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A new wear-resistant pick cutter with hardfacing deposits

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Abstract. A pick cutter is a rock-cutting tool used in partial-face excavation machines such as roadheaders, and the quality of the pick cutter is a key element in the excavation performance and efficiency of such machines. In this study, a new type of pick cutter with hardfacing deposits applied to a tungsten carbide insert was developed to increase durability and wear resistance. The new pick cutters were tested in the field by installing them in a roadheader and comparing their performance with conventional pick cutters under the same excavation conditions for 24 hours. The new pick cutters showed much lower weight loss after excavation (and therefore better excavation performance) compared with the conventional pick cutters. In particular, the damage to and detachment (loss) of tungsten carbide inserts was minimal in the new pick cutters. A detailed inspection using scanning electron microscope–energy dispersive X-ray spectrometry and three-dimensional X-ray computed tomography scanning revealed no macro- or micro-cracks in the pick cutters. The reason for the absence of cracks may be that the heads of pick cutters are mechanically worn after the tungsten carbide inserts have been worn and damaged. However, scanning revealed the presence of voids between tungsten carbide inserts and pick cutter heads. This discovery of voids indicates the need to improve production processes in order to guarantee a higher quality of pick cutters.

Keywords: pick cutter; rock cutting; partial-face machine; wear; hardfacing

1. Introduction

Partial-face machines such as roadheaders and continuous miners are mechanical excavators used for cutting rock in tunnels and mines. Such machines use a pick-laced cutting head that is much smaller in diameter than the tunnel or mining face. In particular, the cutting head, equipped with pick cutters and attached to a movable boom, excavates rock at different parts of the face at different times (Tatiya 2013). Even though partial-face machines are generally suitable for rocks of medium to low strength, they are much more flexible and mobile than full-face machines such as tunnel-boring machines (TBMs) as they are self-propelled and are much lighter than TBMs (Bilgin *et al*. 2014).

Pick cutters as consumable rock-cutting tools have an important influence on the cutting performance and economics of partial-face machines for given rock conditions. Therefore, it is essential to increase the life of pick cutters of partial-face machines because changing cutters is disruptive to production and reduces machine utilization time and production rates (Kim *et al*. 2012a).

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Pick cutters can be classified into radial picks (or drag bits) and conical picks (or point-attack picks). Radial picks are seldom used because their durability is very low. Instead, conical picks are widely used as cutting tools for a variety of partial-face machines. Conical picks have longer lives compared with radial picks and rotate as they cut the rock, ensuring uniform wear of the tip and body, which helps to maintain the tip shape and allow the pick cutter to work efficiently for an extended period (Kim *et al*. 2012b).

A conical pick cutter consists of a tungsten carbide insert, a head holding the tungsten carbide insert, and a shaft connecting the pick cutter to a holder installed in a cutting head drum. During rock cutting, conical pick cutters are subjected to large forces (including normal forces, cutting forces, and side forces), extensive wear, and high temperatures, which together result in short pick-cutter lives and low cutting efficiencies (Bilgin *et al*. 2006, Liu *et al*. 2016). Therefore, it is crucial to minimize the wear of and damage to tungsten carbide inserts in order to guarantee longer lives for pick cutters.

Few studies have been devoted to increasing the cutting performance of pick cutters. Most such studies have focused on the design of cutting heads for partial-face machines (Eyyuboglu and Blukbasi 2005, Hekimoglu and Fowell 1991) and on prediction of the performance of these cutting heads based on experimental, numerical, or statistical approaches (Bilgin *et al*. 2004, 2006, Comakli *et al*. 2014, Ebrahimabadi *et al*. 2015, Yimaz *et al*. 2007).

This study aimed to develop a new wear-resistant conical pick cutter by applying hardfacing deposits to its head. The new pick cutter was developed with particular respect to excavation in a copper mine characterized by very complex and mixed rock conditions. The new pick cutters were tested in the mine and compared with conventional pick cutters under the same conditions to assess their durability and excavation performance when installed in a partial-face machine.

2. Field area location and conditions

The field area of interest is the Boleo Mine, located in Santa Rosalia, Baja California Sur, Mexico. The main product of the mine is copper together with cobalt, zinc, and manganese as by-products. The mine is estimated to contain 238 million tonnes of these minerals.

The mineral deposits lie within the upper Miocene El Boleo Formation, which is characterized by fine to coarse clastic sedimentary rocks. In particular, the deposits in the Boleo Formation consist of several mineralized groups termed “Mantos,” which is a specific Spanish term used in mining for mineralized layers or strata. Mining at the Boleo Mine started in the last quarter of the nineteenth century and continued through most of the twentieth century. However, significant quantities of copper, cobalt, and zinc resources remain in the extensively mined Mantos and overlying breccia, and these resources are currently the main targets for underground re-mining in the Boleo Mine (Agapito Associates 2007). Mantos and brecciated zones vary in thickness, but the main mining areas generally have a minimum thickness of 1.8 m. The Mantos are overlain by massive and relatively soft sandstone, and underlain by relatively hard conglomerate layers with cobbles (Fig. 1). Mantos, the main target layers for underground mining, are very soft with a uniaxial compressive strength of 2 MPa. However, it is difficult to excavate a mine face in the Boleo Mine using roadheaders and continuous miners because the underlying conglomerate with large cobbles offers very high resistance to cutting (Fig. 2), which results in excessive wear of conical pick cutters and damage to or loss of their tungsten carbide inserts (Fig. 3).

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