Mechanical Properties of Mild Steel Rod in Cassava Fluid.

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ABSTRACT

The mechanical properties of mild steel rods soaked in cassava fluid were studied. Emphasis was placed on the tensile, impact, and wear properties of the steel rods as functions of pH, time, and heat treatments. The results obtained from the study revealed that, reductions occurred in the mechanical properties of the steel samples soaked in cassava juice with time, though the pH values of the cassava juice increased with time of soaking from 3.90 (7 days of soaking) to 4.25 (15 days of soaking).

The impact toughness of the steel samples in terms of the energy absorbed was reduced from 33.9J of the annealed samples but not soaked in cassava juice to 12.9J of the annealed samples soaked for fifteen days in the cassava juice. The tensile, yield, and fracture stresses were reduced from 746N/mm^2,463 N/mm^2 and 571.6 N/mm^2, respectively to 183.4 N/mm^2,53N/mm^2 and 152.8 N/mm^2 after being soaked for fifteen days in cassava juice. The fall in the mechanical properties of the steel samples resulted from the transgranular and intergranular cracks in the steel samples due to stress corrosion.

(Keywords: mechanical, properties, mild steel, cassava fluid)

INTRODUCTION

The usefulness of a metal for an engineering project is determined by its mechanical properties. Though metals possess other properties; chemical and physical properties which in appropriate conditions may be of equal, or greater importance. For example, corrosion resistance may be a critical factor since having the positive mechanical properties of a material disintegrate before the end of its expected life, would not be good. Mechanical properties of metals can be grouped under the following:

1. Tensile stress
2. Compressive stress
3. Shear and Torsion
4. Notch toughness
5. Fatigue
6. Damping or internal friction
7. Creep
8. Plasticity
9. Hardness

Mild steel is among the local materials usually engaged in the fabrication of cassava processing machines whose applications are on the increase due to cassava revolution. Cassava is used in the food industry, principally in the form of starch, apart from its direct use as food. Cassava can be hydrolyzed to produce glucose. Cassava is also being used as additive to bread making and in the making of ethanol.

An aggressive liquid, such as an improperly selected lubricant or any other active liquid used in machine operation such as cassava fluid in cassava shredding machine, can react with steel or any other metal surfaces and form thin protective films of compounds (for instance, compounds of iron with active elements, such as sulphur or phosphorous), which are, however, mechanically less strong than the main metal. These films are worn off quickly, removed and worn off again.

This work therefore is aimed at determining the effect of cassava fluid on the hardness, tensile, and impact properties of mild steel.

EXPERIMENTAL DETAILS

Mild steel samples were prepared for the examination of their mechanical behaviors in cassava fluid. Steel samples ST-60-2 (rolled rods from old Oshogbo Steel Rolling Company) were cut and machined to standard impact and tensile testing samples. The compositions of the steel samples ST-60-2 are as follows; C-0.35-0.42%,Si; 0.15-0.25%, Mn; 0.6-0.8%, P; 0.04 max, S; 0.04%, Cu; 0.25%, Cr; 0.10%, Ni; 0.10%, N; 0.11%.

Cassava juice was extracted from the tubers after peeling and grinding. The steel samples were also cut and prepared for metallographic examinations. The steel samples were soaked in cassava fluid and pH measurements taken. Cares were taken in the machining of the steel samples as deviations from the standard dimensions have considerable effect on the results obtained. Some of the machined samples and the samples cut for metallographic examination were annealed in a muffle furnace at a temperature of 720^oC, and held at the temperature for one hour before furnace cooling.

The tensile properties of the steel samples were carried out on the Monsato Tensometer. The annealed steel samples were soaked in the cassava juice and the pH and the potentials of the solution were measured daily. In addition, the pH and the potentials of unsoaked cassava juice were measured daily. Some machined samples were tensile tested as received and as annealed without being soaked in the cassava juice. One of the steel samples soaked in cassava juice was tensile tested after seven days of soaking in the juice. Others were tested one after the other in the intervals of two days. The annealed samples were soaked in the cassava juice, and the pH and electrode potentials of the samples were measured daily. The Impact properties of the mild steel rods were carried out using Charpy Impact Testing machine.

EXPERIMENTAL RESULTS AND DISCUSSION

Tensile Properties of Mild Steel Rod

The as-received sample had a yield stress of 556.46N/mm^2 and Ultimate Tensile Stress (UTS) of 842.54 N/mm^2 and Fracture Stress of 660.2 N/mm^2 with 25 % elongation. The annealed ST-60-2 had yield stress of 463.33 N/mm^2, UTS of 746.13 N/mm^2 and Fracture Stress of 571.63 N/mm^2 with 32 % elongation. The annealed samples soaked in cassava juice for 7days, 9 days, 11 days, 13 days, and 15 days had yield stresses of respectively 427.71N/mm^2, 422.76N/mm^2, 392.42N/mm^2, 371.79N/mm^2, and 53.48N/mm^2. The UTS for annealed samples soaked in cassava juice showed a decreasing trend as soaking days increased from 651.32N/mm^2 for 7 days to 183.35 N/mm^2 for 15 days. The fracture stress for ST-60-2 also decreased in values from 530.28N/mm^2 for annealed samples soaked for 7 days to 152.79N/mm^2 for samples soaked for 15 days. In the same trend % elongation decreased from 30% for 7 days soaking to 21% for 15 days soaking.

The decreasing trend in the tensile properties of annealed ST-60-2 steel samples soaked in cassava juice with time showed the effects of the aggressive environment on the steel samples. The hydrogen cyanide acid reacted continously with the iron of the immersed steel samples, with the formation of ferrous cyanide and the liberation of hydrogen gas.

$$Fe + 2HCN \longrightarrow Fe(CN)_2 + H_2$$

Charpy Impact Properties of Mild Steel Rod

The energy absorbed to break v-notched samples were recorded in ft-ib and converted to Joule (J). 14.917 J was recorded for the as-received sample compared with 33.903J for annealed sample at 720^0C held for 1 hour. The energies absorbed to break the soaked annealed samples decreased as soaking days increased from 32.903J for sample soaked for 7 days to 12,883J for sample soaked for 15 days.

As the reaction proceeded for soaked samples with cassava juice, continuous disintegration of the soaked steel samples occurred due to the dissolution of the pearlites caused by unstable cementite. Thus the grain boundaries were weakened which eventually caused reductions in the impact energies of the steel samples. The non uniformity observed was due to stress concentration factor in Charpy test specimens. The stress concentration factor is defined as the ratio of the maximum stress due to a hole or notch to the normal stress. In an elastic medium that behaves according to Hooke's law, the stress concentration factor Kt due to a 45o notch is given by:

$$Kt = 1 + 2\ (C/P)^{1/2}$$

where C is the length of major axis and P is the notch radius.

pH and Electrode Potential Values of Cassava juice with Soaked Steel Samples

The pH values of the cassava juice with soaked steel samples showed an irregular pattern with an irregular increase in the values. This increase later dropped and increased again. The fermentation process of the cassava juice is a two-stage process which caused the irregularity. Recent studies revealed that the fermentation process involves the production of coryne bacterium manihot which attack starch to produce organic acids hence the juice was acidic and *Geotrichium candidum* which produce flavor compounds such as aldehydes and esters. The actions of the micro organisms involved, account for the fluctuation of the pH values in relation to time of soaking.

The electrode potential values also showed an initial increase in values from -0.2V to -0.175V, later decreased to -0.18 V, and increased to -0.173V. It finally increased to -0.162V. The direction of a given electrochemical reaction at the metal phase boundary is controlled by the relative values of the electrode potential (E) and equilibrium potential (E_o) of the reaction being considered.

When E> E_o oxidation reaction occurs, e.g.:

$$Fe \longrightarrow Fe_2+ +2e-$$

and

$$H_2 \longrightarrow 2H+ + 2e-$$

When E < Eo, the reaction proceeds only as reduction, e.g.:

$$Fe_2+ + 2e- \longrightarrow Fe$$

and

$$2H+ + 2e- \longrightarrow H_2$$

If the electrode potential lies between -0.6V and -0.4V, corrosion of iron occurs with the evolution of H_2. If it lies between -0.4V and -0.2V, corrosion occurs without hydrogen evolution. For the electrode potential greater than -0.2V iron is covered by ferric oxide. This oxide shields the metal from the solution if it is non porous and adhered perfectly. The metal is thus protected by passivation. However, if the oxide is porous or not perfectly adherent to the metallic surface, the metal undergoes localized corrosion.

Table 1: Tensile Testing Results of Mild Steel Rod.

S/N	Steel Condition	UTS	YS	PH
1	St-60-2 as rcd	842.54	556.46	
2	Annealed at 720°C for 1hr	746.13	463.33	
3	,, soaked for 7 days in cassava juice	651.32	427.71	3.90
4	,, ,, 9 days	618.94	422.76	4.00
5	,, ,, 11 days	604.54	392.42	4.10
6	,, ,, 13 days	585.69	371.79	4.12
7	,, ,, 15 days	183.35	53.48	4.25

Table 2: Results of the Fracture Stress and % Elongation.

S/N	Steel Cond.	Fracture Stress	% Elong.
1	ST-60-2 as received	660.20	25
2	ST-60-2 annealed at 720°C for 1hr	571.63	32
3	,, soaked in cassava juice for 7 days	530.28	30
4	,, ,, 9 days	519.46	27
5	,,,, 11 days	463.46	26
6	,,, 13 days	445.45	23
7	,, , 15 days	152.79	21

Table 3: pH and Electrode Potentials of Cassava Juice with Soaked Steel Samples.

Time (hrs)	pH	Potential (Mv);Ag/AgCl
0	3.76	-200
24	3.80	-193
48	3.88	-184
72	3.95	-175
96	3.92	-178
168	3.90	-180
192	3.98	-174
216	4.0	-173
240	3.50	-220
264	4.10	-167
288	4.11	-166
312	4.12	-165
336	4.20	-163
360	4.25	-162

CONCLUSION

The effects of corrosive media on the mechanical properties of mild steels were drastic as deduced from the results of the experiments carried out. Therefore, adequate considerations should be given to strength and corrosion resistance of materials while selecting them for such service conditions.

Figure 1: Stress against Soaking Days of Cassava Juice.

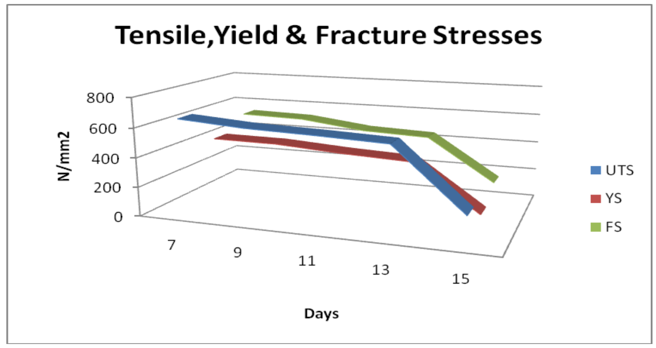


Figure 2: pH against Soaking Days.

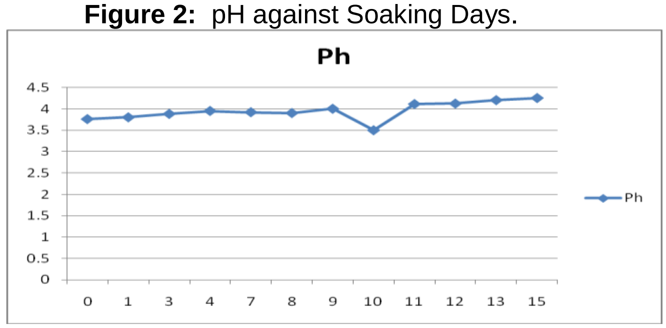


Figure 3: Percentage Elongation against Days of Soakings in Cassava Juice.

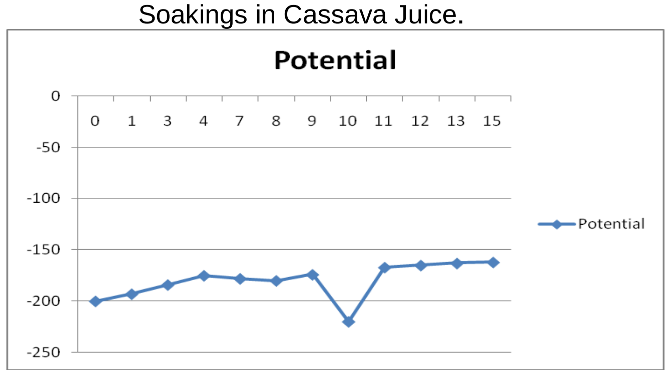
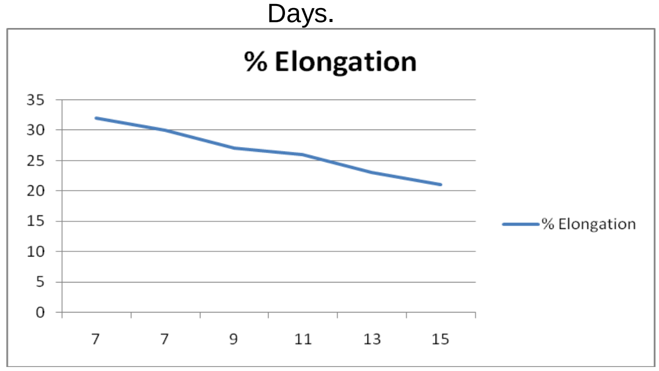


Figure 4; Electrode Potentials against Soaking Days.



The selection of materials for the construction of cassava processing machine should give considerations to toughness, abrasive resistance, and corrosion resistance. The production methods employed in the manufacture of the materials determine the susceptibility of the materials to stress corrosion. For durability of cassava processing machines, materials that combine strength and corrosion resistance should be employed. Mild steels should be adequately protected against corrosion when they are used in cassava or other aggressive media.

REFERENCES

1. Albert, G.G. and Hren, J.J. 1974. *Elements of Physical Metallurgy, 2nd Edition*. Pergamon Press: Oxford, UK.

2. Amuda, M.O.H., Lawal, G.I., and Soremekun, O.O. 2006. “Inhibitive Strength of Some Organic Compounds on the Corrosion Behavior of Mild Steel in Cassava Fluid. *West Indian Journal of Engineering, Trinidad and Tobago*. 228-234

3. Chong, C.V.Y. 1977. *Properties of Materials*. McDonald and Evans Limited: Bungay, Suffolk, UK.

4. Higgins, R.A. 1980. *Engineering Metallurgy. Part I & II*. London, UK.

5. Linchevsky, B., Sobolevsky, A., and Kalmenev, A. 1983. *Iron and Steel Making*. MIR Press: Moscow, USSR.

6. Plucknett, D.L., Philips, T.P., and Kagho, R.B. 1998. “A Global Strategy for Cassava: Transforming a Traditional Tropical Root Crop”. Asian Cassava Stakeholders’ Consultation on a Global Cassava Development Strategy. Bangkok, Thailand. 23-25 November, 1998.

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