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ON POSSIBILITIES OF DIAGNOSING OF CATERPILLAR UNDERCARRIAGES IN LARGE-SIZE WORKING MACHINES

P. Sokolski*

Abstract: *The paper concerns issues of diagnosing a technical state of caterpillar undercarriages of large-size working machines. Exemplary failures of their parts are presented. Different possibilities of performing diagnostic process basing on criterion of location of sensors are discussed. Each of the presented methods is supported by various examples of possible implementation in real operating conditions in an open-pit mine.*

Keywords: Surface mining, Large-size working machines, Caterpillar chain links, Diagnostic signals.

1. Introduction

In basic open-pit machines operated in brown coal mines 3 types of undercarriages are usually applied: walking, rail and caterpillar ones (Durst, 1986; Wong, 1989). The latter are the most common because of number of fundamental advantages, including high mobility in extreme working conditions, high value of thrust and low base compression. Such undercarriages are presented in the Fig. 1.

Fig. 1: A set of 2 caterpillar undercarriages. Source: author's archive.

Durability of driving units plays a key role in terms of reliability of the entire machine (an excavator or a damping conveyor). The character of degradation of subassemblies and parts of large-size working machines' undercarriages strictly depends on loading acting on them. Because of that, to assess the durability of these elements it is needed to evaluate values of the forces generated during the work of such a machine. An empirical method enabling this analysis is presented in work (Smolnicki and Maslak, 2012).

Degradation and damages of different parts of caterpillar undercarriages in large-size working machines is described in details in works (Bosnjak et al., 2010; Bosnjak et al., 2011). A comprehensive attitude to this problem can include both experiments on real elements and numerical simulations based e.g. on FEM.

* Piotr Sokolski, PhD.: Chair of Fundamentals of Machinery Design, Wroclaw University of Technology, ul. Lukasiewicza 7/9; 50-371 Wroclaw; Poland, piotr.sokolski@pwr.wroc.pl

Among all elements of caterpillar undercarriages chain links are one of the most important as even insignificant degradation of their technical state can have a negative impact on the mobility of the driving unit (Sokolski, 2012).

Ovalization of a pin-joint hole or plastic deformation of only one link's lug can make the whole machine unfit for use or at least decrease its serviceability. In case of a tear-off of a link's lug, the caterpillar chain is damaged disabling further movement of this undercarriage. It also can negatively influence the stability of the machine. A caterpillar link in good technical state and links with exemplary failures are shown in the Fig. 2. More detailed description of typical failures of the chain links, including information about their areas especially endangered to damages is presented in work (Sokolski and Sokolski, 2014).

Fig. 2: Caterpillar chain links: a) Bottom view of a part in a good technical state; parts with typical failures; b) Torn-off lug; c) Plastically strained lugs. Source: author's archive.

2. Diagnosing of Caterpillar Undercarriages

In recent years diagnostics have become more and more important in the field of operation of large-size working machines in Polish open-pit mines. Different techniques and procedures are used for evaluation of technical state of parts and assemblies of basic mining machinery (Sobczykiewicz and Kowalczyk, 2009). Thermal and vibroacoustic signals are used most of all. However there are no such procedures applied for monitoring of undercarriages. Because of that there is a particular need for formulation of theoretical principles and practical implementation of monitoring and diagnosing of undercarriage assemblies. It refers to evaluation of technical state of links, plates, supporting wheels and balance lever's units.

In this context, the diagnostic task should meet the following basic requirements (Sokolski, 2012):

- To be achievable in the process of normal functioning of the undercarriage (the working process of the machine), because then the obtained data reflect the real state of the examined parts.
- To provide the necessary information about both the technical state and the wear processes occurring in these parts.
- To ensure acquiring the required information at an acceptable level of running expenses (taking into account economic criteria).

In order to develop effective diagnostic procedures applied for monitoring of undercarriages of large-size working machinery, appropriate observation tools must be selected. The main factor in the applicability of such a system is the character of operating conditions of the undercarriages. In particular one can list extremely high loading and constant adverse environmental influence (mud, dust, rain, snow, etc.). For these reasons, many commonly used diagnostic tools can not be applied for evaluation of technical state of driving mechanisms of excavators or damping conveyors.

To put in order all of the possible monitoring methods, as a criterion of classification one can select the location of the components of the measuring system. If so, then the diagnostic process using sensors placed on the assessed object or sensors located outside it can be distinguished (Sokolski, 2012).

Technical condition of an undercarriage can be evaluated using invasive methods with sensors installed on both stationary and movable elements. In the first case a diagnostic test can be based for example on monitoring interactions between components cooperating directly with the part on which the data is registered. In this variant, it is also possible to measure and evaluate geometric relationships with selected moving parts.

For instance: for a pair of "balance lever - caterpillar plate" an indicator for an assessment of degradation processes may be the distance between the balance lever (a reference element) and selected plates. When this value exceeds limiting ones from the acceptable range, one can make a conclusion that e.g. deterioration of the tensioning system is advanced. Such degradation may result in an increase in so-called overhang of the upper side of the caterpillar chain.

Another example of diagnosing of the technical state of caterpillar driving units using sensors on stationary parts is an acquisition and analysis of vibroacoustic signal registered on the system of balance levers.

For the case of a sensor placed on a moving part, measurements of the caterpillar chain's pitch can be proposed. Such a test may rely on determining the distance between adjacent plates. Mutual wear of links and pins may result in the formation of clearances in this tribological pairs, which directly effect in a change of the chain's pitch.

Another possibility of implementing an assessment of caterpillar chain's technical state using a sensor on a movable part can be a strategy analogous to the one described previously. This method bases on the measurement of the distance between a fixed and a movable element. In such a case a sensor can be placed on a plate and as the reference object one of stationary parts of the undercarriage such as a balance lever can be selected.

To get a diagnostic data in terms of evaluation of the technical state of caterpillar driving units with an outside sensor one of non-invasive methods can be carried out. Recording of diagnostic signals through sensors located outside the tested elements can be implemented using a suitable wireless technology. In this situation there is no need for direct access to the machine what should be considered as one of the main advantages of such a monitoring strategy. Intensive development of wireless signal transmission techniques creates a relatively large choice. Often the decisive criterion is the cost of an implementation of this system.

In the author's opinion the most reasonable among wireless methods can be: analyses based on acoustic signals generated during a movement of a basic mining machine and assessment upon base compression under the caterpillar as well.

In the first case through the evaluation of an acoustic spectrum and determination of basic parameters characterizing this signal, it is possible to assess the progress of degradation processes. Additionally, analyzing such a signal it is possible to identify failures occurred in undercarriages' parts.

Base compression under a moving undercarriage enables evaluation of the distribution of loads transferred from machine to subsoil. It is highly dependent on the state of the chassis' components.

Both of the described methods (the acoustic one and the analysis of base compression) were positively verified by the author. The results of analyses and methods of assessment are described in details in (Sokolski, 2012).

3. Conclusions

The process of diagnosing of the technical state of large-size caterpillar undercarriages is a significant factor increasing the operational reliability of their assemblies. Therefore it is a key issue and comprises a part of a development trend of monitoring of open-pit basic machines.

A typical phenomenon during diagnosing is an unequal influence of changes in the technical state of observed parts on different diagnostic signals. For this reason, a selection of redundant signals is well-founded. It allows reducing the number of failures that could not be registered. In addition, this way of monitoring reduces the possibility of an error in the assessment of the technical state of the tested parts. These factors increase the likelihood of formulating the correct diagnosis.

The monitoring strategies described in the paper allow to conduct differently the diagnostic process. Because of that one can adapt a research method to possessed measuring devices. Another advantage of such a situation is as well a possibility of building a comprehensive diagnostic procedure based on an utilization of complementary and redundant signals.

In most cases because of the real operating conditions of large-size caterpillar undercarriages, the usage of a diagnostic system with sensors installed directly on a tested object can not be performed. It is mainly because of the possibility of a mechanical damage to these devices. For this reason the best (if not only) empirically sensible solution is a usage of sensors placed outside elements of caterpillar undercarriages.

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