An Algorithm for Determining Unloading Cycles in Dump Truck

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Abstract. In copper ore deep mines of KGHM Polska Miedz S.A., the first stage of the transport department is to deliver the spoil to the screen. This stage is carried out by self-propelled mining machines. Transport can be done in two ways: by loaders or loaders cooperating with dump trucks. The amount of dump truck cycles during a single work shift can be used as indicators of a machine and operator performance evaluation. In order to increase the mining potential, it is necessary to continuously acquire and analyze information on work efficiency. The ability to synthesize the obtained data and case-study the relationship between them allows deepening knowledge of industrial processes and supports decision-making. Dump trucks used in the KGHM copper ore mines are equipped with a self-unloading mechanism. The paper describes a developed method and described an algorithm for segmenting signals coming from a dump truck with a self-unloading crate. The operation of the algorithm has been verified on data from a machine operated by several operators, taking into account various operational events.

1. Introduction

In copper ore deep mines of KGHM Polska Miedz S.A., the first stage of the transport department is to deliver the spoil to the screen. This stage is carried out by self-propelled mining machines. The transport of ore by self-propelled mining machines can be carried out in two ways: loaders or loaders cooperating with dump trucks. The selection of the type transportation gratings is conditioned by economic considerations and depends mainly on the length of the haulage route - the transport of ore by loaders only to a distance greater than 300 m becomes unprofitable. The copper ore is pre-crushed on the screen, from where it goes to the belt conveyors department.

The number of self-propelled mining machine courses (cycles) during a single work shift can be used as an indicator of the machine's and operator's performance [2, 3, 6]. In addition, in order to increase the mining potential, it is necessary to continuously acquire and analyze information on the technical condition of machines and the degree of their use. This leads to the generation of many parameters characterizing the operation of the machine in changing operating conditions. The ability
to synthesize the obtained data and study the connection between various parameters allows deepening knowledge of industrial processes and supports decision-making.

Most self-propelled dump tracks used in KGHM copper ore mines are equipped with a self-unloading box mechanism. They perform two operations: driving with an empty or loaded box and unloading. The chest is built of an external (fixed) part and an internal (movable) part. Increasing the pressure in the hydraulic cylinder (HYDOILP parameter) activates the mechanism of extension of the inner part of the box. After the flap opening the ore is pushed out at the place of unloading by the movable part of the box, and finally by the sliding rear wall.

So far, the evaluation of the cyclic operation of the dump truck is carried out on the basis of pressure increases in the hydraulic system during the pushing of the ore from the box. Information from machine users shows that sensors measuring this value are subject to frequent failures. As a result, it is impossible to determine the number of cycles of a dump truck during its further operation. Self-propelled mining machines (including dump trucks) are also equipped with other sensors [1-3]. On the other hand, it is aimed at limiting their quantity due to the large amounts of measurement data generated and the need to process them.

2. Problem formulation
The article developed the method and described the algorithm for signal segmentation and identification of unloading cycles. The input data to the algorithm was obtained from the machine during operation and operated by different operators. The measurements were made into one of the underground copper ore mines and lasted 8 working shifts. However, the machine actually worked 7 full changes. The purpose of the work was to investigate the impact of the unloading process on other machine operation parameters. The length of the cycle is understood as the time between consecutive self-unloading of a self-propelled truck. Figure 1 shows the object that was tested.

![Figure 1. General view on self-propelled dump truck [4]](image)

3. Methodology
The case study carried out showed the impact of depressing the brake pedal on the characteristics of the mining machine engine when parking, driving and unloading. The stand-alone vehicle is equipped with an additional pneumatic system that disconnects transmission from the gearbox during braking. This causes the engine to idle.
The exception to the above scenario is the increase of engine speed (ENGRPM) with simultaneous, increased pressure in the braking system (BREAKP) [5]. This is the case when the hydraulic pump is driven by the internal combustion engine, and thus during the unloading of the truck box. Increased braking pressure in the unloading process is necessary to keep the box directly above the discharge grate during the entire unloading process.

Based on the previous conclusions, a methodology was developed that would enable quantification (detection) of unloading cycles on subsequent work shifts. The detection would be possible without information about the pressure in the hydraulic system. It will be possible to detect cycles and evaluate the operation of the machine or operator even after the failure of the sensor returning the HYDOILP parameter.

In this section authors describe the details of the segmentation algorithm. In figure 2 the flowchart of proposed procedure is presented.

![Flowchart of proposed procedure](image)

**Figure 2.** The flowchart of proposed procedure.
As the first step, we have to divide the data into the shifts because analyzed variables have various behaviour because of two aspects: different operators drive the machine and the different place in mining mine.

Secondly, the signals of pressure in the hydraulic system (HYDOILP), engine rotation (ENGRPM) and pressure in the brake system (BREAKP) are normalized to the range 0-1.

Next, the authors construct the threshold that separates the engine rpm into two groups: idling operation and under load. During unloading, the engine drives the hydraulic system. Therefore, the engine's running under load should be detected. The threshold is given as quantil [7] of max ENGRPM follows:

\[ T_{ENGRPM} = 75\% \cdot \max(ENGRPM) \]  \hspace{1cm} (1)

For these indices where values in ENGRPM variable are lower than the \( T_{ENGRPM} \) we put the zero value in all variables.

Based on histogram of such prepared data two modes are designated. The second threshold \( T_{BREAKP} \) is calculated as a central point between these two modes [8] and analogously that in the first threshold we put the zero values in all variables if the BREAKP<\( T_{BREAKP} \).

These two thresholds allow us to get the new data vectors in which we observe only the behavior corresponding with the cycles. If we calculate sum of them in the window we obtain the values connecting with unloading the dump tracks.

4. Real data analysis

In this chapter, the successive stages of the algorithm's operation have been presented together with the successively obtained results after their implementation. The signals of the HYDOILP parameter were not used in the analyzes. They were presented only to verify the results obtained for the remaining parameters - ENGRPM and BREAKP. Figure 3 presents the output data for the developed algorithm, which was obtained from a period of 7 consecutive work shifts. The values of parameters being the basis for determining decision thresholds are presented.

![Figure 3. Raw data from seven shifts - hydraulic system pressure (HYDOILP), engine rate (ENGRPM) and brake system pressure (BREAKP)](image-url)
After loading the above data, the next step of the algorithm's operation is their standardization. Figure 4 presents parametrised parameters in range 0-1 for a single work shift. The clearly visible peaks in the HYDOILP parameter are clearly visible and coincide with the unloading cycles. These cycles are not observable in other parameters.

![Figure 4](image)

**Figure 4.** Data from the one shift after normalization - hydraulic system pressure (HYDOILP), engine rate (ENGRPM) and brake system pressure (BREAKP)

Figure 5 presents parametrised parameters $[0, 1]$ for a single work shift after applying all reset thresholds in the algorithm: for ENGRPM and BREAKP. It can be clearly seen that the values of both parameters, which have not been reset by the algorithm, coincide with the process of self-unloading the box in dump truck. For a more accurate presentation of the results obtained from the developed algorithm, they were summed up after a given window value and then presented in one graph for a single work shift (Figure 6) and for seven work shifts (Figure 7).

![Figure 5](image)

**Figure 5.** Data from the one shift obtained after thresholds.
5. Conclusions

Self-propelled mining machines, including dump trucks are equipped with many measuring sensors. The working cycles of the haulage truck, understood as the time between consecutive landings, can be observed by tracking the pressure increases in the hydraulic system (HYDOILP) during the pushing of the output from the crate. This information could not be obtained from other sensors so it was decided to investigate the process and its impact on the machine's working parameters. An algorithm for detecting cycles based on information from other sensors has been developed. This allows identification of the unloading process of a haulage box, even in the event of a sensor failure (HYDOILP). The work carried out to date suggests that this is possible after setting the engine speed limits (ENGRPM) and the oil pressure in the brake system (BREAKP).

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