Rice Husk Waste: As Potential Coating Materials of Mild Steel for Engineering Application

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Abstract
Rice husk is one of the agro-waste that is causing environmental pollution worldwide. The work have provided new information on the rice husk waste management for potential used as anti-corrosion and wear resistance of coating of mild steel. The rice husk was turned into rice husk nanoparticle (RHAnp), Epoxy-2wt% RHAnp was developed on the mild steel surface, corrosion, wear and hardness test were used to determine the coating performances. It was established in this work that waste rice husk can be used to increases the coating thickness, polarization resistance and hardness values, decreases the coefficient of friction, corrosion rate and wear rate of epoxy coated mild steel.

Keywords: Rice husk waste, Mild steel, Corrosion, Wear, Hardness values

1. Introduction

Waste management problem of one of the main environmental pollution affecting not only Africa countries but the world at large, this is attributed to the facts that large quantities of waste are generated from industrials and agricultural activities (Bahrami, et al., 2015; Ezema and Aigbodion, 2020). Rice husk is one of the agro-waste that is causing environmental pollution worldwide (Soltani et al., 2015). A large quantity of the rice husk is been disposed to open burning in my Africa countries and effort has been by the researcher to converted this waste for the use of mankind (see Figure 1) (Suwanprateeb and Hatthapanit, 2002; Hassan and Aigbodion, 2016). Some of the recent potential application of rice husk exist in literature (Fernandesa et al., 2018). The authors reveal that rice husk contains carbon, silica, calcium, magnesium, iron and has been used in the production of composites materials, glass and soil stabilization. Bahrami et al (2015) reviewed on the development of metal matrix composites using agricultural and industrial waste for engineering applications. They reported that agricultural and industrial waste materials can be effective used in metal matrix production. Aigbodion (2012) develop an Al-Si-Fe composites using rice husk ash. Pode (2016) report the use of rice husk in biomass power plant. Yao et al (2016) studied the thermo-physical properties of rice husk and rice straw. Cuthbert (2014) present energy features of coffee husks blend with rice husk. Sekifuji and Tateda (2019) study the production of silica fertilizer using rice husk. Many past researchers show that corrosion of mild steel is a mace in the marine industry, oil and gas sector as well as construction and building industry (Brostow et al., 2010; Cui et al., 2013; Ramezanzadeh et al., 2014). This paper is an attempt to contribute to the conversations in rice husk waste management in a manner that can motivate interest in using rice husk as a potential materials for anti-corrosion and wear of mild steel.

Figure 1: Photograph of rice husk and open burning

2. Materials and Method

The rice husk waste was obtained in Nsukka Nigeria. The raw rice husk was cleaned with water and dried before the cleaned rice husk was ashes using muffle furnace operate at 1000ºC. The rice husk ash was turned into nanoparticle using the sol-gel method. Details of the production of the sol-del method are discussed elsewhere [2]. The mild steel used were grounded and polished to obtained mirror like surface and the composition is shown in Table 1.

Table 1: Chemical composition of mild steel used (wt.%)

Element	C	Mn	Si	P	S	Al	Ni	Fe
Composition	0.15	0.45	0.18	0.01	0.031	0.005	0.008	Balance

Epoxy- rice husk ash nanoparticle(RHAnp) coating was employed in this work. Epoxy resin LY556 and Hardener (HY951) were used in ratio 2: 1. RHAnp of 2wt% was added to the epoxy mixture. Spray gun operating at a speed of 250rpm was employed to applied the coating mixture on the mild steel surface and the coated steel was then allowed to dried for 24hours(see Figure 2).

The nano-partice size of the RHAnp was measured using transmission electron microscope (model: JEOL JSM840A). Digital handheld coating thickness equipment was used to determined the coating thickness of the coated sample; microstructures were determined by scanning electron microscope (TESCAN). The simulated sea water was used in the measurement of the corrosion rate using electrochemical corrosion tester (model: CHI604E). ASTM G 99-5 standard was used to determine the dry wear behavior of the composites coating using the TRN tribometer machine.

Figure 2: Photograph of the: RHAnp, Epoxy, composite mixture and coated samples

3. Results and Discussion

The various microstructures obtained are displayed in Figure 3. In Figure 3 it can be seen clearly that there are great difference in the morphology of the four samples in question. In the TEM image of the RHAnp uniform fine particles randomly distributed were achieved, particle cluster and agglomeration of particles was not seen. The TEM image gives average particles of the RHAnp as 98.13-100nm. Evidence of scratch and lines that may remain after the polishing of the steel sample was observed in the microstructure of the uncoated mild steel. Evidence of coating materials covered the surface of the mild steel was visible in Figure 3. In the coated sample one can observed that the coating formulation with 2wt%RHAnp-epoxy covered the entire surface of the mild steel. However, porosity and void space were observed in the sample coated with 100%Epoxy as a result of air trapped. Presence of 2wt% RHAnp was able to avoid the porosity and filled the gap of the air trap.

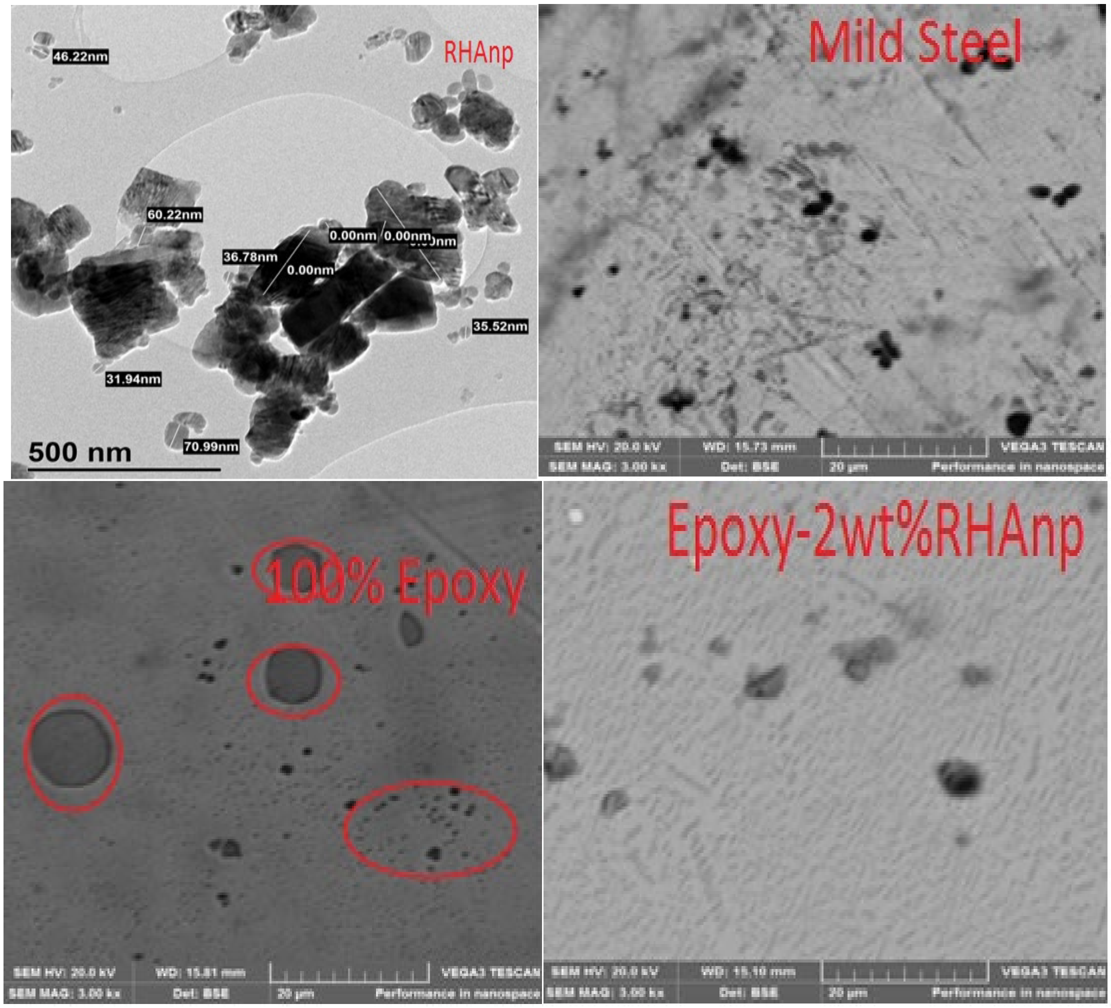

Figure 3: Displayed various Microstructures obtained

Figure 4 displayed the coating thickness and the hardness values results. It was observed that coating thickness of 0, 98.34 and 111.2 µm were obtained for the mild steel, mild steel coated with 100%epoxy and 2wt%RHAnp-epoxy formulation. The increases in the coating thickness was attributed to the presence of RHAnp in the formulation that covered the entire mild steel surface and hence lead to increment in the coating thickness. The results of the hardness values shows similar pattern as that of the coating thickness. Average hardness values of 286.70, 378.90 and 407.20HV were obtained for the mild steel, mild steel coated with 100%epoxy and 2wt%RHAnp-epoxy respectively. The high hardness values of the mild steel coated with 2wt%RHAnp-epoxy was attributed to the presence of hard SiO_2 phase in the RHAnp[1, 3]. This hard phase hel\=-i0u9p to strengthened and increased the load bearing capacity of the mild steel.

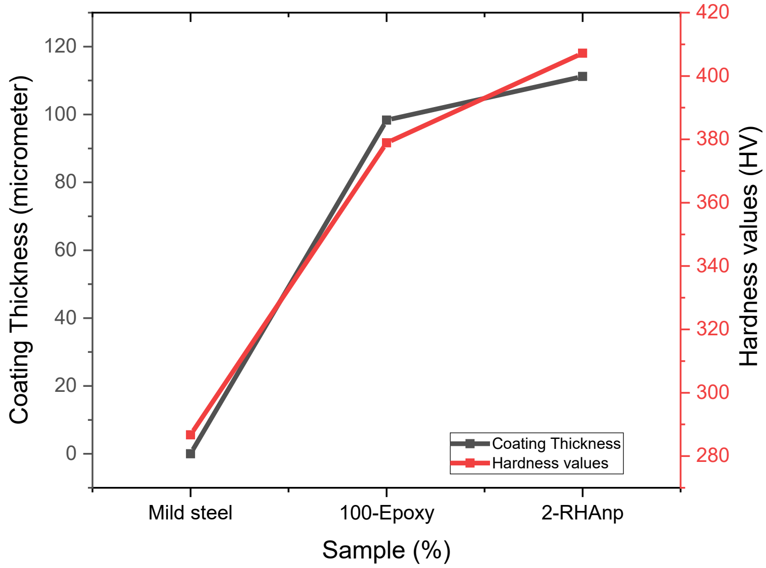

Figure 4: variation in coating thickness and hardness values with sample condition

Wear is importance engineering properties of materials. The results of the wear rate and coefficient of friction of the samples are displayed in Figure 5. It was observed that the results of the coefficient of friction and wear rate decreased with the addition of the RHAnp. For example coefficient of friction of 0.48, 0.35, 0.05 and wear rate of 0.00058, 0.00035 and 0.00024mm^3/m were obtained for the mild steel, mild steel coated with 100%epoxy and 2wt%RHAnp-epoxy respectively. The enhancement in wear resistance obtained in this work was attributed to hardness values and anti-friction of the developed composites as discussed above which aid in toughing the materials and decreased the expansion caused by epoxy

Wear worn out surface was used to describe the level of damage to the sample surface. Figure 6 presented the images of the worn out surface. It was seen that there is great wear damage on the mild steel uncoated in respect to the coated samples. Low wear debris, without cracks were observed in the 2wt%RHAnp-epoxy coated mild steel. Evidence of large wear debris, plow and adhesive wear surface were more visible in the substrate (mild steel)(see Figure 6).

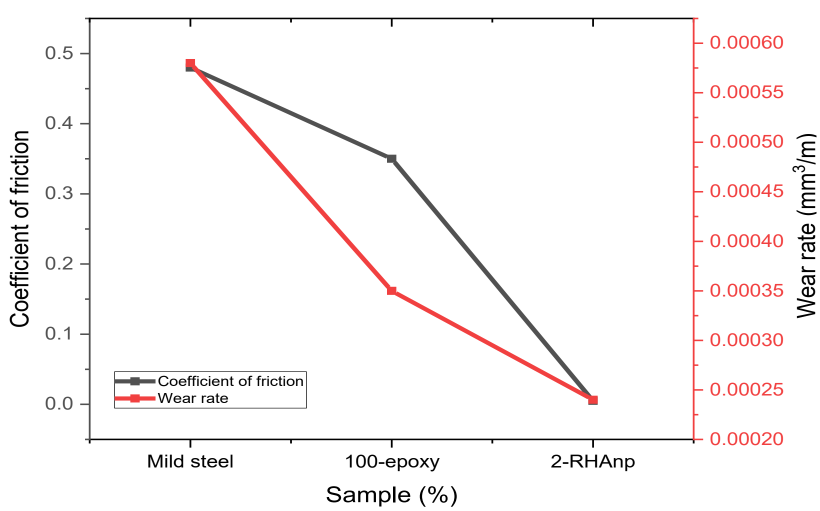

Figure 5: Variation in coefficient of friction and Wear rate with sample condition

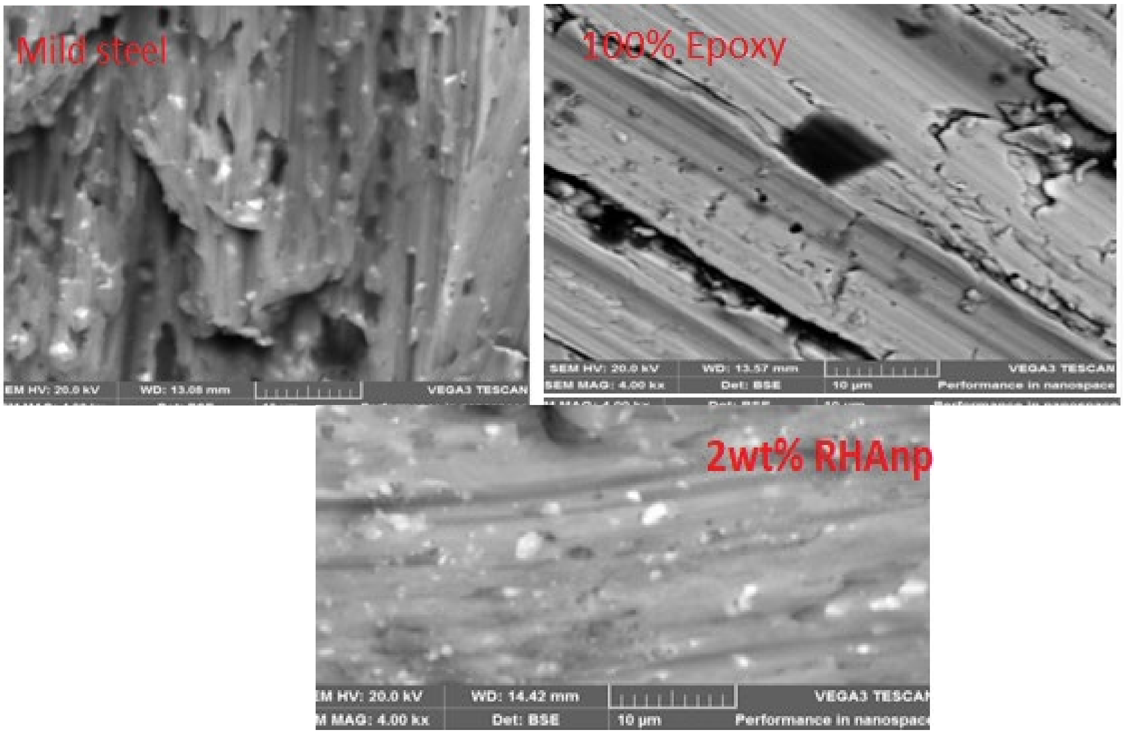

Figure 6: Wear worn out surface of the samples

Simulated seawater using 3.5%Nacl was used for the corrosion rate of the samples. Figure 7 presented the Tafel polarization curves obtained in course of the research. It was observed that the potential of the uncoated mild steel sample was lower than the coated sample. The sample with epoxy-2wt% RHAnp has the higher potential of all the samples under investigation. This high potential of the epoxy-2wt% RHAnp results to lower the corrosion rate, high polarization resistance and lower current density. For example corrosion rate of 2500, 1010 and 850 mpy and polarization resistance of 10.23, 85.15 and 106.81 Ωm were recorded for the substrate, 100% epoxy, epoxy-2wt.% RHAnp. This anti-corrosion behavior obtained in this work was attributed to the presence of RHAnp which contain hard phase of SiO_2 that covered the entire surface of the mild steel and prevent direct corrosion attack.

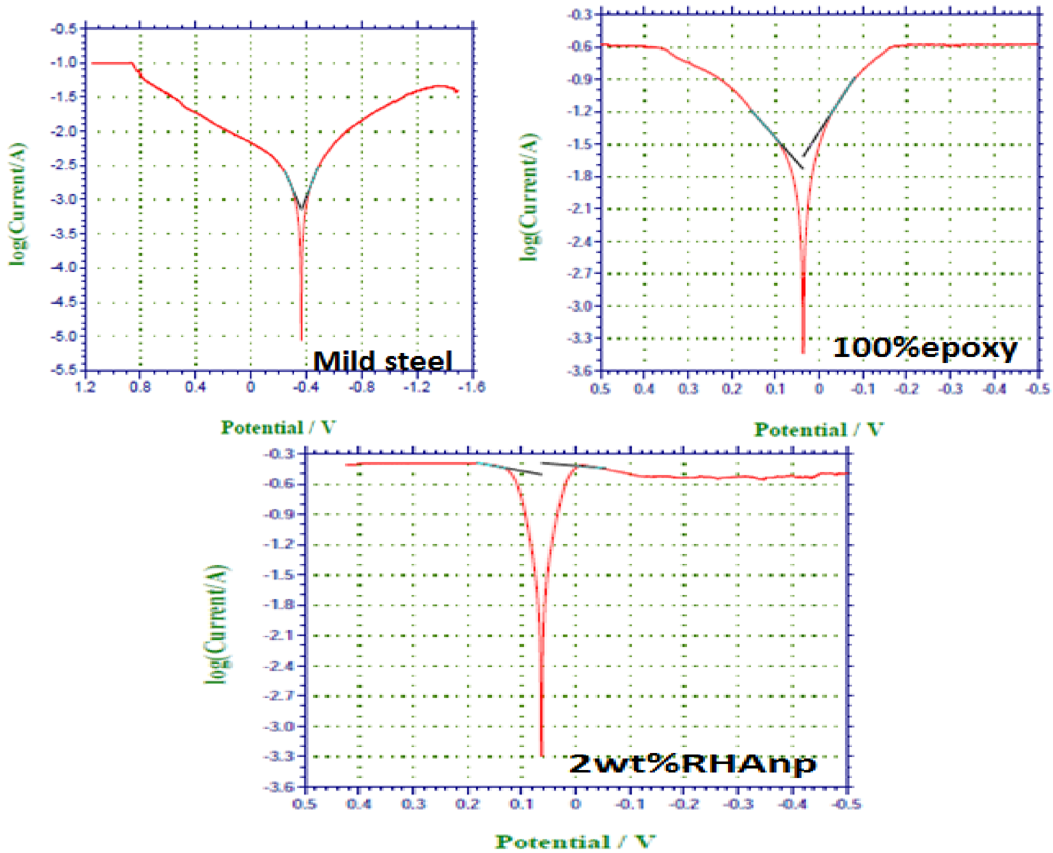

Figure 7: Tafel polarization curves for the corrosion

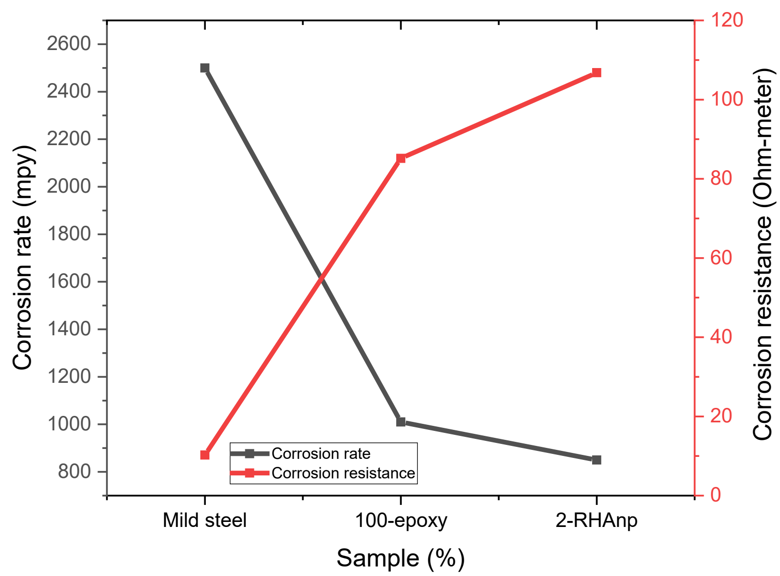

Figure 8: Variation in corrosion rate and resistance with sample condition

4. Conclusions

The work have provided new information on the rice husk waste management for potential used as anti-corrosion and wear resistance of coating of mild steel. Corrosion rate of 2500, 1010 and 850 mpy and polarization resistance of 10.23, 85.15 and 106.81 Ωm, wear rate of 0.00058, 0.00035 and 0.00024mm^3/m were recorded for the substrate, 100% epoxy, epoxy-2wt.% RHAnp. It was established in this work that waste rice husk can be used to increases the coating thickness, polarization resistance and hardness values, decreases the coefficient of friction, corrosion rate and wear rate of epoxy coated mild steel.

5.0 ACKNOWLEDGEMENT

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Biographies

Professor Sunday Victor Aigbodion work with the Department of Metallurgical and Materials Engineering, University of Nigeria, Nsukka, Nigeria. He is a scholar of international repute and currently a visiting Professor to the University of Johannesburg as well as University of Benin Nigeria. Prof Aigbodion has published over one hundred and eighty-four (184) research papers in several local, international journals and conferences. He has also served as an external assessor to many international bodies among which are the National Center of Science and Technology Evaluation Ministry of Education and Science Astana, Republic of Kazakhstan, Anna University Centre for Research Chennai, India, University of Johannesburg, Nova Science Publishers Inc Hauppauge USA, National Research Foundation (NRF), South Africa, just to mention a few. Prof Aigbodion has headed and also a member of many accreditation teams in University and Polytechnic, Member, Council of Engineering and Regulation of Nigeria professional Registration interview team. **Prof Aigbodion is a National Research Foundation (NRF) South Africa C3 rated researcher.**

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