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Effect of heat treatment on corrosion of mild steel weld metal in cassava juice

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The effect of heat treatment on the corrosion behaviour of the fusion zone of welded mild steel in cassava juice was investigated by weight loss and potential-time studies. Water quenched specimens were somewhat more corroded and tempered specimens somewhat less corroded than air cooled specimens but the differences between them were small.

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INTRODUCTION

In west African and other tropical countries cassava tubers are a source of major staple foods. They are also used in the manufacture of ethyl alcohol and the production of starch used as a binder in tablet making and as an animal feed, and are being proposed for use as an addition to wheat flour for bread making.

Corrosion of mild steel machinery, storage facilities, and agricultural implements used in processing cassava roots has been widely reported by the processing industries. Though some work has been published on other aspects of corrosion in agriculture,¹⁻⁴ there is no reported research outside our laboratory specifically concerned with corrosion by cassava juice. The present investigation examined the corrosion behaviour in cassava juice of various heat treated fusion zone samples from welded mild steel bars with the object of establishing the heat treatment procedure that gave the highest corrosion resistance. The knowledge thus gained should contribute to the control of corrosion in such conditions and the minimising of economic losses through improved welding fabrication processes.

EXPERIMENTAL PROCEDURE

Preparation of test specimens

Hot rolled type RST37-2 cylindrical steel bar supplied by the Aladja Steel Company Limited (Nigeria), with an average chemical composition (wt-%) of Fe-0.15C-0.23Si-0.50Mn-0.04P-0.04S-0.1Cr-0.11Ni-0.025Cu-0.05Sn, was cut into 120 mm lengths which were welded end to end in pairs using the ac manual metal arc process. Gauge 10 electrodes to ISO E432 R11 were used at 80 V and 110 A. The specimens were prepared with a symmetrical double V and welded round as shown in Fig. 1a. After welding, some samples were water quenched and some allowed to cool in air. Cylindrical testpieces were cut from the fusion zone as shown in Fig. 1b. Some water quenched samples were then tempered at 450°C for 1 h.

Selected specimens were mounted individually in Araldite resin after spot welding to flexible wire connections at one end. They were then ground using abrasive papers ranging from 240 to 600 grit and polished with 1.0 and 0.05 µm diamond, washed with distilled water, rinsed with methyl alcohol, dried, and stored in a desiccator.

Cylindrical specimens for weight loss experiments were separately scraped round the cylindrical surface and then thoroughly rinsed with distilled water. After further cleaning with hand wire brushes they were washed with distilled water, ultrasonically cleaned in acetone, dried, and stored in a desiccator.

Preparation of cassava juice

The cassava juice used as the test medium was obtained from cassava tubers from the Obafemi Awolowo University Farm. The tubers were peeled, washed, sliced, and

crushed. The crushed material was pressed to extract the juice which was collected, filtered, and stored in a clean 5 l bottle in a refrigerator. The pH of the juice was recorded immediately. Further readings of pH, with and without metal specimens immersed, were taken daily for 18 days. The results are presented in Fig. 2.

Weight loss experiments

Weighed testpieces were totally immersed in cassava juice contained in a 100 ml beaker for 30 days. They were taken out every 2 days, washed with distilled water, rinsed with acetone, dried, and reweighed. Plots of weight loss versus time of exposure were made (Fig. 3). Curves of corrosion rate (calculated) versus time of immersion were also plotted (Fig. 4).

Potential measurements

Each mounted specimen was immersed in cassava juice in a corrosion cell. The potential was recorded at 24 h intervals using a digital voltmeter and saturated calomel reference electrode. The potentials were plotted against exposure time (Fig. 5).

RESULTS AND DISCUSSION

Variation of pH with exposure time

Figure 2 shows curves of pH versus exposure time for cassava juice with and without immersed test specimens. The pH values first decreased from the initial value of 3.94 and later increased, which can be attributed to fermentation of the juice during the first 7 days.

Cassava juice is known⁵⁻⁷ to contain ~93% of the cyanogenic glycoside linamarin - 2(β d-glucopyranosyloxy) isobutyronitrile - with ~7% of the closely related lotaustralin - 2(β d-glucopyranosyloxy) 2-methyl butyronitrile. During fermentation these substances hydrolyse under the influence of the endogenous enzyme linamarase to liberate hydrogen cyanide.⁵ This increases both the toxicity and the acidity of the juice. The decrease in pH value of the juice during the first 7 days of the experiment is attributable to the formation of hydrogen cyanide by fermentation. The observed increase of pH after the ninth day of the experiment could be due to a reaction producing dimethyl hydroxycyanide^{6,7} occurring when all the linamarin had been hydrolysed.

Figure 2 shows that the pH values of cassava juice with an immersed specimen are more acidic from the fourth to the tenth day of the experiment but less acidic from the eleventh day onwards than the values for the juice without an immersed specimen. This could be due in part to the formation of iron (III) cyanide, which is acidic. Later, the increase in corrosion products, which could stifle the corrosion reactions, and the reduction in the strength of the juice could account for the reduced acidity after the eleventh day.

molybdenum, tungsten, or chromium adsorbed on to the surface. The chromium and tungsten concentrations and film thicknesses were significantly larger than those of the molybdenum films. The iron oxide associated with the molybdenum oxide film remained as iron oxyhydroxide. In contrast, much of the iron oxide associated with the chromium and tungsten oxides was in the form of Fe_2O_3 or Fe_3O_4 .

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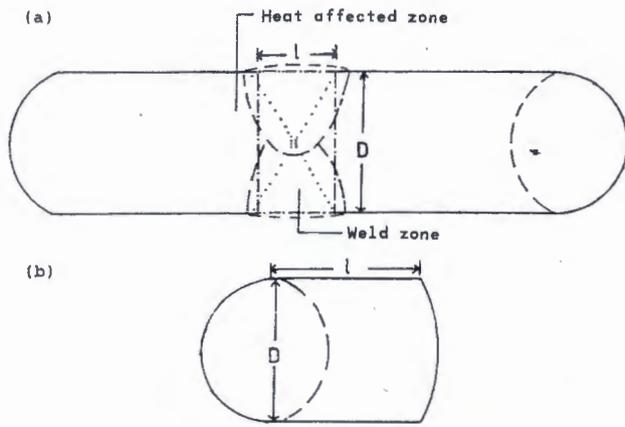
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a schematic welded cylindrical specimen showing weld zone (dashed line) and outline of test specimen (dash-dotted line); dotted lines indicate double V (symmetrical) specimen preparation; l = length of cut weld bead, D = diameter of cylindrical weld bead specimen; b schematic test specimen cut from weld fusion zone: l = specimen thickness, D = specimen diameter

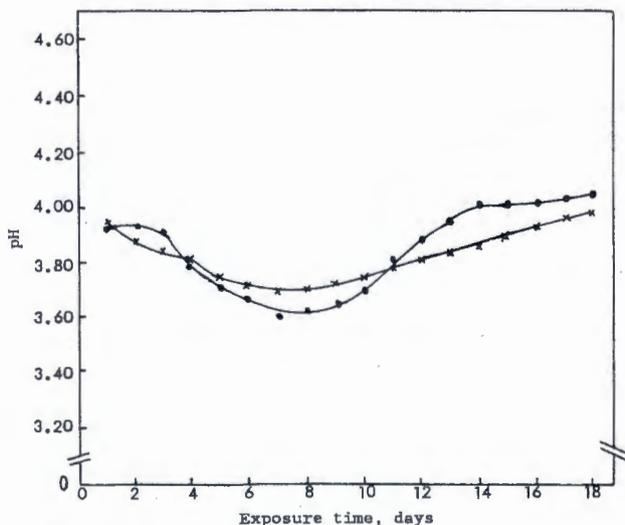
1 Schematic diagrams of weld assembly and test specimens

Effect of exposure time on specimen weight loss

The results presented in Fig. 4 show that corrosion occurred throughout the experiments at rates which depended upon the condition of the weld metal but, in all cases, decreased with increasing exposure time for ~6 days, after which an almost constant corrosion rate was attained.

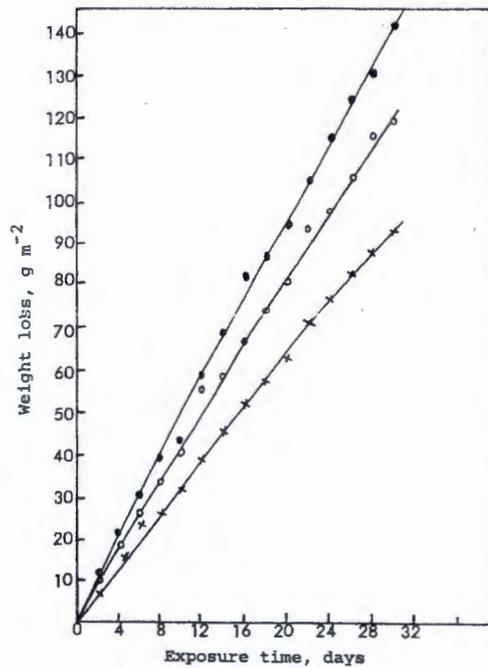
The initial decrease in corrosion rate with time, in spite of the fall in pH of the cassava juice during the first 6 days, is attributed to progressive weakening of the juice due to the formation of corrosion products. In addition, deposition of corrosion products on the specimens tended to stifle the corrosion reactions. The rise in pH, over the last 4 days in particular, could also cause a decrease in corrosion rate.

The different types of specimen behaved differently in the cassava juice. As indicated in Fig. 3, the water quenched specimens were most susceptible to corrosion. The air cooled specimens were the next most susceptible and the tempered specimens least susceptible. The differences in performance were, however, minimal.



● with specimen; × without specimen

2 Variation of pH with time for cassava juice with and without immersed test specimen

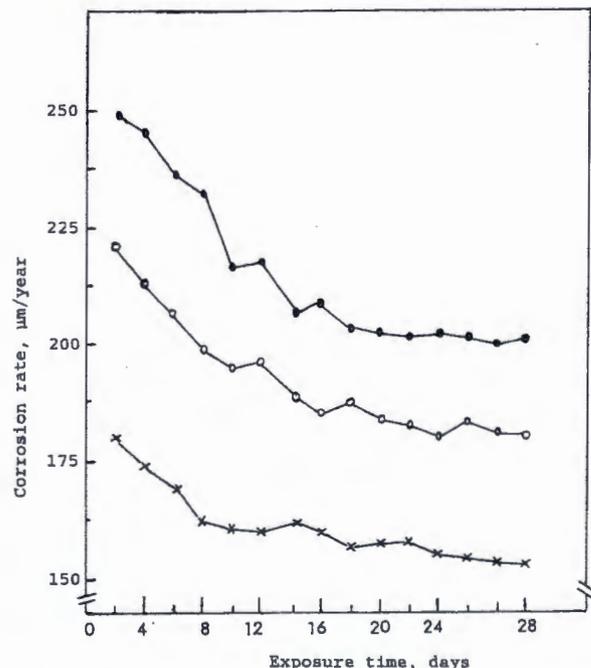


● water quenched; ○ air cooled; × tempered

3 Variation of weight loss in cassava juice with time for mild steel weld zones given various heat treatments

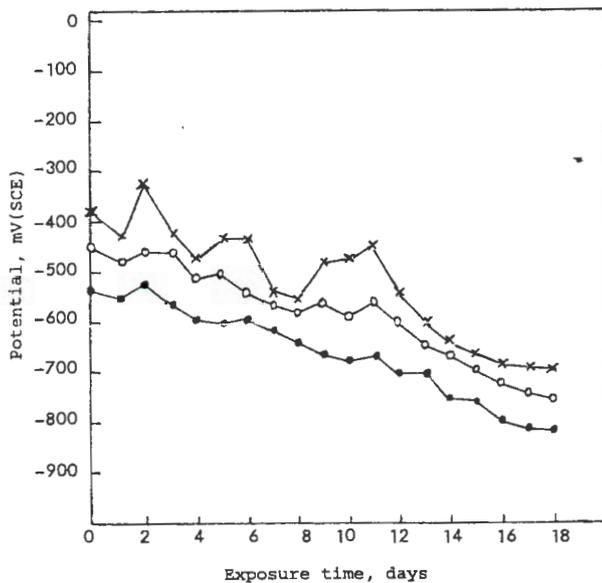
Potential measurements

Potential-time curves for samples immersed in cassava juice for 18 days are presented in Fig. 5. All show a general tendency to decrease with time, following a period of approximate stability or rising potential during the first 2-3 days. This suggests an initial period of passivation, probably due to formation of a film of $Fe(OH)_2$. This is easily penetrated by the cyanide ions produced by hydrolysis of the juice, resulting in subsequent depassivation and anodic dissolution.



● water quenched; ○ air cooled; × tempered

4 Variation of corrosion rate in cassava juice with time for mild steel weld zones given various heat treatments



● water quenched; ○ air cooled; × tempered
 5 Potential-time curves for mild steel weld zones given various heat treatments immersed in cassava juice

As with the weight loss results, the corrosion potentials show minimal differences between the various samples. They did, however, again indicate that the water quenched sample was somewhat more corrodible and the tempered sample slightly less corrodible than the air cooled sample.

Effect of heat treatment and microstructure

The water quenched specimens showed the greatest grain refinement of the three types of specimen tested. These had the finest pearlite and the lowest ferrite contents and

contained a small amount of martensite. It is possible that the slightly greater rate of corrosion of this material is due to its greater grain boundary area, since the grain boundaries, as regions of higher free energy, are more susceptible to attack.

The air cooled specimens contained more ferrite and less pearlite than the water quenched specimens, with no trace of martensite. The tempered specimens showed slightly superior corrosion resistance – probably because the tempering treatment reduced the residual stress levels and hence the tendency towards corrosion.

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Both Ta and Nb under passive conditions did not absorb hydrogen. This result indicates that the passive films in HBr solutions are compact enough to avoid hydrogen permeation.

In the previous paper,⁵ the authors concluded that both Ta and Nb were passivated in HBr solutions, judging from their electrochemical behavior and thermodynamic examinations on the stability of Ta₂O₅ and Nb₂O₅ in HBr solutions. Evaluation of corrosion resistance without information on their surface states and hydrogen absorption led us to an incorrect conclusion for Nb. At present, it can be said that Nb in HBr solutions free from oxidizing agents at high temperatures is not in a passivated state but in an active state.

CONCLUSIONS

► It has been reconfirmed that Ta is passivated in HBr solutions up to the azeotropic concentration of 47 wt% and to temperatures as high as 100°C. The passive film consisting of Ta₂O₅ can grow in HBr solutions. The film is stable enough to protect Ta from corroding and hydride formation.

► Nb is corrosion-resistant to HBr solutions at 25°C.

► Nb exhibits active and passive behavior, dependent on the condition of the HBr solution at high temperatures. In solution of a reducing condition, the growth of the protective oxide film does not proceed. Fine pits are formed initially and extend to general corrosion accompanied by hydrogen absorption. However, in the presence of an oxidizing agent, Nb is passivated, and the passive film

consisting of Nb₂O₅ can grow.

► The stronger passivating tendency of both Ta and Nb in HBr solutions containing bromine than in HBr solutions bubbled with hydrogen is responsible for the difference in the rest potentials. The corrosion resistance of both metals is enhanced by shifting the electrode potential to the noble side. Although Nb is attacked by HBr solutions at high temperatures, the addition of oxidizing agents such as bromine to HBr solutions is effective in preventing Nb from corroding and from hydride formation.

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