Corrosion Effects of ASTM A513 Steel in Cashew and Pineapple Juice Using RSM

Lateef O. Mudashiru, Emmanuel O. Olafimihan, Sunday O. Adetola and Temitayo M.Azeez

***Abstract*—The corrosion behaviour of ASTM A513 steel in both pineapple and cashew fluid media was investigated in this research. The weight loss method was used to evaluate the corrosion rate of ASTM A513 steel in both environments. The pH of the environments was measured each monitoring day. It was observed that ASTM A513 steel corrodes faster in pineapple fluid than cashew fluid, the two media having highest values of 0.71mm/yr and 0.54mm/yr at the end of five days respectively. Formation of protective oxide film and dilution of the environment by the corrosion products were observed to reduce corrosion rates in the investigated environments. The investigation lasted for a period of twenty-five days, with the checking interval of five days.**

***Keywords*— ASTM A513 steel, Cashew juice, Corrosion rate, Duration and Pineapple**

I. Introduction

Corrosion is a complex process characterized by a chemical or electrochemical reaction which proceeds in a relatively uniform manner over the entire area of a material or structure [1] [2]. Steels are widely applied in many important engineering industries including petroleum industry, chemical engineering, food processing industries, power and nuclear engineering [3]. Under the conditions of highly polluted environment of chloride ions, [3] revealed that stress corrosion cracking and serious pitting corrosion often take place in 304 stainless steel. However, corrosion is said to be a destructive phenomenon of which its economic effects is detrimental to the appearance of metals and in some cases can cause equipment failure [4] [5].

[6] investigated the corrosion resistance of nickel-plated medium carbon steel and 18/8 stainless steel in cassava fluid containing hydrogen cyanide. [7] examined the corrosion of mild steel in orange juice environment, weight loss technique was used and the result revealed that corrosion rate was higher in orange juice with preservative while water had the least corrosion rate compared to natural orange juice. In this study, the corrosion rates of mild steel A513 in a pineapple and cashew fluid was investigated.

L.O. Mudashiru is aSenior Lecturer in LadokeAkintola University of Technology, Ogbomosho, Oyo State, Nigeria. Department of Mechanical Engineering.

E.O. Olafimihan is a Senior Lecturer in LadokeAkintola University of Technology, Ogbomosho, Oyo State, Nigeria. Department of Mechanical Engineering,

S.O. Adetola is a Lecturer I in LadokeAkintola University of Technology, Ogbomosho, Oyo State, Nigeria. Department of Mechanical Engineering,

T M. Azeezia a lecturer II in AfeBabalolaUniversity,AdoEkiti,Ekiti State, Nigeria Department of Mechanical Engineering,

II. Material And Method

ASTM A513 steel specimen of 1.5mm thickness was used in the experimental set up. The samples were machined into rectangular sections to form a coupon. Each sample was cut on the lathe machine at National Centre for Agricultural Mechanization workshop (Ilorin) into 20mm by 30mm by 1.5mm thickness specification leaving tolerance of 0.2mm at both sides so as to make the sectioning even at the end of the surface preparation process.

The samples were treated by abrading them through successive grades of abrasive paper. The sample was rinsed in distilled water and then in acetone before drying. The prepared specimens were stored in desiccators until they were needed for the experimental study to avoid atmospheric corrosion. Table 1 shows the compositional analysis of the samples conducted at Grand Foundry Engineering Limited, Ikeja, Lagos using Minipal 4 Spectrometer.

Table I: Elemental Compositional of the A513 Steel

C	Si	Mn	P
0.112	0.001	0.313	0.011
S	Cr	Ni	Mo
0.018	0.013	0.029	0.0001
Al	Cu	Co	Ti
0.0064	0.028	0.0022	0.0007
Nb	V	W	Pb
0.0072	0.003	0.0001	0.008
B	Sn	Zn	As
0.0004	0.0013	0.0009	0.0001
Bi	Ca	Ce	Zr
0.0009	0.0002	0.0064	0.0023
La	Fe		
0.0005	99.40		

Fresh cashew and pineapple fruits were obtained from market. The outer skin was peeled, grated, squeezed and sieved manually to obtain fresh juice. This was done weekly for each of the experimental set up. The pH value for the pineapple and cashew juice was checked on a weekly basis to ascertain the variation of hydrogen and hydroxyl ions as a result of environmental process (fermentation). Each of the metallic samples were suspended a beaker with the aid of thread each containing pineapple and cashew juice; and the beakers were kept stationary to avoid displacement effect. The exposure periods were a total of 25 days with measurements taken at an interval of 5 days respectively. The specimens for pineapple and cashew media were removed and the corrosive films were clean using a soft brush after which the samples were gently cleaned in distilled water before drying. The dried samples were weighed carefully on weighing balance until a stable weight was achieved.

Moreover, similar experimental procedure was observed throughout the study. The results obtained were used in plotting corrosion rate against exposure time for each samples prepared. The weight loss measurement was used to evaluate the corrosion rates using equation below [8].

Corrosion Rate = $\frac{87.6W}{DAT}$

Where W – Weight loss (mg)

D - Density of ASTM A513 steel ($7.85 g/cm^3$)

A – Surface area of the specimen (cm^2)

T – Exposure time (hours)

III. Results And Discussion

TABLE I: ONE FACTOR EXPERIMENTAL DESIGN BASED ON RESPONSE SURFACE METHODOLOGY

Experimental Runs	Duration	Media	Corrosion rate
1	15.00	Cashew	0.31
2	5.00	Cashew	0.54
3	5.00	Cashew	0.54
4	15.00	Pineapple	0.29
5	25.00	Cashew	0.21
6	10.00	Cashew	0.39
7	20.00	Pineapple	0.25
8	15.00	Pineapple	0.29
9	25.00	Pineapple	0.23
10	20.00	Cashew	0.25
11	25.00	Pineapple	0.23
12	10.00	Pineapple	0.40
13	5.00	Pineapple	0.71
14	25.00	Cashew	0.21
15	5.00	Pineapple	0.71
16	15.00	Cashew	0.31

TABLE II ANALYSIS OF VARIANCE (ANOVA TEST)

Source	Sum of Squares	DF	Mean Square	F Value	Prob> F	
Model	0.42823	6	0.071372	576.9232	< 0.0001	Significant
A	0.008838	1	0.008838	71.43746	< 0.0001	
B	0.000732	1	0.000732	5.91771	0.0378	
A2	0.050353	1	0.050353	407.0218	< 0.0001	
AB	0.010336	1	0.010336	83.55048	< 0.0001	
A3	0.002939	1	0.002939	23.75609	0.0009	
A2B	0.01081	1	0.01081	87.3805	< 0.0001	
Residual	0.001113	9	0.000124			
Lack of Fit	0.001113	3	0.000371			
Pure Error	0	6	0			
Cor Total	0.429344	15				

The analysis of variance (ANOVA) for second order response surface model for corrosion rate is given in Table 2. The input parameter “A” which is the most significant on the output performance i.e. corrosion rate, showed the largest F-value of 71.44 and the least effect is the media because of its least F-value of 5.92.Cubic model is suggested by the design program for this response to test for its adequacy and to describe its variation with independent variables. From ANOVA test in Table 2, the Model F-value of 39.90 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" may be large due period of exposure.

TABLE III ANOVA TEST FOR CORROSION RATE

Std. Dev.	0.01112	R-Squared	0.99741
Mean	0.36688	Adj R-Squared	0.99568
C.V.	3.0317	Pred R-Squared	0.9911
PRESS	0.00382	Adeq Precision	67.9237

From Table 3, the "Predictive R-Squared" of 0.9911 is in reasonable agreement with the "Adjuated R-Squared" of 0.99568. "Adeqate Precision" measures the signal to large period of exposure. A ratio greater than 4 is desirable. This model can be used to navigate the design space.

A. Diagnostic test for the Response (Corrosion Rate)

All diagnostic plots are also tested for all responses for adequacy of the models (normal plot of residuals; residuals versus predicted value; residuals versus factor; studentized residuals and leverage). As shown in Fig. 1, the corrosion effect shows progressive increase corrosion rate against period of exposure with and it deviation is said to be insignificant.

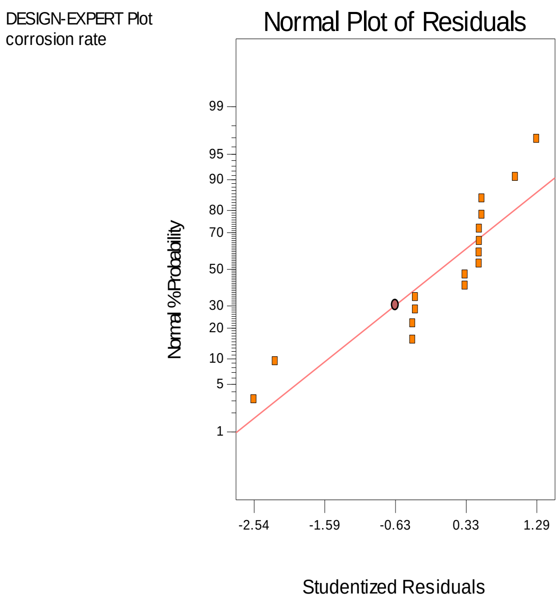

Fig.1:Predictive Model for Residual Corrosion Rate

Examination of the response surface plot indicates that the corrosion rate decreases in the two media with increase in the exposure days. After the 5th day, the corrosion rate for the pineapple medium was higher, followed by cashew, Fig. 2. As the exposure days increases, there was a gradual decrease in the corrosion rate. The initial decreased corrosion rate could be attributed to formation of protective oxide film which shielded the metal from the environment.

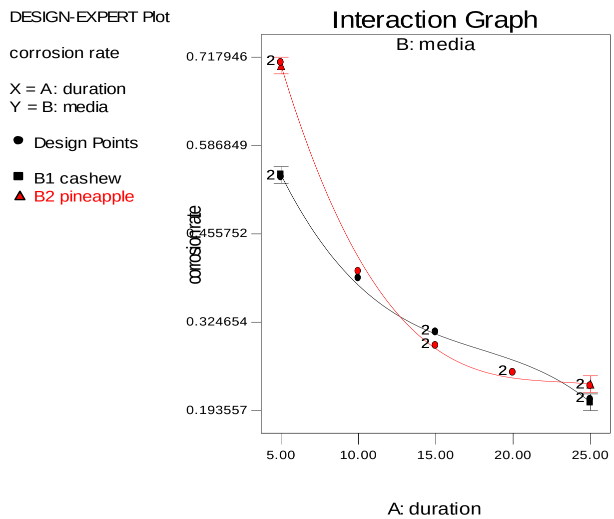

Fig. 2:Corrosion rate against Exposure time

IV. CONCLUSION AND RECOMMENDATION

The corrosion performance of ASTM A513 steel was investigated in cashew and pineapple juice as the experimental media. The following conclusions were drawn from the result.

Fruit juice demands a considerable degree of processing such as milling, pressing, and concentration by evaporation, storage and packaging using metallic constructional materials. However, carbon steel corrosiveness relatively renders it undesirable economically and health-wise because these corrosion products may find their ways into the bulk of the juice and thereby causing it to be off-taste, off-flavour and off-texture which may equally be hazardous to health.

Carbon steels are corrosive in fruit juice environments due to the evolution of hydrogen gas (a cathodic reaction product) at low pH, which tends to eliminate the possibility of protective formation (H2).

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Born in Ibadan on 8th March, 1973. B. Tech degree in mechanical engineering, LadokeAkintola University of Technology Ogbomoso Oyo State in 1997, M.sc degree in mechanical engineering, University of Ibadan, Oyo State in 2005 and Ph.Ddegree in mechanical engineering, Ladoke Akintola University of Technology, Ogbomoso Oyo State Nigeria in 2015.

Previous worked experience at Broadcasting Corporation of Oyo State (BCOS) as Engineer II between 2001 and 2005. Involve in maintenance of generating sets and supervision of ancillary services. Currently working in the Department of Mechanical Engineering, Ladoke Akintola University of Technology Ogbomoso Oyo State Nigeria, as Lecturer since 2005. Published Books include, Fundamentals of Engineering Thermodynamics, Ibadan Oyo State, Keller Prints 2014.My research works have been in the areas of production/design; evaluating the mechanical properties of materials under different service conditions and fabrication of machines (for recycling of used materials). My current area of research is focusing on the development of new engineering materials from recycled steel and plastic materials as well as agricultural and animal wastes. I am also working on the development of process model for the recycling processes of steel and plastic materials. Dr Mudashiru is a corporate member of Nigerian Society of Engineers (NSE), Nigerian Institute of Mechanical Engineers (NiMeche) and registered engineer with Council Regulating Engineering Profession in Nigeria (COREN). Award: Best Graduating Student in Engineering Thermodynamics in 1997. Involved in different committees work among which are:

Member, Faculty Postgraduate Programmes Committee (2014- till date)

Departmental Postgraduate Programmes Assistant Coordinator (2006- till date)

Member, Faculty Board of Examiners 2006- till date

Academic Advisor undergraduate (1998 – 2003)

Departmental Time table Officer (2008-2014)

Publications: Mudashiru L.O., Azeez T. M., Afolabi S.O. and Babatunde I.A.(2015): Characterization of Phosphide Platelets in Eutectic Sand Cast Cu-Sn-P Alloy.*International Journal of Nonferrous Metallurgy4:28-35*. USA

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