CORRELATION BETWEEN BLASTING WEAR RESISTANCE AND IMPACT TEST ON HADFIELD STEEL

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Abstract

The key characteristic of austenitic Hadfield steel is high resistance to the abrasion wear. Different applications mean various operating conditions and different types of abrasive wear.

This paper compares the two abrasive resistance testing methods on rolled sheets of manganese (Hadfield) steel. As the base for samples selection were chosen the sheets of standard production. For the comparison of abrasive resistance was used test in shot blasting machine and impact test on laboratory equipment developed at University of West Bohemia. The aim was to verify if new method (Impact test) can be used for abrasion wear resistance testing. The Shot Blast Test compares the weight loss of the tested material, while the Impact Test evaluates the magnitude of the repeat imprint of the test indenter.

The Sample A reached the best wear resistance results in the both testing methods. The Impact Test method is a simpler and cheaper alternative to the blast test in terms of determining the expected resistance to abrasive wear.

Keywords: Hadfield steel (X120Mn12, ASTM 128), wear resistance, shot blasting, impact test

1. INTRODUCTION

The key characteristic of Hadfield steel is its high resistance to abrasive wear. Due to these features, is particularly applicable in mining and construction industry, agriculture and in shot blasting machines construction. This paper describes abrasion wear tests which compare and evaluate erosion wear resistance. All major manufacturers of manganese steel provide basic steel characteristics such as chemical composition, mechanical properties, hardness, but no manufacturer provides any nor typical resistance value to abrasive wear. The aim is to define available and repeatable testing method which gives comparable results.

1.1. Types of abrasive wear

Wear by abrasion is form of wear caused by contact between a particle and solid material. Abrasive wear is the loss of material by the passage of hard particles over a surface. Abrasion is rapid and severe form of wear and can result in significant costs if not adequately controlled. Abrasive wear occurs whenever a solid object is loaded against particles of a material that have equal or greater hardness [1, 4].

Abrasive wear is typically categorized by the contact environment and the type of contact. The contact type defines the abrasive wear mode. In general, there are several types of abrasive wear namely:

- Two-body abrasive wear - This type takes place when hard particles or grit eliminate material from the opposing surface.
- Three-body wear - This occurs when the particles are unconstrained and can slide down and roll on a surface.
- Erosive wear - Progressive loss of original material from a solid surface due to mechanical interaction between that surface and fluid, multi-component fluid or impinging liquid or solid particles.
- Impact wear - Wear due to collisions between two solid bodies where some component of the motion is perpendicular to the tangential plane of contact.

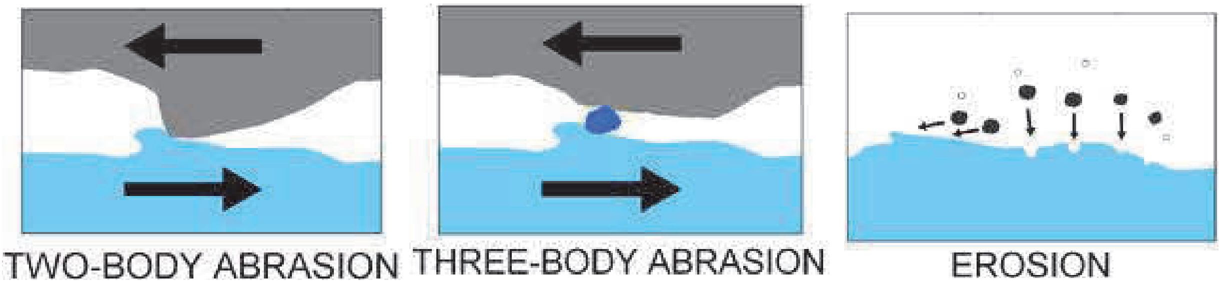

Figure 1 Basic types of abrasive wear *[2]*

Another aspect of abrasive wear categorization is high-stress and low-stress loading. [1, 3, 4].

1.2. Abrasive wear tests on steel

In general, there are two ways for wear resistance testing. It is test in laboratory conditions and field test in operation conditions. Field wear testing, while being more time-consuming, has the advantage that the materials are exposed to the actual environmental conditions and abrasives responsible for the wear loss. The most common laboratory abrasive wear tests - pin-on-drum, dry-sand rubber-wheel, jaw crusher, and impeller-in-drum (see **Figure 1**) [2].

ASTM G65-94, Standard test method for measuring abrasion using the dry sand rubber wheel apparatus

ASTM G81-89, Standard practice for jaw crusher gouging abrasion test,

ASTM G132-96(2013) Standard Test Method for Pin Abrasion Testing

ASTM G99-17 Standard Test Method for Wear Testing with a Pin-on-Disk Apparatus

ASTM G105-16 Standard Test Method for Conducting Wet Sand/Rubber Wheel Abrasion Tests

All the tests mentioned above are relating to the 2-body or 3-body abrasive wear. Our aim is to define such test which could simulate erosion abrasion caused by abrasive grits. We decided to compare two tests that most simulate the blasting conditions (see **Figure 2**) [3, 5].

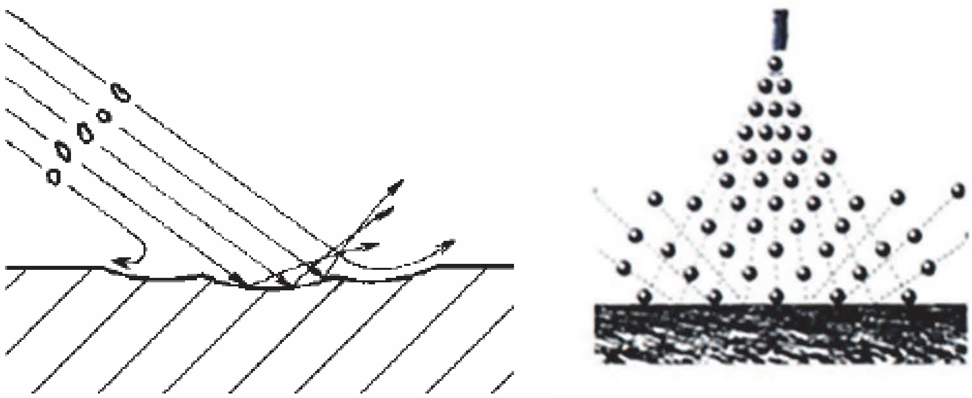

Figure 2 Abrasive - Erosion / Impact wear, shot blasting principle [5]

2. EXPERIMENTAL PROCEDURES

Both of our tests are not standardized abrasive resistance tests. The first test was conducted at Wheelabrator test laboratories in Schaffhausen, the second test was conducted on Department of Material Science and Techology at University of West Bohemia in Pilsen.

2.1. Samples

Four different samples of Hadfield steel (X120Mn12 acc. to DIN 1.301) were collected from 12 mm thick rolled sheets for the tests. The samples were selected from metal sheets commonly available on the market but from different manufacturers. Specimens of size 30x30 mm were prepared. Chemical composition is in **Table 1**.

Table 1 The chemical composition of Hadfield steel according to DIN X120Mn12 (1.3401)

Element	C	Si	Mn	Cr	P	S
Range [%]	1.1 - 1.3	0.3 – 0.5	12 - 13	max. 0.5	max. 0.1	max. 0.04

2.2. Testing methods

Both testing methods were chosen due to their best simulation of operational stress. The first test method is Shot Blasting in the blasting machine, which logically directly corresponds to the operational loading. Second test method is loading at one point with cycling period (Impact test). The aim is to compare abrasion wear resistance results of the same samples on different testing equipment.

2.2.1. Shot blasting test

This method is based on the wear which is caused by blasting beam of abrasive particles shot on the sample surface. For this test is used wheel shot blasting machine. The weight loss in g/h of the tested samples is evaluated.

Testing Equipment:

Blast machine with blasting wheel type: WHEELABRATOR U70 x 500

Samples holder (fixture)

Test set up:

Blasting parameters: 606 kg / min at 2300 rpm with cut wire 0.8 mm 640HV (the average size is 0.7 mm) - see **Figure 3.**

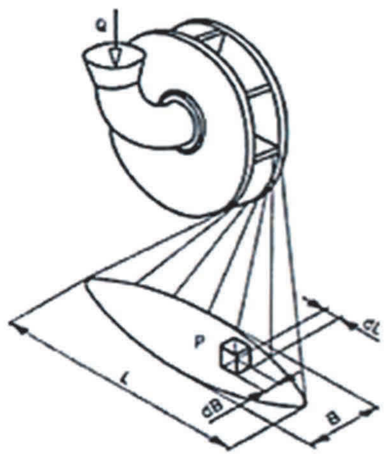

Figure 3 Shot blasting principle [5]

Note: abrasive size is controlled by separator airflow and checked by sieve analysis.

The samples are placed into the fixture and placed in the blast chamber in the outrunning blast stream whereas the blast stream is of axis to the test fixture. See **Figures 1** and **2.** As the fixture is turning around the center, every sample is blasted the same way. Every 4 hours the machine will be stopped and the weight of the samples will be measured.

2.2.2. Impact force cycling loading test

An Impact Test instrument developed at KMM UWB was used for testing. This device works on the Prince of Brinell Hardness Cycle Repeat Test. The loading force was 800 daN (dynamic force). The stroke frequency was 10 Hz. A carbide ball was used with the dynamic effect of the indented indentor (see **Figure 4**).

Two types of craters were created for 10.000 strokes and 100.000 strokes in one row. At first, 2 craters were created as a result of 10000 strokes. In another independent test, 2 craters of 100.000 strokes were created. To confirm the results, an independent test was then created, in which one crater was created 100.000 strokes.

The samples were first finely ground-metallographically abraded to remove the oxide layer. Further, the samples were cleaned with ethanol and attached to the measuring table by means of a second adhesive. At the start of the test, the Kistler measuring probe was calibrated.

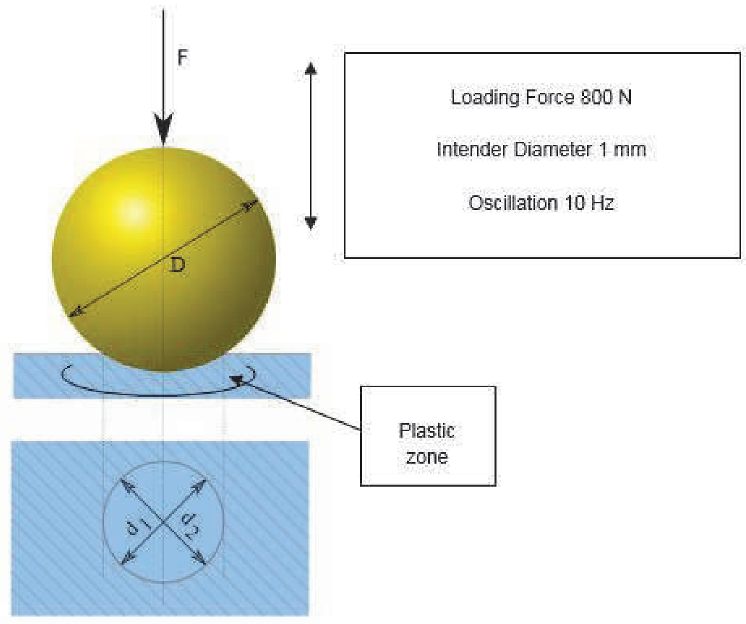

Figure 4 Load principles for impact test

Table 2 Comparison of wear resistance results

	Hardness HB	Diff in %	Shot Blast Test (g / h)	Diff in %	Impact Test Cycle II (μm)	Diff. in %
Sample A	233	100	0.215	100	728.5	100
Sample B	240	103	0.275	128	801	110
Sample C	196	84	0.260	121	858	118
Sample D	234	100	0.240	112	838.5	115

3. RESULTS AND DISCUSION

3.1. Brinell hardness

Hardness was measured by Brinell Hardness (HB 5 / 500 / 10), the results are in **Table 2**. Sample C shows the lowest hardness value, less in 20% than the other samples.

3.2. Shot blast test

All results are summarized in **Figures 5** and **6**.

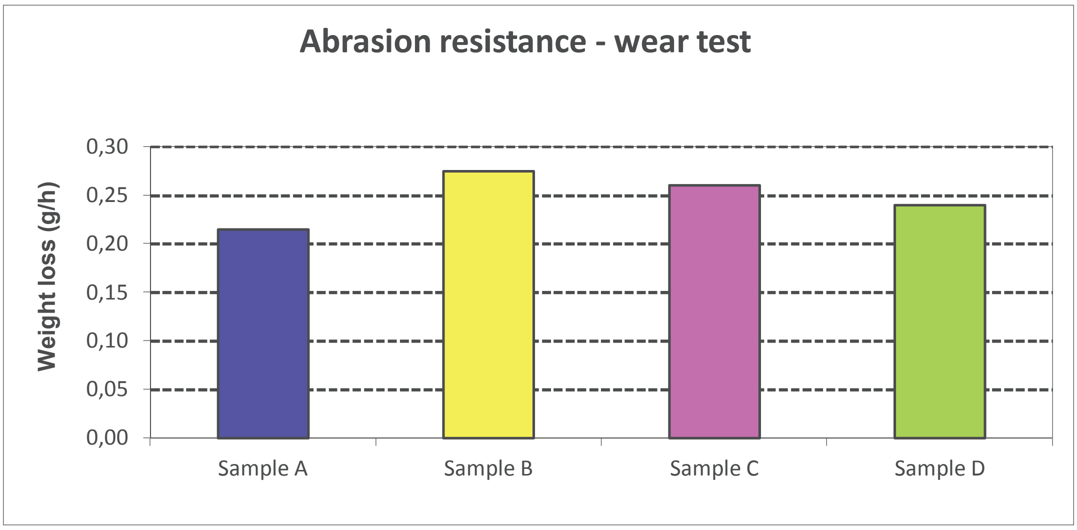

Figure 5 Results of blasting test - weight loss

3.3. Impact test

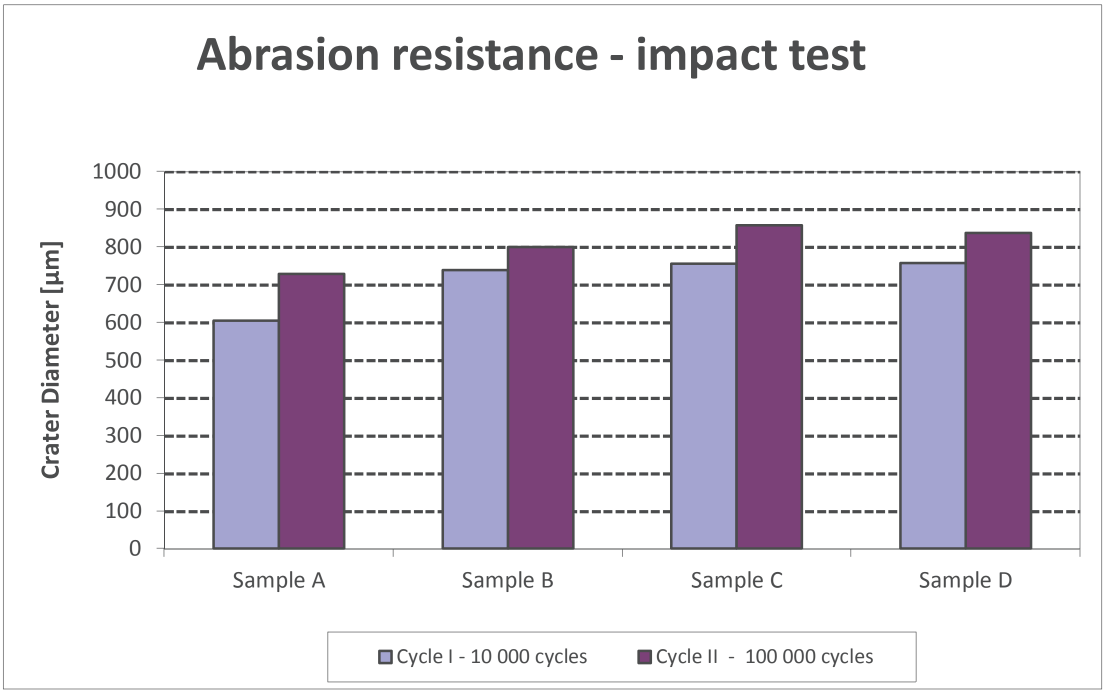

Figure 6 Imprinted diameter of crater after Impact test

4. CONCLUSION

The results of both tests have shown that there is no clear direct link between wear resistance and material hardness when comparing samples of the same material of similar hardness. For Sample C, the hardness was by 20 % lower than the other three specimens. Abrasion resistance of Sample C was not the worst, resp. significantly lower than the other samples. Conversely, Sample B with the highest measured hardness had the worse result at the Shot Blast test and comparable to the others in the Impact Test. The Sample A indicated the best results of wear resistance in both methods.

This shows that hardness measurement alone cannot predict wear resistance in operation life with sufficient precision. This also confirms that the wear resistance of Hadfield steel is not directly proportional to hardness. Wear resistance more depends on other factors. If the laboratory conditions of both tests are the same for all four samples, then material defects (e.g., grain boundary carbides, micro-cleanness, inclusions, etc.) have a significant impact on wear resistance.

However, the main objective was to verify whether the newly designed Impact Test method could replace the Shot Blast Test. The Shot Blast Test compares the weight loss of the tested material, while the Impact Test evaluates the magnitude of the repeat imprint of the test indenter. Both methods differ mainly in the size of the load and the subsequent affected area of the test specimen. The fact that a very small area is impacted on the Impact Test is also a disadvantage because it is a limitation for greater accuracy of the test. The Sample A reached the best wear resistance results in the both testing methods. The Impact Test method is a simpler and cheaper alternative to the blast test in terms of determining the expected resistance to abrasive wear. The additional tests in the lab will examine why sample A has achieved the best results.

For further comparison of both test methods, it would be desirable to incorporate other abrasion-resistant materials such as hardened tool steel or white chrome cast iron.

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