Wear 328-329 (2015) 391–400

Contents lists available at ScienceDirect

Wear

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

Erosive wear of various stainless steel grades used as impeller blade materials in high temperature aqueous slurry

M. Lindgren [a,*], R. Suihkonen [b], J. Vuorinen [b]

[a] Outotec Research Center, P.O. Box 69, 28101 Pori, Finland
[b] Department of Materials Science, Tampere University of Technology, P.O.Box 589, 33101 Tampere, Finland

ARTICLE INFO

Article history:
Received 29 December 2014
Received in revised form
13 March 2015
Accepted 15 March 2015
Available online 20 March 2015

Keywords:
Mixing
Impellers
Wear
Erosion
Slurry
Stainless steels

ABSTRACT

Two austenitic stainless steel grades, 316L and 904L, and three duplex stainless steel grades, LDX 2101, 2205, and 2507, were erosion tested as impeller blade materials for hydrometallurgical applications. Samples were attached to the pressure and suction sides of an impeller and were tested for 72 h at 80 °C and 95 °C in a small-scale reactor using quartz sand slurry. Based on the mass losses measured, the steel grades could be ranked into two distinct categories; LDX 2101 and 2507 comprising the category with the better erosion resistance. The categories were the same for the pressure and suction side tests even though the erosion mechanism differed. In most cases, erosion was more severe in the suction side samples, which has practical implications for wear protection design. In the pressure side samples, the variation in the erosion mass loss with different experimental parameters was in line with earlier reported findings. In contrast, in the suction side samples, under some experimental conditions, increasing tip speed and increasing particle size were found to reduce erosion mass loss. This emphasizes the fact that the erosivity of particles for the impeller suction side cannot be deduced solely based on particle size. The reasons for the observed behavior are discussed.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

Global trends of declining ore grades, more complex raw materials, and the increasing use of secondary resources have promoted the use of hydrometallurgical processing techniques for the treatment of non-ferrous metals. The hydrometallurgical processing route is a versatile one. It typically involves leaching stages, solution purification stages, and recovery stages [1]. The processing conditions, especially in leaching, are aggressive: sulfuric acid solutions at elevated temperature are often employed [2]. As a result, the corrosion properties of the construction materials are of paramount importance. The efficiency of hydrometallurgical unit processes is governed by the reaction kinetics. Effective mixing of constituents is required to ensure high process performance [3,4]. In the leaching stage, solids and sometimes gases are also mixed with the process solution. Consequently, the construction materials are subjected not only to corrosion but also to solid-particle erosion.

The corrosion resistance of stainless steels has been evaluated in environments relevant to hydrometallurgy [5,6]. The effects of various parameters on the erosion resistance of stainless steels have been widely investigated. Influences of particle velocity [7] and shape, angle of impingement [8,9] and solid concentration [10] have been reported. Erosion and corrosion often interact to produce weight losses, which are higher than the sum of those in individual processes [11,12]. The interaction between erosion and corrosion is extremely complicated and depends greatly on the test parameters. The understanding of both corrosion and erosion and their governing factors creates the first step for interpreting the more complex erosion–corrosion phenomenon.

Erosion of the impeller blades in the hydrometallurgical processes is a well-known phenomenon [13,14]. The flow fields generated during mixing and erosion of the impeller blades depend on the geometry of the system [15,16]. It is well established that a trailing vortex is typically generated behind a moving impeller blade [17–20], which causes turbulence leading to extensive localized wear [13,14]. This type of wear is, however, seldom studied in a quantitative manner. The wear pattern on the pressure side is typically more uniform and the test data generated with slurry pot devices [21,22], for example, are more relevant.

The erosion resistance of austenitic stainless steels, especially those of 304 and 316, has been investigated. Less research activity has, however, been dedicated to the erosion properties of more corrosion resistant grades, like 904L. In the slurry pot experiments

* Corresponding author. Tel.: +358 40 829 7293.
E-mail addresses: mari.lindgren@outotec.com (M. Lindgren), reija.suihkonen@tut.fi (R. Suihkonen), jyrki.vuorinen@tut.fi (J. Vuorinen).

http://dx.doi.org/10.1016/j.wear.2015.03.014
0043-1648/© 2015 Elsevier B.V. All rights reserved.

of Tsai et al. [21], the erosion resistance of austenitic grades 304 and 316L was found to be identical.

For the duplex stainless steel family, the erosion resistance of the relatively new lean grades is less well understood. Aribo et al. [23] compared the erosion resistance of various stainless steel grades under jet impingement. They concluded that the lean duplex grades LDX 2101 and 2304 had a higher erosion resistance than the austenitic 304 and duplex 2205 grades. A recent study [24] compared various austenitic and duplex stainless steel grades using various types of erodant relevant to the hydrometallurgical processing in short slurry-pot tests. The duplex stainless steel grades showed on an average a higher erosion resistance than the austenitic grades. Among the austenitic grades, 316L had slightly higher erosion resistance than 904L, especially when tested with erodants causing high erosion rates. Among the duplex grades, 2205 had the lowest erosion resistance. The relative ranking of LDX 2101 and 2507 depended on the type of erodant.

It is known that slurry pot test arrangements are incapable of detecting the effect of individual experimental parameters independently because the slurry flow and particle impact conditions are too complex and particle-size dependent. This means that the results obtained with different particle sizes, even under the same nominal test conditions, are not directly comparable [7,25]. The exact collision velocity may differ substantially from the nominal one thus creating a distribution of impact angles [26].

Owing to the above-mentioned factors, the relationships between the various experimental parameters and erosion of materials determined with, for example, slurry pot devices, cannot be transferred directly to the erosion of impeller blades. As the ultimate aim is to understand the erosion–corrosion of stainless steel grades as impeller materials, understanding of pure erosion under similar experimental conditions was required. This work provides data to understand the effect of various parameters on the erosion of various austenitic and duplex stainless steels tested on the pressure and suction sides of impeller blades.

2. Experimental

Two austenitic stainless steel grades: 316L (EN 1.4432) and 904L (EN 1.4539), and three duplex stainless steel grades: LDX 2101 (EN 1.4162), 2205 (EN 1.4462), and 2507 (EN 1.4410), were tested in the as-received condition. Samples of $35 \times 35 \times 3$ mm^3 were laser cut from the larger sheets for erosion tests. The cut edges were protected by the sample holder so that they were not exposed. The mechanical properties of the tested grades are shown in Table 1. The duplex grades exhibited somewhat higher strength and hardness compared to the austenitic grades, but their ductility was slightly lower.

The stainless steel surfaces before erosion testing are presented in Fig. 1. Surface roughness values were measured (Mitutoyo Surftest 211) as an average of five measurements in two perpendicular directions and the values obtained are given in Table 1. Grade 316L had the smoothest surface and the measured roughness was the same for both perpendicular directions. The duplex grades had a fairly similar surface roughness that was substantially higher than that of 316L. For LDX 2101, a small difference was measured in the roughness values in the two directions. Grade 904L had the highest surface roughness, about double that of the duplex grades. Its surface roughness varied slightly between the measurement directions. The measured surface roughness values were consistent with the appearances of the surfaces.

Two quartz erodants (Nilsiä quartz supplied by Sibelco Nordic) were used, having different particle sizes. They were labeled fine and coarse based on their particle sizes. The fine quartz had a nominal particle size of 50–200 μm and its measured D_{50} and D_{80} values were 121 μm and 150 μm, respectively. The coarse quartz had a nominal particle size of 100–600 μm and D_{50} and D_{80} values obtained were 277 μm and 398 μm, respectively. The density of the fine quartz was measured to be 2.66 g/cm^3 and that of the coarse quartz 2.70 g/cm^3. Fig. 2 shows the scanning electron images of the fine and coarse quartz. In addition the particle shape was elucidated by observing ground and polished cross-sections using scanning electron microscope (Jeol JSM-7000F) combined with INCAFeature image analysis software. The average aspect ratio and the circularity were calculated from individual measurements of thousands of particles. The results are given in Table 2. In addition spike parameter – quadratic fit (SPQ) [27] was calculated for twenty particle by using image analysis program ImageJ and Matlab. The SPQ parameter was found to have a similar value for both quartz types when the experimental scatter was taken into account. Based on these metrics no differences in shape between the fine and coarse sand could be noted.

A schematic presentation of the testing apparatus is shown in Fig. 3. It is a small-scale reactor (about 200 l) and the samples were attached to the impeller blades. A total of 12 samples were tested simultaneously. Six samples were attached to the pressure side of the impeller blades and the other six were attached to the suction side of the impeller blades (Fig. 3). The impeller blades formed a 45° angle with regard to the impeller axis. The test temperature and rotation speed were continuously monitored during the tests. It is well established that the erosion conditions on the pressure and suction sides differ. The pressure side samples are subjected to more uniform erosion, whereas the suction side samples are exposed to more turbulent flow conditions, as so-called trailing vortices are generated behind the blades [17–20]. The high local wear rates generated by the local turbulence have been illustrated, e.g., by the multilayer paint technique [14]. As a result, the suction side samples characterize the resistance of various materials against more turbulent conditions, i.e., localized wear compared to the pressure side samples. In industrial mixing applications, both properties are of importance.

Tip speed was tested at two levels, 4.8 and 7.2 m/s. Based on the computational fluid dynamics (CFD) modeling of the test setup it can be estimated that the flow pattern causes the maximum particle impact velocity to be about 20% less than the tip speed. Sand concentration was 15 wt%. The sand was replaced after every test as it was observed that significantly lower erosion rates were obtained with recycled sand even when no significant changes in particle size distribution could be detected by sieving. The nominal

Table 1
Typical mechanical properties of the stainless steel grades given by the supplier and measured surface roughness Ra values in two perpendicular directions.

Grade	Proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation A_5 (%)	Hardness HB	Surface roughness Ra (μm)
316L	280	570	50	165	0.3 ± 0.02; 0.3 ± 0.04
904L	260	330	45	150	5.6 ± 0.4; 4.9 ± 0.5
LDX 2101	570	770	38	230	2.8 ± 0.3; 2.5 ± 0.09
2205	620	820	35	250	2.9 ± 0.3; 2.8 ± 0.2
2507	590	900	30	265	2.2 ± 0.2; 2.2 ± 0.2

Download English Version:

https://daneshyari.com/en/article/7004421

Download Persian Version:

https://daneshyari.com/article/7004421

Daneshyari.com