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A Study on Wear and Erosion-Corrosion Resistance of Two Typs of Cast Irons.

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Abstract

The wear and erosion-corrosion resistance of gray and ductile cast irons were studied for their important in most applications. The wear tests were carried out using a pin-on-disc machine by applying different loads (10,20 and 30 N). The wear rate was measured using weighting loss method.

Erosion-corrosion rate measurements for both types of cast iron in (0.01%,0.58% and3.5%) NaCl solutions using a rotating disc of 450 rpm indicate that erosion-corrosion resistance of ductile iron is better than that of gray cast iron.

Microstructure observations after erosion-corrosion indicate that it plays a role in erosion-corrosion ; the predominant ductile matrix on the microstructure of ductile iron is at lower erosion-corrosion rate than that of gray cast iron . Localized attack usually has bright surfaces free from corrosion product. Pits are often observed on the line flow direction on these materials. These pits have a characteristic horse shoes shape for both types of cast irons. Optical microscope examination for the specimens indicates the presence of white and dark areas which refer to graphitization and pitting corrosion respectively. The wear rate is influenced by the form of phases therefore the flake graphite form in gray acts more like a lubricant film between two contact surfaces than spheriodal graphite. Brinell hardness measurements for both materials show that gray iron has higher hardness than ductile iron so that wear tests at different loads (10, 20 and 30 N) for both materials indicate that gray iron has high wear resistance than ductile iron and the wear rate increases sharply after (20N) for ductile iron. These results are related to high hardness and graphite phase form on the microstructure of gray iron.

الخلاصة

تم دراسة مقاومة البليان والتآكل بالتعرية لحديد الزهر الرمادي و ألمطيلي لاهميتها فـي معظـم تطبيقات هذه المواد. تم تنفيذ اختبارات البليان باستخدام ماكنة ابره على قرص باستخدام أحمـال مختلفة (10و20و30) نيوتن. تم قياس معدل البليان باستخدام طريقة فقدان الوزن.

اختبارات مقاومة التآكل بالتعرية لكلتا المـادتين بمحاليـل (%0.01,%0.58,%3.5) كلوريـد الصوديوم باستخدام قرص دوار بسرعة (450) دورة/ دقيقة تشـير إلـى إن مقاومـة التآكـل بالتعرية للحديد ألمطيلي أفضل من مقاومة الحديد الرمادي.

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ملاحظات البنية ألمجهرية لعينات التآكل بالتعرية تشيرالى إنها تلعب كقاعدة في التآكل بالتعريـة وان معدن الأساس ألمطيلي الأكثر شمولا يكون الأول معدل تآكل بالتعرية.يظهر التآكل الموضعي سطوح براقة خالية من نواتج التآكل , غالبا ما تلاحظ ان التنقرات تحت اتجاه التدفق تمتلك هـذه القنوات خصائص بشكل حذاء الفرس لكلا المعدنين.
تشير المساحة البيضاء إلى حصول الكر فتة والمساحة الداكنة تشير إلى تأكـل التنقـر الشـكل والأطوار في معدل البليان لذلك شكل الكرافيت(flake) في حديد الزهر الرمادي يعمل اشبه مـا يكون طبقة مزيتة بين السطحين المتماسين مقارنة بالكرافيت الكروي.

1. Introduction

Wear resistance is an important property of gray cast iron .The effect of microstructure and load on the wear rate of cast iron has been investigated under dry sliding condition using a pin -on-disc machine .The gray cast iron has better wear resistance than that of ductile cast iron because of the form of graphite.

In gray cast iron, the forms of graphite are flakes, this type of graphite will slide easily due to applied load. The high wear resistance of gray iron is due to the random distribution of the graphite flakes in its microstructure. A nodular cast iron has been shown to give a lower wear resistance than flake graphite [1].

Erosion-corrosion is a complex material degradation mechanism involving the combined effects of mechanical erosion and electrochemical corrosion; and the effects of erosion-corrosion impose economic constraints in many industrial applications. To date studies relating to erosion-corrosion have focused on determining relative mass losses for material in different conditions to establish ranking orders to assist in material selection. Erosion-corrosion is a form of corrosion ,typically affecting pipelines. It involves a combination of pitting and erosion .When movement of a corrosive over a metal surface increases the rate of attack is due to mechanical wear and corrosion ,especially abrasive particles, the attack is called erosion-corrosion. Nearly all turbulent corrosive media can cause erosion-corrosion. The attack may exhibit a directional pattern related to the path taken by the corrosive as it moves over the surface of the metal [2].

Erosion-corrosion is commonly observed at elbows, bends and tees piping .In piping systems ,erosion-corrosion can be reduced by increasing the diameter of the pipe ,thus decreasing velocity and turbulence .Inlet pipes should not be directed on to the vessel walls if this can be avoided [3]. The focus of the project is to investigate the wear and erosion-corrosion behavior of ductile cast iron and compare it with that of gray cast iron.

2.Experimental Work

2.1. Materials

The materials used in this work were gray cast iron (type G2500) and ductile cast iron type (60-40-18). Chemical analysis of these materials

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was carried out using (Atomic absorption method) in Ibn-Sina Company as shown in Table (1).

2.2. Hardness Test

The Brinell hardness test is used for all cast irons because the Brinell test impression is large enough to average the hardness of the constituents in the microstructure. In cast iron practice, it is usual to employ load of 750kg and ball 5mm. The Brinell hardness HB is calculated according to following equation [4].

$$HB = \frac{2F}{3.14D(D-\sqrt{D^2-d^2})} \quad \text{-- (1)}$$

where:
F- applied load kgf.
D- diameter of ball indenter (mm).
d-diameter of indentation (mm).

2.3 Solutions

Solutions used in this work were 0.01%, 0.58% and 3.5% NaCl. These solutions were prepared by dissolving 0.1, 5.8 and 35 gm ANALAR sodium chloride in 1 liter of distilled water for each solution. After the solutions were prepared, pH of each solution was measured using pH-meter type (GT.BRITIAN) Philips.

2.4 Erosion-Corrosion Test

2.4.1 Erosion-Corrosion Specimens

The specimens were cut out in dimensions of 10 mm diameter and 3 mm thick for erosion test. After the specimens were cut, they were cleaned in sequence with emery paper of grades 180, 220, 500, 800, 1000 and 1200 then polished, washed with distilled water, acetone and then were dried. The specimens were weighted before and after each test in solution.

2.4.2 Erosion-Corrosion Device

The erosion-corrosion test was carried out using the device shown in Fig. (1). This device uses a rotating disc with modification by changing the rotating wheel to the flat plate of the same material of rotating shaft. It consists of electric motor with speed of 3000 rpm, rotating shaft of mild steel with diameter of 1.5 cm and flat plate of mild steel with dimensions of 20 cm in length, 2cm in width and 3mm in thickness. Specimen were fixed on it and tank with dimensions of (60×60×60) cm. After fixing the specimens on the end arm of the rotating shaft of electric motor, it was immersed in the tank. The erosion-corrosion test was applied to the gray and ductile cast iron using (0.01%, 0.58% and3.5% NaCl) solutions. The erosion rate was calculated using the following formula [5]:

$$E.R = \frac{\Delta W}{T} \quad \text{-------- (2)}$$

where:
E.R- erosion rate (gm/hours).
ΔW - weight loss (grams).
T- time of duration (hours).

2.4.3 Sliding Wear Test

2.4.3.1 Sliding Wear Specimens

The gray and ductile cast iron specimens were cut out in dimensions of 10 mm diameter and 20 mm length. After cutting, the specimens were cleaned in sequence with emery papers 180, 220, 500, 800, 1000 and 1200. Then, they were polished, washed with distilled water and acetone and then dried. The specimens were weighted before and after each test.

2.4.3.2 Sliding Wear Device

The device used in this test involves electric motor of 940 rpm, and this speed can be changed by many belts and discs as shown in Fig. (2).It consists of a rotating disc fixed on the

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shaft of the electric motor. The specimen is fixed in the holder and the circular face is in contact with the rotating disc. The loads of 10, 20 and 30 N were applied to the holder which carried the specimen. The wear rate is calculated using the weight formula [6]:

$$WR = \frac{\Delta W}{S_D} \text{ ----------- (3)}$$

where:
WR= wear rate.
ΔW =weight loss.
S_D = sliding distance.

3. Results and Discussions

3.1 Microstructure Evolution

The microstructures obtained of two materials used are shown in Fig. (3 a and b). The microstructure of gray cast iron appears in flake graphite form in matrix of ferrite and pearlite. The matrix also contains small amounts of graphite as shown in dark large areas shown in Figure (3 a). This microstructure description is also present in the international standard [9]. The measured hardness of gray cast iron is equal to (222HB), which is within the standard values of gray cast iron of (179-229) HB. The standard value of tensile strength of gray cast iron is of (173) Mpa. The microstructure of ductile cast iron consists of spheroids graphite in matrix of full ferrite [Fig. (3 b)]. The measured hardness of ductile type is equal to (186HB) and this value is within the standard limits of (143-187) HB. The standard tensile strength of this type of cast iron is (414) Mpa. The microstructures shown in Figure (3 a and b) are the typical microstructure of gray and ductile cast irons. The tensile strength values of spheroid graphite irons are generally about twice those of flake graphite.

3.2 Erosion-Corrosion Study

The erosion-corrosion rates were measured for two types of cast irons in the same solutions of corrosion tests as shown in Figures (4) and (5). The erosion rate is very small during the early part of erosion test. During this period, the material undergoes permanent changes due to the repeated erosive forces. After the incubation, the material starts increasing the erosion rate with further exposure time to erosion. It is observed experimentally that the rate of erosion becomes very nearly independent of the exposure time, and hence is called steady state period. When a slurry of corrosive liquid is used, the whole of the test surface is subjected to uniform erosion condition. This is of major importance in conducting erosion-corrosion tests. No material removed will occur when the states of stress in the target material do not exceed the elastic limit .

Microstructure plays a role in erosion-corrosion; The more continuous the ductile matrix is the lower erosion rate as shown in Fig. (4) and (5). Localized attack due to erosion-corrosion usually has bright surfaces, free from corrosion products. The pits are often undercut in the direction of the flow and their cross sections exhibit an under cut surface zone pointing against the flow. Sometimes, these pits have a characteristic horse shoe shape as from a horse running up stream as shown in Fig. (6)for gray and (7) for ductile. The white area indicates the graphitization and dark areas indicate the pitting corrosion.

The erosion rate is affected by the concentration of particle in the fluid stream and this concentration is also affected by the flow rate. By increasing the concentration of sodium chloride, the number of impacts is increases, which affects the erosion rate. The erosion rate decreases as the amount of harder phase increased. The failure does not occur in erosion when the particle stream is moved parallel to the specimen, the criterion of failure must be some function of both shear forces and normal impact forces. Plastic flow occurs and material is removed by the cutting action of the particles [10].

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3.3 Sliding Wear Test

The sliding wear tests were performed by using pin-on-disc equipment for two types of cast iron as shown in Fig. (8). This figure shows the relationship between the wear rate and the different applied loads at constant time of 30 minutes .The microstructure plays a role in wear rate which is directly related to the distributions of hard, brittle and soft phases in the investigated metals. The wear rate of ductile is greater than that gray cast iron. The wear rate of gray cast iron is increased uniformly as load increases because the gray has flake graphite forms which are interconnected and disposed in the form of plates, constituting an easy path for heat dissipation.

For ductile cast iron, the wear rate is increased linearly because spherical graphite particles are isolated from each other, the contribution of that phase for the thermal conductivity is very small when load is increased due to heat generation. The higher hardness of gray cast iron (222 HB) than ductile cast iron (186HB) will lead to lower wear rate of gray cast iron than ductile.

Fig. (9) and (10), represent the effects of wear on the microstructure of gray and ductile respectively. Firstly, at low load of 10 N, the worn surface of cast iron is covered with continuous layer of compacted reddish iron oxide powder and exhibits no significant evidence for plastic deformation for two types. At applied load of 20 N, the ductile cast iron suffers from transition to severe wear due to increase in load and temperature, but gray cast iron does not suffer from this phenomenon. Finally, when load is increased, the oxide films that are formed on the wear tracks are thin and discontinuous under these conditions and the contact area is covered with dark oxide film. On high load conditions of 30 N, the temperature and load on the particles appear to be significantly high to cause welding of those particles to the counterface. The flake graphite form in gray iron acts more like a lubricant film between two contact surfaces than spheriodical graphite.

4.Conclusions

1. Graphitization appear. more clearly on gray iron than on ductile iron.
2. Erosion-corrosion resistance of ductile iron is better than that of gray iron.
3. Hardness and wear resistance for gray iron are higher than those of ductile iron.

Table(1) Chemical compositions of gray and ductile cast irons.

Chemical composition	Gray	Ductile
C%	3.5	3.1
Si%	2.02	1.68
Cr%	0.053	0.25
Mo%	0.0098	0.017
Ni%	0.054	0.085

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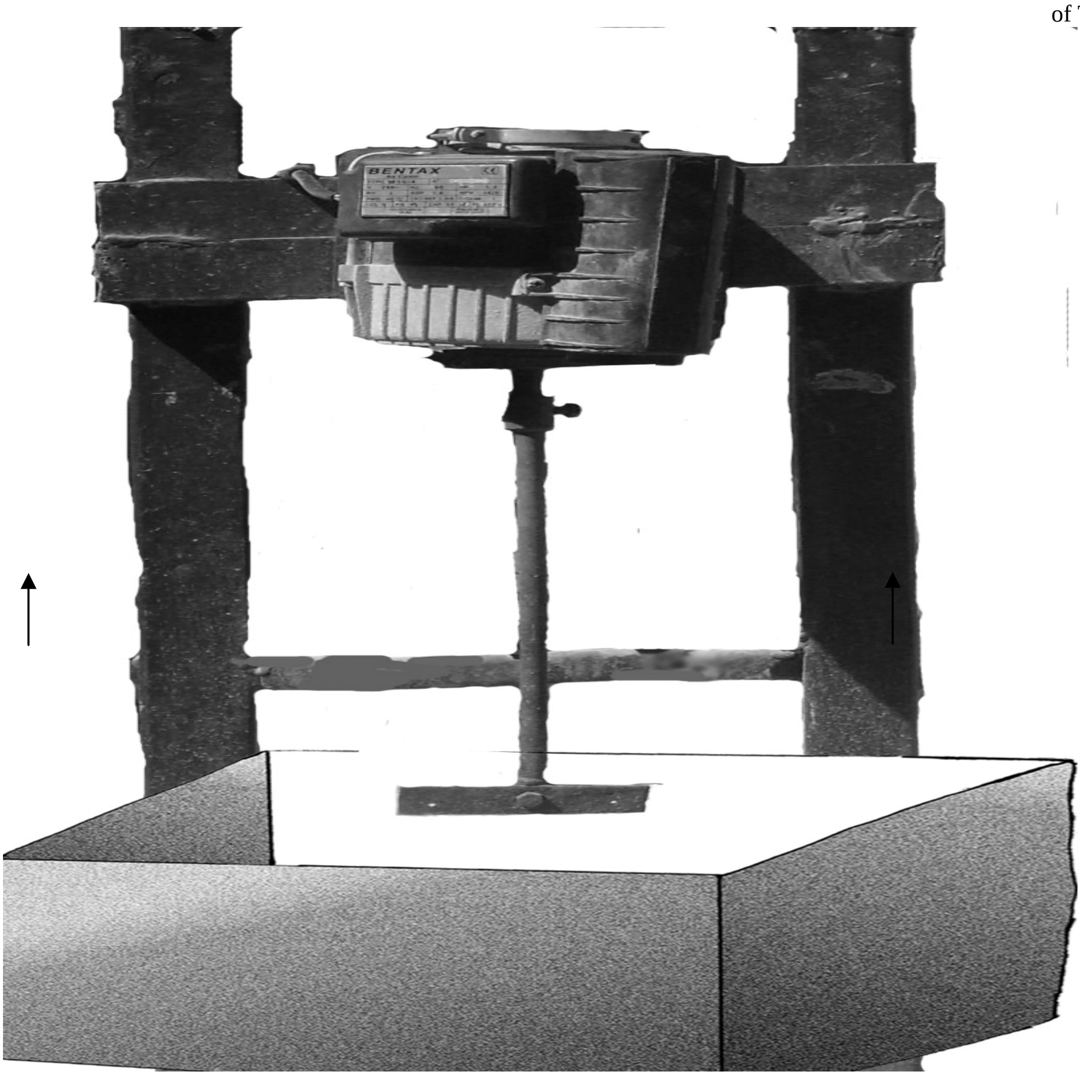

Figure (1) The device of erosion corrosion test [7,8].

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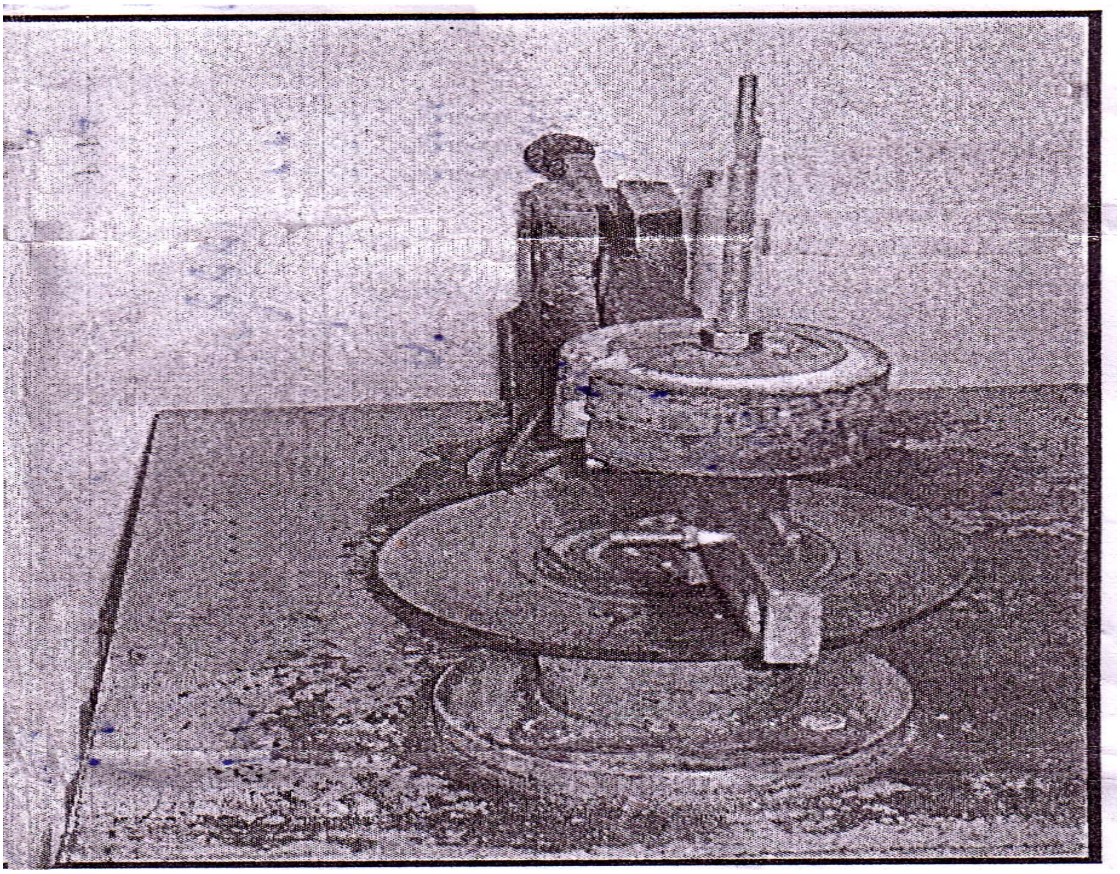
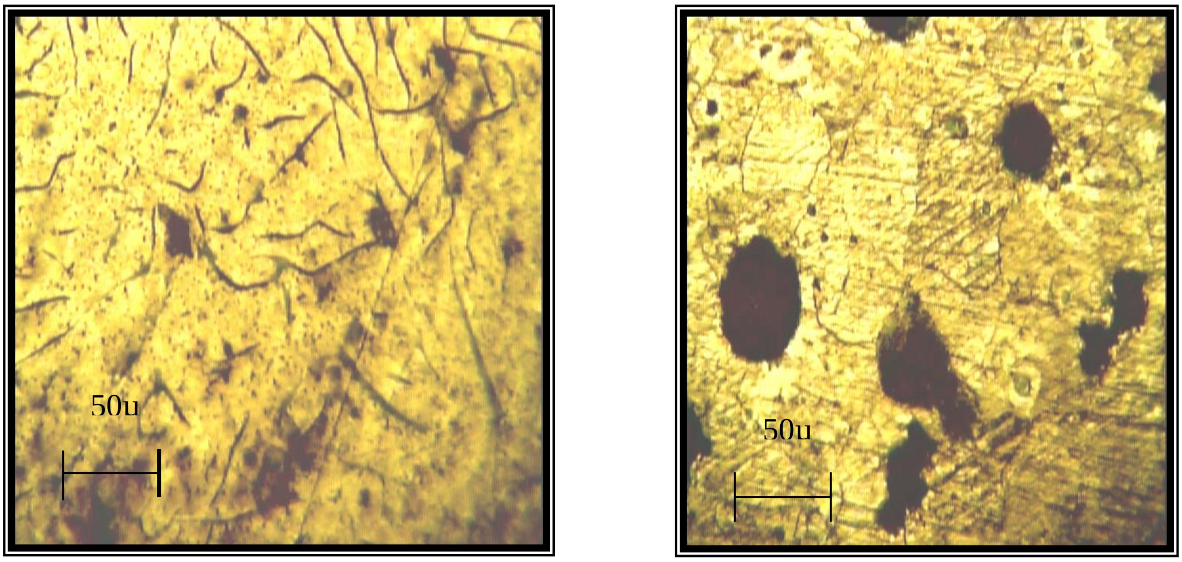


Figure (2) Pin- on- disc device for sliding wear [6].



(a) **(b)**

Figure (3) The microstructure of (a) gray (b) ductile cast irons

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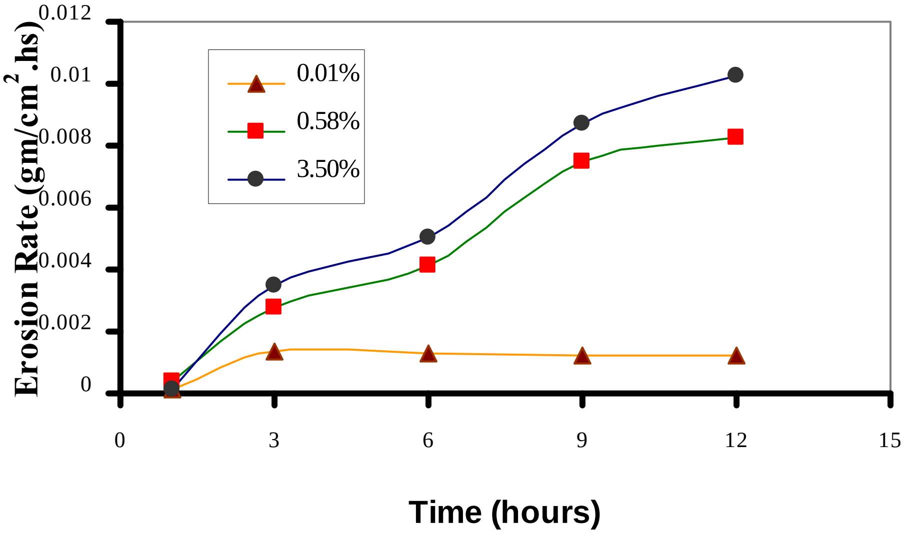

Figure (4) Erosion-corrosion of gray cast iron in different NaCl solutions.

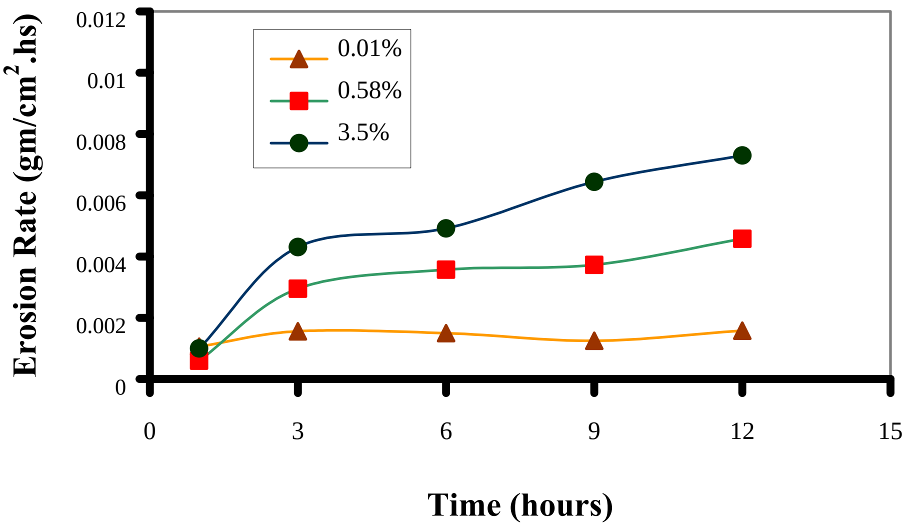

Figure (5) The erosion-corrosion of ductile cast iron in different NaCl solutions.

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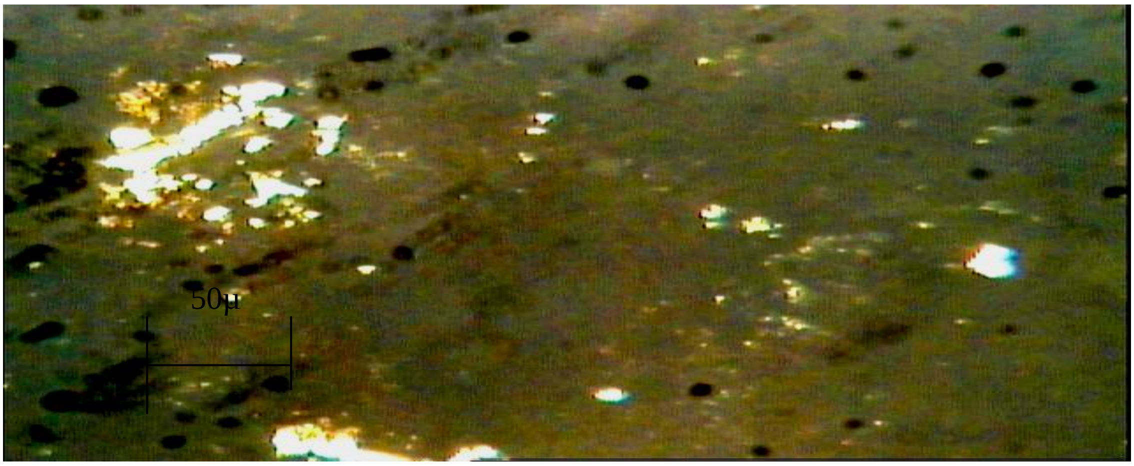
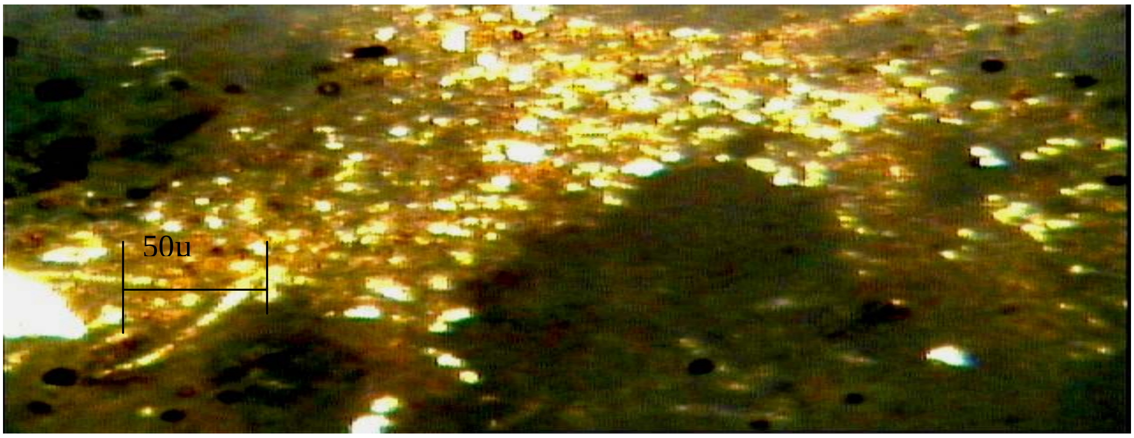


(a)



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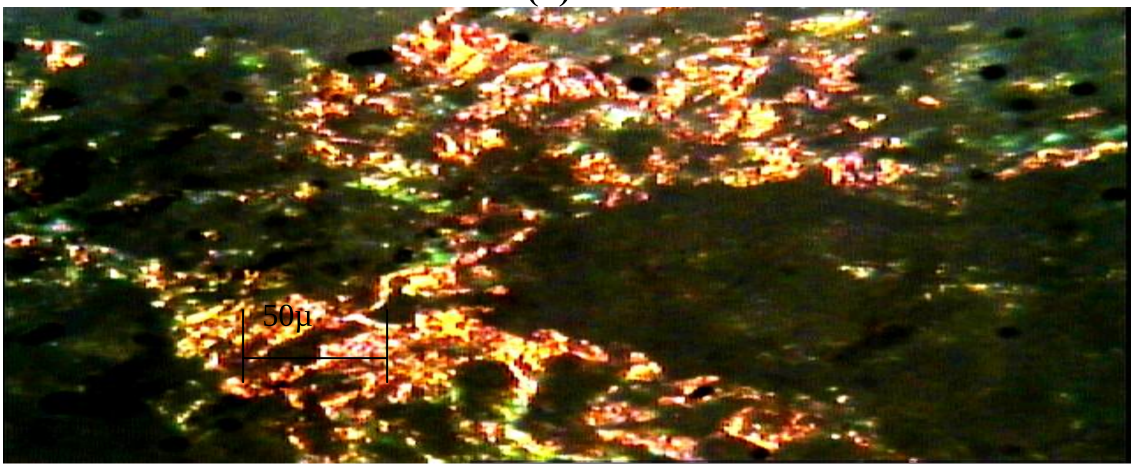

(c)

Figure (6) The microstructures of erosion-corrosion of gray cast iron in (a) 0.01% (b) 0.58% and (c) 3.5% NaCl.

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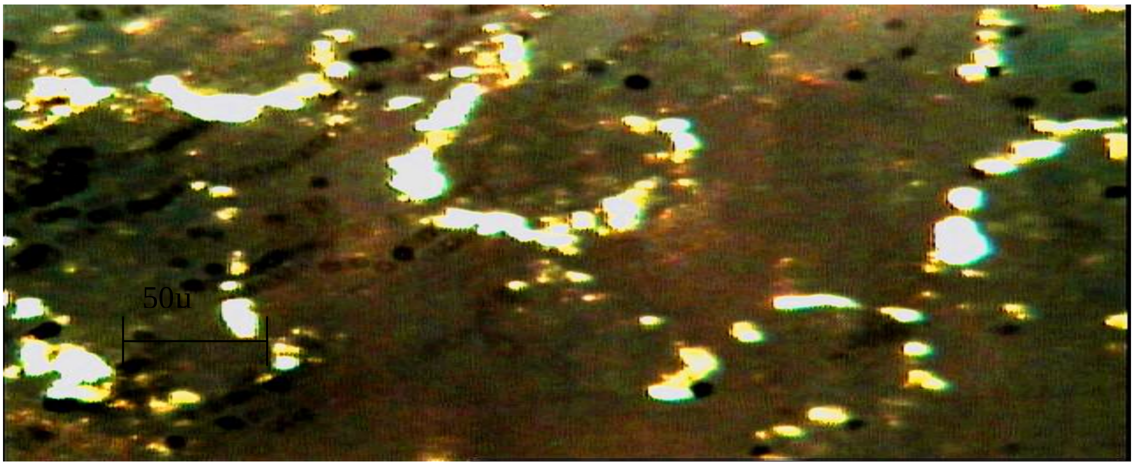

(a)

(b)

(c)

Figure (7) The microstructures of erosion-corrosion of ductile cast iron in (a) 0.01%, (b) 0.58% and (c) 3.5% NaCl.

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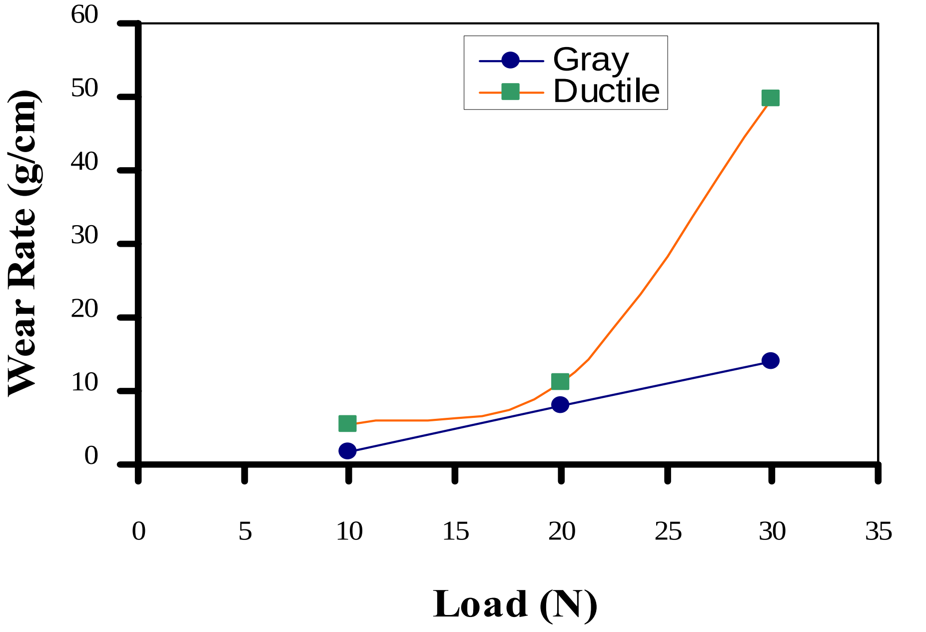
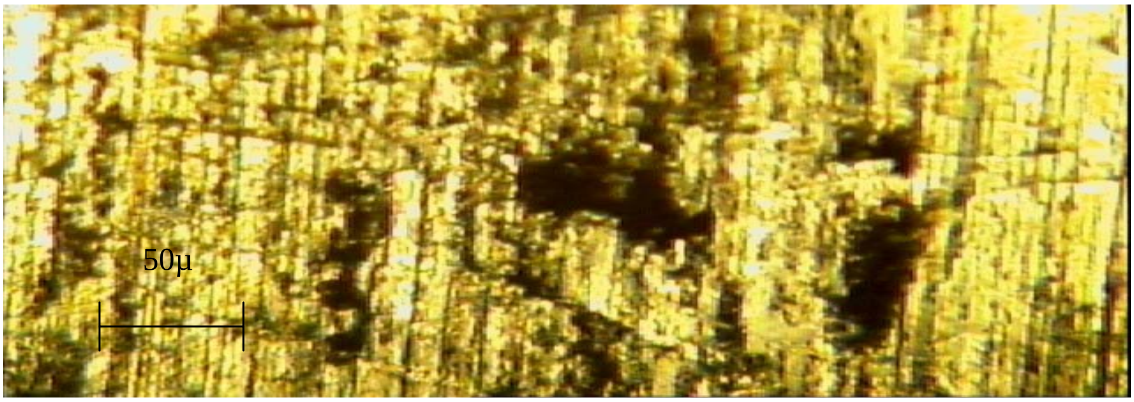
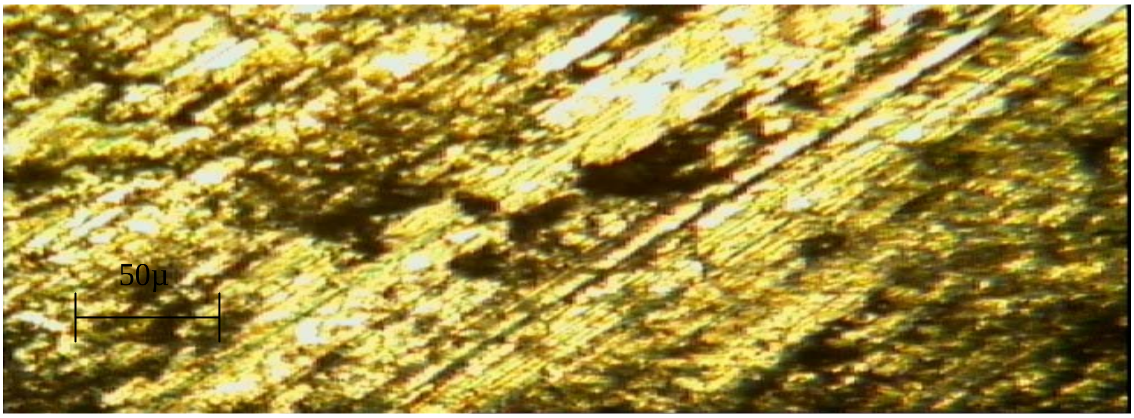


Figure (8) The wear rate of gray and ductile cast iron for 30 minutes.



(a)



(b)

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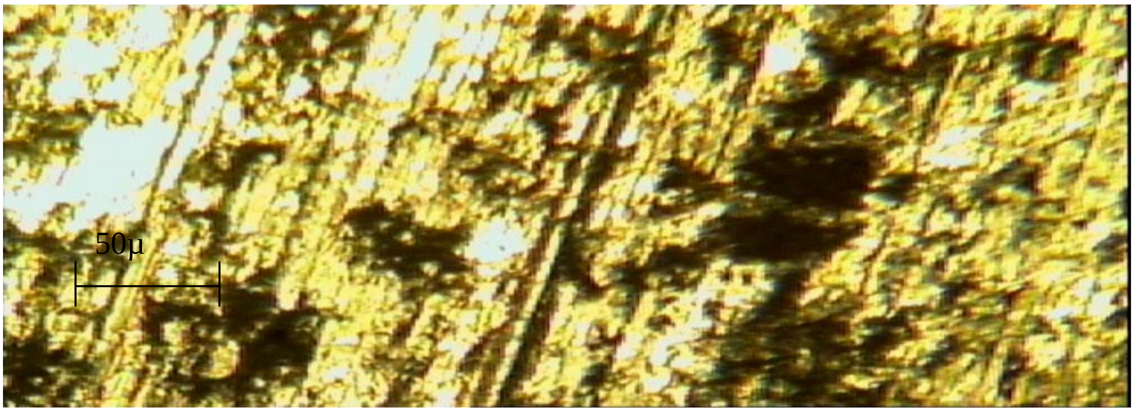

(c)

Figure (9) The microstructure of gray cast iron after wear test with different loads (a)10N (b)20N and (c) 30N.

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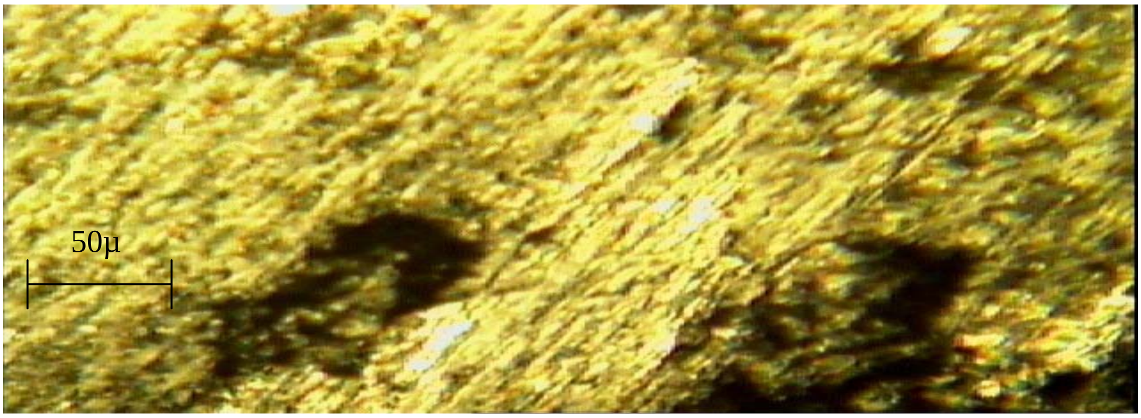

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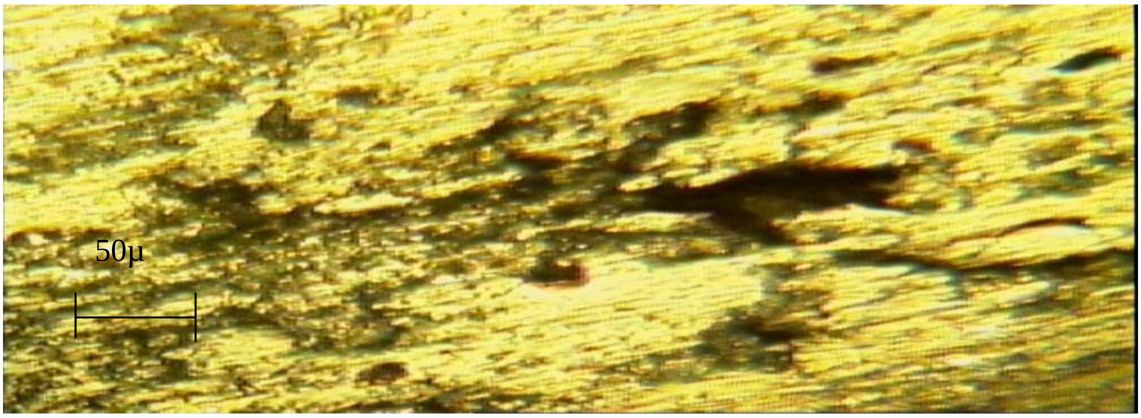

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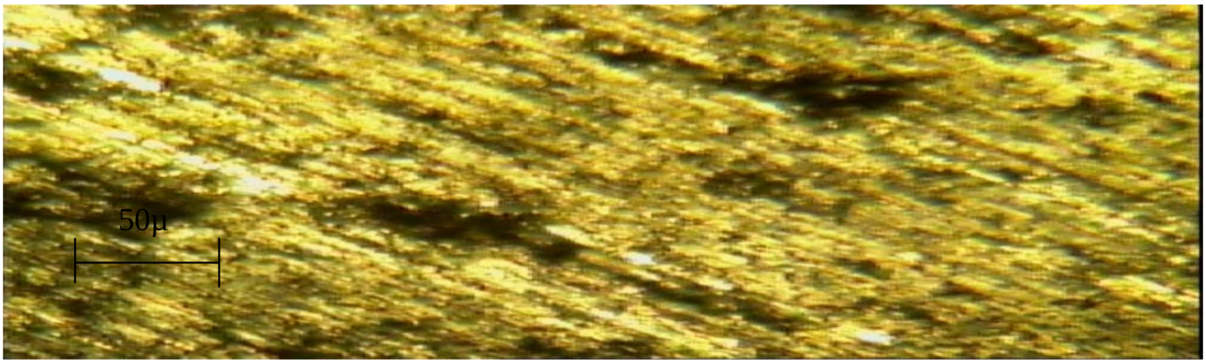

(c)

Figure (10) The microstructure of ductile cast iron after wear test with different loads (a)10N (b)20N and (c) 30N.

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References

[1] Sarkar.A.D., Wear of Metals , Pergamon International Library, (1976).

[2] Ashbaugh.W.G. in Failure Analysis and Preventation, ASM Handbook, Volume 11, (1986) , P 172-202 .

[3 Stephen M.McIntyre,Douglas B.DeWitt-Dick and DunnJoseph Hofilena,Metallurgical Examination of Cooling Water Equipment Failures, Ashland Specialty Chemical Company,Volume xii,(2005).

[4].Gunter Petzow, Metallographic Etching, Max Plank, Institute for Metals Research, Institute for Materials Science, Stuttgart, West-Germany(1982).

[5].Bolton.W, Engineering Materials Technology,3rded. Butterworth-Heineman, (1998),.

[6]. Sabah Noori Mahmood, Modification of Steel Surface after Diffusion Coatings,M.Sc.thesis, University of Technology, (2005).

[7].American Water Works Association Infrastructure Conference, Investigating Large Gray Cast Iron Pipe Failures: a step by step Approach, pp.1-16, Maker, J.M, Orlando, Florida, (2004).

[8]. ASTM Annual Book “Standardes”, Vol.0.3-0.2,(1987).

[9]. Thrence McGuinnes and A.Thiruvengadam, ASTM, Erosion, Wear and Interface with Corrosion, (1973).

[10]. ASTM Annual Book ,”Laboratory Immersion Corrosion Testing of Metals”, G31-72, Vol. 0.3-0.2, (1988).

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