International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 3, pp: 478-484 www.ijaem.net ISSN: 2395-5252

Evaluation of the Corrosion Behavior of Mechanically Improved Mild Steel Surface Designed For Marine Application

[1]Dongo E.I., [1]Momoh M.I., [2]Barnabas A.A.
[1]Department of Metallurgical & Materials Engineering, Kogi State Polytechnic, Lokoja, Nigeria
[2]Department of Metallurgical & Materials Engineering, Federal University of Technology, Akure, Nigeria
Corresponding Author: Dongo E.I.,

Date of Submission: 25-07-2020 Date of Acceptance: 05-08-2020

ABSTRACT: The need to enhance the corrosion resistance of mild steel for engineering application has necessitated this experiment. Animal bones, periwinkle shell and snail shell were selected as the carburizer. Each of these carburizers were pulverized and mixed with calcium carbonate ($CaCO_3$) which acts as an energizer. The treatment was carried out at different temperatures ranging between 700 – 1000^oC at 100^oC interval. 3.5% of Sodium Chloride was prepared as simulate to marine environment. Linear polarization technique was adopted for the corrosion experiment and optical microscope was used to view the effect of the treatments on the structures. From the results obtained, it was observed that the selected carburizers can favourable compete and perform better than the as-received (AR) sample in the chosen simulated marine environment. This is as a result of the diffusion of carbon atom from the carburizer, through the sample's skin of the steel. Finally, it was generally observed that the carburized samples exhibited better corrosion resistance as compared to the AR.

Keywords: marine environment, carburizer, periwinkle, animal bones, snail shell.

I. INTRODUCTION

Corrosion, as an unwanted process in science and technology, is understood to mean the irreversible damage or destruction of materials due to a chemical or electrochemical reaction that take place among the contending elements present in the material especially alloys (Michael et al., 2011). One good example of materials that have corrosion as a major hazardous process is the iron-base material, steels and its alloys. It is categorized as irreversible due to the complete engineering relay processes (Geology-Mining-Mineral Processing-Metallurgy) the corroded products need to be subjected to in order to regain its usefulness.

Metals in general, corrode due to its natural tendency to return to the more stable oxide/salt state prevailing in their ores (Michael et al., 2011). Among the several methods adopted to reduce corrosion is surface hardening of steels with low amount of carburizer.The low carbon steel, being the greatest quantity of steel produced generally contains less than about 0.25% of carbon (Callister, 1987; Khana 2010). By reasons of its dominance and workability among the classes of steel, it has found a wide application in the production of engineering parts like gears, Camshaft, keys, hand tools, agricultural equipmentetc (Kalpakjian and Shmid, 2010).These steel parts usually require mechanical properties of hardness, tensile strength and impact strength for their safe and durable functions. Importantly, such parts produced requires heat treatment of carburizing and case hardening in order to build-in these required mechanical properties (Hazizi and Ahmam, 2010; Oyetunji and Adeosun, 2012).

Literatures in recent times has revealed that most of these high-tech equipment and facilities for carburizing treatment of Low carbon steel with which fabricators and mechanist easily use to produce their parts naturally lack the required mechanical properties. Carburizing is one of the most commonly performed steel heat treatments performed by packing the low carbon wrought iron parts in a carbonaceous material, then Raising the temperature of the pack to a predetermined temperature and holding (soaking) for some specified time and then allow cooling down using a quenching media. The surface of the parts becomes very hard while the core is very soft which retained the toughness of the low carbon steel (Ihomet al., 2013).

A survey of Nigerian industrial stock market revealed a death in commercial pack-carburizing compound with which fabricators,

International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 3, pp: 478-484 www.ijaem.net ISSN: 2395-5252

mechanists and blacksmith produce parts or recondition vital engineering parts. The resultant effect of this is that the non-treatment of such product or reconditioned part consequently results into fast wear, tear and fracture.

Thestudy is specifically tounearth the possibility of some local carbonaceous material such as animal bone,snail shell and periwinkle shells to improve corrosionbehaviors. It is intended to alsojustify the behavior with the microstructural evaluations of the prepared samples.

II. RESEARCH METHODOLOGY

The experimental procedures forthisresearchinvolve the selection of the low carbon steel with known chemical composition using mass spectroscopy analyzer from the Universal Steel Limited, Nigeria. The steel was machined to corrosion coupon in accordance to Dongo et al., 2019 and little were cut for microstructural evaluation. Local carbonaceous materials was obtained from different sources i.e animal bone from the Abattoir market in Okene Kogi State;Periwinkle shell from Port Harcourt market in River state and Snail shell from Akure market in Ondostate, Nigeria.The energizer, calcium carbonate $CaCO_3$was obtained from theDangote Cement Company Obajana in Kogi state.The carburizing boxes werefabricated using a mild steel plate in the central workshopof School of Engineering,Kogi State Polytechniclokoja.Heat treatment furnace (muffle furnace) obtainable at School of Engineering Kogi State Polytechnic Lokoja - Itakpe campus was used for the heat treatment operation(Dongo, et al 2016). The coupons were subsequently subjected to linear polarization experiment in accordance to ASTM G-31.

Table1: Chemical Composition of the Mild Steel

Elements	C	Si	Mn	S	P	Cr	Ni	Cu	Nb	AL	B	W	Mo	V	Ti	Fe
Avg	0.1810	0.1450	0.6180	0.00550	0.0410	0.1040	0.0920	0.2640	0.0001	0.0430	0.0001	0.0001	0.0001	0.0001	0.0050	98.4520

2.1 Carburization Processes

Each identified carburizing boxes were packed with specified number of the work samples covered with their respective carburizing materials and sealed with clay to prevent the escape of the carbonaceous material. it is then charged into the furnace (Muffle Furnace)having a maximum temperature capacity of 1600°C to austenitize the carburized steel samples at various heat treatment temperatures ranging from 700°C(T_1), 800°C(T_2), 900°C(T_3), 1000°C(T_4). Varied soaking time of 1hr, 2hrs, 3hrs, 4hrsfor each temperature were ensured to allow for carbon diffusion.Three different metal containers of sufficientvolumetric capacity were adapted as baths for quenching purpose using industrial oil as the quenchant.The materials were there after tempered at 350°C with a soaking timeof 45min and then allowed to cool in free air for all the samples. The samples were identified by their respective carburizing medium and heat-treated temperatures, 700°C snail is identified as ST, while PT is periwinkle and AT is identified as the animal bone. Similarly, other treatment temperatures are identified in this order.

Table 2: Specimen identification

Label	Treatment Carburizer	Temperature (°C)
ST1	Snail	700
ST2		800
ST3		900
ST4		1000
PT1	Periwinkle	700
PT2		800
PT3		900
PT4		1000
AT1	Animal Bone	700
AT2		800
AT3		900
AT4		1000

International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 3, pp: 478-484 www.ijaem.net ISSN: 2395-5252

2.2 Corrosion Experiment

The corrosion behaviour of the samples was studied in simulated marine environment (i.e 3.5 wt% sodium chloride) using the Potentio-dynamic electrochemical measurement technique. All electrochemical measurements were performed at room temperature (25^{o}C) using an Auto-lab Potentiostat. Prior to the experiment, the samples were immersed in the electrolytes for suitable time to stabilize at the open circuit potential (OCP). The TAFEL trends, was measured at a scan rate of 1mV/S starting from -250 mV (with respect to the OCP) to about +250 mV. After each scan, the electrolytes were replaced with fresh electrolytes, while the samples were polished, rinsed in water and washed with acetone to remove the products that might have formed on the surface.

2.3 Metallographic Analyses

Microstructural examination of as received and all the carburized samples were carried out. Each of the samples was subject to grinding in decreasing coarseness 220, 320, 400 and 600 grits silicon carbide abrasion paper and polished using gamma alumina (Al_2O_3) paste carried on a polishing cloth. The surface of the polished sample was etched in 2% Nitalsolution. The microstructural examination of the etched surface of the specimens was captured under an inverted metallurgical microscope with an in-built camera with magnification of X200 through which the resulting microstructures were all photographically recorded.

III. RESULTS AND DISCUSSION

3.1 Discussion

Summary of the analyzed data and its results are presented with relevant interpretations in Figures and Plates.

3.1.1 Effects of carburizer at constant temperature

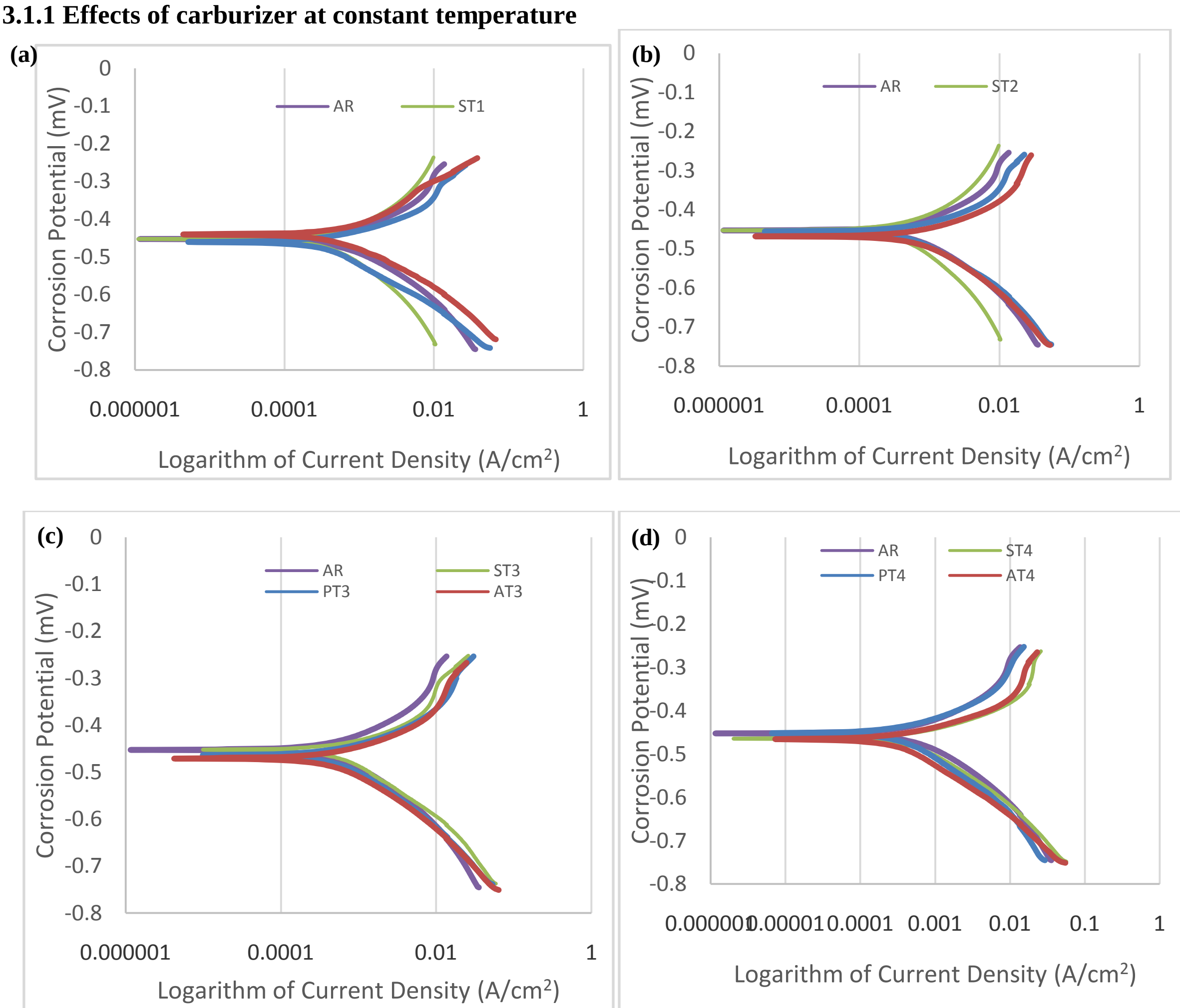


Fig. 1: corrosion plot of carburized samples at (a) 700^{o}C (b) 800^{o}C (c) 900^{o}C (d) 1000^{o}C using varied carburizers in acidic environment.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 3, pp: 478-484 www.ijaem.net ISSN: 2395-5252

3.2 Effect of Temperature using same carburizer

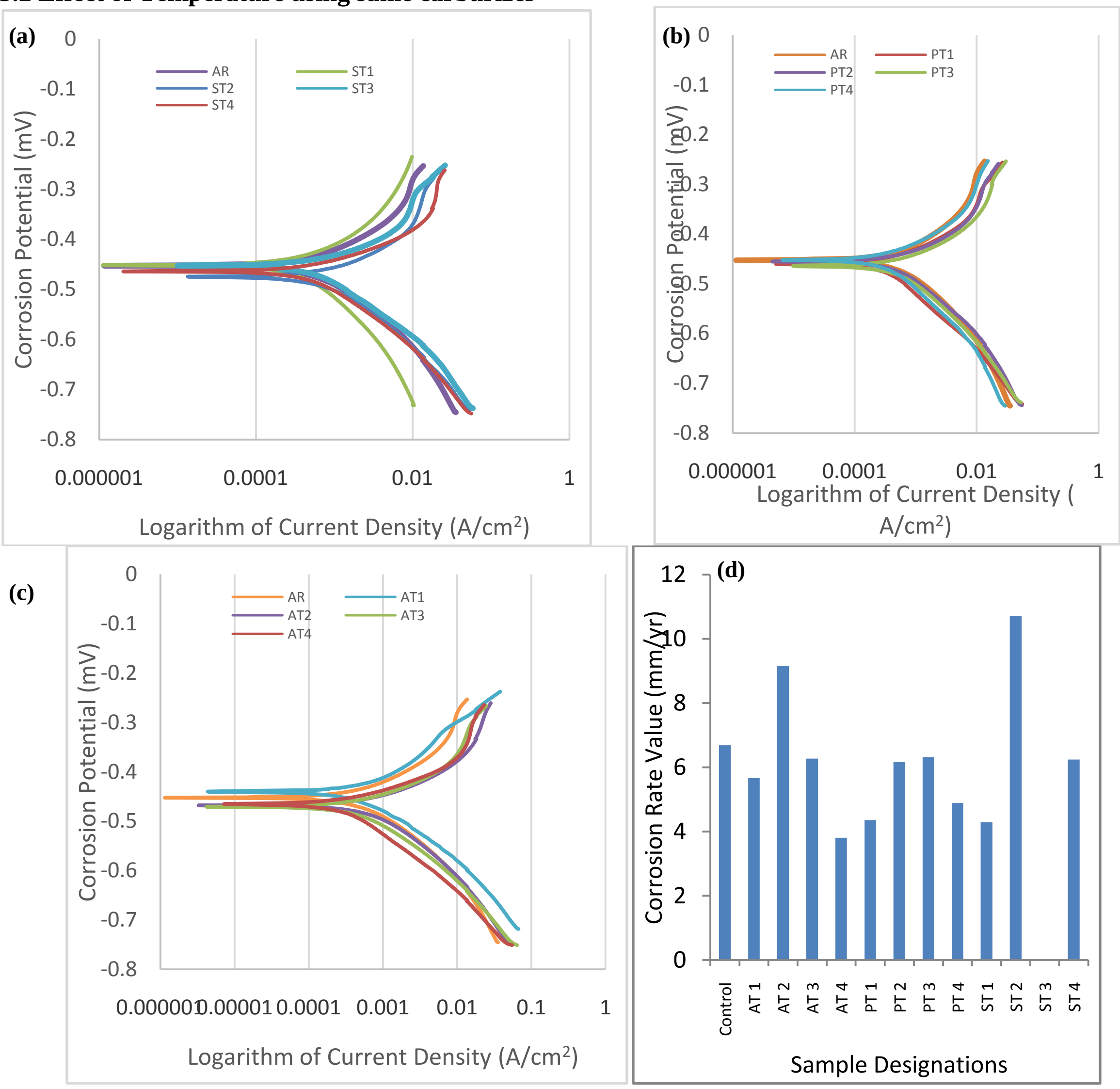


Fig. 2: Corrosion plots of samples treated using (a) snail shell powder (b) periwinkle powder and (c) animal bone powder at varied temperatures. (d) Corrosion rates of the samples at varied carburizers and temperatures

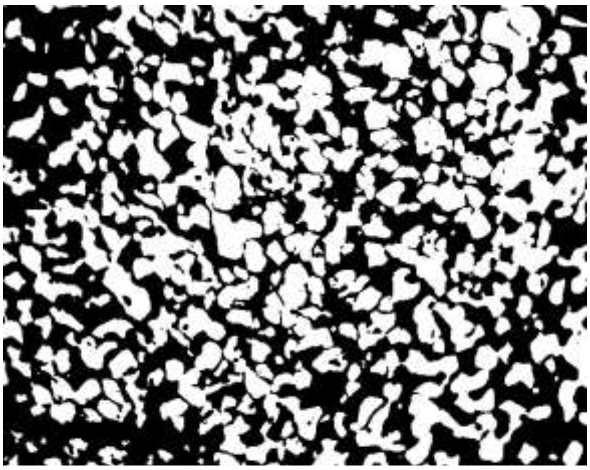
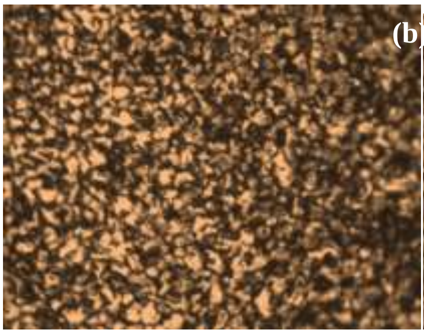
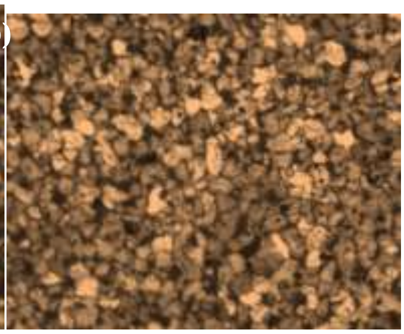


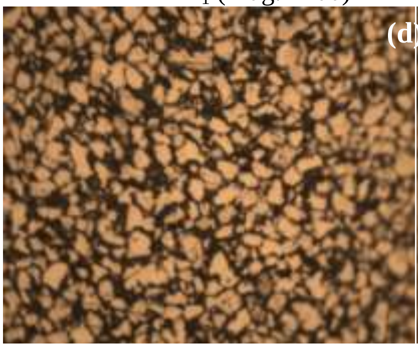
Plate 1: Normal pearlite structure of the control samples

International Journal of Advances in Engineering and Management (IJAEM)
Volume 2, Issue 3, pp: 478-484 www.ijaem.net ISSN: 2395-5252





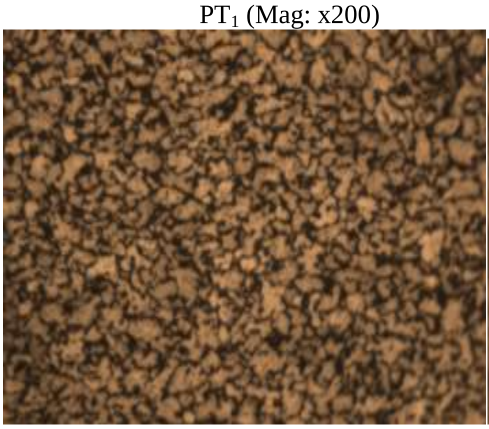
AT$_1$ (Mag: x200) AT$_2$ (Mag: x200)



AT$_3$ (Mag: x200) AT$_4$ (Mag: x200)

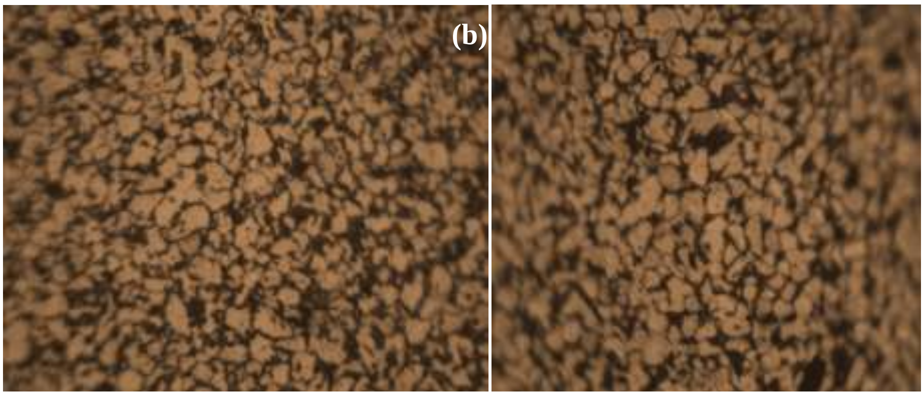
Plate 2: Micrograph of case hardened steels carburized with pulverized animal bone at (a) 700^{o}C (b) 800^{o}C (c) 900^{o}C (d) 1000^{o}C showing varied structure responsible and justifying the observed variations in the corrosion trends.

PT$_1$ (Mag: x200) PT$_2$ (Mag: x200)

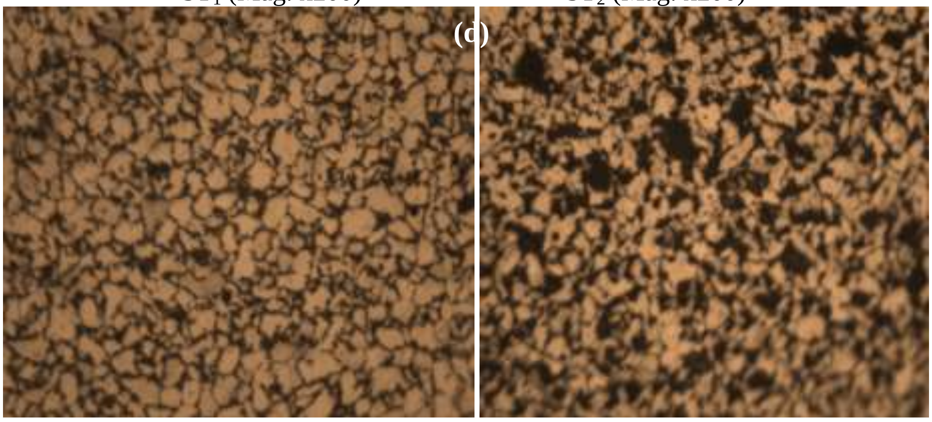


PT$_3$ (Mag: x200) PT$_4$ (Mag: x200)

Plate 3: Micrograph of case hardened steels carburized with pulverized periwinkle shell at (a) 700^{o}C (b) 800^{o}C (c) 900^{o}C (d) 1000^{o}C showing varied structure responsible and justifying the observed variations in the corrosion trends.



ST_1 (Mag: x200) ST_2 (Mag: x200)



ST_3 (Mag: x200) ST_4 (Mag: x200)

Plate 3: Micrograph of case hardened steels carburized with pulverized snail shell at (a) 700^{o}C (b) 800^{o}C (c) 900^{o}C (d) 1000^{o}C showing varied structure responsible and justifying the observed variations in the corrosion trends.

3.2Discussion

3.2.1 Effects of varied carburizer and temperatures on the corrosion of the selected steel

Pulverized animal bones, periwinkle shell and snail shell were used to carburized mild steel at varied temperature. These treatments were carried out as precedence to corrosion experiments. The corrosion results shows varied trend as a reactions to the treatment it is subjected to. This is represented in Figure 1. Figure 1(a) shows the response of the steel carburized at 700^{o}C. The Tafel plots were plotted with respect to the untreated steel designated as AR (As-Received) for comparison. Varied responses were observed in all the superimposed plots with the AR from the results, it was observed that the snail shell displays relatively high corrosion resistance in the marine environment. Same was also observed when the treatment was carried out at higher temperature of 800^{o}C (See Figure 1(b)). at this temperature however, the periwinkle shell was also able to compete with the improvements in corrosion resistance. This interesting response of the periwinkle shell was reverted at a further increase in the temperature of 900^{o}C (See Figure 1(c)). The response of snail shell remains constant in the four selected temperatures used regardless of the carburizer used. Having the least current density, the samples carburized with snail shell cannot be recommended for application in comparison to the AR.

Figure 2 shows the Tafel plots of same samples but at varied temperatures and the summary of the corrosion rates variations of the corrosion experiments. In the three separate plots (a, b and c) of Figure 2, the pulverized periwinkle shell was still found to perform better in an engineering applications where relatively high corrosion resistance is required of effectiveness. Figure 2(d) shows the rate at which the carburized still will corrode per year. With reference the AR sample, in spite of the trends displays in the previously discussed Tafel plots, most of the samples actually exhibited good and better resistance to corrosion in marine environment. Sample AT_4 and ST_2 were however found to display an unusual high corrosion rate value, thus very low resistance.

3.2.2 Effects of varied carburizer and temperatures on the photomicrographs of the selected steel

A normal pearlite of mild steel was observed in the AR sample prior to carburizing at varied temperatures (See Plate 1); all micrographs were captured at x200 magnification. After treatment however, different structural orientations were observed to in the samples. This structure justifies the corrosion responses discussed earlier. Plate 2 shows the micrographs of samples carburized with animal bone at different temperatures. Apart from the pearlitic structures, some dark spots were also observed as deposits of carbon from the pulverized snail shells that travelled through the skin of the steel. Sample AT_4 (carburized with animal bone at 1000^oC) however did not have much penetration and as such displays a coarse ferritic phase possibly responsible for the high corrosion rate value. This observation is similar to that of Plate 4 where ST_2 (carburized with snail shell at 800^oC) was found to exhibit structure similar to conventional pearlite structure with no effect of the carburizer through the skin. On the other hand, Fine pearlitic structures with deposits of carbon from periwinkle shell was observed in Plate 3. These accounts for the relatively high resistance in corrosion earlier observed and discussed in the Tafel plots.

IV. CONCLUSION

This experiment has proven thatanimal bones, periwinkle shell and snail shell can effectively serves as carburizer in an attempt enhance the corrosion susceptibility of mild steel in marine environment. Each of this carburizer were pulverized and mixed with cement which acts as an energizer. The treatment was carried out at different temperatures between 700 – 1000^oC at 100^oC interval. From the results, it was observed that the selected carburizer can favorable compete and perform better that the AR in the chosen simulated marine environment. This is as a result of the flow of carbon atom from the carburizer, through the sample's skin of the steel. Finally, it was generally observed that the carburized samples exhibited better corrosion resistance as compared to the AR.

ACKNOWLEDGEMENTS

The authors of this article heartily appreciate the management of Tertiary EducationTrust Fund (TET Fund) for sponsoring this research and to the managementof Kogi State Polytechnic, Nigeria for their support.

REFERENCES

[1]. CallisterJr; W.D (1987); Material Science and Engineering An Introduction, John Wiley and son, New York:USA Pp322-328
[2]. Dongo E.I, Seidu, S. O, Ogbodo, J. F (2016): Effect of Locally Source Carbonaceous Materials on the
[3]. Mechanical Properties of Mild Steel, International Journal of Engineering & Technology,5 (3) (2016) 77-82
[4]. HaziziAzri Bin Ahmad Sabri (2010): Experimental Study of Pack Carburizing of Carbon Steel University Malaysia Pahang
[5]. IhomA.Paul,,Nyior G. Bem, Nor I. Justine, Ogbodo N. Joy (2013):Investigation of Egg Shell Waste as an Enhancer in the Carburization of Mild Steel, American Journal of Materials Science and Engineering, 2013, Vol. 1, No. 2, 29- 33
[6]. Kalpakjian S, Shmid S, R, (ed) 2001, "Manufacturing Engineering and Technology," Prentice-Hall, Upper saddle River, New Jersey, America.
[7]. Khana O.P. (2010); Material Science and Metallurgy, 4th Edition; New Delhi DhanpatRaiPublication Pp 186-195, Pp 437-446
[8]. Michael S., Noah L., Benjamin V., Eliezer A., and Monica C. (2011): Metals Corrosion and Biological Respiration: Similarities and Disparities: An Overview. Journal of Materials Education Vol. 33 (3-4): 133 - 140
[9]. Oyetunji and Adeosun (2012): Effects of Carburizing Process Variables on Mechanical andChemical Properties of Carburized Mild Steel, Journal of Basic & Applied Sciences, 2012, 8, 319.
[10]. Smith, W.F. &Hashemi, J. (2006) Foundations of Materials Science andEngineering, 4th ed., McGraw-Hill.

International Journal of Advances in Engineering and Management
ISSN: 2395-5252

IJAEM

Volume: 02 Issue: 01 DOI: 10.35629/5252

www.ijaem.net
Email id: ijaem.paper@gmail.com