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POLYURETHANE COATINGS AND METHODS OF EXAMINATION OF THEIR PROPERTIES

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Abstract: *The paper concerns problems of counteracting excessive wear of parts of mining machines. Key issues regarding tribology of polymer coatings are discussed. Methods of testing of properties of manufactured coatings on given elements are presented as well. Examples of utilization of polymer coatings are presented.*

Keywords: Coatings, Polyurethane, Mining, Abrasive wear, Tribology.

1. Introduction

Brown coal is one of the most significant fuels. Such countries like Germany, China, United States and Poland are world leaders in terms of production of energy from brown coal. This fuel is excavated in open pit mines utilizing among others bucket wheel excavators and stackers. Their working conditions are extremely demanding as their parts are endangered to abrasive wear most of all. To lower this disadvantageous influence of rocks, enormous loadings and changeable weather conditions, polymer coatings, including polyurethane ones, are applied on surface layers of selected parts (Augustynowicz, 2002). Most important properties of such coatings are: thickness, hardness, adhesion to substrate, resistance to both scratches and abrasive wear.

2. Tribological aspects of usage of polymer coatings

Wear resistance is a key parameter when analyzing operation of members of tribological pairs. Machines and devices in working conditions of a mine are especially endangered to disadvantageous influence of abrasive particles (abrasive wear) and environment (corrosion) most of all. Because of that special coatings are applied on tribological surfaces. Abrasion and cohesive wear are main mechanisms observed in polyurethane coatings (Mirhosseini et al., 2016). In (Kotnarowska, 2010) a study of process of wear of polymer coatings is done. It was found out that wear rate depends mainly on relative velocity between coating and particles which act as abrasive. Nonlinear character of this phenomena was observed. Also such parameters like residual strain which results from plastic deformation and ultimate elongation of a given coating influence wear resistance of polyurethane are crucial (Ashrafizadeh et al., 2016).

Key issue in terms of durability of coatings, including polyurethane ones, is to improve their wear resistance. To achieve this goal special nanofillers can be applied (Kotnarowska et al., 2011). It was found out that all of tested nanofillers had beneficial impact on wear resistance. It is worth noting that this is not a rule in case of other materials used for coatings, e.g. for epoxy coatings different dependency was observed.

Polyurethane itself is considered as an excellent material for coatings in terms of wear resistance improvement (Ashrafizadeh et al., 2016). Those coatings are characterized by extremely advantageous mechanical parameters, thermal and chemical stability as well (Mirhosseini et al., 2016). Polyester polyoles as coatings improve wear resistance as a result of hydrogen bonding between soft and hard structures.

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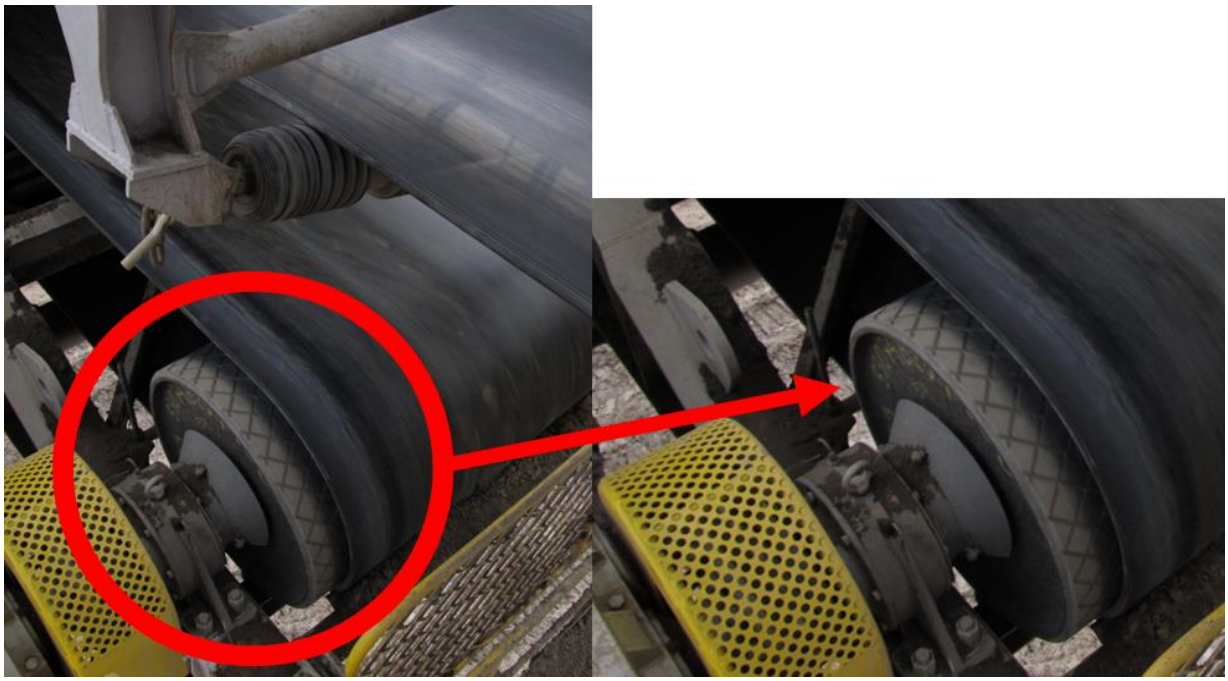

Fig. 1: Examples of utilization of polymer coatings in real mining conditions. Coatings applied on driving wheel of belt conveyor.

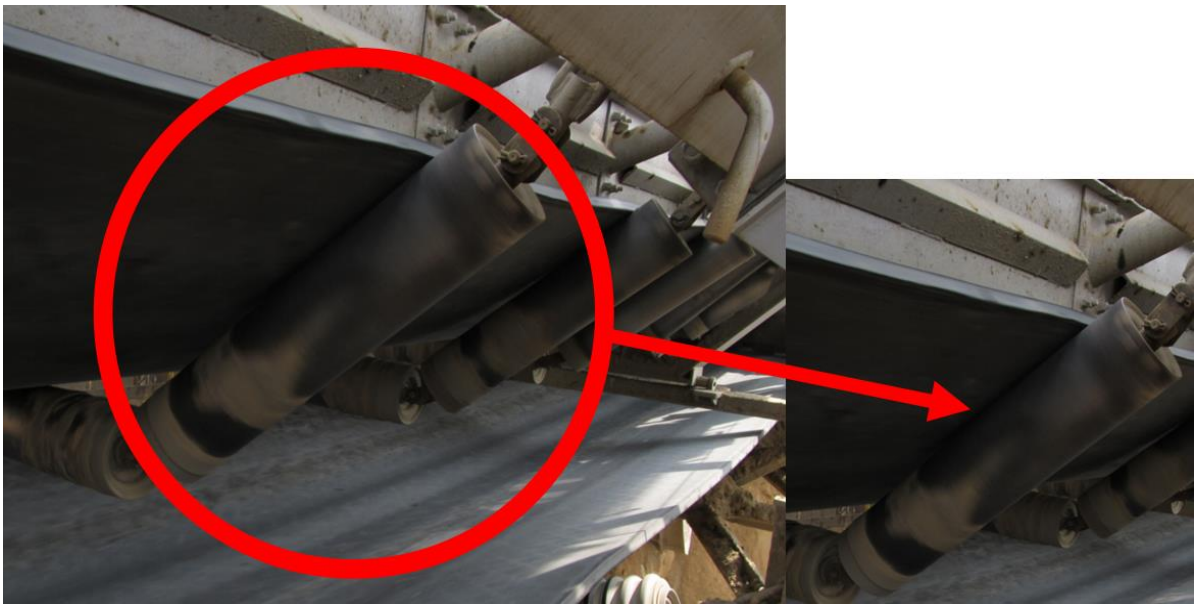

Fig. 2: Examples of utilization of polymer coatings in real mining conditions. Coatings applied on rollers of belt conveyor (Author's archive).

As mentioned earlier, environmental influence can be very adverse for parts of mining machinery, especially their surface layers. If there is a coating applied, this negative impact takes place in the structure of those additions. Roughness of coatings is the parameter which increases with time when coating is exposed to air influence (Kotnarowska, 2013). Main factors contributing to this process are: temperature and humidity changes and UV radiation. The latter is considered as the most significant climatic factors. This influence can in the long run lead to both physical and chemical destruction of a given coating, which can be revealed through corrosion which can be escalated by another phenomena. Among them is influence of aggressive media and microorganisms. If the process of ageing of coatings in such conditions lasts too long even loss of adhesion and following delamination and crumbling of fillers occur (Kotnarowska, 2013). All in all process of ageing of coatings results in deterioration of their protective function.

Wear resistance of coatings can be significantly improved due to formation of so-called interpenetrating polymer network based on polyurethane and epoxy. What is more, addition of nanodiamonds enables achieving similar results (Xia et al., 2014).

In open pit mining polyurethane is primarily applied for wheels and rollers of belt conveyors. Exemplary coatings are presented in Figs. 1 and 2.

3. Tests of selected polyurethane properties

There are several types of measurements which are used to examine properties of already manufactured coatings. The most significant testing methods are discussed below.

3.1. Thickness of coatings

Depending on the method which was used, destructive or non-destructive methods can be utilized to evaluate thickness of a given coating (Kotnarowska and Wojtyniak, 2010):

- Using mechanical contact devices (can be used for flat surfaces only).
- Using microscopes (on a sample of a element with coating, on a coating separated from substrate or on a coating cut at a defined angle).
- Using magnetic gauges (gauges utilize magnetic induction or magnets). This method enables measurements of coatings applied on substrates with any shape. This method is very useful in mining conditions.
- Contactless method based on β particles dispersion or X-ray Fluorescence. This method is dedicated to cases when measuring device should not be in contact with examined surface.

3.2. Adhesion to substrate

There are 2 methods of testing of adhesion of a coating to substrate (Kotnarowska and Wojtyniak, 2010):

- Method of cuts meshwork. It consists in performing of 6 cuts in a coating (through entire thickness) in 2 perpendicular directions. Distance between cuts depends on coating thickness and type of the substrate. There should be 3 measurements made on all samples. After evaluation of examination results, one should attach a parameter described in a standard to the meshwork. The lower this value is, the better adhesion is (minimum value is 0 and maximum value is 5).
- Tear away method. It consists in tearing away a given coating perpendicularly to the substrate with a special device. A test stamp initially glued to the examined surface is torn away with increase of stress up to 1 MPa/s. The lowest values of tensile stress needed to separate the weakest boundary surface characterizes adhesion in this method. The results of this test are both the value of tensile stress and areas on which separation took place.

3.3. Resistance to abrasive wear

Resistance to abrasive wear is tested with flux of an abrasive material which strikes a given coating from a selected distance (Kotnarowska and Wojtyniak, 2010). The examination is carried out until a previously defined area of a substrate's surface with coating is unveiled. Artificial corundum is used (3,5 kg of mass) which strikes the tested surface from 1 m of height until entire thickness of the coating is worn. Subsequent portions of abrasive material are smaller until there is 0,5 kg of material left. The end of the examination is when elliptical hole in coating with bigger diameter of 3,6-3,7 mm is observed. Wear is proportional to used mass of the abrasive material and inverse to average thickness of the tested coating.

3.4. Resistance to scratches

This test is performed with a needle which scratches a substrate under some loading. The device is placed perpendicularly to the sample and is moved at 30 – 40 mm/s. The scratch must be continuous and have a length of 60 mm. During the test the loading is increased. The parameter which characterizes this resistance is the lowest value of loading which scratched the sample.

4. Conclusions

Application of polymer coatings, including polyurethane ones, gives plenty of advantages. It improves primarily resistance to: corrosion, influence of chemical substances and abrasive wear of a part where it was used. There are different tests which enable verification whether an analyzed coating was manufactured correctly. A very disadvantageous process is when a coating structure is penetrated by micro-peaks of a mated elements' surface layer. It is more probable when the other element has higher hardness than the coating. If such a situation occur, strong dissolution and accelerated corrosion can be observed (Dobrowolska et al., 2015).

Additionally one can notice that tribological processes which include polymers are extremely complex. For these materials friction coefficient and wear data only are not sufficient to fully evaluate tribological properties of a pair in which these materials are used (Capanidis, 2007). Among needed parameters one can list characteristic of a material of a counterface and condition of both surface layers most of all. The latter includes such parameters as chemical composition, surface roughness, hardness of the sliding surfaces and information about producing technology as well (Capanidis, 2007).

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