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Investigation and modernization of buckets of surface mining machines

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ABSTRACT

The article presents the results of experimental tests, design work and numerical analyses aimed at optimizing the operating costs of buckets used in the Turów Lignite Mine. The presented approach to designing and optimization takes into consideration the results of tests in real mining conditions as well as modern numerical tools that support the process of designing such structures. The results of the presented work include two buckets with quickly replaceable and permanent teeth, which significantly improve the technical and operational indicators and enable their users to achieve real savings.

1. Introduction

In a time when people are searching for solutions that minimize operational costs of surface mining machines [9,17–19] and eliminate the likelihood of failures [1,11,12], it is becoming increasingly important to optimize the technical and operational parameters related to the mining of overburden and coal in surface mines. Such attempts are being made, among others, in the field of excavating units of bucket-wheel excavators and bucket chain excavators. The primary goals of such undertakings are as follows:

- to increase the durability of excavating units,
- to decrease maintenance activities,
- to increase the efficiency of excavation,
- to reduce the dynamic effects related to excavating,
- to increase the uptime of machines.

The main objective behind the designing and modernizing activities is either to obtain high durability of excavating components or to increase the durability of existing machines [2]. Increasing of safety of the heavy duty machines is also common trend [8].

The element of the excavating unit which is most prone to degradation, is the bucket mounted on the bucket wheel of a bucket-wheel excavator, or on the bucket chain of a bucket chain excavator. Buckets are the elements of the unit which are in direct contact with the excavated material [13,15]. They strip away the material from the working block, which is then delivered using the transporting system of the machine onto conveyors, from where it is either transferred to stackers, in the case of overburden, or to the power plant's coal supply, in the case of coal. The contact of the corners, teeth and cutting edge of the bucket with the working block causes their wear and, consequently, an increase in the forces and dynamic loads [7,6] acting on the bucket wheel, its drive mechanism and the excavator structure. The deterioration of buckets mainly manifests itself in abrasive wear or, less frequently, in instantaneous damages caused by impact overload, which occurs during contact with marginally-mineable or non-mineable material [3]. There have also been cases of fatigue damage of buckets, but these incidents are relatively rare. Fig. 1 shows excavating units of a bucket chain excavator and bucket-wheel excavator [4], and examples of worn and damaged buckets.

In order to modernize the existing buckets, or to develop new bucket solutions, a number of activities are required, which enable a detailed assessment to be made of the new or existing structures, and allow for the introduction of solutions that could improve the technological and operational properties of such structures [5]. These activities include the following:

- testing the actual loads on excavating units,
- measuring the wear rate of buckets,
- analyzing the trajectory of cutting elements of the bucket,

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- analyzing the distribution of loads and optimizing the geometry of cutting elements with the application of numerical methods,
- performing strength analysis using numerical methods.

The following part of the article presents examples of work carried out in the Turów Lignite Mine, whose objective was to devise new or modernize the existing buckets of surface mining machines.

The Turów Lignite Mine excavates overburden and coal using a technological system consisting of an excavator, conveyor belt and a stacker (ECS). The excavation is performed by bucket-wheel excavators and bucket chain excavators (Fig. 1), which use buckets with permanent or replaceable teeth for digging. A typical bucket consists of the following elements (Fig. 2):

- shell,
- cutting edge,
- set of cutting teeth.

Based on the many years of experience in the use of buckets, it is recommended that their cutting elements, i.e. the cutting edge and teeth, be designed to excavate a particular material and to be used with a specific type of excavator. For many years numerous works have been carried out in the Turów Lignite Mine designed to improve the teeth and cutting edge of the bucket so as to extend the operating cycle of the tooth and cutting edge, and thus reduce their wear.

The Turów Lignite Mine uses Rs. 560 buckets on bucket chain excavators, mainly to excavate coal below the bench level and to dig sumps. The R12 0 buckets with replaceable WKL-3 teeth are used to excavate upper layers of overburden composed of unconsolidated material (sand and gravel). These functions are performed primarily by KWK 1500 bucket-wheel excavators. The R12 0M buckets remain the most widely used type of buckets, in particular for excavating consolidated rock, which is characterized

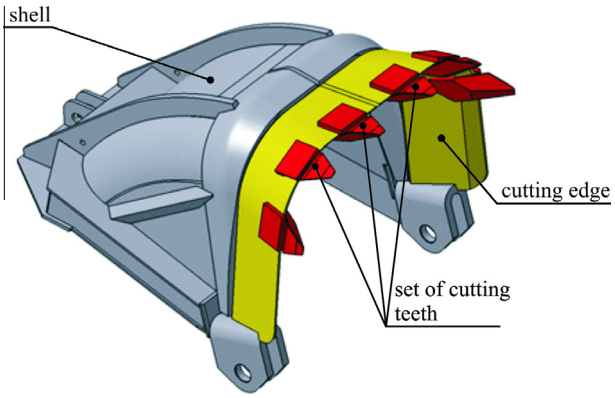

Fig. 2. Structure of a typical R12 0M bucket with permanent teeth.

by a wide spectrum of excavating forces. The fundamental drawback of these buckets is their rapid wear, and thus the necessity to replace and repair them. Fig. 3 presents the three above-mentioned bucket types.

The fact that different types of buckets are used for different excavation levels confirms that wear is significantly influenced by excavating forces and abrasiveness of excavated material. Other important factor that affects the durability of the teeth is the material which they are made of, and their heat treatment. Also the digging technique used by the excavator operator has been observed to have a significant impact on the durability of the buckets. This aspect may only be controlled through training and supervision of operators and by monitoring whether excavation techniques are properly applied.

With respect to the technological and operational aspects, numerous activities were carried out to improve the shape and structure of permanent teeth. Additionally, cast and forged teeth were produced which were then welded to the cutting edge of

Fig. 1. Excavating units of a bucket chain excavator and a bucket-wheel excavator and examples of wear and damage to buckets.