



The Study and Prediction of Corrosion Rate of Ductile Iron in Cassava Fluid Using Java Oriented Program

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Authors' contributions

This work was carried out in collaboration among all authors. Author TJS carried out the laboratory tests and wrote the JAVA codes while author MDS prepared the manuscript and author SAI reviewed and corrected the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

This work studied the corrosion rate of ductile iron in cassava fluid and developed prediction software for the process using Java programming language. The work measured the corrosion effect of the cyanotic cassava fluid on ductile iron by determining the corrosion rate using gravimetric method. Cassava tubers were procured, grated and their fluid were manually squeezed out. The ductile iron samples used were slightly machined and treated with silicon carbide papers and were immersed in the cassava fluid for a period of 30 days. The corrosion specimens were weighed with a digital chemical weighing balance and recorded, this continued at regular interval of 5 days. The results achieved from the experiment were used to model and simulate a Java-oriented program that is capable of predicting the longtime effect of corrosion rate of ductile iron in cassava fluid. Exposure time in days and specific area of samples are the required parameters to generate corrosion rate, weight lost, and the graph of weight loss versus exposure time using the software. This Java application was also expanded to accommodate other metals in different environments.

Keywords: JAVA; ductile iron; corrosio; guided user interface; cassava fluid.

1. INTRODUCTION

Corrosion, the deterioration of a material of construction or its properties due to reaction with the environment [1,2], is a problem to a lot of industries and is even a greater challenge in the food processing and pharmaceutical industries, where in addition to the loss of production time for maintenance and risk of equipment failure, there exists the additional risk of product contamination by corrosion products which may result in food poisoning. As a consequence food processing machinery, in spite of cost considerations has been as a standard constructed using stainless steels [3].

Whereas most industrial food processing equipment are fabricated/specified in stainless steel, other materials like tinned copper had been employed successfully [4] and the suitability of other materials especially for specific environments should not be overlooked. Over the years in Nigeria, there has been an increase in the local fabrication of food processing equipment using materials that are not stainless steel, thus reducing cost, making these attractive to the food processing needs of the small scale farmers mainly due to price considerations. These have been fabricated in a variety of metallic materials ranging from mild steel (coated and uncoated), galvanized steel to different grades of stainless steel. Ductile iron has now been used to replace some of these metals because it has greater strength and ductility than gray iron. Those properties allow it to be used effectively in a wide variety of industrial applications, including pipe, automotive components, wheels, gear boxes, pump housings, machine frames for the wind-power industry, and many more [5]. Although ductile iron has lower corrosion rate compared with steel but it also corrode and the need to find its degree of corrosion is imperative [6].

Cassava (*Manihot utilissima*) is intensively cultivated and processed into products like *Gaari*, *fufu*, cassava flour etc in almost every part of Nigeria [7]. "Corrosion in cassava processing machinery especially those made of carbon steel is a common phenomenon in Nigeria's agriculture processing industry. Because most of these firms are small scale and cooperative industries, there is the tendency to use the cheapest and most available metal, i.e. low and medium carbon steel to minimize setup costs" [8]. "Cassava is a widely grown root crop that harbours two cyanogenic glucosides,

linamarin and lotaustalin [9]. Linamarin produces the toxic compound hydrogen cyanide (HCN) which is corrosive to processing machinery components. The primary processing operations of cassava into any of food products ('*gaari*', '*lafu*', flour, etc.) include: peeling, washing, slicing, grating, dewatering, fermentation, sifting, drying/frying, grinding, packaging, and storage. All these processes involve the use of machinery of varying sophistication through which corrosion problems are likely to be encountered" [7]. "Corrosion problems in cassava fluid becomes more pronounced as the cassava tubers are broken into pulp and thereafter left to ferment naturally by yeast and other microorganisms in which the sugar in the mash are hydrolyzed. The critical issue is the presence of the two cyanogenic glucosides released during cassava processing. The water used in the cassava processing carries a high concentration of these glucosides which explains the relatively high amounts of these toxic compounds in the residual liquid waste" [7]. "The chemical composition of the cassava fluid contains various amounts of cyanogenic glucosides, tannic acid, lotaustalin, and high contents of carbohydrate and fats, these substances could deteriorate metallic materials if immersed in cassava effluent" [10,11]. Linamarin and lotoaustralin are hydrolyzed in the presence of acid and enzymes to produce CN_2 and subsequently, hydrocyanic acid (HCN). Corrosion rate prediction software is needed in the study of corrosion to help calculate, predict, and monitor the rate of corrosion on material in service. Accuracy which is required will be achieved timely. Efficiency, minimal waste and careful control would be effectively maximized.

2. MATERIALS AND METHODS

2.1 Materials used for the Work

The materials used for this research include diameter 4mm x 50mm ductile iron rod, silicon carbide papers, cassava tubers, H_2SO_4 and distilled water, zinc electrode while the equipment used include digital weighing balance, DT8300D digital multi-meter and a personal computer installed with JAVA Software and Netbeans Development IDE.

2.2 Methods

2.2.1 Preparation of specimen

The ductile iron was obtained from Nigeria Machine Tools Limited, Osogbo and was used

as received. The diameter 4mm rod was cut into 50mm length and three test pieces of such were used for the research. The samples surface were slightly machined, abraded with successive grades of silicon carbide papers of grades P320, P400 and P600 grit and finally polished with a 5mm polishing cloth. They were rinsed in distilled water before drying. The prepared samples were stored in desiccators to prevent any reaction with the atmospheric air before use.

2.2.2 Preparation of cassava fluid (corrosion environment)

The corrosion environment under study was cassava fluid. Fresh cassava tubers were procured, grated, and their fluid were manually squeezed out into a clean bowl and stored in a 10 litre container.

2.2.3 Gravimetric immersion and corrosion monitoring

The metal samples were removed from the desiccators in turn and pickled in 0.5M H₂SO₄ for 2 minutes, then rinsed in distilled water. The

samples initial weights were taken using a digital weighing balance model (Metler Toledo). The samples were then immersed in cassava fluid for duration of 30 days. After a period of 5 days, the corrosion samples were carefully removed from the cassava fluid with a pair of tong; they were properly cleaned in distilled water, rinsed with methylated spirit and then dried with a cotton wool. The dried samples were weighed with a digital chemical weighing balance and recorded and this continued at regular interval of 5 days for the 30 days of immersion. From the average weight loss, corrosion rate was then calculated using the formula [12].

$$\text{Corrosion Rate (mpy)} = \frac{534 \times \text{Weight Loss (g)}}{\text{Density (g/cm}^3\text{)} \times \text{Area (in}^2\text{)} \times \text{Time (hours)}} \tag{1}$$

2.2.4 Application development

The Java Program codes were compiled and made into an executable program which can be run without operating in the JAVA Runtime environment. The program working flow-charts is as shown in Fig. 1.

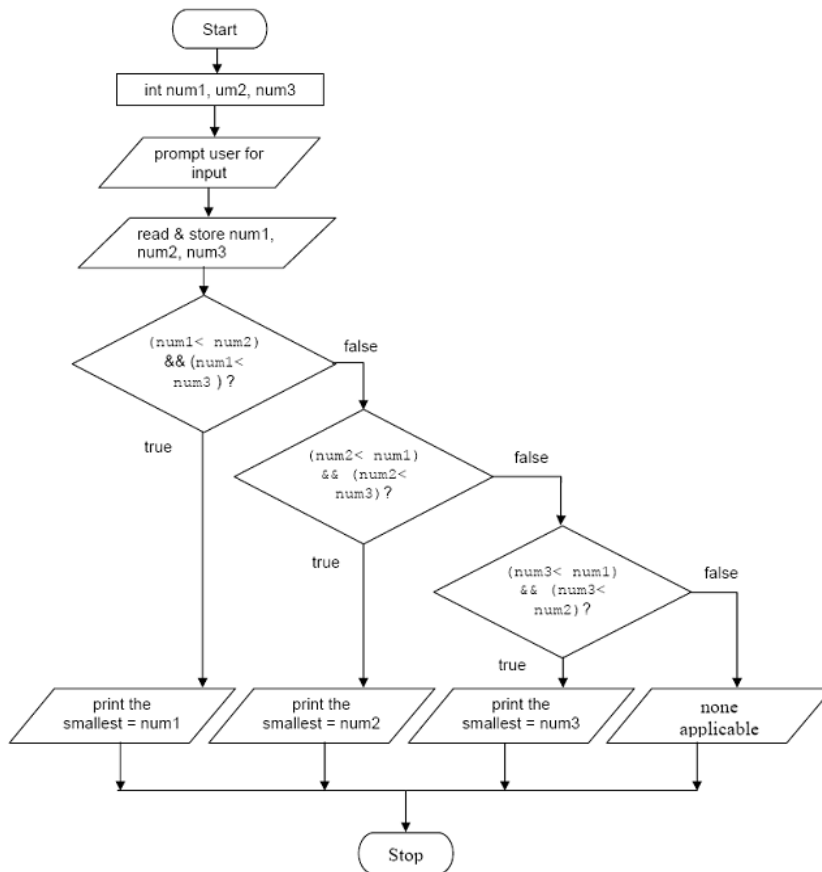


Fig. 1. JAVA Program working flow-chart (Jon [13]; Lewis and Ulrich [14])

3. RESULTS AND DISCUSSION

3.1 Results

Fig. 2 depicts the curve of weight loss (g) against the exposure time (days) while Fig. 3 shows the

curve of corrosion rate (mpy) against the exposure time (days). Figs. 4, 5 and 6 show the Corrosion Predictor User Interfaces, User Interface Configuration for other Metals in other Environments, and Print and Save User Interface respectively.

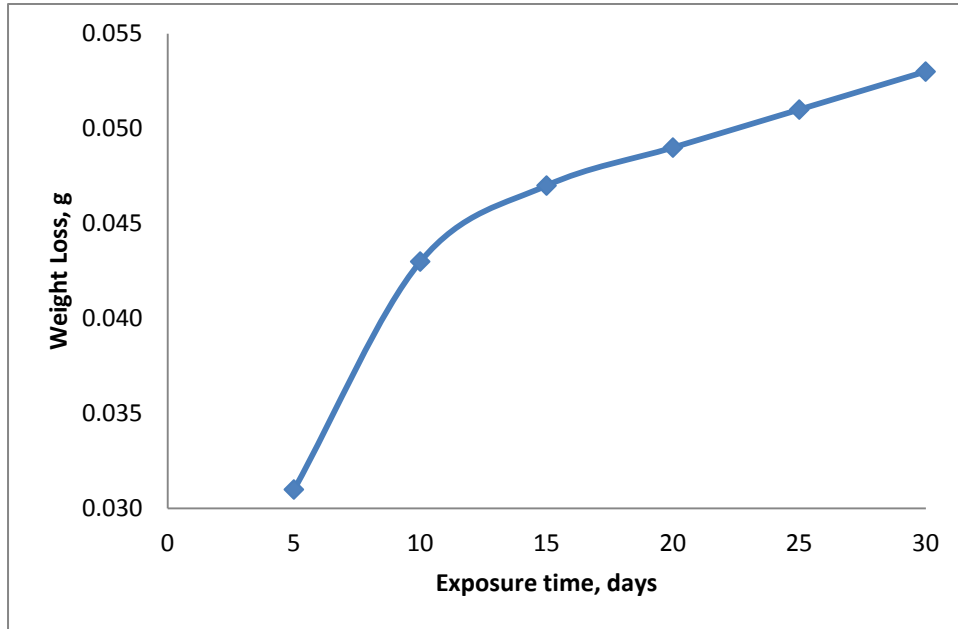


Fig. 2. Curve of weight loss (g) against exposure time (days)

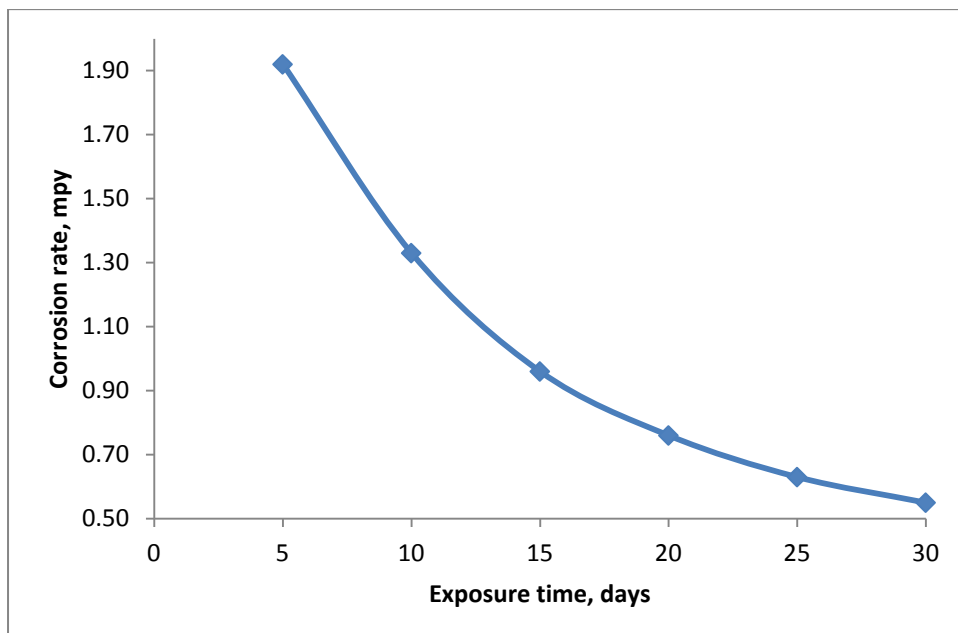


Fig. 3. Curve of Corrosion rate (mpy) against exposure time (days)

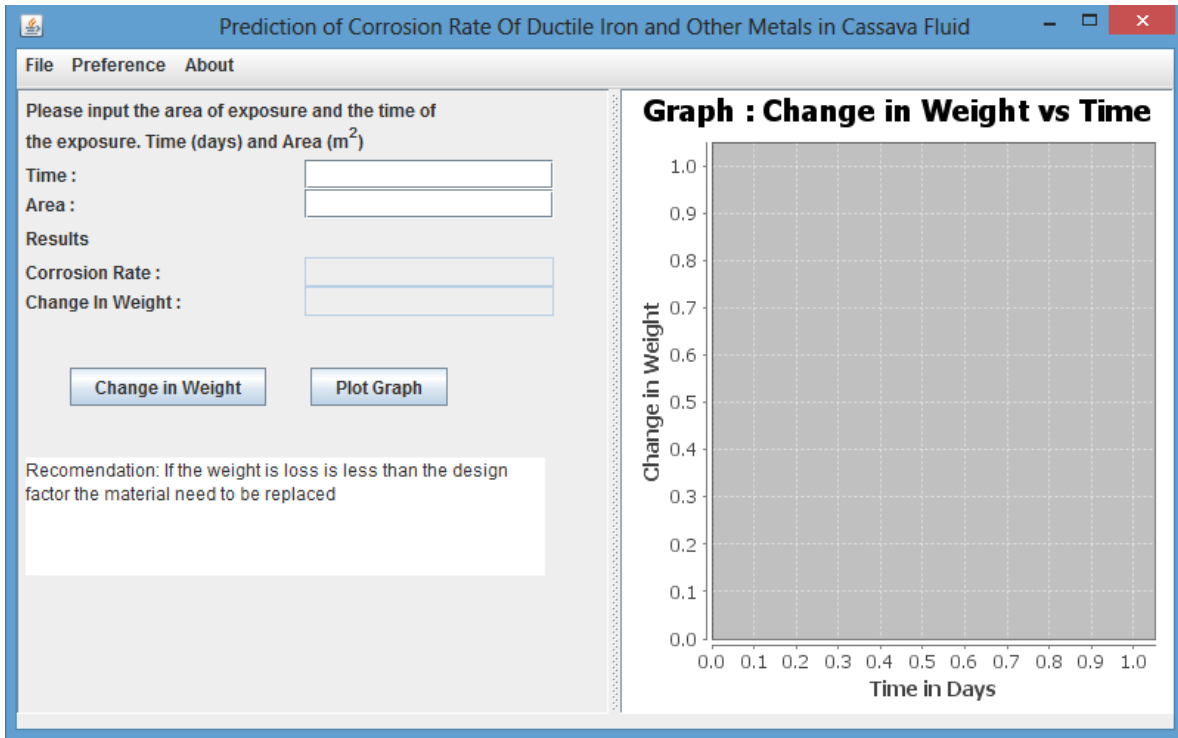


Fig. 4. Corrosion Predictor User Interface

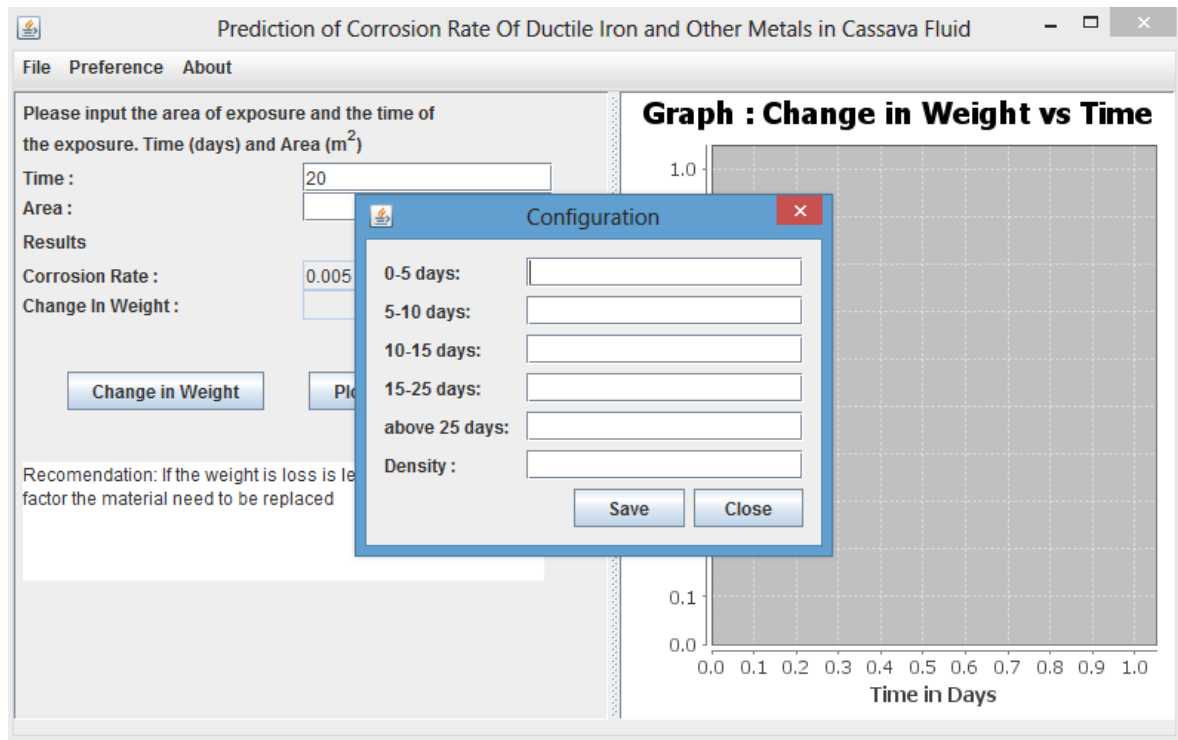


Fig. 5. User Interface Configuration for other Metals in other Environments

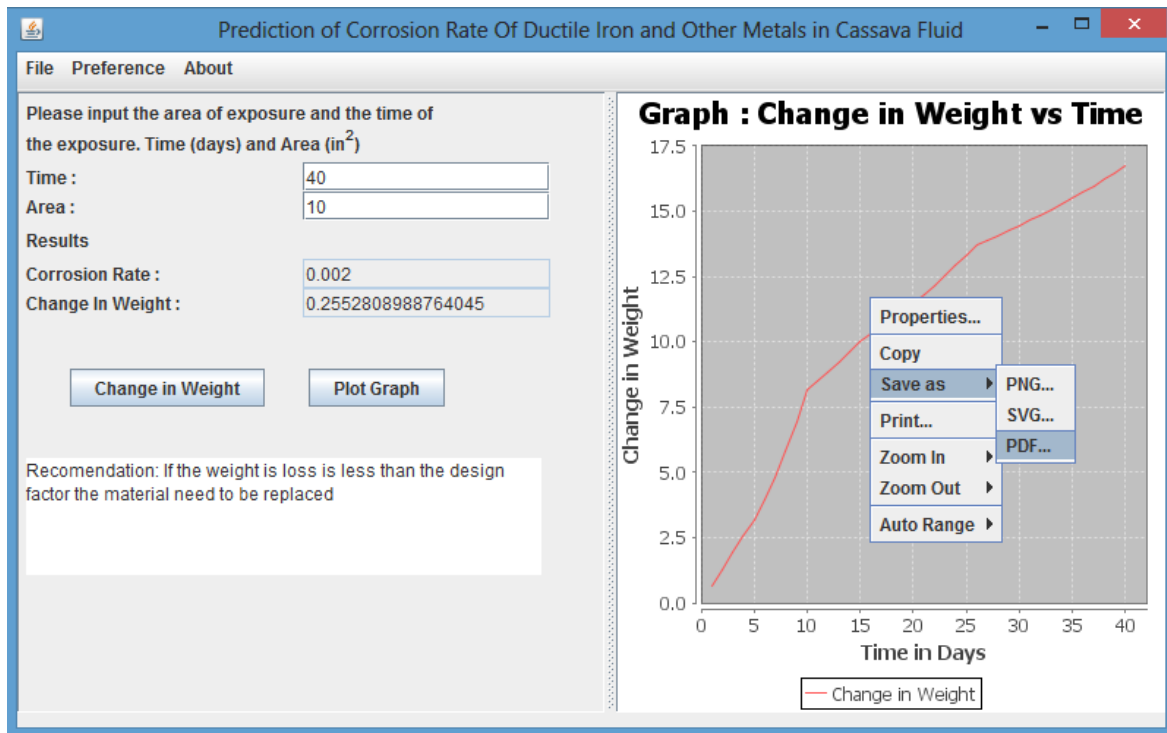


Fig. 6. Print and save user interface

3.2 Discussion

Fig. 2 depicts the curve of weight loss (g) against the exposure time (days) while Fig. 3 shows the curve of corrosion rate (mpy) against the exposure time (days). It is observed that loss in weight increases with the exposure time but the rate of weight loss decreases with exposure time. This is evident in the slope of the curve in Fig. 2. This can be ascribed to corrosion sediment/product that settled on the sample plus the fact that the strength of the corrosion environment got decreasing as time of exposure increases [15]. Similar reasons were deduced for the corrosion rate (Fig. 3).

The JAVA application developed has the user interface as shown in Fig. 4 where the exposure time in days is required through an alert. The desired value of exposure time in days can then be inputted and the software automatically predicts the corrosion rate for that time (specifically for ductile iron in cassava fluid). The exposed surface area of the sample is also important to be inputted in squared inches (in^2) because corrosion is a surface phenomenon and different samples with different sizes and structures have different surface areas. With these two parameters inputted, the change in weight for that specific time of exposure could be

calculated by clicking the 'change in weight' button. The 'plot graph' button generates a graph that is a cumulative of all the changes in weight, that is, the total amount of the changes in weight of the metal.

Other important feature of the application is the ability to work for other metals in any condition environment similar to the gravimetric immersion we carried out. This can be achieved by clicking the File button then click on Configure as show in Fig. 5 and a page to input new parameter is then prompted up which can now be changed to desired values and constraints. Some other functions of the application include:

'Preference' – This is where the look and feel of the application can be changed.

'About' - It contains help and information on the application developer.

The application allow for easy copying of result which could also be saved in different format such as PDF, PNG and SVG (Fig. 6). The result could also be printed directly from the application by clicking 'print'. It can be zoomed in and zoomed out. Fig. 6 also shows an example of prediction for 40 days exposure of a material with surface area 10 in^2 .

4. CONCLUSION

A JAVA oriented software package was successfully developed to study and predict corrosion rate of ductile iron in cassava fluid. The developed application will enhance higher productivity because better planning can be done based on the corrosion result and prediction with cost and design in mind. The software also applies to other metals in different environments so as to help in solving more complex corrosion monitoring and prediction problems. The application would help both the corrosion sensitive industries and researchers to perform at optimum during machine design for corrosive environments, monitoring of corrosion and forecasting of what would happen in the future.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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