Experimental Investigation on the Corrosion of Ductile Iron on Three Different Media

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Abstract: Ductile iron is one of the major construction materials used in the industries. It has a young modulus of 166GPa. This paper focuses on the experimental study of the corrosion behavior and mechanism for ductile iron in three different media namely 3M of sulphuric acid, 3M of potassium hydroxide and underground(Soil). Ductile iron of dimension; 15cm length, 3.1cm width and 0.8cm height was used for this experimental studies for a period of 3 Weeks interval weighing and re-immersing. The weight losses were tabulated and analyzed graphically. It was observed that ductile iron corroded in the different environments with decreasing intensity in the order of 3M sulphuric acid, 3M Potassium hydroxide, and soil.
Keywords: Ductile iron, Corrosion, Different Environments, Sulphuric Acid, Potassium Hydroxide, Underground (Soil).

Introduction

Over forty years ago, the birth of a new engineering material ductile was announced at the 1984 American foundry men's society annual conference (Durazil*et al*, 1986). Ductile iron is not a single material but a versatile cast iron exhibiting a wide range of properties which are obtained through micro structural control. The most important and distinguishing micro structural properties of all ductile irons is the presence of graphite nodules which act as "crack-arresters" and give ductile iron ductility and toughness superior to other cast irons and equal to many cast and forged steels (Dipra, 2010).

Ductile iron is specifically useful in many automotive components, where strength needs surpass that of aluminum but do not necessarily require steel. Ductile iron finds application in the oil and gas industry, especially in the oil well pump (Wikipedia, 2011). Ductile iron can be used in heavy duty farm machineries like class 8 trucks, agricultural tractors. Other major industrial applications include off-highway diesel trucks.

Corrosion is one of the most destructive agents and probably the greatest consumer of metal known to man. Corrosion is an electrochemical process involving the oxidation of metal (the anodic reactions) and the corresponding reaction of another material (the cathodic reactions) (Simpson, 1997). Corrosion may be defined as "the undesirable of metal or alloy with its environment" and it follows that the control of the process may be affected by modifying either of the reactants (the metal or the environment).Corrosion in the modern society is one of the outstanding challenging problems in the industry. Recent industrial catastrophes have it that many industries have lost several billions of dollars as a result of corrosion. Report around the world have confirmed that some oil companies have their pipelines ruptured due to corrosion, oil spillages are experienced which no doubt created environmental pollution, in addition , resources are lost in cleaning up this environment mess and finally large scale ecological damage resulted from corrosion effects (Oyelami and Asere, 2010).

Methodology

Ductile iron sample was purchased at Nigeria foundry Lagos, Nigeria. The weight of the sample was weighed using analytical weighing balance. The sample as received was in form of square having 0.8cm thickness. The chemical composition of the ductile iron is shown in table 1 below

Table 1: The chemical composition of ductile iron sample

Element	C	Si	Mn	Mg	P	S	Cu	Fe
Comp	3.40	2.50	0.30	0.04	0.02	0.01	0.30	93.43

The ductile iron sample was cut into four pieces using cutting machine. The cut ductile iron samples were labeled "SAMPLE A", SAMPLE B" and "SAMPLE C" while the remaining one was used as control sample.The weighed ductile iron "SAMPLE A", "SAMPLE B" and "SAMPLE C" were completely immersed into the prepared 3moles of H_2SO_4, potassium hydroxide (KOH) concentration and soil environment respectively. The initial weights of the prepared samples were weighed using electrical weighing balance of 0.01g accuracy. The weights were recorded as initial weight. After every 72 hours (3 days) of immersion, the samples were removed out of the environments, cleaned with moist cloth, dried, and reweighed. The weights

read were then recorded at **"72hrs"**. After being reweighed, the samples were immersed back into their various environments. This procedure was repeated for "**144hrs**" "**216hrs**", "**288hrs, "360hrs**", **"432hrs",**and **"504hrs**", having an interval of 72 hours for 21days. Each weight measured was recorded and the corrosion rate (CR) in mm/yr was calculated using corrosion rate equation below;

$$C.R = \frac{87.6W}{DAT} \qquad \text{equation 1}$$

Where W is the weight loss in milligrams, D is the density in g/cm^3, A is the area in cm^2, and T is the time of exposure in hours. Curves of corrosion rate (calculated) versus time of immersion were also plotted.

Plate. 1: The image of "SAMPLE C" completely immersed in soil environment

Fig 1: Geographical location of the soil environment

Experimental Results and Data Analysis

Exposure Time
The number of days the specimen had spent in solution by number of hours.
e.g   72hours = 3 days

Total Surface Area
    $TSA = 2(lw + lh + wh)$
    The ductile iron area was in form of a cuboid = $2(lw + lh + wh)$ Equation 2
        Where l = 15cm
                 w = 3.1cm
                 h = 0.8cm
A = 2 (15x3.1+15x0.8+3.1x0.8)
A = 2 (46.5+12+2.48)
A = 121.96cm^2

Weight Loss
Difference in weight of specimen at initial time before corrosion and the final time after corrosion.
Eg.   Initial weight = 256.6g
         Final weight = 250.41g
         Weight loss = 6.19g

Corrosion Rate
    $C.R = \frac{87.6W}{DAT}$

W = weight loss in Thrs (mg)
D = density of specimen ($7.1g/cm^3$)
A = total surface area of specimen ($121.96cm^2$)
T = exposure time (hrs)

Corrodants

Sulphuric acid (H_2SO_4) – acidic environment
Potassium hydroxide (KOH) – basic environment
Soil environment.

The tables below show the data for the weight loss used in determining the rate of corrosion. The corrosion rate was calculated using equation 1 above.

Table 1: Corrosion rate of ductile iron in acidic environment (H_2SO_4)

Time (hr)	Initial weight (g)	Final weight (g)	Cumulative weight loss (g)	Cumulative weight loss (mg)	Corrosion rate (mm/year)
0	256.60	256.60	-	-	-
72	256.60	250.41	6.19	6190	8.61122
144	256.60	246.28	10.31	10310	7.17554
216	256.60	244.42	12.18	12180	5.65127
288	256.60	243.27	13.33	13330	4.64069
360	256.60	242.46	14.14	14140	3.93858
432	256.60	241.95	14.65	14650	3.39976
504	256.60	241.56	15.04	15040	2.99123

Table 2: Corrosion rate of ductile iron basic environment

Time (hr)	Initial weight (g)	Final weight (g)	Weight loss (g)	Weight loss (mg)	Corrosion rate (mm/year)
0	227.13	227.13	-	-	-
72	227.13	226.10	1.03	1030	1.6204
144	227.13	226.08	1.05	1050	0.8259
216	227.13	226.06	1.07	1070	0.5611
288	227.13	226.02	1.11	1110	0.4365
360	227.13	226.04	1.09	1190	0.3429
432	227.13	226.06	1.07	1170	0.2404
504	227.13	226.07	1.06	1160	0.2382

Table 3: Corrosion rate of ductile iron in soil environment

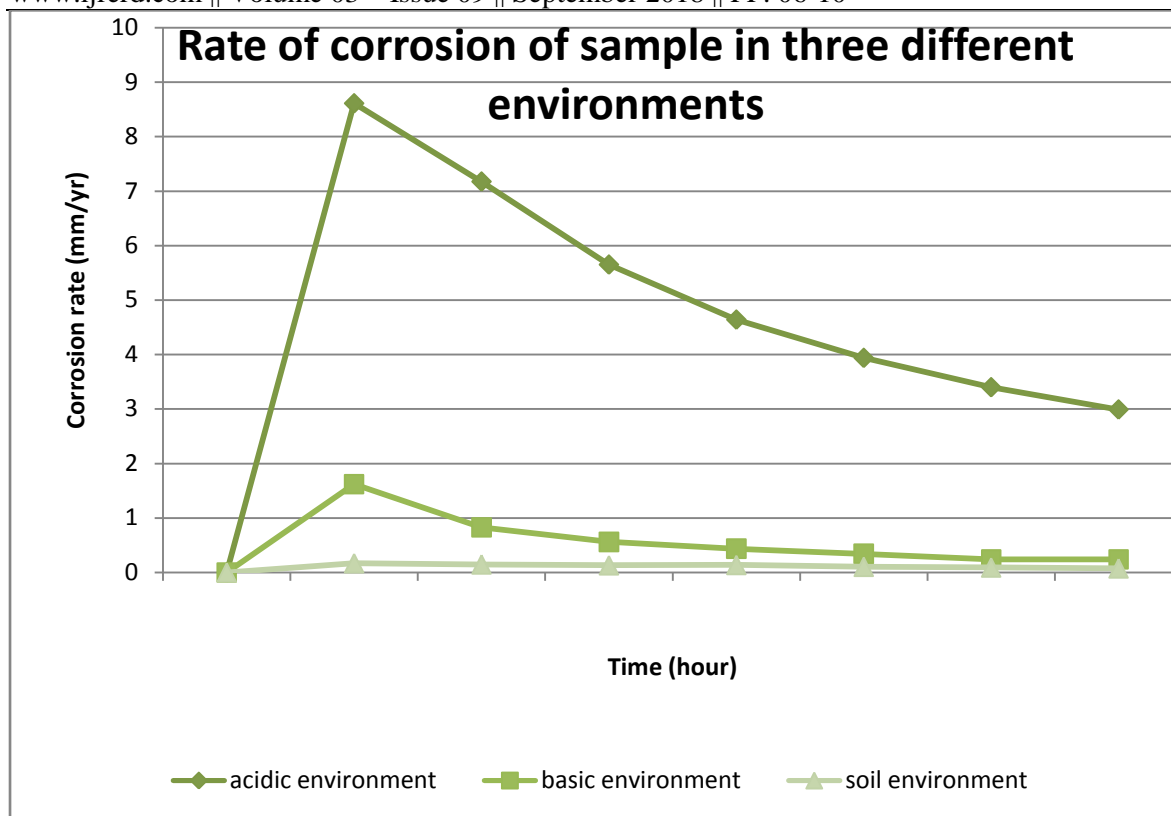| Time (hr)	Initial weight (g)	Final weight (g)	Weight loss (g)	Weight loss (mg)	Corrosion rate (mm/year)
0	252.16	252.16	-	-	-
72	252.16	252.04	0.12	120	0.1686
144	252.16	251.95	0.21	210	0.1475
216	252.16	251.88	0.28	281	0.1311
288	252.16	251.77	0.39	390	0.1369
360	252.16	251.79	0.37	370	0.1039
432	252.16	251.77	0.39	390	0.09132
504	252.16	251.79	0.37	370	0.07426

Figure 1: The graph of corrosion rate (mm/yr) in three different environments

Discussion

The results of the experiment obviously showed that corrosion slightly occurred because weight losses were rarely evident. It is obvious that the rate of corrosion for the various specimens varied increasingly in the following trend. In the first 72hours, all the samples had a sharp rate of corrosion. At 72 hours, the acidic sample had a corrosion rate of 8.6112 mm/yr, and the basic sample had a corrosion rate of 1.6204mm/yr while soil sample had a corrosion rate of 0.1686mm/yr. Comparing the tables, it was observed that the weight loss in acidic environment is higher than that of the basic and soil. The weight loss of soil environment was small compare to other environments. Between 72 hours and 144 hours of tables, there was a decrease in corrosion rate compare to other period. It was observed that the ductile iron sample placed in acidic environment was found to have the highest rate of corrosion followed by basic environment and soil environment had the least corrosion rate.

Conclusion

As the period increases, the corrosion rate decreases. There was a sharp corrosion rate at the first 72hours for the entire environments but as the period increase, the rate of corrosion slows down .Acidic environment (H_2SO_4) had the highest rate of corrosion followed by the basic environment(KOH) then soil environment which had the lowest rate of corrosion. In the presence of an acid, corrosion can be detrimental in a short period of time. It was concluded that corrosion in the acidic environment has the greatest effect on ductile iron.

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