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FAILURE ANALYSIS OF BELT CONVEYOR SYSTEMS FOR CONDITION MONITORING PURPOSES

The paper deals with failure analysis for condition monitoring (CM). Before applying CM one shall investigate a key point in monitored machinery, what tools and methods need to be applied in order to minimise the cost of CM in harsh industrial environment as an open pit or underground mine is. The paper focus on the first step in condition, i.e. estimation of the scale of a problem: the most frequent failures, types and the location of failures and their importance in the context of maintenance of a conveyor belt transportation system. Some comments regarding possible ways for detection of mentioned faults are considered. The examples of failures and time related to replacement or repair have been provided.

1. INTRODUCTION

Condition monitoring in mining industry is not as well developed as it is in other branches (i.e. power engineering, oil industry etc). One of the reasons is that mine is the specific kind of company with harsh environment and dissipation of assets in wide area. There are a lot of different mechanical systems in a lignite mine but one of the most important is a transportation system. One may consider two types of transportation systems: type 1 that convey overburden from bucket wheel excavators to dumping site and type 2 that is used for transportation of desired material (coal mainly) from bucket wheel excavators to a power plant or to another transportation system. A special feature in both cases is length of conveyor that may even reach 30 km. For example in one of the biggest lignite mine in Poland total length of conveyors is 100 km, see fig. 1.

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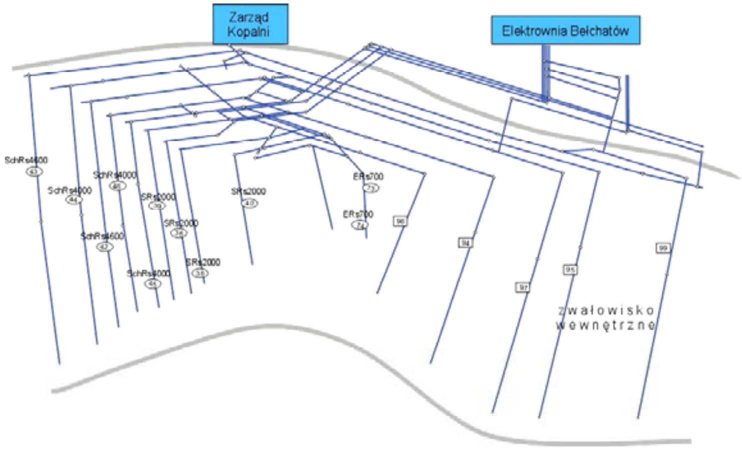

Fig. 1. Scheme of transportation system in the biggest Polish lignite mine [3]

Another example that will be discussed here is an underground copper ore mine that is probably more difficult and complicated case.

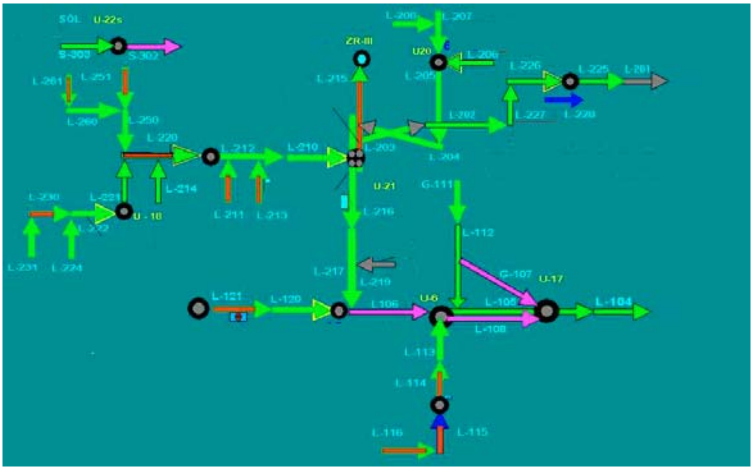

Fig. 2. Structure of transportation system in underground mine

In figure 2 one may see the structure of a transportation system in an underground mine. Each arrow means belt conveyor. In order to apply condition monitoring based maintenance one needs to "recognize" and select crucial problems otherwise diagnostics may appear too expensive and inefficient. As it was suggested before using CM it is necessary to take into account as much as possible factors that influence it (design, technology, operation and change of condition) [2]. In next section we will introduce main of them with some comments related to application of CM techniques.

2. CONVEYOR BELT SYSTEM

The belt conveyor system (BCS) consists of (fig. 3):

- drive unit (electric motor, coupling multistage gearbox, figs. 4, 5),
- pulleys (drive pulley and other),
- belts (textile or with steel cords) with their joints,
- idlers,
- other (belt cleaning systems, control system, et.).

Belt conveyor may be viewed as a part of bucket wheel excavator or dumping machine. In such case CBS is rather short in length, fig 6 (<100 m).

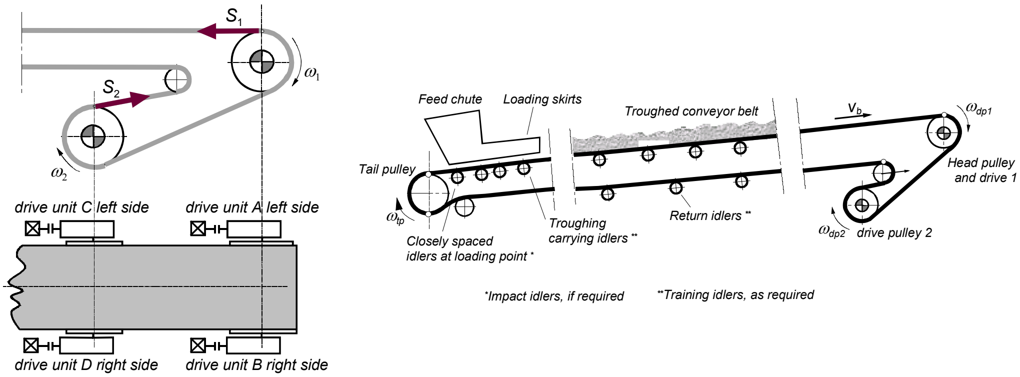

Fig. 3. scheme of belt conveyor [1]

Fig. 4. View on drive units (drive station in (opencast mining))

Fig. 5. View on the drive unit (opencast mining)

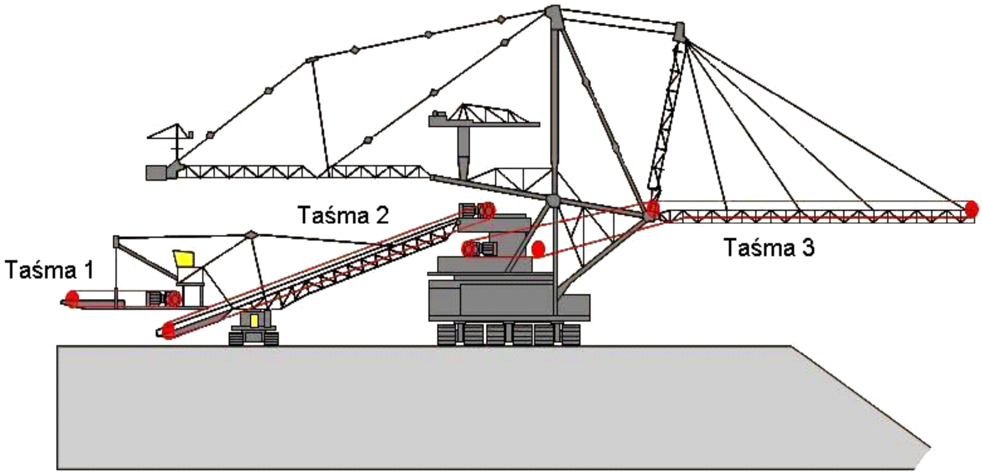

Fig. 6. CBS as a part of dumping machine

It should be noted, that, although relatively simple design, BCS are very important part of mechanical systems and failures of them are quite costly, Fig. 7. Moreover because of their dispersion and number of moving/rotating part it is difficult to maintain it.

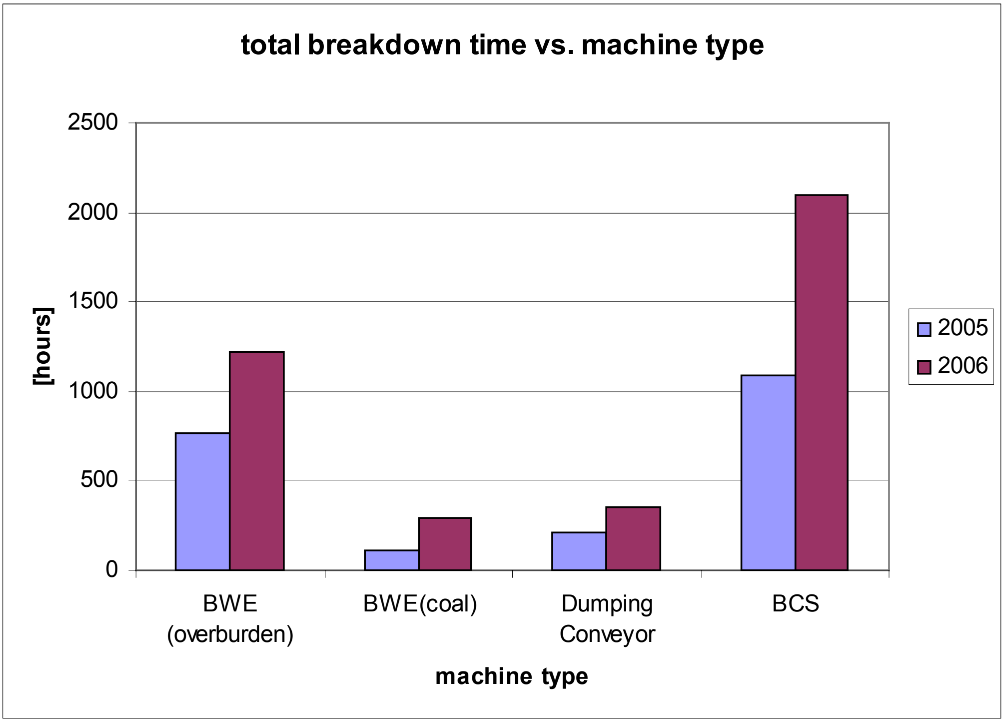

Fig. 7. Comparison of breakdown time for different machines (one mine) [4]

3. TYPE OF FAILURES IN CONVEYOR BELT SYSTEM

In this section we will consider the type of faults that may appear in belt conveyor systems with reference to conveyor components. It will be focused mainly to drive units, pulleys, idlers and belts as the most significant components. It should be noted that there are nearly no investigation in this area.

3.1. DRIVE UNIT

The drive unit consist of electric motor, damping coupling, two or three stage gearbox and coupling that connect output shaft with pulley (fig. 8). A crucial object in this subsystem is gearbox. According to Matuszewski [5] in a considered lignite open cast mine even 14% of gearboxes may be replaced each year due to unexpected failures. These failures are related to the geared wheel wear or damages (broken tooth) and bearings (mainly over limit backlash due to environmental impact, also typical failures like outer/inner race, rolling element).

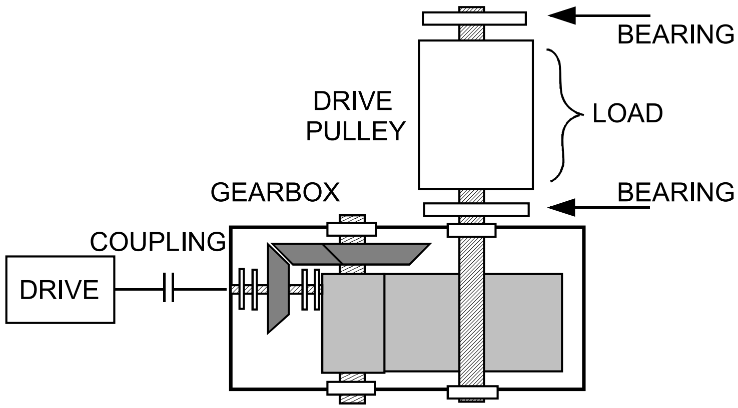

Fig. 8. scheme of drive unit used in CBS

It is easy to notice the significant decreasing number of failures for 2004–2006. One of possible reasons is this that mine started using CM system.

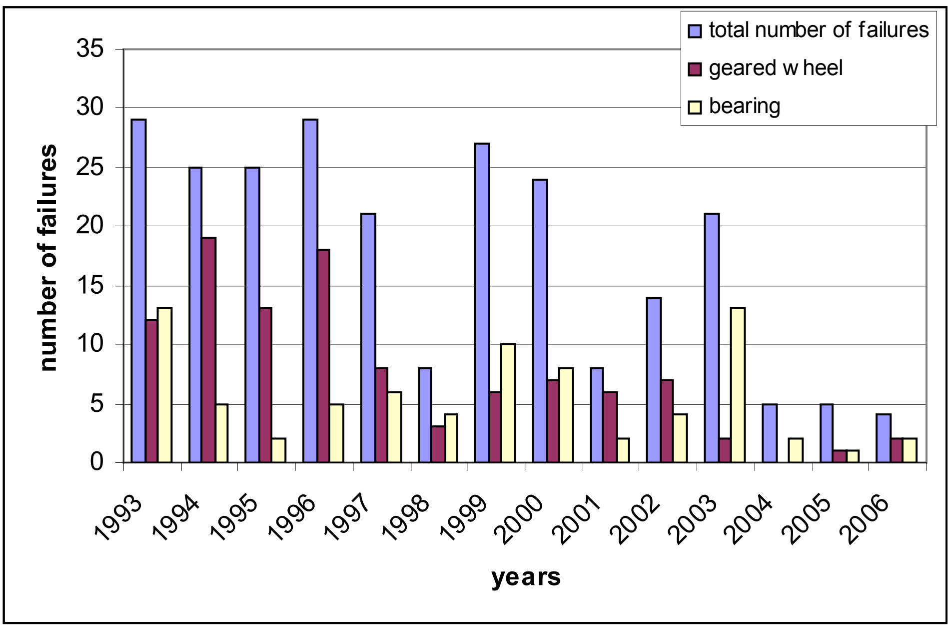

Fig. 9. Number of failures of drive unit gearbox used in CBS

Analysis for drive units used in underground coal mines done by Skoc [6] show that over 50% problems are related to input stage that is a bevel stage. In lignite mines one may notice the similar problem.

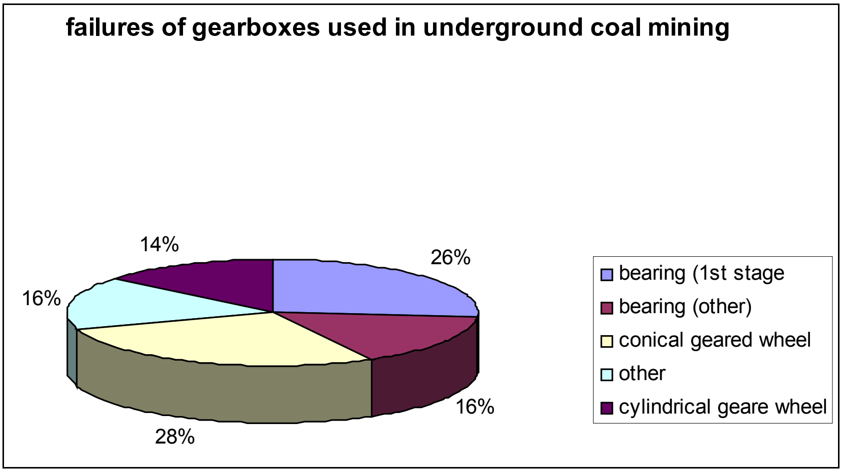

Fig. 10. Percentage of failures for gearboxes used in underground coal mine [6]

Fig. 11. Example of worn geared wheel

3.2. PULLEYS

The mining pulley consist of two bearings, shaft, shell and coating (special material in order to improve belt-pulley contact), fig. 12.

Fig. 12. Mining pulley – general view

As it is shown on fig. 13 (the number of failures depending on pulley type) especially drive pulleys are very sensitive elements.

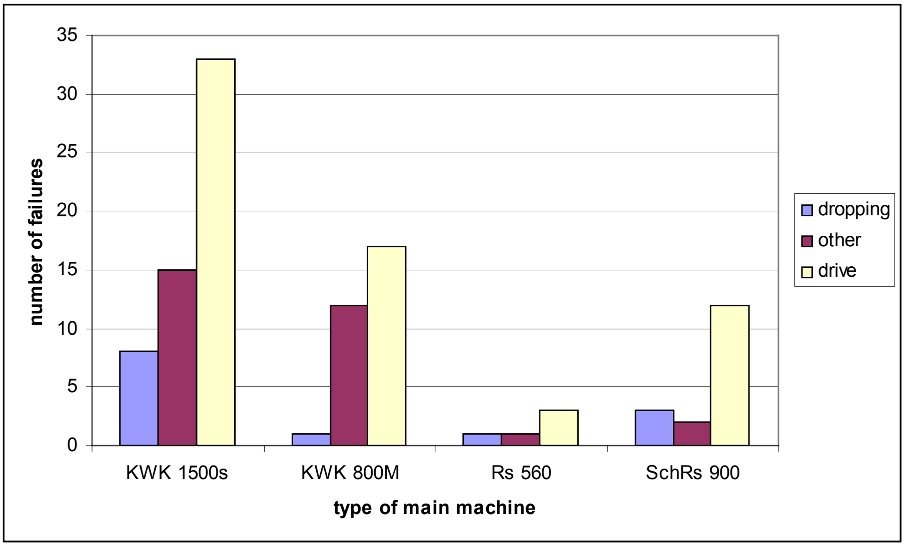

Fig. 13. Number of failures for different types of pulleys used in mine machines in lignite mine

As Matuszewski [5] shown number of pulleys failures may reach over 60 per year that is 12% of used pulleys, fig. 14. One may notice two sources of primary problems, namely: bearings, shells and coating.

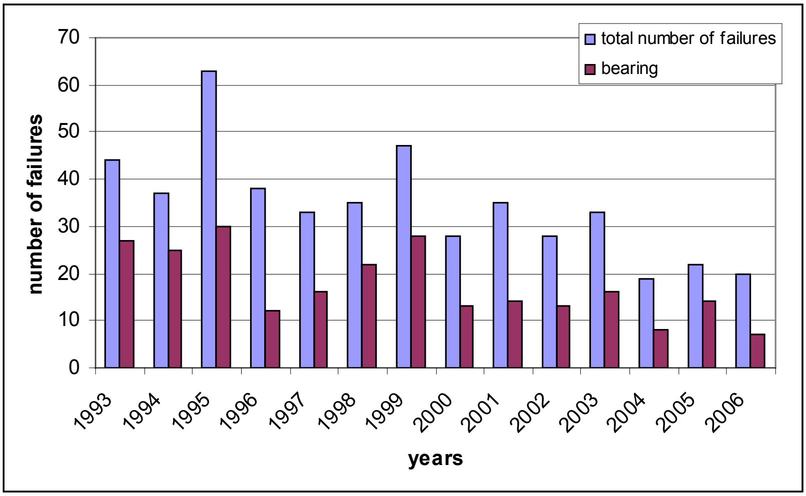

Fig. 14. Failure analysis for pulleys (number of total failures and with respect to bearings)

In figure 15 one may see examples of damaged pulley coating and bearing.

Fig. 15. Examples of pulleys faults (underground mine)

3.3 MOTOR-COUPLING-GEARBOX-PULLEY IN UNDERGROUND MINE

Based on data obtained from Maintenance Department (data from period January–November 2008) in one underground mine a simple analysis have been performed in order to get the convince that many breakdown situations could be omitted if CM is used. In Fig16 we show that for so called main BCS (MBCS) number of breakdowns is much higher than that for smaller, so called department/flat BCS (DBCS). The reason of this is that MBCS is heavier loaded than DBCS (see fig. 2).

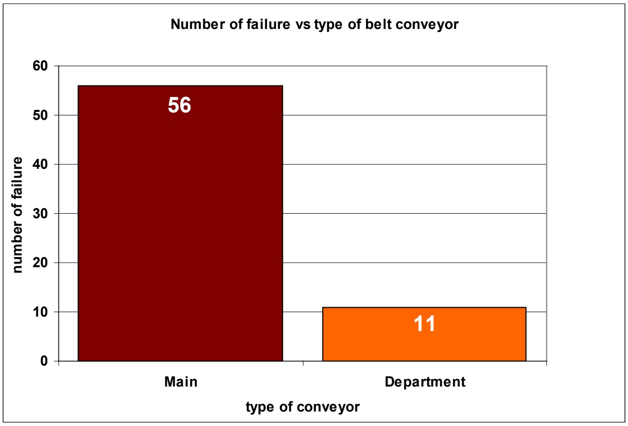

Fig. 16. Number of failures related to MBCS and DBCS

In figure 17 the number of failures related to elements of a drive unit is presented. As one may see the number of failures is more or less similar for each element, however the number of failures of gearboxes is in the highest value.

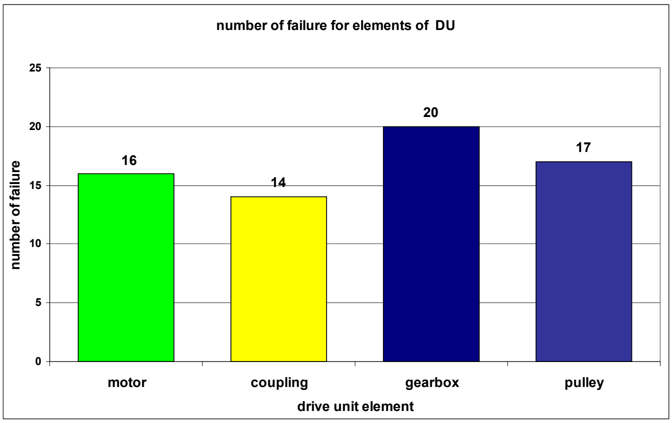

Fig. 17. Number of failures related to elements of drive unit (motor-coupling-gearbox-pulley)

More interesting is to get information regarding failures with respect to type of failure. Figure 18 shows this information for motors and couplings and figure 19 provides similar information for gearboxes and pulleys.

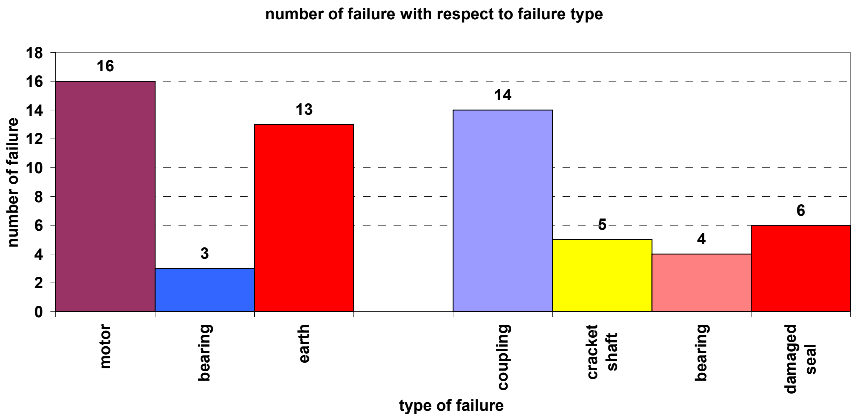

Fig. 18. Number of failures related to DU elements with respect to type of damaged part

From figure 18 one may notice that for motors the most frequent failure is an electrical problem (earth). For couplings one may see that it is hard to select the dominated type of failure.

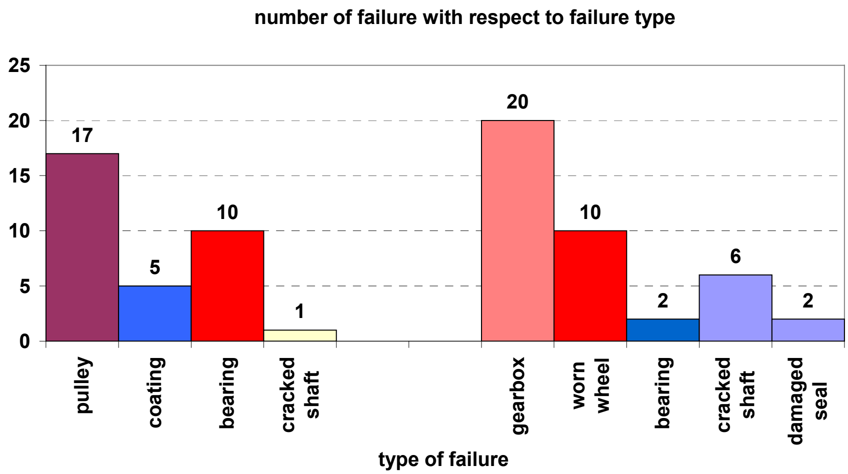

Fig. 19. Number of failures related to DU elements with respect to type of damaged part

The most frequent failures for pulleys are: bearings and shells. For gearboxes number of failures related to geared wheels is 50%. Other critical failure is the damage of input shafts (probably because of overloading). It may be surprising that bearing faults are not so frequent in gearboxes.

Another important issue from the maintenance point of view is the type of event. First kind of event is a replacement done during a scheduled stop or when a repair was planned and problem was fixed during the scheduled stop. Second kind it is unexpected, breakdown and production is lost.

These types of events are typical for mining industry that:

- often requires stops due to for example rock blasting,
- don't use any CM approaches,
- uses machines with shorter life time (degradation processes are quick and different than in other branches).

It is obvious that the most dangerous and expensive are unpredicted breakdowns. The maintenance staff usually not ready for repairs etc. Now we will investigate data in this context.

One may notice that breakdowns are the most frequent type of events for every type of elements. It means that current maintenance strategy is probably not sufficient enough.

Replacement of machine during expected scheduled stop is not frequent. That may mean that it is difficult to "recognize" fault "by eyes", without any CM methods. The third type of event "minor repairs" which is less critical form of breakdown-transportation system is stopped however, repair time so selected to obtain minimal impact for a production output.

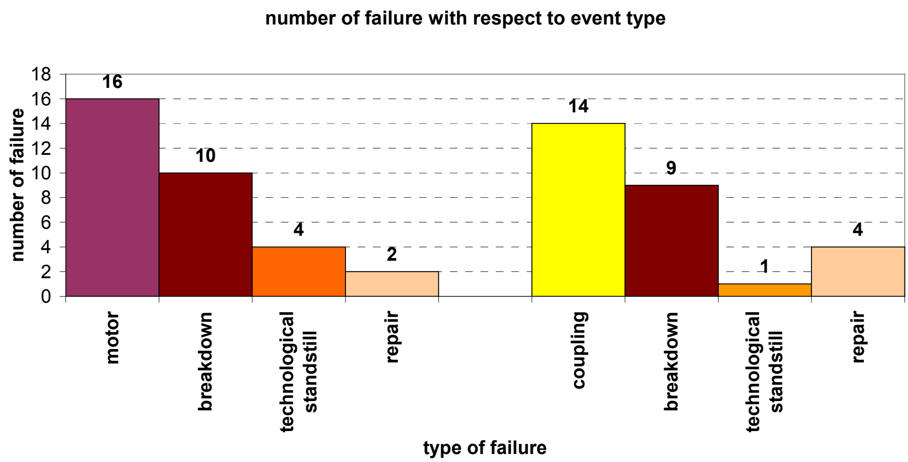

Fig. 20. Number of failures related to DU elements with respect to type of type of event (motor and coupling)

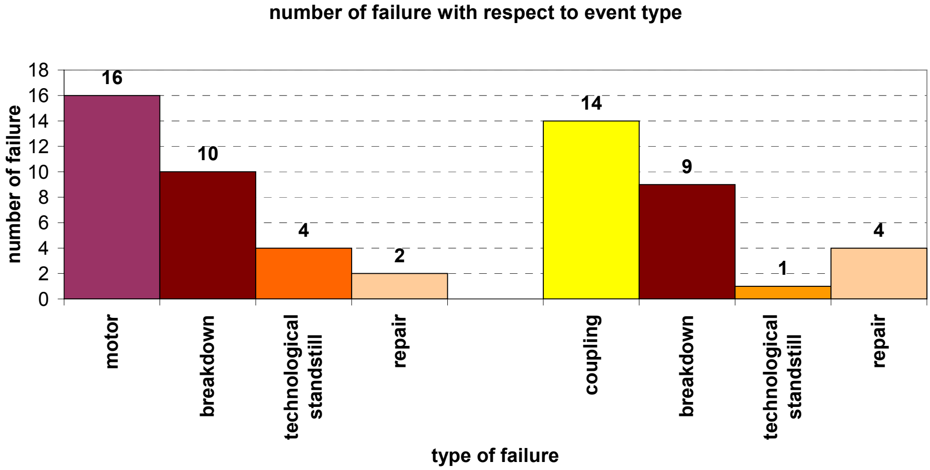

Fig. 21. Number of failures related to DU elements with respect to type of event (gearbox and pulley)

3.4 IDLERS AND BELTS

The failure analysis of idlers and belts are a bit different issue [7, 8, 11]. Idlers are used for supporting belts with transported materials. In some sense idlers are similar to pulleys and consist of bearings and shells. One may expect similar types of failures. The support system for belt consists of three idlers. Because of different load for each idler usually side idlers are more subjected to damage. It needs to be added that in CM context of idlers change of condition is not the only one. Worn bearings in idlers will significantly increase external load for drive units so power consumption will increase. Damaged idlers and pulleys may be the reason of damage for belts.

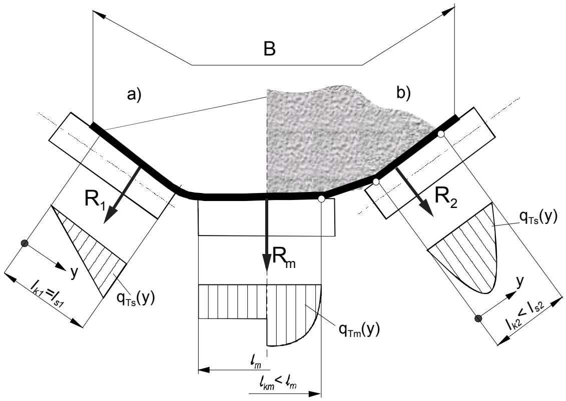

Fig. 22. Distribution of load along belt-idler contact area [9]

Depends on application, belts used in conveyor systems may be divided into two groups: textile belts and steel cords belts. In underground mines usually the textile belts are used. In lignite mines both types may be applied. Expected problems for belts are related to belt (tear, puncture, cut of belt and abrasion of bottom/top covers) and its joints (connected using glue, vulcanized or mechanical joint) [10, 11]. Because of dimension and weight of a belt it needs to be transported in rolls, pieces up to 100–400 m long, depends on a belt type. In order to replace damaged a gearbox or pulley heavy machinery is required. In some cases due to environmental impact (for example rain) it takes a few times longer time.

If one consider the impact of damaged idlers it is another story. The idlers are quite small in comparison to pulleys; however, number of idlers is huge. Damaged idlers may cause failure of belt (the cut of a belt) or even may start fire (belt slipping on damaged idler may increase temperature up to 400°C, 450°C is the limit for so called “difficult-to-burn” belt) and as it was mentioned energy consumption is arising dramatically.

Any of mentioned failure generates cost of breakdown of machines working in series. It has to be mentioned that a conveyor system, that consists of elements in nearly bad condition generates higher level of noise that is not environmental friendly and often requires compensation for a near mine living inhabitants.

4. CONDITION MONITORING OF BELT CONVEYOR SYSTEM

As it was shown the different components of conveyors may be damaged in different ways so different techniques are required to monitor their condition.

For gearboxes (geared wheel and bearings) and pulleys (bearings) one may use a vibration based CM (real time or according to schedule) [2]. It may be also useful to use temperature measurements for bearing condition monitoring. For pulley coating a shell damage detection modal analysis may be used. For idlers condition thermography measurements or noise may be used [13]. For belts with steel cords non-destructive techniques may be applied (measurement of magnetic field of steel cords) [14]. For belt joints for condition measurements some magnetic field sources may be placed in a joint area and by the measurement of magnetic field the distance between these points may be easily calculated [15]. In order to detect cut of covers it was proposed by one of belt produce to place kind of electromagnetic field transmitter. If belt is cut, electric circuit will be damaged and transmitter will stop working [16, 17]. Very often similar approaches like speed measurement (for rotating shaft or moving belt) may provide sufficient information about conveyor condition Monitoring of consumed power/current also may be useful; one of the simplest (technically) is temperature monitoring

5. CONCLUSION

In this paper the problem of failure analysis has been considered. It is based on literature analysis, and failure reports from 3 mine companies and own experience. It was used to produce first conclusion regarding maintenance strategy:

– current strategy used in mining industry (depends on mine) is not sufficient due to high number of unexpected failures, or more precisely breakdowns of elements (sometimes very dramatic – for example fire in underground mine)
– some failures are results of primary failures (damaged of belts due to pulley or idler faults, crack of shaft in gearboxes, pulleys, couplings is results of overloading due to increased turning resistance of idlers and pulleys).
– consequences (listed in section above) of current maintenance policy are very costly and repairs may even takes a few days, due to mining law regulation many procedures must be applied before start of operation.

An application of CM methods has been also discussed. Depends on element of CBS different physical variables must be use (vibration, speed, current, magnetic field, temperature etc). However, failure analysis gives an opportunity to select first the most frequent failures, failures that lead to breakdown, primary failures (that forced to start secondary damages) etc.

It is obvious that application CM methods requires some money, but by failure analysis, root cause analysis [18] and some minimal CM techniques it is possible significantly improve the reliability of conveyor belt systems.

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REFERENCES

[1] *Belt conveyor for bulk materials*, fifth edition. *The conveyor Equipment Manufacturers Association*, CEMA Press, USA, 1997.
[2] BARTELMUS W., *Condition Monitoring. Opencast Mining Machinery*, Published by Śląsk, Katowice 1998.
[3] Internal Materials from KWB Bełchatów Mine.
[4] KOSTANSKI D., *Failure analysis of belt conveyor systems in KWB Konin mine*, Diploma thesis Mining Faculty (Supervisor dr. R. Zimroz), Wrocław 2008.
[5] MATUSZEWSKI P., *Condition Monitoring in BOT KWB Belchatow mine*. Diploma thesis Mining Faculty (supervisor prof. W. Bartelmus), Wrocław 2007.
[6] SKOC A., *Dynamics of bevel gears in mining machines*, Mining, No. 226, Silesian University of Technology, Gliwice 1996.
[7] GLADYSIEWICZ L, KROL R., *Condition Monitoring of idlers.* 1st Conference on Mechanisation of Mining Industry, Institute of Mining Mechanisation Silesian University of Technology, 2002.
[8] KROL R., JURDZIAK L., GŁADYSIEWICZ L., *Economy of Belt Conveyor Idlers Renovation Based on Results of Laboratory Tests*., Industrial Transport, nr 2(2)/2008, Wrocław 2008.
[9] GŁADYSIEWICZ L., *Belts Conveyor – theory and calculation*, WUT Press, Wrocław 2003.

[10] HARDYGÓRA M., WACHOWICZ J., CZAPLICKA-KOLARZ K., MARKUSIK S., *Conveyor belts*, publ. by WNT Warszawa 1999, ISBN 83-204-2402-X.
[11] JURDZIAK L:, *Failure analysis of textile and steel cords belt used in KWB "Turów mine"*, Industrial Transport, 2002.
[12] *Effectiveness analysis of KWB Konin for period January–September 2007*, unpublished internal materials.
[13] DUDEK D., FALKOWSKI M., SZTORCH S., *Termography for condition monitoring – experience from KWB "Konin". Experimental techniques in machine operation*, 3rd Conference, Szklarska Poręba, 1997, Wrocław, Institute of Design and operation WUT, 1997, s. 219–233.
[14] KWASNIEWSKI J., MACHULA T., *Diagnostics of steel cords belts Industrial*, Transport, 2006, nr 4 (26), s. 22–24.
[15] MAZURKIEWICZ D., *Monitoring the condition of adhesive-sealed belt conveyors in operation,* Eksploatacja i Niezawodność, nr 3, 2005, p. 41–49a.
[16] *The system for damage detection for belts*, Becker Mining System.
[17] SZCZYGIELSKA M., MRÓZ J., BROJA A., AUGUSTOWSKI W., *The system for damage detection for belts.* Mechanizacja i Automatyzacja Górnictwa, 09(369), 2001.
[18] BARTELMUS W., *Root cause analysis. Insight*, Journal of British Institute of Nondestructive Testing, 2006.

ANALIZA AWARYJNOŚCI PRZENOŚNIKA TAŚMOWEGO NA POTRZEBY MONITOROWANIA STANU TECHNICZNEGO

W pracy przedstawiono analizę awaryjności przenośnika taśmowego w kontekście diagnostyki technicznej. Przed zastosowaniem technik diagnostycznych należy zidentyfikować kluczowe elementy układu, które należy monitorować, na podstawie tych analiz można dobra narzędzia i metody diagnostyczne, szczególnie w w przypadku tak niekorzystnych warunków środowiskowych jak kopalnia odkrywkowa czy podziemna. W artykule skoncentrowano się na pierwszym etapie diagnostyki: oszacowania skali problemu: najczęściej występujących uszkodzeniach, ich typach i lokalizacji oraz ich znaczenia w kontekście zarządzania przenośnikiem taśmowym. Uwagi na temat metod detekcji tych uszkodzeń są także rozważane. W artykule przedstawiono także przykłady uszkodzeń i czas wymagany do przywrócenia pełnej gotowości.