Abrasive Wear Behaviour of Manganese Steel used as Wear Protection Material

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Abstract

The study explores the tribological behavior of manganese steel (Mn-steel) material based on particle size and load at different sliding distances. The work was carried out on pin-on-disc apparatus. For tribological experiment, the specimen was prepared from Mn-steel material as per ASTM G99 standard. It was observed that wear on the test specimen increases with the increase in particle size but decreases as load and sliding distance increases.

Keywords: Manganese steel, wear, particle size, load, sliding distance.

1.0 INTRODUCTION

Reduction of ores into a required particle size is a most common activity involved in mining and mineral processing industries. It takes lots of crushing pressure to shear the ores particle to reduce it to minimum size of production [1]. In this operational work of particle size reduction, generation of surface stresses are very high near the surface of crushing area of crushing equipment [2]. There are extensive literature based on abrasive wear but some of them focused their ideas of work on load and stress condition observed during crushing of ores. Abrasive wear occurs in the form of plastic deformation [3], fracture of particle [4], heat occurs due to friction forces and work hardening on surface [5] and rolling of particles during three-body abrasion [6]. In the study of effects of particle size on abrasive wear it has been observed that wear reduces at some critical size of particle [7]. Lindqvist et al. [8, 9] discusses about the ideas related to prediction of worn geometry of compressive crusher. Although their vast study in this area of work created a new space for worn geometry prediction but they neglected some of the variables which are more important to consider. With respect to their reports one of the variables is particle size used for crushing. It has been found that various sizes of ores are crushed against the surface of steel in compressive crushing.

For the protection of surface of crusher, protective steels called as wear protection material or liner, are used for compressive crushing of ores. Compressive crushing is a pure compression process as there is no relative motion of ore particles and steel surface. In most of the literatures it has been described that wear is proportional to sliding distance [10]. However, in compressive crushing, there is some movement of ores against the steel surface. Although in this process wear proceeds with material losses. If the area where compressive crushing acted on the ores particle were judged under microscopic investigation then there is less possibilities of formation of surface ploughing on metal surface. It becomes difficult to observe the wear where ores particle have some sliding effect on the metal surface during crushing. Ngan (2004) [11] expressed an idea of statistical distribution to derive the result obtained for loads at contact point with the particulate material. The results for their work were successfully verified in experiments. Hansson [12] states in his work that where there is variability in particle size then statistical distribution results has its significance effect. Yao et al. [13,14] observed ores of fine particle results less wear when comparing with coarser particles. In his investigation at microscopic level of sliding wear he informs that the crushed fine particles therefore produces less wear while dealing at some applied pressure.

For wear analysis of roll crusher liner, procedure of experimental design based on statistical design of experiment has been adopted. This statistical design of experimental is the experimental planning technique to analyze the effective variables used in wear measurement. The widely used statistical design and method are design of experiment (covered by factorial design), response surface methodology (RSM) and Taguchi methods. These statistical methodologies found to be useful to get appropriate result for wear analysis. Horng et al. [15] evaluated the effective parameters using RSM and analysis of variance (ANOVA) on Hadfield steel machinability. Senthil kumar et al. [16] attempted to notice the wear mechanisms on ceramic materials. They reported in their work about the influence on machinability by three chosen variables which were force, surface finish and tool wear. Mandal et al. [17] took suitable parameters as an input to reflect an idea on wear analysis by using mathematical model. Their mathematical model developed through regression analysis from ANOVA.

Even though, many work were carried out to observe the effect of particle size on wear loss from crusher liner surface during compressive crushing. Least of the works were based on effect of particle size during sliding on liner surface of roll crushers. Apart from the work of many researchers, least of the work has been focused on experimental investigations of worn out crusher liner material. The present study is based on identifying the influence of abrasive particle size on manganese steel material used as wear protection on the roll used for compressive crushing.

2 MATERIALS & METHOD

2.1 Specimen Preparation

Test specimen of dimension 30 mm in length and 12 mm in diameter was prepared from manganese steel material, as shown in Figure 1. Oxide layer from the test specimen was drawn out by metallographically polishing its surface. The prepared test specimen was used for tribo-testing to determine the effect of particle sizes and load.

Figure 1. Image of test specimen samples made from Mn-steel material.

2.2 Particle Size

The two size of coal, 500 µm and 710 µm, were taken to investigate the weight loss of specimen material as shown in Figure 2. This was done to identify the changes on weight loss of test specimen due to size particle of coal at different load. The sizes of coal were separated out using sieve analysis process with 80 % passing through sieve.

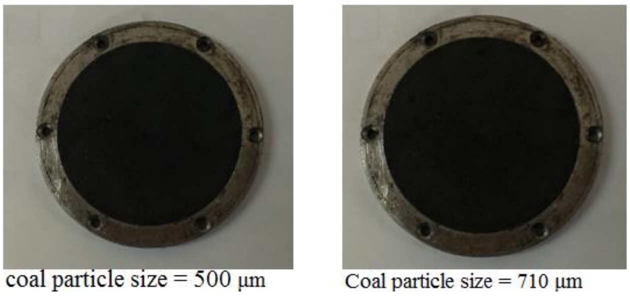

Figure 2. Image showing coal particles of two different sizes.

2.3 Experimental Procedures

The wear tests were carried out to identify the influence of load and particle size on weight loss of manganese steel test specimen. Wear tests were conducted using Pin-on-disc apparatus as shown in Figure 3, at two different discs, as shown in Figure 2. One disc is having coal particles of size 500 µm. Whereas, another disc with coal particles of size 710 µm was distributed at its surface. Hardness of coal particles is 4.5 in mohs scale. Fixing of coal particles was done using strong adhesive. Before conducting the wear test, the coal was dried in oven at temperature of 40ºC for 2 hour. It was done to remove the moisture content from the coal particles. After removing the disc from the oven, the manganese steel specimen was fitted to the apparatus and its surface was made in contact with the coal particles as shown in Figure 4. The experiments were conducted separately on the two discs, with coal particle sizes 500 µm and 710 µm, to measure the weight losses of test specimen by varying load and maintaining constant sliding distance.

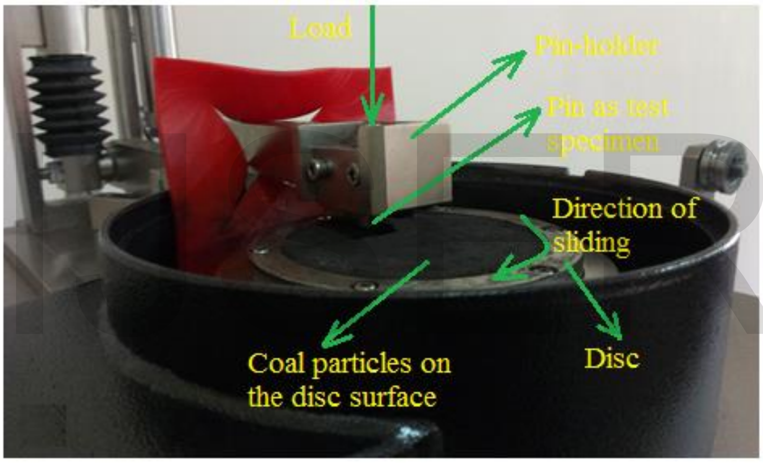

Figure 4. Image showing the experimental procedure using Pin-on-Disc apparatus.

3.0 RESULTS & DISCUSSIONS

Figure 5 and Figure 6 represents the weight loss of test specimen at different loads and sliding distance. Effect of coefficient of friction is also noticed. Figure 5 (a) shows the weight loss of test specimen, sliding on 500 µm of particle size, at sliding distance of 1000 m for load ranging from 5 N to 30 N. It also shows that weight loss increases as the load increases to 25 N and thereby decreases. As the sliding distance is changed to 1500 m, as shown in Figure 5 (b), decrease in weight loss was observed after 15 N of load. This phenomena changes as the sliding distance is further increased to 2000 m and 2500 m which is shown in Figure 5 (c) and Figure 5 (d).

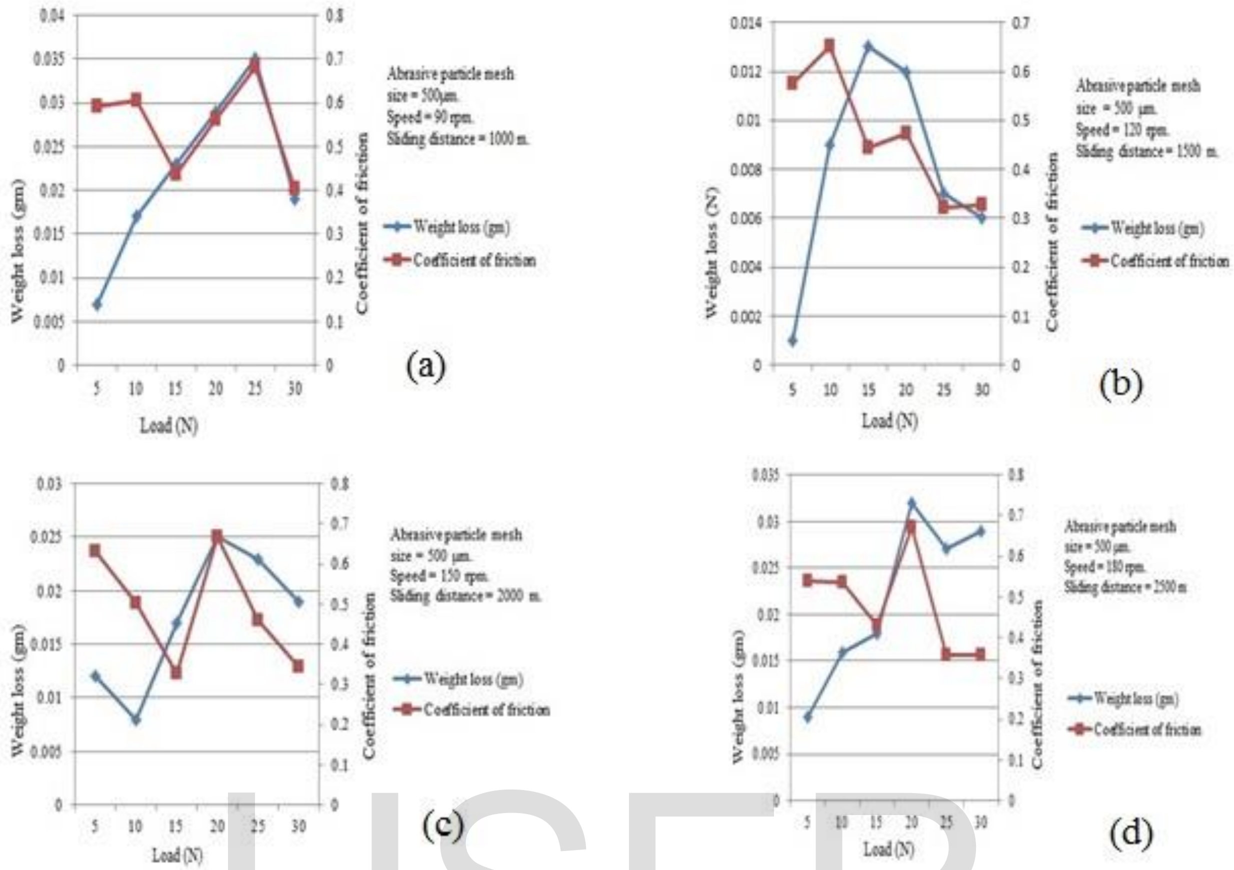

Figure 5. Abrasive wear experimental result obtained at different sliding distance, and load for 500 μm coal particles.

Similar nature of graphs was also obtained for the test specimen sliding against the particle size of 710 μm, as shown in Figure 6. But in this case continuous decrease in weight losses were observed as the load and sliding distance changes.

The difference in both the condition can be explained as coal contains silicon particles, which change the nature of coal from soft to abrasive, and is more effective in decreasing the weight losses of the specimen. The smaller sized coal particles are having sharp edged apex angle as compared to the larger one. This reduces the attack angle and results in decrease in material losses. The small sized coal particles, with sharp edged, which gets destroyed during number of cycling abrasion process and results in decrease in weight loss with the increase in load. However, as the particle size increased, apex angle decreased. This results in continuous decrease in weight loss with the increase in coal particle size of 710 μm and at different sliding distances.

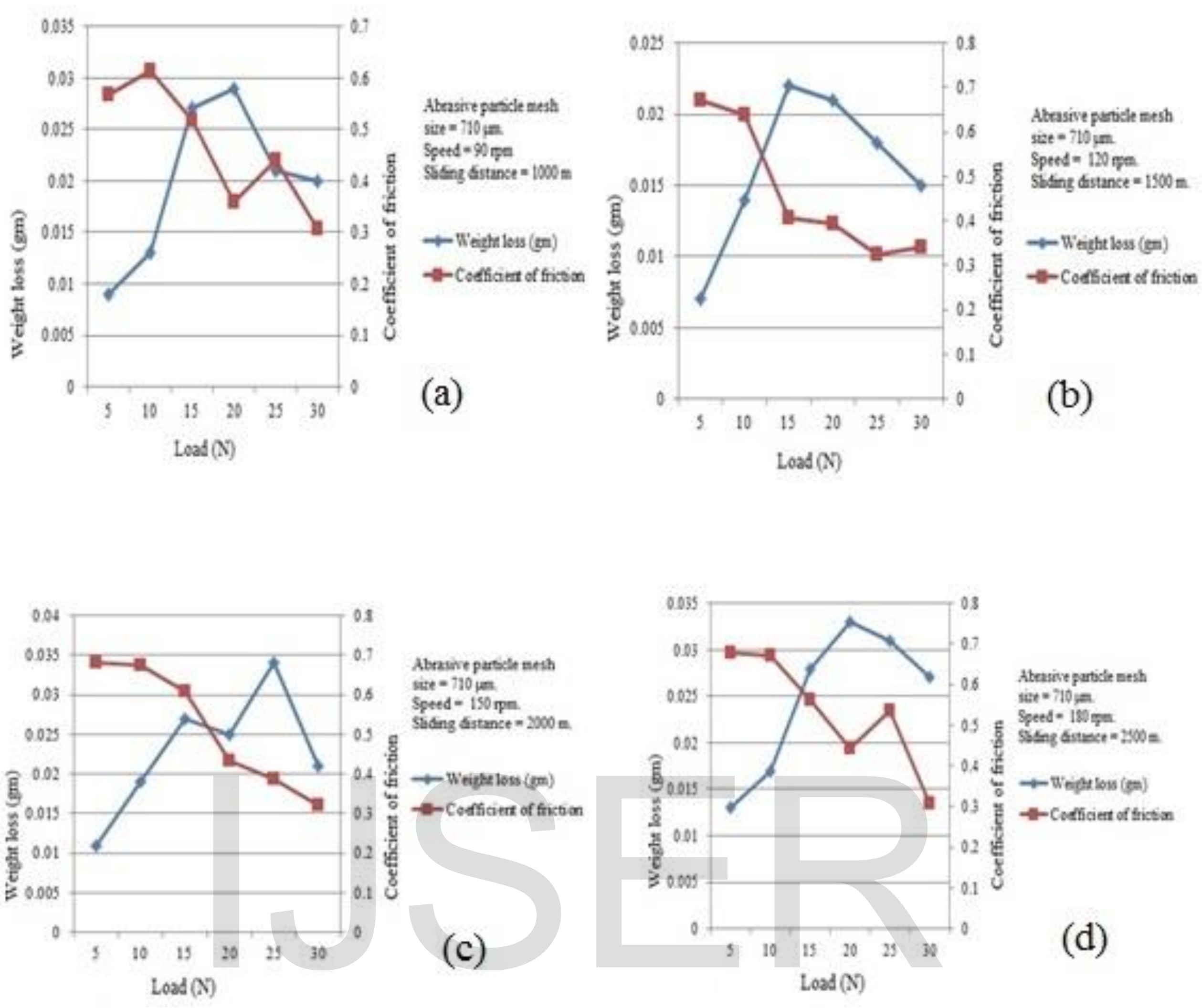

Figure 6. Abrasive wear experimental result obtained at different sliding distance, and load for 710 µm coal particles.

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