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CORROSION DAMAGE IN THE CASSAVA JUICE MEDIUM ON HEAT TREATED MILD STEEL AND CHROMIUM-PLATED MILD STEEL

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Abstract

Plain carbon steel is the cheapest and most readily available metal in Nigeria for agri-tech processing equipment. It is used for its low cost and ease of access. They are, however, vulnerable to corrosion due to their use in a corrosive medium, such as fluid extracted from cassava tubers. The corrosion resistance of heat-treated mild steel and Chromium-plated mild steels used as tools in the cassava processing environment was investigated in this study. The untimely failure of this material while in service is caused by malignant ions found in food and raw farm products, which attack the steel components, causing gradual failure of the processing machinery. According to the findings of this study, annealed mild steel materials, whether coated or uncoated, are preferred. The study results revealed that the control annealed mild steel sample has the lowest corrosion rate of 0.027 mm/yr, while the corrosion rates of the heat-treated hardened, normalized, and tempered samples increase by 0.054, 0.067, and 0.10 mm/yr, respectively. The effect of coating time on the amount of chromium deposition was reflected in chromium-plated heat-treated samples that were heat-treated for 10 to 20 minutes at 5 minutes intervals. The corrosion rate was lowest in annealed chromium-plated samples, with an average grain size of 118.46 um and a corrosion rate of 0.04 mm/yr. According to the findings of this study, annealed mild steel materials, whether coated or uncoated, are preferable for use in the cassava processing operation.

Keywords:*Agric-tech-processing, Annealed, Corrosion, Heat-treated, Steel*

Introduction

Corrosion is a complicated process characterized by a chemical or electrochemical reaction that occurs in a relatively consistent manner over a material's whole surface [1, 2]. Steel is used in a variety of critical equipment in the petroleum industry, chemical engineering, power generation, nuclear engineering, food processing, and other engineering sectors [1, 3]. Chloride ions are extremely polluted in a highly polluted environment. Stress corrosion cracking and pitting corrosion are common in 304 stainless steel [3]. Corrosion, on the other hand, is described as a destructive phenomenon whose economic consequences include deterioration of metal appearance and, in some situations, equipment failure [3, 4]. In cassava fluid containing hydrogen cyanide, corrosion resistance of nickel-plated medium carbon steel and 18/8 stainless steel was investigated; the corrosion of mild steel was studied using cassava tuber fluid [4, 5]. The investigation includes weight loss analyses of 0.8 percent carbon and 0.36 percent carbon steel rods regularly. The weight loss of the exposed samples was linked to the length of time they were exposed. Numerous experimental and theoretical studies have been conducted using various corrosion data to elucidate the properties and mechanism of these various localized

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corrosions in steel [6]. The effect of heat treatment on the hardened and impact properties of medium carbon steel [9]. [10] studied corrosion behaviour of 188 stainless steel and nickel-plated low-carbon steel in cassava fluid. The effects of microstructure on the corrosion behaviour of differently heat treated 'weld-zones of mild steel in cassava juice [11]. [12, 13] carried out investigation of underground corrosion of mild steel and carbon steels. The corrosion behaviour of mild steel in hydrochloric acid was investigated by [14]. [15] worked on the corrosion behaviour of austenitic and duplex stainless steels in lithium bromide. The corrosive effect of Magnesium addition on Aluminium-Zinc–Copper alloy was treated by [22].

The kind and degree of corrosion in a system are determined by the metal's composition and structure, as well as its service envelope, which is the environment, the operation temperature, pressure, and the immediate vicinity of the metal including the extent of mechanical stressing [6, 7]. The process of heating and cooling metals and alloys in their solid states to give them desirable properties is known as heat treatment. Many technical components require heat treatment as part of the final manufacturing process [8]. Annealing, normalizing, tempering, hardening, and isothermal procedures are some of the different types of heat treatment. Heat treatment increases the metal's microstructure, which provides it the qualities it needs for various applications [16]. Four components must be present and active for electrochemical reactions to take place. The anode, cathode, electron route, and electrolyte are the components [17, 20].

Materials and Method

Material selection

A mild steel rod with a diameter of 10mm was chosen because of its low cost and wide availability in the market, and because it is regularly utilized by most industries, engineers, and fabricators in most engineering outputs. The test medium was cassava juice, which was made from cassava tubers harvested from the Polytechnic agricultural farm. The tubers from the species esculenta Crantz were peeled, washed, and cut into pieces. The bits were subsequently crushed using a Stephan machine. The juice was taken from the crushed pieces and collected, filtered, and preserved. The chemical composition of the steel was determined in Nigeria's Sango Otta Foundry to determine the steel class/group, to reveal other alloy elements present, which are important in determining the properties of steel, and to see if the composition complied with international chemical composition standards.

Table 1. Chemical Composition of the Commercial Mild Steel.

Element	**Carbon**	**Manganese**	**Silicon**	**Potassium**	**Sulphur**	**Iron**
Composition [Wt.%]	0.051	0.734	0.126	0.016	0.004	99.069

Heat Treatment

According to the furnace specifications, the coupon was cut to a diameter of 10mm see Fig. 1. The surface of the specimen was prepared by removing abrasive. In a pre-heated electric furnace, the mild steel test specimen was subjected to multiple heat treatments, including annealing, hardening, normalizing, and tempering. The first four prepared samples were placed into the furnace and heated to 920ºC, then let to cool in the furnace for 30 minutes to allow homogeneity to occur. This process is known as Annealing. The second four produced samples were placed into the furnace and heated to 920ºC, then held for 30 minutes to allow for homogeneity before being removed from the furnace and quenched in water, which is the Hardening process. The third four prepared samples were placed inside the furnace and heated to 920ºC, then held for 30 minutes to allow for homogeneity before being removed and cooled in still air, and the procedure was completed. The remaining four prepared samples were placed inside the furnace and heated to 920ºC, detained for 30minutes for homogenization to occur. After cooling within the furnace, they were reheated to 400ºC for another round of homogenization, then removed from the furnace and quenched in water to complete the Tempering process [19, 21].

Fig. 1. Commercially available mild steel rod of 10mm diameter

Electroplating Procedures

For the corrosion experiment, mild steel rod samples were cut into average dimensions of 30mm x 30mm, with a 1mm stepped turn on the upper edge of each specimen for easy hanging during the electroplating process. Surface preparation phases for establishing uniformity on the metal's surface and activating the surfaces in preparation for electroplating and corrosion response are mentioned below. The edges of the specimen were ground using the grinding machine to reduce the edging effect. After grinding, the specimens were labelled with a lettering punch on the sample surface edges to identify Hardening, Quenching, Tempering, and Normalized samples from one another [18].

To eliminate the abrasive particles, the acidic solution of the specimens was put in a bucket containing a quantity of acidic solution for a few seconds. In preparation for the test specimen, the samples were cleaned using a chemical. 100 mL sulphuric acid (H_2SO_4) and 100 mL distilled water make up the cleaning solution. The samples were cleaned for 1 minute in the solution, washed with distilled water, and promptly dried with sawdust. To clean the surface and avoid moisture in the samples, the specimens were dried using a sawdust medium. Abrasion and polishing machines use coarse and fine abrasive paper to remove the rough layer of the test specimen and provide a fine finish and smooth surface. To avoid moisture, clean the surface with kerosene and then dry with sawdust [19].

These samples were made to pass through a medium of nickel with the time duration of a minute and thereafter rinse off in a few seconds in the degreasing tank before being immersed in the chromium tank for 10, 15, and 20minutes respectively see Table 2.

Table 2. Electroplating and Analysis of Samples.

20 minutes	15 minutes	10 minutes
Hardening	Hardening	Hardening
Tempering	Tempering	Tempering
Normalizing	Normalizing	Normalizing
Annealing	Annealing	Annealing
Control Sample		

The decreasing process was to remove from the surface of the metal oil that may affect the sample before the process of nickel and the chromium see Figures 4 to 6.

Result and Discussion

Microstructural Analysis

The microstructural analysis indicated that the annealed sample A had a microstructure consisting of pearlite with an average grain size of 118.46µm when compared with the hardened sample H which had a high concentration of martensite mixed with ferrite average grain size 151.25µm. The normalized sample N has a finer grain with an average grain size of 41.3µm (Fig. 2).

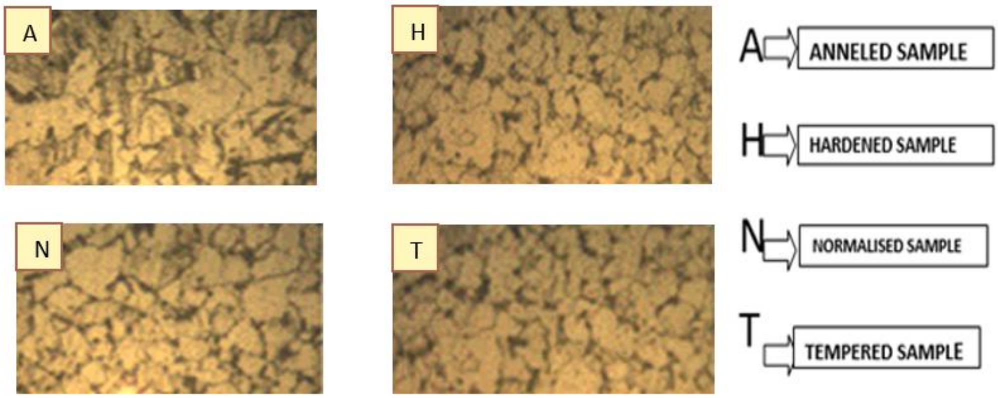

Fig. 2. Microstructures of Heat-Treated Samples before Corrosion

The hardened sample contained martensite structures while the Tempered sample contained a granular form of fine ferrite and cementite with an average grain size of 34.6µm. Retained after reheated has the austenite transforms to fine ferrite and austenite.

Corrosion Test results

The test samples consisting of the electroplated samples and the non-plated but heat-treated samples (annealed, tempered, normalized, and quenched) and (control specimen) were presented for corrosion test.

Table 3. Control sample Tafel data results.

Samples	βa (mV/decade)	βc (mV/decade)	Ecorr (mv/)	Icorr (µA/cm^2)	Corr rate mm/yr
1 A	60.69	52.51	-555	3.36	0.027
1 C	56.63	38.7	-619	5.81	0.048
I H	81.44	56.89	-655	6.58	0.054
I N	52.65	51.39	-653	8.09	0.067
1 T	49.66	36.6	-611	13.26	0.10

Table 4. Tafel data for10minutes electroplated samples results.

Samples	βa (mV/decade)	βc (mV/decade)	Ecorr (mv/)	Icorr (µA/cm^2)	Corr rate mm/yr
2 A	68.63	42.35	-537	4.45	0.03
2 H	75.4	61.55	-594	6.93	0.05
2 N	59.59	45.37	-628	9.87	0.08
2T	63.58	42.68	-589	7.22	0.05

Table 5. Tafel data for 15 minutes electroplated samples results.

Samples	βa (mV/decade)	βc (mV/decade)	Ecorr (mv/)	Icorr (μA/cm^2)	Corr rate mm/yr
3 A	74.12	49.45	-528	5.37	0.04
3H	80.62	67.75	-583	8.72	0.07
3 N	66.24	55.38	-644	10.29	0.08
3T	72.26	49.8	-656	9.81	0.08

Table 6. Tafel data for 20 minutes electroplated samples results.

Samples	βa (mV/decade)	βc (mV/decade)	Ecorr (mv/)	Icorr (μA/cm^2)	Corr rate mm/yr
4A	76.26	50.48	-518	6.82	0.05
4C	82.05	36.35	-510	8.95	0.07
4H	65.88	54.87	-576	9.45	0.07
4N	82.76	49.37	-637	13.87	0.11
4 T	58.25	44.46	-615	18.35	0.15

Table 3 (Control Samples) shows the Effect of Heat Treatment on Corrosion Resistance. It can be observed from the result obtained from the Tafel data presented in table one above that the annealed mild steel sample has the least corrosion rate of 0.027 mm/yr while the other heat-treated samples (hardened, Normalized and the Tempered samples) has a slight increase in the corrosion rate of 0.054,0.067 and 0.10 mm/yr respectively. A superior corrosion resistance obtained from the annealed sample might be as a result of a fine-grain ferrite structure with uniform distribution of pearlite within the matrix of a sample because ferrite has been known to possess excellent corrosion resistance as stated by [23]. Nevertheless, the heat-treated samples can adjudge to have a good impact on all the heat-treated samples as the corrosion rate for the samples fall less than 0.2mm/yr. Electroplated Samples of 10min., 15min., and 20 min., respectively show the effect of coating time of chromium plated-heat treated samples and the amount of chromium deposition. In Table 4, it was observed that the chromium-plated annealed sample which shows a better corrosion resistance also shows the least corrosion rate as per the coating time of chromium deposition which increases the resistance and also justifies the report. With a corrosion rate of 0. 03mm/yr. Hardened and Tempered plated samples have the same corrosion rate of 0.05mm/yr while the normalized plated sample shows a slight increase in corrosion rate.

The better results are shown by the plated annealed sample also shows the least corrosion rate as coating time of chromium deposition increases while also justifying the report from [24, 25]. However, at 10 min there was a change in the corrosion rate of the chromium-plated hardened sample afterward the sample displayed no changes in its corrosion rate concerning the coating time which might be attributed to the effect of chromium protecting the martensite structure of the hardened sample. Looking at the overall corrosion results obtained from the total data, the annealed sample displayed a superior corrosion rate while the other samples can also be adjudged to perform very well as their corrosion rate never goes down beyond 0.15 which was displayed by the tempered sample coated for 20minutes. The amount of chromium deposition of the electroplated samples for 10, 15, and 20 minutes follow this order of value 0.03, 0.05, and 0.08 respectively.

Conclusion

In the food and agriculture industries, product quality, health, and sanitation are major considerations. Corrosion deposits in manufactured items are not accepted in the industry, thus machinery material selection is crucial. As a result of the findings of this investigation, mild steel materials are unsuitable for cassava processing without some form of surface treatment, such as heat treatment, coating, or electroplating, as was done in this project.

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