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Erosion–corrosion performance of high-Cr cast iron alloys in flowing liquid–solid slurries

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ABSTRACT

In many slurry transportation systems, such as in FGD (Flue Gas Desulphurization) and chemical processing applications, corrosion and erosion are the two main mechanisms of material degradation of the pump wet-end components including pump casing, impeller and liners. The performance of a selected material is mostly dependent upon its relative corrosion and erosion resistance to the service environment. In these cases erosion, corrosion and the related synergistic effects can be very complicated since they are affected by numerous factors including solid and slurry properties, chemical contents, hydraulic conditions and temperatures. In this experimental study, sliding Coriolis erosion testing has been performed with various corrosion factors such as pH value, chlorides content and temperature to evaluate the erosion–corrosion resistance of some high-alloyed white cast irons containing different levels of chromium and other elements. Optical microscope and SEM-EDS have also been used to examine microstructure and surface conditions of tested materials. Results indicated that material loss due to corrosion factors increased as acidity-chlorides and temperature increased. At relatively high corrosion intensity, the white cast irons with higher alloy content (especially chromium) clearly showed improved corrosion resistance and combined erosion–corrosion resistance over those with lower alloy content. Under certain corrosion and hydraulic conditions, particle size is perhaps the single most influential factor on erosion–corrosion rate of the high-Cr cast iron alloys. Relatively large particles are much more effective than small ones at removing both the corroded surface layer and the fresh material, causing substantially higher rate of material loss. Some other related factors have also been addressed.

1. Introduction

Many engineering applications require materials with excellent resistance to both corrosion and wear. While high alloy white cast irons are primarily for severe abrasion and erosion conditions, they also demonstrate fair to excellent corrosion resistance in various environments when they contain relatively high levels of chromium and other alloy elements [1,2]. High-chromium white irons, under ASTM A532 Class-III Type-A, contain 23–30% Cr (by weight), and may contain considerably higher weight percents for some special grades used in erosion–corrosion applications. Higher alloy content especially chromium can significantly improve the corrosion resistance of high-Cr white irons to corrosive conditions, such as to reducing acids [3].

Numerous experimental studies have used the Coriolis wear testing approach to investigate erosion of materials in flowing slurry environments [3–10]. The original principle of such Coriolis erosion testers was proposed and developed by Tuzson and Scheibe-Powell [4]. The basic work principle of such tester was to apply the Coriolis effect to enhance the interaction between flowing slurry and target surfaces. Research has shown that Coriolis wear testing is an effective methodology to study the erosive wear of a material within centrifugal slurry pump, cyclones and other applicable systems.

It was observed that, during Coriolis sliding erosion testing, the material loss on white iron samples was generated mostly by sliding wear, along with a limited amount of low angle impact fatigue cracking from solid particles in slurry [8]. In general, larger and more angular solid particles will cause higher material wear rates, including white iron alloys [8,10]. Previous studies have revealed that the material loss mechanisms and synergistic effect in a corrosion–erosion environment of various material systems can be very complicated [3,11–14]. When corrosion becomes a significant factor, the total weight loss of a material will depend upon its combined corrosion–wear resistance. However, the study on corrosion–erosion properties of materials such as white cast irons is rather limited. The objective of the present research was to conduct further investigation on combined erosion–corrosion behaviors of three alloy white irons by means of Coriolis sliding

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Table 1
Test materials.

Materials	Description	Relative wear resistance	Relative corrosion resistance
HCW-I	25% Cr white iron with medium carbon (ASTM A532, Class III Type A)	High (650 HB hardness)	Moderate
HCW-II	30% Cr white iron with relatively low carbon (ASTM A532, Class III Type A)	Medium (500 HB hardness)	Medium–high
HCW-III	>40% Cr specialty white iron with low carbon	Medium–low (450 HB hardness)	High

wear tests with different levels of corrosion factors such as pH value, chloride content and temperature. The effect of solid particle sizes on material loss occurring in erosion–corrosion conditions is discussed. Optical and electron microscopes were also used to examine microstructure and surface conditions of test samples.

2. Experimental details

In this study, three high-chromium white iron alloys (HCW-I, HCW-II and HCW-III) were tested in combined erosion–corrosion Coriolis tests. As described in Table 1, these white irons respectively containing 25%, 30% and >40% chromium possess different levels of corrosion and wear resistance. Typically, high-chromium white irons contain 20–40% (Cr–Fe) carbides by volume in their microstructure, providing good to excellent wear resistance. The high or ultra-high level of chromium and other elements in these alloys result moderate to outstanding corrosion resistance in relatively severe corrosion conditions. The microstructures of the selected alloys are shown in Fig. 1.

As shown in Fig. 2, the sliding wear testing setup of the GIW Coriolis erosion tester consists of a bowl with four specimen holders, which rotates around a vertical axis. The sample holders have a T-shaped cavity with a flow passage adjacent to the specimen. During a test, the slurry is pumped into the spinning bowl from a 400-l slurry tank through the flow loop. The agitating system in the tank effectively keeps the solid particles suspended in test slurries. The bowl speed and flow rate are adjustable. The major hydraulic and testing parameters, including specific gravity (or solid concentration) of the slurry, flow rate and hydraulic head are measured and monitored by a computerized system. A heating element with controller was installed in the system to adjust slurry temperature within certain limit.

In a Coriolis wear test, up to four specimens can be tested simultaneously. The ASTM G75 high-Cr material is normally included in each Coriolis test as a reference/control sample. The dimension of the sliding Coriolis wear specimen is 63.5 mm by 19.1 mm by 6.4 mm, with an effective erosion testing surface area of 63.5 mm by 12.7 mm.

The test slurries were made of commercial grades of silica sands and clean water. Sulphuric acid (H_2SO_4,) and sodium chloride (NaCl) were used to adjust the corrosion intensity. Three corrosion intensity levels were tested in terms of pH value and chlorides (Cl^-) content, including pH 7–0 ppm Cl^- (the base-line condition), pH 4–20,000 ppm Cl^- and pH 1.5–60,000 ppm Cl^-. Two test temperatures were set at 32 °C and 47.5 °C, respectively. Three particle sizes (D50) were selected for the tests, 10 μ, 148 μ and 660 μ. The shape of silica sand particles varied between semi-angular and semi-round (Fig. 3).

Each Coriolis wear test in the experiment consisted of four one-hour cycles carried out at a flow rate of 15 gal/min, 1.20 slurry S.G. (or corresponding to 12.1 vol.% solids concentration) and a bowl speed of 925 RPM. The weight and surface condition of specimens were checked before and after each test cycle. A Sartorius BP 121S 120-g digital balance with 0.1-mg repeatability was used for mass loss measurement of test specimens. Optical microscopy and SEM-EDS system were used for detailed analysis.

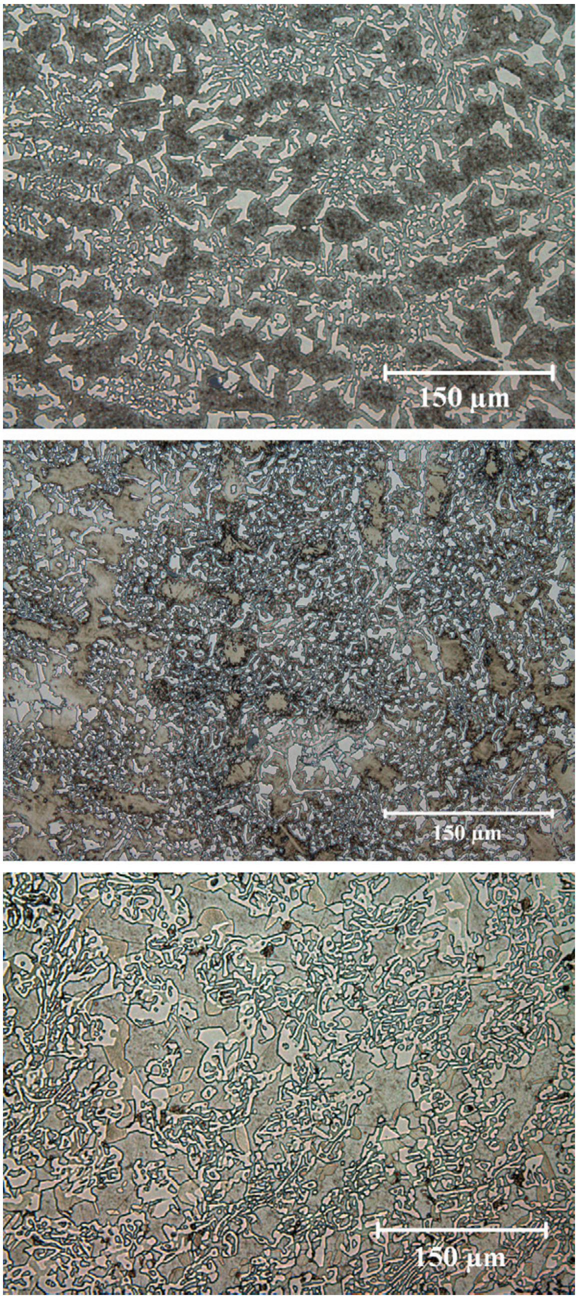

Fig. 1. Microstructures of the selected alloys (top: HCW-I; middle: HCW-I; bottom: HCW-III).