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ON WEAR PROCESSES IN PIN JOINTS IN CATERPILLARS OF LARGE-SIZE WORKING MACHINES

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Abstract: *The paper is focused on wear processes which occur in undercarriage units during operation of large-size working machines. Special attention is paid to pin joint pairs which have the biggest influence on durability of driving units and for this reason the mobility of the entire large-size working machine as well. Two main negative processes which can take place in elements of those joints while such a machine is moving are distinguished: a gradual degradation and sudden damages. Those phenomena are discussed and illustrated.*

Keywords: Mining machinery, Wear, Friction, Failures, Pin joints.

1. Introduction

In most of large-size working machines which are operated in open-pit mines, caterpillar driving units are used. Those units are extremely endangered to failures as a result of adverse working conditions. For this reason it is essential to understand all phenomena and processes which run within large-size undercarriages. This knowledge plays a key role in safe and reliable operation of the machinery where those subassemblies are applied. Among factors which influence such an operation one can list most of all loading acting on parts of undercarriages and wear processes which take place there.

2. Problem identification

A verified method of identification of both loads within those undercarriages and areas which are endangered to occurrence of the highest stresses is presented in (Maslak et al., 2013). Also in that article attention is paid to a significant problem that even during normal and stable movement of a large-size machine, forces acting inside caterpillar units are of a stochastic character. Variations of values of those loads are considerable.

To ensure reliable work of friction joints one should most of all properly match mating materials and correctly shape geometrical features of joint members. Because of that, knowledge about tribological parameters is a key requirement for both the designer and the operator of a machine in which a given tribological node is applied (Capanidis, 2007). Both friction and wear are very complex processes and for this reason a comprehensive approach must be applied to study them properly. Such a research is even more difficult when corrosion is included as well (Dobrowolska et al., 2015). A comprehensive study on wear processes in mining conditions is presented among others in (Petrica et al., 2013; Petrica et al., 2014). Abrasive wear is the most common type of wear which is observed during operation of large-size caterpillars. One of the most important conclusions from those works is that rocks' influence strictly depends on character of work of a machine. What is more, mechanical properties of rocks, e.g. uniaxial compressive strength primarily influence wear rate: the highest wear rate of undercarriages parts is when those elements are in contact with rocks with the highest values of uniaxial compressive strength. On the other hand, influence of rocks with low uniaxial compressive strength results in abrasive embedment most of all. Another important factors on which wear rate depends are hardness and grain size of a material subjected to wear (Petrica, 2014).

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The most significant failures of undercarriages are those which influence movement and for this reason operation of the entire machine. Among such failures those located in caterpillar chain are the most critical (Wocka, 2011). Durability of the chain depends most of all on technical condition of elements of pin joints kinematic pairs. A typical pin joint node consists of a links' lug, a pin and a bushing which separates them.

Degradation of pins, regardless of the nature of its course, is relatively easy to remove by exchanging pins with new or remanufactured ones (Onichimiuk, 2004). In case of a bushing defect, if the damage is not too large an effective solution may be a replacement of the bushing with a new one. Much more difficult is to remove the effects of degradation of pin joint holes. It is unacceptable to operate a basic machine if at least 1 member of its caterpillar chain is damaged (for example there is a degradation of a pin joint, cracks in welds, large deformation or rupture of lugs or rupture of a plate). Pictures of pin joint nodes without pins are shown in Fig. 1.

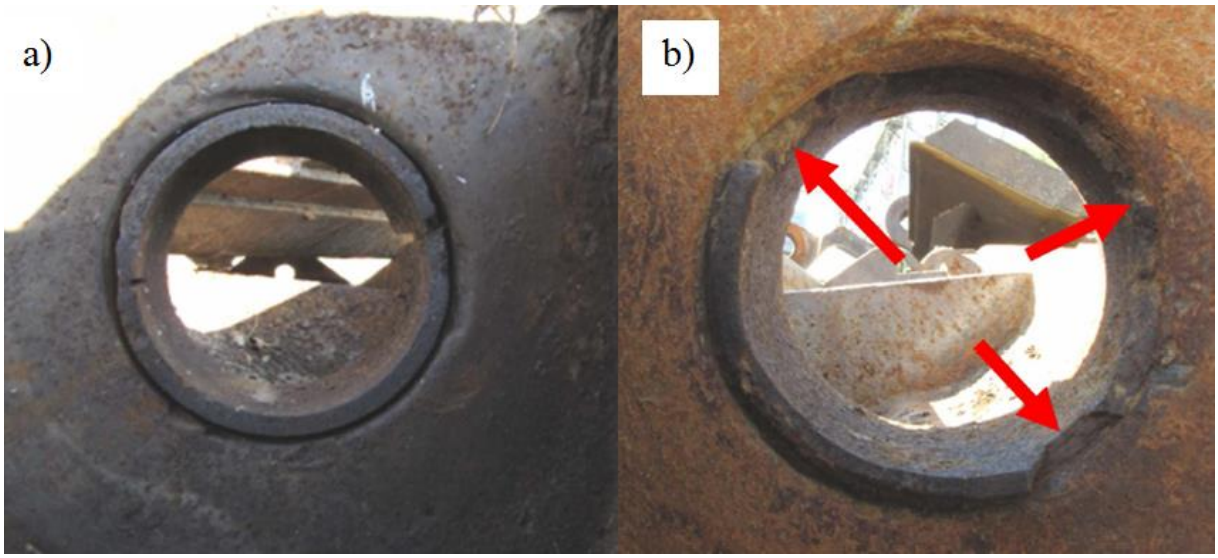

Fig. 1: Examples of a pin joint pair in large size caterpillar undercarriage: a) new bushing, b) bushing with its edges chipped off, highlighted with arrows (author's archive).

Nowadays in most cases in holes of pin joints of large-size undercarriages, one applies interchangeable bushings made of manganese steel. Based on years of operational experience it is assumed that limiting level of diametric wear in holes/bushings in undercarriages of basic open-pit mining machines should not exceed the value of 1.5 mm (measured in the diameter). If the degradation is greater, it is necessary to replace a worn element with a new chain link what is difficult, time consuming and most of all requires the machine to be out of service for some period of time.

The process of replacement of a part of a chain link includes the following steps (Onichimiuk, 2004): to set a damaged item in the position under the driving wheel, to unscrew the chain by shifting the idler wheel, to disassembly the link-plate pair by removing pins connecting the link with adjacent elements. After replacing a given element with a new one tension of the chain is set so that the value of overhang between the roller bearings is kept within a required range (typically a range of 80 to 120 mm).

Replacement of bushings or regeneration of holes in lugs of links is carried out in workshops on special stands which are partially or completely robotic. Nowadays virtually all working surfaces of links are regenerated by welding operations, and the regenerated links are connected with plates using semiautomatic technique (Onichimiuk, 2004; Wocka and Warcholak, 2011).

3. Processes of degradation of pin joints in large-size undercarriages

Wear processes which occur in pin joints in large-size caterpillars can be divided depending on how long do they evolve. If it takes time to progress a failure one can classify it as a gradual one while if it occurs instantly, i.e. with no earlier symptoms, it can be named as a sudden damage.

3.1. Gradual failures

The gradual degradation takes place in chain links in large-size undercarriages under the influence of tribological processes, most of all because of abrasive wear. Such a wear is caused by soil particles which get into rotating joints. Additionally electrochemical (oxidizing) influence results in corrosion which occurs in these kinematic pairs.

As a result of mud particles getting into the friction nodes at contact surfaces between the cooperating parts a peculiar kind of lubricant is obtained. Under conditions of considerable surface pressure (several dozens of MPa or more), this substance is squeezed between the surfaces of a bushing and a pin. Under the influence of these processes on the working surfaces of nodes micro-cracks can be formed. These defects gradually enlarge and the final result is chipping of portions of the surface layer in pin joint holes or bushings.

If wear of a node is small, further usage of the caterpillar chain is allowed conditionally and for a limited period of time. It can proceed without further increase of degradation of neither pin nor hole.

However due to wear exceeding the limit value, increased clearances are formed, causing a further deterioration in terms of cooperation between the pin and its hole and as a result additional dynamic loads occur and intensification of the processes of abrasive wear can be observed. Through increased clearances larger quantities of subsoil, sand and hard rock particles can penetrate inside the node and act as abrasives.

In order to prevent these negative phenomena in pin joint holes in large-size caterpillar undercarriages tight fitting bushings are mounted. These bushings are made of a material of lower hardness comparing to the material of the pins, so that the bushing wears quicker than pin and surfaces of holes in link's lugs. After crossing the limiting values of wear (described as a specified loss of volume) in a given bushing, it is removed and replaced with a new one. That significantly reduces wear process of pins and holes in the caterpillar links and contributes to lower operating costs of these assemblies (a set of bushings is in fact much cheaper and its replacement is faster than regeneration of the hole in the links' lugs or production of new links which also must be attached to plates).

In the initial stage of wear processes of a bushing fragments of its subsurface are chipped off (Fig. 1b). In the next step, as a result of further degradation the holes are exposed. Continuation of operation of the links under these conditions results in direct wear of the links.

In extreme cases of degradation of the pin joint nodes, bushings can fall out of the hole under excessive lateral forces that arise during driving a curvilinear trajectory. Another factors favoring the tendency to fall out of the bushings from the holes in links can be manufacturing or mounting errors (e.g. improper fit of a bushing). Therefore mounting of a bushing should be performed with a particular care.

3.2. Sudden damage

Sudden damages of pin joints most commonly occur as a result of an excessive burden of additional loading (unexpected by the designer). It can occur for example when a machine is moving on a straight line on the ground with large bumps. In such a case additional forces occur causing movements of the plates in the vertical plane. These extra loads may result for example in movement of a bushing (Fig. 2a), its fall out of the hole (Fig. 2b), plastic deformations of pins and links' lugs or even rupture of links' lugs.

Formation of brittle cracks in lugs is often a result of a combination of several destructive factors. One of the factors of a structural nature is weakening of a cross-section in the area of a lug whereas among technological factors one can distinguish imperfections in material or inadequate thermochemical treatment (obtaining an incorrect structure of the links' material). Destructive operational factors are: gradual degradation like wear of a hole or corrosion and errors committed by the operator (e.g. to perform unauthorized maneuvers such as turning with too small turning radius, driving on highly uneven ground). Sudden damages of elements of caterpillar chain are essentially unrecoverable. Exceptions are damages of pin joint bushings which can be exchanged with new ones.

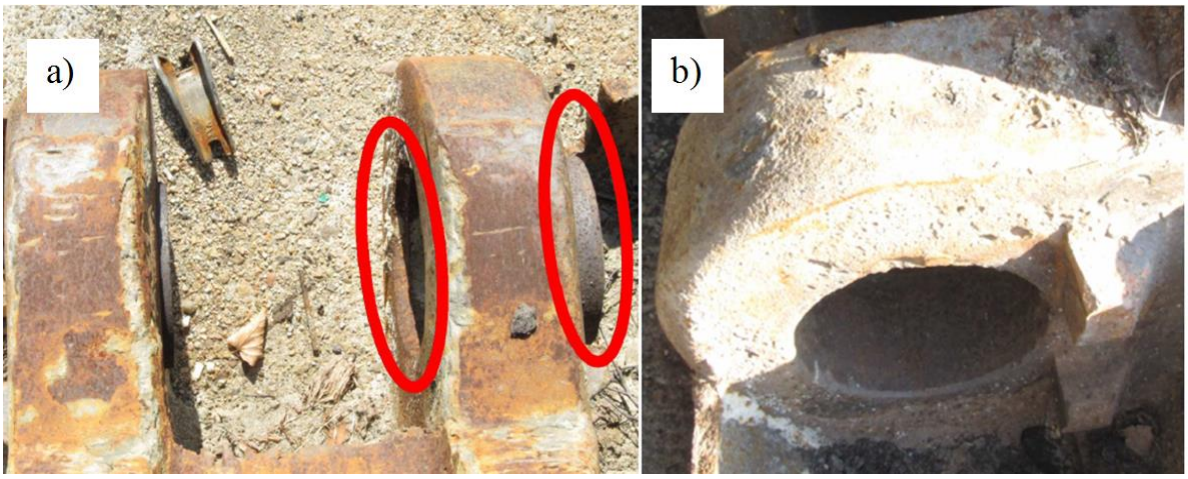

Fig. 2: Examples of sudden damages: a) translated bushing, b) links' lug with its bushing fallen out of the hole (author's archive).

4. Conclusions

Issues of wear are of a special importance in such compound mechanisms as caterpillar chains. Basing on experience of previous researches pin joint nodes can be considered as key elements in terms of proper work of those assemblies. Study presented in this paper contributes to understanding those phenomena what is indispensable to use large-size undercarriages effectively. What is more, for safe and failure-free operation of large-size caterpillar undercarriages their reliability should be taken into account. A method of evaluation of this parameter is presented in (Sokolski, 2017).

References

Capanidis, D. (2007) Selected aspects of the methodology of tribological investigations of polymer materials. Archives of civil and mechanical engineering, 7(4), pp. 39-55.

Dobrowolska, A., Kowalewski, P. and Ptak, A. (2015) Influence of the lubricating fluid on the changes on rubbing metallic biomaterials surface. Colloids and Surfaces A-Physicochemical and Engineering Aspects, Vol. 480, pp. 419-425.

Maslak, P., Smolnicki, T. and Pietrusiak, D. (2013) Strain gauges measurements and FEM analysis of elements of chassis of open cast mining machines. Tehnicki vjesnik—Technical Gazette, 20(4), pp. 655-658.

Onichimiuk, M. (2004) Regeneration of caterpillar links in SRs-1200 excavators and A2RsB-8800 stackers. Surface Mining, 46(1), pp. 33-36 (in Polish).

Petrica, M., Badisch, E. and Peinsitt, T. (2013) Abrasive wear mechanisms and their relation to rock properties. Wear, 308(1), pp. 86-94.

Petrica, M., Painsi, M., Badisch, E. and Peinsitt, T. (2014) Wear mechanisms on martensitic steels generated by different rock types in two-body conditions. Tribology Letters, 53(3), pp. 607-616.

Sokolski, P. (2017) Method of reliability assessment of pin joints in undercarriages of open-pit mining machinery - a case study, in: Risk, reliability and safety: innovating theory and practice: proceedings of the 26th European Safety and Reliability Conference, ESREL 2016, Glasgow, Scotland, CRC Press/Balkema, pp. 2472-2477.

Wocka, N. and Warcholak, A. (2011) Innovative activities to increase exploitative durability and reliability of crawler mechanism for driving excavators and spreaders in Polish coal mines Mining and Geoengineering, 35(3/1), pp. 291-307, (in Polish).