Improvement of Corrosion and Erosion Resistance Properties for Cast Iron

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Abstract. Cast iron is considered a very common material for manufacturing applications due to its low cost, easy casting and high stress compression sustains. One of the obstacles in the application of cast iron are the corrosion and erosion phenomena which limits using the cast iron in certain applications. To improve the resistance rate of cast iron to corrosion and erosion. Chromium material had been added to the gray cast iron as a function of weight with different ratios to check which ratio is perfect to increase its resistance. The effect of corrosion and erosion on cast iron was investigated experimentally with and without chromium additives on the resistance of gray cast iron with and without chromium additive. Results showed that the mechanical properties increased with the increase of the chromium ratio in the four cases in general to minimize the risk of material destruction from erosion-corrosion.

1. Introduction

Cast iron alloys are widely used to manufacture a variety of engineering parts due to its special characteristics, such as high compressive strength, low cost, easy casting, and availability in abundance. Gray cast Iron have been used to produce brake disc, cylinders, gas exhaust manifold and pump casing [1,2]. Erosion and corrosion are the material degradation phenomena causing the failure of many engineering components like pump components including impeller and liners. It is clear that material loss due to corrosion factors increased as acidity-chlorides and temperature increased [3]. A study demonstrated that the heat treatment increased the corrosion resistance of the high chromium cast irons [4]. Erosion-corrosion phenomena are very important in oil and gas industries such as those occurring in offshore piping. To minimize the erosion-corrosion, Cermet-based coatings are being increasingly used in recent studies as accomplished in paper review [5]. A study was conducted to assess the erosion effect in pipeline made of stainless under high velocity of liquid with different working condition water [6]. High chromium cast irons (HCCIs) with 45 wt.% of chromium to the alloy has been studied. The microstructure of the extended higher chromium concentration changed to improve the performance of the alloy under various operating conditions [7]. A study accomplished by experimental results cleared that the effect of tungsten on wear resistance of high chromium white cast iron would be increase due to the tungsten additive in the matrix alloy [8]. Experimental investigations were conducted to know the changes in the mechanical properties and in the microstructure of grey cast iron by adding chromium with cerium oxide and lanthanum oxide of
various earth oxides using salt spray chamber for 120 hours [9]. The result showed enhancement in resistance to corrosion. Many strategies may be applied to reduce the corrosion –erosion on material surface. Laser surface alloying has emerged as an important tool to form a wear resistant layer over the nodular cast iron and their effects on microstructure [10,11]. Another method to reduce the corrosion and to improve the surface properties of iron is by using Fe-B alloy and boronizing, which is used as a new kind of wear resistance and corrosion material. This is accomplished by a review that described the progress of using boride morphology [12,13]. In addition, for a particular application, a convenient selection of heat treatment of chromium cast iron can improve and control the material properties for customized hardness level [14]. The improvements of erosion resistance after laser treatment were considered due to the very fine structure, high micro hardness with the resistance to plastic flow and to the dissolution of the graphite nodules [15]. The elements mentioned are either used individually or combined with each other, which in turn affects the composition and properties of cast iron [4]. In recent years, iron foundries have had to face stiff competition, and every year there are iron productions such as plastic molding and construction steel at the same time, improving the quality and methods of production.

In the present work, Gray cast iron is selected for experimental investigation. Gray cast iron is one kind of cast iron which has a graphitic microstructure and its composition depends on how much silicon component is embedded to differ from white cast iron. Current research aims to improve the properties of corrosion and erosion resistance. Chromium metal is added to the gray cast iron with different weight percentage in order to improve the properties of cast iron against corrosion and erosion. Results showed good enhancement in corrosion and erosion resistance of gray cast iron.

1.1. Corrosion
Corrosion is defined as the dissolution of the metal because of its interaction with the medium to which it is exposed. Corrosion is considered as a failure that affects the surface of the metal and leads to weight loss due to the decay of the metal and then leads to change in its dimensions. For this reason, permits are often given for the possibility of corrosion in a design [2].

1.2. Erosion
It is created by a mechanical action that happens because of a relative movement between the surface of the metal and a corrosive fluid. This type has a local effect and it is characterized by a problem that may differ from different types of corrosion [2].

2. Experimental part
In this work, we use gray cast iron alloy to conduct the corrosion and erosion test. The first step in this work is to check the gray cast iron alloy composition. The actual chemical composition of the alloy that was used in the experimental part is listed in table 1. Five samples are prepared according to the chromium addition to the gray cat iron as in table 2 starting from 0.10% to 10% as a function of cast iron weight. The samples were prepared in the form of rectangle cross section with dimensions of (16,8, and 2 mm) as in figure 1. The samples are prepared by smoothing the surface after puncturing them with a diameter of (2 mm) for the purpose of suspension. Samples exposure to normal water and weights were recorded before and after testing with different exposure times. The measurements are accurately (0.01 mg). Corrosion rate and erosion rate are estimated as weight loss percentage to the unit area and time for each sample.
2.1. Corrosion test
The procedure that was used to compute and study this phenomenon was by hanging the samples into a tester with containers filled with normal water in room temperature in the Babylon university lab. The tester has five positions prepared to hang the samples. This test was performed at room temperature by suspending the samples in normal water and then the change in weight was recorded at different times for a 20-hour period.

2.2. Erosion test
The test was investigated on cast iron samples for 20 hours where the weight for each sample was computed in different times to check the weight changes. This test was conducted by making the samples spin in normal water at a rotational speed of 1,420 rpm in the test device designed for this purpose.

3. Results and Discussion
3.1. Corrosion results and discussion
The results of corrosion rate are presented in figure 2 for cast iron specimens according to the chromium ratio. It can be seen from the figures that the corrosion rate is in general very different. This is not unexpected due to the random occurrence and difference of the chromium ratio. The results showed significant differences in the corrosion rate among the samples according to the chromium.

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**Figure 1.** Cast iron specimen.

**Table 1.** The chemical composition of gray cast iron.

| Gray cast iron component | ASTM  | Actual |
|--------------------------|-------|--------|
| C %                      | 2.5-3.8 | 3.3    |
| Si %                     | 1.1-2.85 | 1.2    |
| Mn %                     | 0.4 - 1.0 | 0.4    |
| P %                      | P < 0.15 | 0.01   |
| S %                      | S< 0.1  | 0.04   |
| Fe %                     | Remaining | Remaining |

**Table 2.** Chromium addition ratio to the gray cast iron.

| No of samples | Cases     | Cr addition % |
|---------------|-----------|---------------|
| 1             | Original  | 0             |
| 2             | Case 1    | 0.01          |
| 3             | Case 2    | 0.05          |
| 4             | Case 3    | 0.08          |
| 5             | Case 4    | 0.10          |
The first sample showed very high corrosion rate compared to the third and fourth samples. In addition to the occurrence of scaling in the first and second samples as in figure 2. This behavior of these samples is expected because the layer of oxides growing on them is unrealistic and they are weak adhesion and porosity, most of which are iron oxides that have these characteristics.

**Figure 2.** Effect of normal water exposure period on the corrosion rate of cast iron.

The curves of the different chromium ratio of 0, 0.01, 0.05, 0.08 and 0.1 are shown in figure 3. At low chromium ratio, the weight gains of the different chromium except 0.1 Chromium were very high. The parabolic rate constant of 0.1 chromium was lower that of the others. Overall, decrease in weight gain with increase in chromium content of the cast iron was clearly observed.

**Figure 3.** Weight gain relation with time and chromium ratio.

From figure 4, it can be observed that the sample Chromium ratio at 0.1 Chromium has the highest corrosion resistant in this medium since the lowest weight was lost during the exposure period. This is followed successively by the samples Chromium ratio at 0.08, 0.05, 0.01 and 0 Chromium lastly the control sample. The general observation on these results is an evident increase of weight loss with exposure time and a similar progression pathway of cumulative weight losses for all the samples with increase in exposure time. The reason for the constant difference in cumulative weight loss from the start until the end could be the difference in composition and structure generated by the different chromium ratio.
Figure 4. Relation between corrosion rate and weight loss with chromium ratio.

Figure 4 shows the rate of loss with the exposure time and shows the very high rate of the first sample as well as the second sample. Other samples showed lower rates and cast iron behavior was similar to that of other alloys. It generally consists of four regions: the incubation period, the acceleration phase, the third stage of deceleration, in which the surface of the metal becomes rough, with visible grooves and the fourth stage of stabilization, which is characterized by a stable loss rate.

3.2. Erosion results and discussion
The results showed a significant increase in the lost weight of the samples as shown in Fig.5. The samples are exposed to water as the relationship tends to appear linear for the first three samples were the chromium addition ratio are 0, 0.01 and 0.08 respectively, while the fourth sample with 0.05 and the one with 0.1 are low. This result due to the formation of protective layers of the element chromium oxide that has high adhesion ability to the metal surface, as many studies refer to this property [8] and samples are stabilizing in less time than other samples.

Figure 5. Effect of normal water exposure period on the lost weight of cast iron in Erosion rate.
4. Conclusions
The purpose of the current research is to study and assess the resistance of corrosion and erosion of gray cast iron when chromium additive is used. The following conclusions can be drawn by the analysis, results, and discussion of this paper.
1. Improvement of corrosion and erosion resistance properties of gray cast iron was achieved.
2. The resistance of cast iron to corrosion and erosion increased as the chromium ratio increased.
3. The results showed that the corrosion rates mostly have one form, when drawing the relationship between the rate of corrosion and the time with respect to the chromium additive.
4. The incubation period did not appear to be low because the chromium content was low as the iron oxides formed at the beginning fall into the impact of the layer on the surface of the water.

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