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Assessing wear performance of two high-carbon Hadfield steels through field tests in the mining industry

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Abstract

Hadfield steels are widely used in the production of liners for rock crushing applications due to their good wear resistance and high toughness. Because of the high replacement frequency and cost of these liners, improvements in the properties of Hadfield steels may represent a great economic benefit for mining operators. Therefore, correctly assessing wear performance is a relevant matter in the research and development activities regarding Hadfield steels. However, conventional laboratory tests may not accurately mimic the conditions of impact and gouging abrasion occurring in crushing applications. Field tests may represent a complementary source of information particularly useful in the optimization of Hadfield steels. In this work, the wear performance of two Hadfield steels was investigated through field testing. Their characteristics included high carbon content and two different levels of manganese content. Two sites were chosen for the assessment: a pebble crushing plant and an aggregate plant. The first site presented very hard material and compression crushing conditions, whereas the second site presented impact crushing conditions. The use of field tests allowed comparing wear ratios between both steels and it also permitted to identify critical issues constraining steels performance, such as microstructure embrittlement. Despite some limitations, the results from the field tests demonstrated that better wear performance was associated with higher manganese content.

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1. Introduction

Almost all crushing equipment employed in the mineral processing industry is conditioned by the wear performance of their liners. Therefore, enhancing the wear performance of the materials involved in liner manufacture has always been a challenge for the metallurgical industry. Thanks to its good wear resistance and high toughness properties, Hadfield steels are one of the most commonly found materials in crushing liner production. However, research on Hadfield steels wear properties requires two special considerations. One is the presence of impact during crushing operation. The other is the influence of casting thickness on the mechanical properties of the steel. These two considerations are difficult to reproduce by using common laboratory tests. This work addresses the application of field tests to assess the performance of crushing liners in terms of wear ratio and service life. These liners were produced with two different Hadfield steels, one with 12% Mncontent and the other with 16% Mn content. Both steels where produced with 1.4% Ccontent, in order to increase their wear resistance.

Hadfield steels are a particular type of austenitic manganese steel denominated after its 19th century British inventor, R. Hadfield. For crusher liner manufacturing, the main controlling factors for optimum performance of a Hadfield steels are the heat treatment, the pouring temperature and the chemical composition. These factors must always be considered in relation to casting thickness, which is usually between 30 mm and 200 mm in crushing applications; Maratray (2006),Kuyucak and Zavadil (2003).

Chemical composition is a determinant factor in the resulting mechanical properties of the Hadfield steel. The key components controlling wear performance are carbon and manganese; Maratray (2006). In literature, it is widely established that the practical limit of carbon in solution is about 1.2%. High carbon content in Hadfield steels increases wear resistance. Conversely, manganese acts as an austenitic stabilizer and delays isothermal transformation of the phases, by keeping carbon in the austenitic matrix. Carbon contents of approx. 1.4% are rarely used since carbon tends to segregate to the grain boundaries as carbides; Lencina et al. (2013a). Santos et al. (2010) have presented evidence that this segregation or carbide re-precipitation will result in the embrittlement of the microstructure. Grain boundary precipitation is an important phenomenon to be considered during production of large cast pieces (e.g. cone crusher liners). If casting thicknesses are larger than 100 mm, embrittlement can cause a significant loss of toughness; Lencina et al. (2013b). In industrial conditions, carbide re-precipitation could be the consequence of inefficient heat treatment.Therefore, an inefficient heat treatment may lead to failure of the final product during operation at the mine or quarry; Kuyucak and Zavadil (2003).

In the mining industry, it is widely accepted that Hadfield steels abrasive wear resistance depends on the presence of impact during the crushing operation. In crushing applications, abrasive wear can be associated with heavy or moderate impact or no impact at all, depending on the equipment and the circuit configuration. The presence of impact is important because deformation is a necessary prerequisite for the workhardening of Hadfield steels. The wear resistance of Hadfield steels is mainly the result of the phase transformation of austenite into martensite, which occurs on a thin layer of the surface of the material; Hawk (2001), Garcia et al. (2005).

The comparison between laboratory results and industrial performances is particularly inaccurate in situations where the industrial application involves considerable impact (or repeated impact), because laboratory test can hardly simulate these impacts. Thus, the use of the pin-on disc tests for wear assessments of Hadfield may produce inaccurate results. Moreover, research conducted in the laboratory scale can seldom representatively replicate the characteristic of the feed material that acts as abrasive during crushing operation; Sare and Constantine (1997).

In discussing metallic wear, it is largely acknowledged that wear resistance is not an inherent material property. Consequently, there is not a single laboratory test or standard available that accurately measures wear performance in crushing processes. The loading conditions in service must be suitably mimicked by a laboratory test in order to estimate or predict the wear rate of a crusher liner; Hawk (2001),Sare and Constantine (1997).

Another important factor controlling wear in Hadfield steels is the force transmission mechanism from the machine to the rock. Cone crushers work mostly by compression of the abrasive material, whereas horizontal shaft impactors comminute by impact rather than compression, by applying sharp blows at high speed to free-falling rock. One of the main wear mechanisms in compression and impact crushing is gouging abrasion, i.e. the removal of large volumes of material per event from the wear surface. Hadfield steels have relatively good performance exposed to gouging abrasion because of its good mechanical properties. That is the reason why they are so widely diffused in crushing applications; Hawk (2001), Wills et al. (2006), Yao and Page (2000).