Minerals Engineering 128 (2018) 238–246

Contents lists available at ScienceDirect

Minerals Engineering

journal homepage: www.elsevier.com/locate/mineng

Important factors affecting the gouging abrasion resistance of materials

Jiaren (Jimmy) Jiang[a], Yongsong Xie[a,*], Weimin Qian[a], Robert Hall[b]

[a] Mining Wear and Corrosion Laboratory, National Research Council Canada, 4250 Wesbrook Mall, Vancouver, BC V6T 1W5, Canada
[b] School of Petroleum and Mining Engineering, University of Alberta, 9211-116 Street NW, Edmonton, AB T6G 1H9, Canada

ARTICLE INFO

Keywords:
Gouging abrasion
Jaw crusher
Abrasion resistance
ASTM G81 standard

ABSTRACT

Gouging abrasion occurs in many processes in comminution where large and hard abrasives such as rocks/ores are handled with high contact or impact stresses. In the past decade or so, the National Research Council Canada has systematically investigated the gouging abrasion performance of a wide range of materials per the ASTM G81 standard testing method using a jaw crusher. Materials evaluated include carbon and low alloy steels, high alloy tool steels, austenitic manganese steel, white cast irons, austempered ductile irons, chromium carbide and tungsten carbide overlays. In this paper, the main test results are summarized and the key properties/characteristics that are conducive to enhancing materials' gouging abrasion resistance are discussed.

1. Introduction

Gouging abrasion is "a severe form of abrasive wear in which the force between an abrading body and the wearing surface is sufficiently large that a macroscopic gouge, groove, deep scratch, or indentation can be produced in a single contact" (ASTM, 2007). Such wear occurs in many mining and earthmoving applications where large and hard abrasives such as rocks/ores are handled with high contact or impact stresses, such as wear components in crushers and shovel teeth for hard rock mining. Such damages are also encountered in the oil sands applications such as crusher and sizer teeth/picks, crusher hopper and chamber liners and rotary breaker plates. Improving gouging abrasion resistance or selecting appropriate materials for each application will not only lead to direct cost savings, but also reduce shutdowns/downtimes for critical operations, thus significantly increasing productivity and profitability. However, there is only relatively scarce literature on gouging abrasion resistance of materials (Pintaude and Bartalini, 2018).

In the past decade or so, the Mining Wear and Corrosion research team at the National Research Council Canada (NRC) has conducted several campaigns to assess the gouging abrasion resistance of a wide range of potential materials for various industrial clients per the ASTM G81 standard testing method. Some test results have been published in the open literature (Llewellyn et al., 2004; Jiang et al., 2015). The performance of materials has been generally compared and ranked within each campaign. Thus, the information is relatively scattered and there is a lack of systematic overview.

The main objective of this paper is to review and analyze the gouging abrasion test results obtained so far and to identify key properties/characteristics that are conducive to enhancing materials' gouging abrasion resistance. The materials selected for evaluation in this program included carbon and low alloy steels, high alloy tool steels, austenitic manganese steel, white cast irons, austempered ductile irons, chromium carbide and tungsten carbide overlays.

2. Experimental method

2.1. Equipment

As stipulated in the ASTM G81 standard, a jaw crusher with a feed opening of about 100 by 150 mm (4 by 6 in.) was used to conduct the gouging abrasion test. The movable and stationary jaw frames of the crusher were modified so that the jaw working surfaces were each formed of an identical pair of a reference wear plate and a test wear plate. The plates were arranged such that a test plate was facing a reference plate. The crusher system and testing plate assembly are shown schematically in Fig. 1.

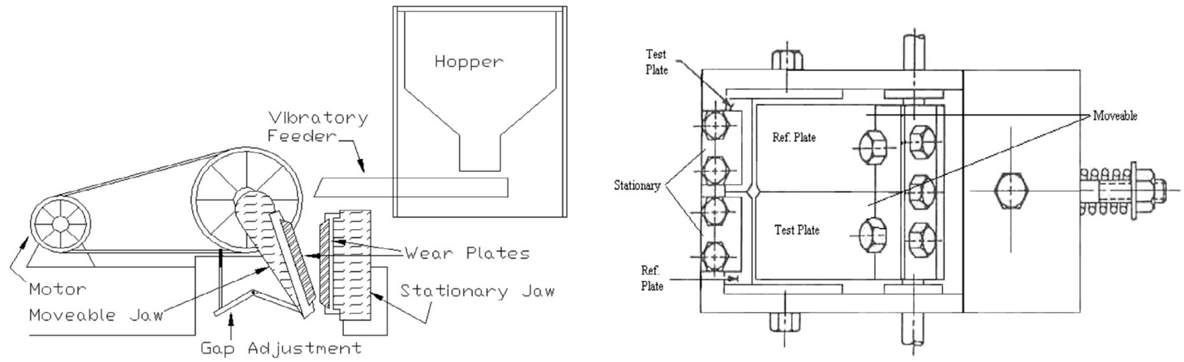
2.2. Rock

Pre-crushed morainal rock with a size around 20 mm was used as the jaw crusher feed. Fig. 2 shows typical rock before and after the crushing. Typical sieve analysis of the crushed rock is shown in Fig. 3. The average median size (d_{50}) of the crushed rock is about 3.8 mm.

The compositions of the rock varied over the different campaigns. One example of the rock composition analysis is as follows (wt.%): 44.2% volcanic, 20.7% metamorphic, 18.8% granitic and 16.3% of

* Corresponding author.
E-mail address: yongsong.xie@nrc.gc.ca (Y. Xie).

https://doi.org/10.1016/j.mineng.2018.09.001
Received 9 May 2018; Received in revised form 29 August 2018; Accepted 1 September 2018



(a) (b)

Fig. 1. Schematics of (a) the jaw crusher (side view) and (b) test/reference plate arrangement (top view) in the machine setup.

(a) (b)

Fig. 2. (a) Pre-crushed rock feed and (b) crushed product.

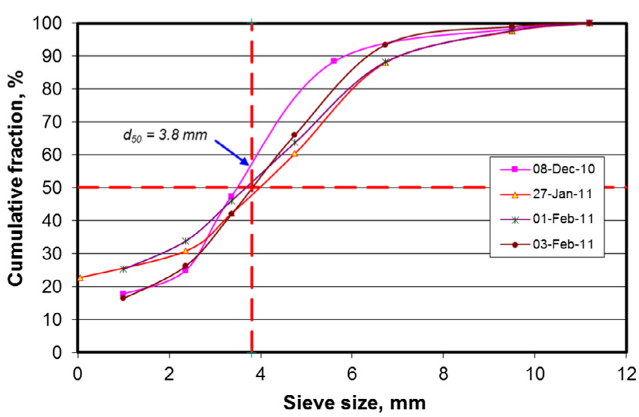


Fig. 3. Typical sieve analysis of the rock after crushing.

other rock types. The hardness of the rock was measured using a microhardness tester. Several crushed rocks were mounted in epoxy resin as the samples for the hardness measurement. After curing, the mounted rocks were successively ground/polished by 240, 400, 600, 1000 grit SiC abrasive papers. The hardness values of the polished rocks were measured using a Vickers diamond indenter at normal load of 100 g. The measured hardness values were in the range of 420–689 HV (kgf/mm^2), with mean value of 525 HV.

2.3. Test plates

The dimensions of the test and reference plates are shown in Fig. 4. In some of the tests, 25.4 mm thick test and reference plates were used.

All test surfaces were ground to provide a flat consistent finish, to remove any decarburized layers in the steels and/or also to remove any surface zones in the tungsten carbide overlays that could have suffered sinking of high-density carbide particles in the weld pool during deposition. Hardness tests were carried out on all ground test surfaces.

2.3.1. Reference plate material

In all the tests, quenched and tempered 100 steel, which conforms to the ASTM A 514 Grade B structural steel standard, has been used as the reference plate material. Its hardness is in the range of 230–273 HB.

2.3.2. Test plate materials

The test plate materials evaluated in the program along with brief descriptions are listed in Table 1. The hardness values for some of the materials were converted into the Vickers hardness from Rockwell hardness HRC according to the ASTM E140 – 97 standard (ASTM, 1997).

2.4. Test procedures

The test and reference plates were cleaned and weighed before being installed in the crusher frames. The minimum jaw opening was set at 3.2 mm (0.125 in.) and a total of 908 kg (2000 lb) of prescreened rock was crushed. The minimum opening was reset to 3.2 mm (0.125 in.) after crushing every 227 kg (500 lb) of rock. The test plates were then recleaned and weighed and the mass loss (accuracy of 0.1 g) was recorded. A non-dimensional wear factor, F, was then calculated using the following formula

$$F = 0.5(Xs/Rs + Xm/Rm) \quad (1)$$

where Xs and Xm are the volume losses for the stationary and movable test plates and Rs and Rm are the volume losses for the stationary and movable reference plates, which have the unit of cm^3. The volume