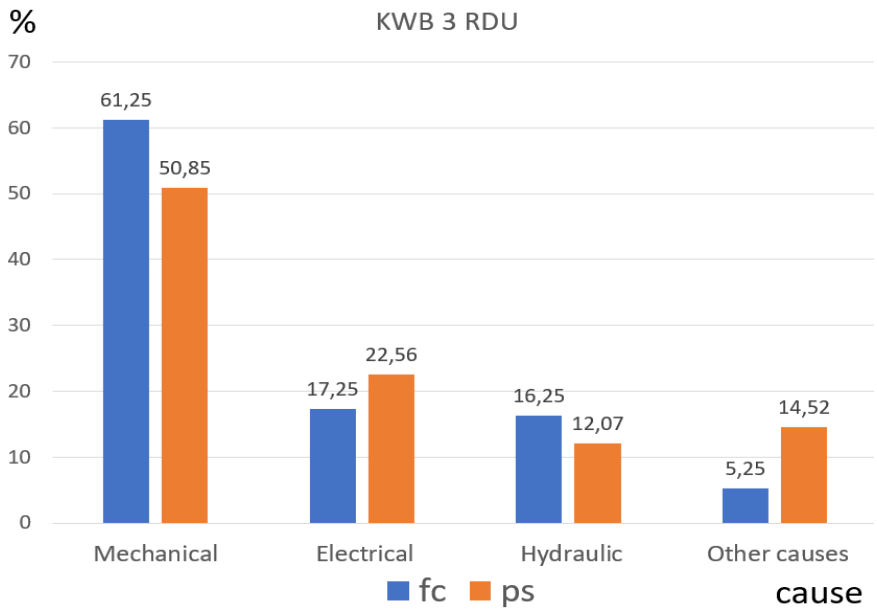

Fig. 4. Pareto Failure frequency f_c and repair time share due to failures p_s depending on the nature of the failure for the KWB-3 RDU shearer

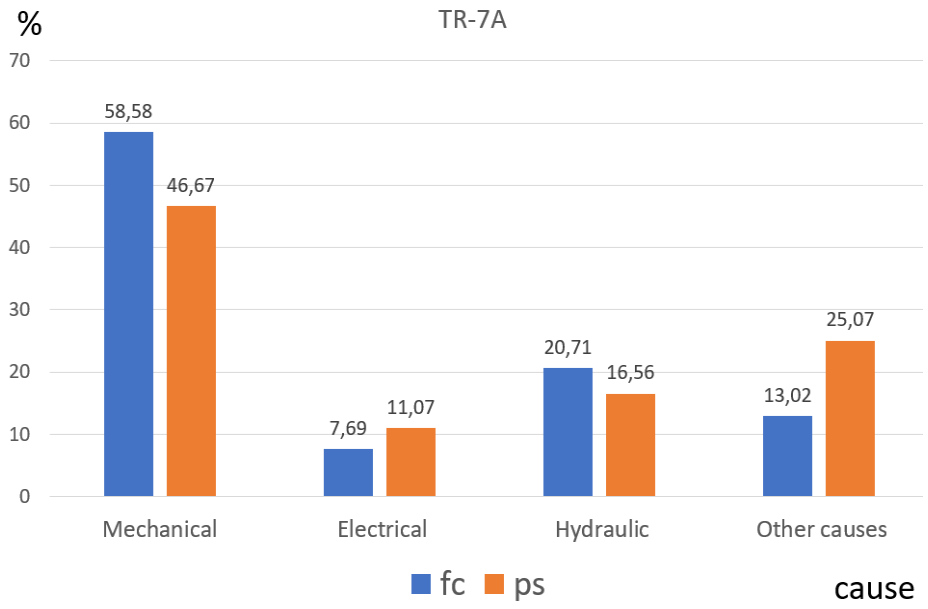

Fig. 5. Pareto Failure frequency f_c and repair time share due to failures p_s depending on the nature of the failure for the TR-7A conveyor

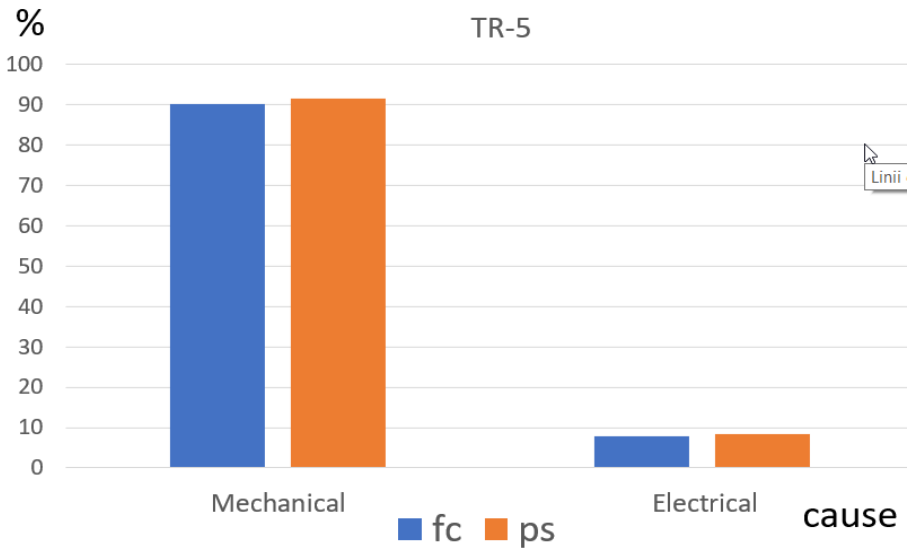

Fig. 6. Pareto Failure frequency f_c and repair time share due to failures p_s depending on the nature of the failure for the TR-5 conveyor

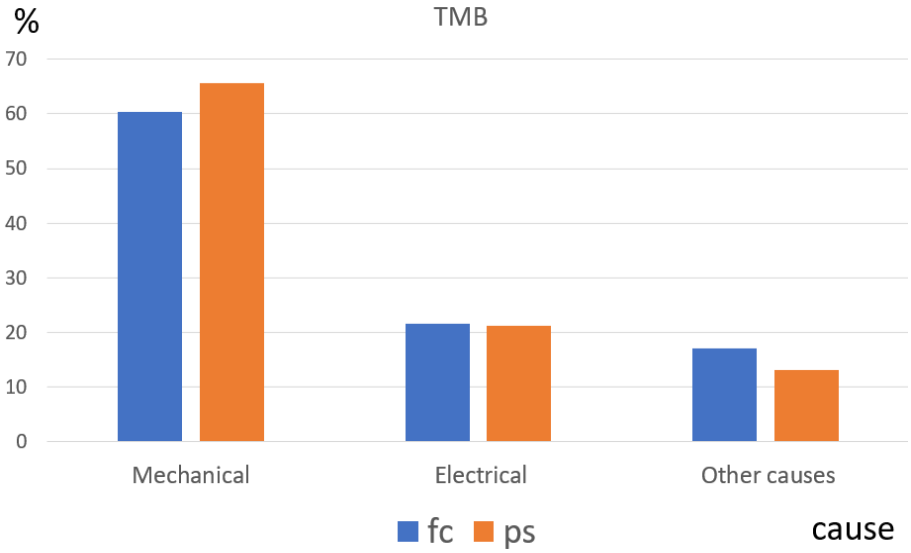

Fig. 7. Pareto Failure frequency f_c and repair time share due to failures p_s depending on the nature of the failure for the TMB-1000 belt conveyor

b) electrical:
- electric motor burnout (2 falls and 36 hours for remediation);
c) hydraulic:
- valve seals, pipes (10 falls and 11 hours for remediation);
- in the case of the TR-7A conveyor, the main defects are:

a) mechanical:
- chain breakage (35 falls and 35 hours for remediation);
b) electrical:
- electric motor (2 falls and 6.6 hours for remediation);
c) hydraulic:
- turbine blockage (9 falls and 11.2 hours for remediation);
d) other causes:
- material blockages from the front (3 stops and 12 hours for remediation);
- in the case of the two TR–5 conveyors, the main failures are of a mechanical nature: chain breakage (29 falls and 22.3 hours for remediation);
- in the case of the seven TMB–1000 belt conveyors, the main failures are:
a) of a mechanical nature:
- belt breakage (32 falls and 36.1 hours for remediation);
- equipment breakage (32 falls and 14.5 hours for remediation);
b) of an electrical nature:
- control circuit (9 falls and 6.5 hours for remediation);
c) other causes:
- material blockages (10 stops and 19 hours for remediation).

4. CONCLUSIONS

The main conclusions resulting from this case study regarding the reliability of technological flows are the following:

- the total downtime of the flow due to failures represents about 20% of the available time. Considering an average production, over the 8 months, of 38.8 t/h, it results that the loss recorded due to downtime due to failures represents the equivalent of a production of 30156 tons of coal;

- comparing the flow equipment in terms of the time consumed in fixing the failures, it results that, compared to the total time of the interventions, the share of these times represents: 58.38% for the felling equipment (30.88% for the TR–7A conveyor and 27.5% for the shearer), 16.08% for the two TR-5 conveyors and 25.54% for the seven belt conveyors. From the above, it follows that the largest share of the time spent on troubleshooting was recorded for the TR-7A conveyor;

- if the times spent on troubleshooting the two TR-5 conveyors are approximately the same, there are significant differences for the belt conveyors, with the TMB 57 and 58 conveyors recording times 2-3 times longer than the other belt conveyors;

- for all the machines in the flow, the main cause of the stops is mechanical failures, which represent approximately 59% of the total downtime due to malfunctions. For the other types of failures, the shares are electrical at approximately 17%, hydraulic at 9% and other causes at 15%;

- among the mechanical failures, we note, with a high share: chain breakage 19.1% of the total duration of mechanical failure repair, respectively 11% of the total

duration of flow standstill; shearer drum failures 12.74%, respectively 7.3% and belt breakage 7.9%, respectively 4.6%;

- analyzing the downtime due to chain breakage used in the shearer, the TR-7A conveyor and the TR–5 conveyors, it is found that the largest share of the downtime is with the TR–7A conveyor chain (7.7% of the duration of mechanical failure repair and 4.45% of the total duration of flow standstill, then the shearer chain 6.5%, respectively 3.76% and the TR-5 conveyor chain 4.9%, respectively 2.83%).

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