

## Investigating Corrosion Performance of MCS and KS7 SS in Different Fluid Environments

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### ABSTRACT

The objective of this paper is to investigate and compare the corrosion resistance of medium Carbon steel (MCS) and KS7 stainless steel in cassava fluid, natural orange fluid and distilled water environments. The MCS and KS7 SS were exposed to 200ml each of these fluids for a period of 36 days. The weight loss was taken at a 3-day interval in order to assess CPR. The experimental results revealed that KS7 SS generally offers a superior corrosion resistance compared to the MCS in the selected fluids media. While MCS is established to be inapt alloy in cassava, orange and distilled water fluids, KS7 SS is a more reliable alternative material for fabrication of machineries for processing cassava, orange and distilled water. However, MCS exhibited fairly satisfactory corrosion resistance behaviour in distilled water when compared to in natural orange and cassava fluids media where corrosion degradation was very highly significant.

**Keywords:** MCS, KS7 SS, CPR, Cassava Fluid, Orange Fluid and Distilled Water

### 1. INTRODUCTION

The problems of corrosion in various industrial sectors cannot be overstressed. It is a great challenge in petroleum, agricultural, food processing and water treatment industries. It has caused plants shutdown, equipment breakdown, products contaminations and health hazards. Quite a number of efforts have been made towards research that helps in ascertaining the corrosion characteristics and relevant applications of alloy materials. Ibegbulam et al in 2011 investigated the corrosion inhibition of aluminum in HCl and NaOH using *Chromolaena odorata* leaf extract. The study was conducted with 15 litres of 1M HCl and 0.5M NaOH to which 10ml, 15ml, 20ml, 25ml, of the extract were used. Appreciable corrosion inhibition of the aluminum was achieved by *Chromolaena odorata* in the acid and base solutions. Results obtained showed that lowest corrosion rate was attained with inhibitor concentration of 25ml/liter in both the acid and base solutions. Furthermore, corrosion was higher in the base solution than in the acid solution based on weight losses which were 1.241g and 0.965g per day, respectively. *Grajcar et al (2010)* compared the corrosion resistance of two-new developed high manganese austenitic steels in 1N H<sub>2</sub>SO<sub>4</sub> and 3.5%NaCl solutions. The test results of this study showed the low corrosion resistance of high manganese steels in acidic and chloride media. The authors found that both 26Mn-3Si-3Al-Nb-Ti and 24.5Mn-3.5Si-1.5Al-Nb-Ti manganese steel alloys are liable to general pitting

corrosion especially and more aggressive in the sulphuric acid solution. Jason et al (2004) studied the corrosion behaviour of carbon steel under stagnant seawater conditions. 1020 carbon steel coupons were subjected to natural seawater for a period of one year. The study revealed that this alloy is more corrosive in anaerobic stagnant seawater conditions than aerobic conditions. The study also revealed that in both aerobic and anaerobic exposures, corrosion was more destructive on horizontally oriented coupons in comparison to vertically oriented samples. Ciubotariu et al (2010) studied the electrochemical corrosion behaviour of carbon steel X60 employing the electrochemical impedance spectroscopy and potentiodynamic polarization methods. 0.5M test solutions of sodium chloride, sodium sulphate and sulphuric acid were used in a three electrode open cell. The findings of the authors showed that the rate of corrosion penetration is higher for carbon steel X60 in 0.5M sulphuric acid and smaller in 0.5M sodium sulphate. Hashim (2009) analyzed pitting corrosion using electrochemical noise technique. Both mild steel and stainless steel samples were immersed in NaCl solution. Two different concentrations of NaCl solution were used; 1.0 M and 0.1 M. CaOH solutions was added to the electrochemical cell which contains mild steel sample to create a passivating layer on the sample. Results revealed that the chloride ions attacked the layers and form pitting corrosion. The corrosion effect of orange fruit juice has been investigated through the study of the corrosion of carbon steel in citrus sinensis (*Badmos and Ajimotokan,*

2009). Weight loss method was used in which test coupons with identified weight were immersed in the test media which are natural orange juice, orange juice with preservatives and water for a total exposure time of 10 days. The experimental results revealed that the corrosiveness of sweet orange juice relative to carbon steel were mainly a function of its acidity. The author concluded that the packed orange juice with preservatives was most corrosive followed by natural orange juice and water respectively. Wei (2008) developed back-propagation artificial neural network to predict the corrosion rates of steels in sea water. The author applied Leave-one out method in order to train the ANN model. Test results showed that the prediction performance of the ANN model is satisfactory. ANN model was equally used to analyse the quantitative effects of parameters of environment in sea water on the corrosion rate. The results obtained indicated that the corrosion rate decreases with the increase of temperature and pH value, increase with the increase of oxygen content and oxidation-reduce potent, and change little with the increase of salt content. Halama in 2011 employed ANN in prediction of atmospheric corrosion of carbon steel. Possible environmental factors include temperature, relative humidity, wet-dry patterns, hours of sunshine, pH of rainfall, amount of precipitation, concentration of main pollutants and other factors constituted the variables in artificial neural network (ANN) modeling. In this analysis, artificial intelligent sensor which was the model designed for the assessment of atmospheric corrosion of carbon steel under local geographical conditions was applied. The author asserted that the variable impact analysis and 2D maps gave accurate prediction of the atmospheric corrosion of carbon steel. Corrosion of copper in the Cu-IUD was anticipated to be affected by galvanic action due to electrical contact between copper and stainless steels (Xue, 1998). Electrochemical measurements were carried out in physiological saline with or without indomethacin, which was introduced for bleeding control. In the copper/stainless steel couple, the open-circuit potential of stainless steel was discovered to play a decisive role. In most cases, when stainless steel was in the passive state and acted as the cathode, the contact aggravated copper corrosion. Additionally, the area ratio of stainless steel to copper altered copper corrosion behaviour. The larger the area of stainless steel, the greater the acceleration of copper corrosion. It was noted that the stainless steel surface might be activated due to improper handling of the IUD. The paper concluded that when copper became the cathode of the couple, its corrosion was suppressed. Using the Drop Evaporation Test (DET), the stress corrosion resistance of highly alloyed stainless steels under severe evaporative conditions has been compared by Poul-Erik(1993). The Drop Evaporation Test involves electrical heating of a

tensile specimen under constant load and at the same time slowly dripping a dilute (0.1 M) sodium chloride solution onto the specimen. The paper presents the performance of the newly developed high nitrogen superaustenitic stainless steel grade Avesta Sheffield 654 SMO as well as Avesta Sheffield 254 SMO and 904L in the Drop evaporation test and compares these results with the performance of the duplex stainless steels Avesta Sheffield SAF 2507™, Avesta Sheffield 2205 and Avesta Sheffield SAF 2304™. Findings showed that the steels perform far better than ordinary stainless steels type 304 and 316. The authors concluded that the highly alloyed, fully austenitic stainless steels rank higher than the duplex stainless steels in their SCC resistance under the severe evaporative conditions established in the test. The corrosion behaviour of austenitic and duplex stainless steels in various concentrations of lithium, bromide solution was investigated by (Afolabi et al, 2009) using the conventional weight loss measurement method. The results of the experiment revealed that corrosion of these steels occurred due to the aggressive bromide ion in the medium. Duplex stainless steel shows a greater resistance to corrosion than austenitic stainless steel in the medium. This was attributed to equal volume proportion of ferrite and austenite in the structure of duplex stainless steel coupled with higher content of chromium in its composition. The authors asserted further that both steels produced electrochemical noise at increased concentrations of lithium bromide due to continuous film breakdown and repair caused by reduction in medium concentration by the alkaline corrosion product while surface passivity observed in duplex stainless steel is attributed to film stability on this steel. The corrosion resistance of 18-8 stainless steel in cassava fluids containing principally hydrogen cyanide was studied by *Oluwole et al (2009)*. The work simulated the effect of continuous use of this material in a cyanide environment where corrosion products are left in place. 18-8 stainless steel was then subjected to cassava fluid environment for thirty days. The results obtained by the authors showed that 18-8 stainless steel was found appropriate for the fabrication of cassava processing machinery because of its very high corrosion resistance behaviour.

## 2. MATERIALS AND METHODS

### 2.1 Chemical Composition Analysis

The MCS was obtained from the universal steel Limited, Ikeja, Lagos state while KS7 SS was procured from a stainless steel merchant in Nigeria. KS7 SS is one of the 200 series stainless steels fabricated by KAD Steel Rolling Mills in India. The chemical composition analysis of both MCS and KS7 SS were carried out at the Universal Steel Limited, Ikeja, Lagos state.

## 2.2. Weight Loss Evaluation

The MCS and KS7 SS samples were machined into cylindrical and rectangular coupons of 15mm diameter and 41 mm long and 44mm by 45mm respectively. The coupons surfaces were pretreated by abrading them through successive grades of silicon carbide papers of grades 60 and 120 grit, and finally on the 0.05 μm emery cloth grade. They were rinsed in distilled water and then in acetone and later dried. The prepared coupons were stored in desiccators until the third day. After three days of storage; the coupons were immersed in 200ml each of cassava, orange and distilled water fluids for a period of 36 days. The corrosion coupons were taken out of the corrosion media with the aid of a tong. These were then appropriately cleaned in distilled water and dried with cotton wool. The dried coupons were weighed with the electronic digital weighing balance and recorded. Weight

loss evaluation of coupons was recorded at interval of 3 days. The corrosion penetration rate (CPR) were measured from the weight loss measurements using the equation (1)

$$CPR = \frac{KW}{\rho At} \tag{1}$$

Where K = constant = 3.45 x 10<sup>6</sup>

CPR = Corrosion Penetration Rate in mils per year (mpy)

W = the weight loss in grams

A = Area of exposed specimen in cm<sup>2</sup>

t = time or duration of exposure in hours

ρ =Density of material in g/cm<sup>3</sup>

## 3. RESULTS AND DISCUSSION

### 3.1 Results

**Table 1: Chemical Composition Analysis of Medium Carbon Steel (MCS)**

Run	C	Si	S	P	Mn	Ni	Cr					
1	0.3397	0.2191	0.0573	0.0620	0.8294	0.0960	0.1242					
2	0.3426	0.2204	0.0605	0.0597	0.8343	0.0961	0.1245					
<b>Avg</b>	0.3411	0.2198	0.0589	0.0609	0.8318	0.0960	0.1244					
Mo	V	Cu	W	As	Sn	Co	Al	Pb	Ca	Zn	Fe%	
0.0188	0.0057	0.2066	0.0035	0.0056	0.0252	0.0088	-0.0007	0.0001	0.0001	0.0035	97.9951	
0.0191	0.0058	0.2077	0.0035	0.0059	0.0262	0.0088	-0.0007	-0.0000	0.0001	0.0038	97.9816	
0.0189	0.0058	0.2071	0.0035	0.0058	0.0257	0.0088	-0.0007	0.0001	0.0001	0.0036	97.9883	

**Table 2: Chemical Composition Analysis of KS7 Stainless steel**

Run	C	Si	S	P	Mn	Ni	Cr
1	0.1099	9.3663	0.0150	0.0640	10.0512	0.3414	11.4664
2	0.1105	0.3534	0.0187	0.0728	10.6255	0.3532	11.1139
<b>Avg</b>	0.1102	0.3598	0.0169	0.0684	10.7384	0.3473	11.292

Mo	V	Cu	W	As	Sn	Co	Al	Pb	Ca	Zn	Fe%
-0.3414	0.0748	4.6323	0.0817	0.0246	0.0219	0.0444	0.0146	0.0236	0.0004	0.0340	71.8657
-0.0291	0.0731	4.0527	0.0800	0.0242	0.0229	0.0450	0.0121	0.0206	0.0003	0.0326	73.0176
-0.0306	0.0739	4.3425	0.0808	0.0244	0.0224	0.0447	0.0134	0.0221	0.0003	0.0333	72.4417

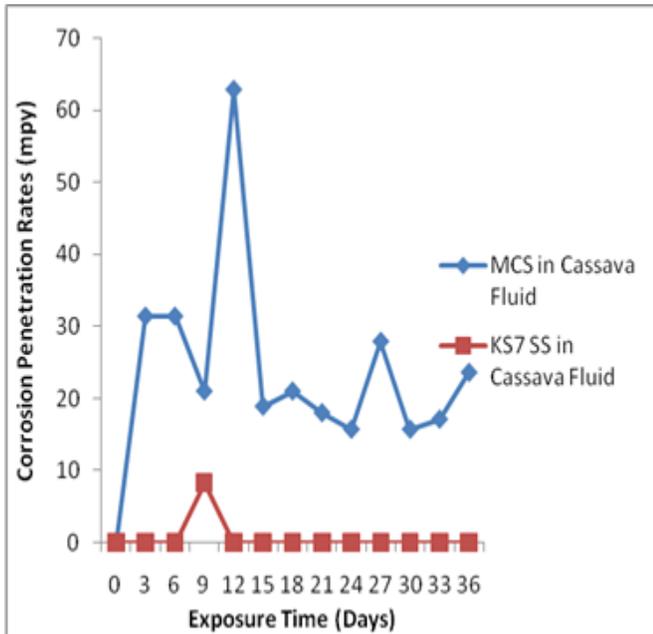


Fig.1 : CPR of MCS and KS7 SS in Cassava Fluid

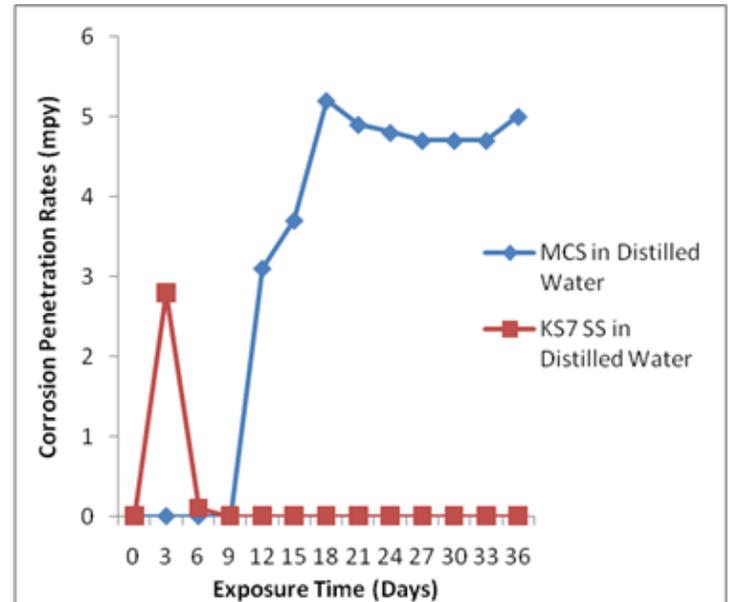


Fig.3 : CPR of MCS and KS7 SS in Distilled Water

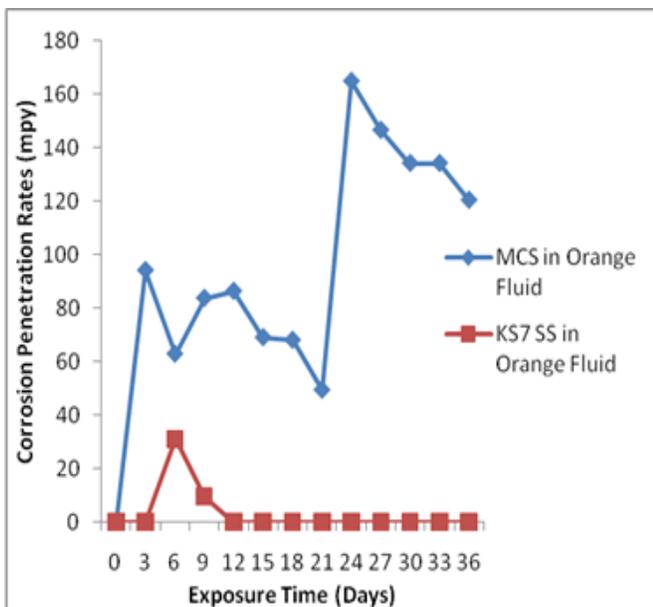


Fig.2 : CPR of MCS and KS7 SS in Orange Fluid

### 3.2 Discussions

Fig.1 gives explanation of the corrosion resistance behaviour of MCS and KS7 SS in 200ml cassava fluid. This figure shows a very high instability in the corrosion degradation of MCS. In the first 6 days, a CPR of 31.4mpy was recorded. Between the 6th and 9th days, a slight decrease to 21.0mpy was obtained and this later increased greatly to 62.9mpy. This haphazard but high corrosion deterioration was clearly noticeable throughout the 36 days experimentation period. In the contrary, KS7 SS was highly passive throughout the 36 days except in the 9<sup>th</sup> day when the CPR was 8.3mpy (This 8.3mpy CPR was however very low compared to the least CPR of 15.7mpy obtained for MCS). The formation of a very strong protective layer of chromium oxide was responsible for this approximate no corrosion degradation. It is obvious that KS7 SS has a very high corrosion resistance capability when compared to the MCS. Fig.2 describes the corrosion behaviour of MCS and KS7 SS in 200ml natural orange fluid. It can be shown in fig.2 that MCS has a poorer corrosion resistance in orange fluid

compared to cassava fluid. The highest CPR recorded for MCS in cassava fluid is among the least CPR values obtained in orange juice. At the end of the 3rd day, the CPR has reached 94.2mpy. It continued with this degrading experience throughout the 36 days of experiment with the peak CPR of 165.0mpy in the 24th day. MCS also exhibited unsteadiness in the trend of corrosion deteriorations with uneven increase and decrease in CPR values. With the exception of between the 6th and 9th days when the peak CPR of 31.0mpy was recorded, KS7 SS displayed a highly passive corrosion characteristic in orange fluid environment throughout the experiment. The reason for this is simply because in the 12th day, a protective film of chromium oxide which served as a shield against corrosion throughout the remaining period of experimentation. Therefore, KS7 SS has far better corrosion resistance behaviour compared to MCS in natural orange juice. The corrosion behaviour of MCS and KS7 SS in distilled water (pH=6.98) is shown in fig.3. In the first 9 days, corrosion was not in any way noticeable in MCS. A general increase in corrosion degradation was experienced from the 12th day till the end of the 36th day. The CPR values obtained were generally low compared to when in cassava and orange fluids media (as shown in fig.1 and Fig.2). The highest value of CPR recorded was 5.0mpy. In the contrary, KS7 SS only experienced insignificant corrosion degradation in the first 3 days with CPR of 2.8mpy but later exhibited an approximate no corrosion deterioration from the end of the 3rd day till the end of the 36th day experimentation period. Fig.3 clearly explains that MCS has a very low corrosion resistance performance characteristic compared to its KS7 SS counterpart.

#### 4. CONCLUSIONS

It is obvious from this study to conclude that KS7 SS has distinct corrosion resistance performance in comparison to MCS and therefore highly reliable alternative alloy material for fabrication of cassava tubers, orange juice and distilled water processing machines and facilities. As a result of the general high corrosion deterioration characteristics of MCS, it is considered anecdotal and inappropriate alloy in the fabrication of these machineries and facilities.

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