

Morphological and Mechanical Behaviour of Welded Joint of a Steel Using Nano-Flux Powder (MnO) From Agrowaste (Banana Peel) During MIG Welding

Sunday Adeniran Afolalu^{*1}, Samuel Olusegun D.², Owoeye F. Taiwo³, Bello, K. A⁴

¹Department of Mechanical Engineering, Covenant University, Ota, Nigeria.

²Department of Mechanical Engineering, Federal University of Petroleum Resources, Effirin Delta State. Nigeria.

³Department of Chemistry, Covenant University, Ota, Nigeria.

⁴Mechanical and Mechatronics Engineering Department, College of Engineering, Afe Babalola University, Ado Ekiti, Ekiti state, Nigeria.

Abstract

Flux is important in welding for a number of good reasons. Nano- flux powder (MnO) powder developed from agro waste (banana peel) and commercial flux powder were used. Sixteen pieces each galvanize, Stainless and mild steel plates and rods of 60 x 60 x 10 mm were prepared. The SEM and EDX of the fluxes were carried out while the welded joints of each samples were subjected to tensile, impact, hardness and surface morphology using SEM. The high volume of 57.10% Iron and 29.45% Manganese respectively confirmed that the fluxes were Iron and Manganese Oxides suitable as fluxes for the welding. The mechanical properties of the joints proved better in Nano flux than the commercial and when no flux applied.

Keywords: Nanoparticles; Nano-Flux; Powder; Welding; MIG; Morphology; Characterization.

1.0 INTRODUCTION

Welding has various advantages, disadvantages and applications. Welding is made easy in every position when using MIG. Due to the neatness of the weld, only very little work is done on the finishing. It welds metals that are usually never easy to weld. Arc and weld pool are easier to see when MIG welding is used [1]. On the other side, there is a possibility of occurrence of error if the operator is not very skilled. The welding location has to be covered for jobs done outdoors. It requires high capital and maintenance. Its application varies wildly from metals that it is most compatible with to the industries in which it can be applied [2]. Metals like steel, aluminum and copper is joined with MIG and industries like ship building, automobile and aircrafts apply it.

MIG welding, which is also known as Gas Metal Arc Welding (GMAW) is a top developing welding process that gives a better quality and productivity in the welding processes generally [3]. MIG welding involves heating the parent and filler metal, melting it together, and then it solidifies to become a joint. The filler metal is fed automatically through the welding

torch. It has various effects on parameters in welding such as hardness, microstructural qualities, penetration of weld, depth of weld, etc. different variables can be altered like voltage, welding speed and welding current, when it is MIG welding in view [4]. Previous studies observed that the most favorable results were attained in MIG welding when variables geometry of the weld, base metals and type of weld was considered.

MIG welding is used independently during operations. MIG welding makes use of CO₂ as the shielding gas. It welds thick metal plates and rods with high speed [5]. Mechanical properties of the weld are enhanced when this welding type is applied. Less operator skill is required in this type as compared to TIG welding [6]. Factors like the strength of the joint, neatness of the joint, small heat affected zone, shape of the weld bead and weld penetration are much better using MIG welding than the traditional arc welding [7]. The mechanical properties are determined by measuring ultimate tensile strength and yield strength. In a research study, effects of using both TIG and MIG to form a hybrid method was applied and it was found that using TIG and MIG hybrid welding enhances the mechanical qualities of the weld. TIG and MIG welding machines were used to weld and a lathe machine to prepare the specimen [8-10] carried out a review on agro waste and how they can be effectively utilised. It was stated in the research that agro waste consisted of some carbohydrates and complex proteins [11]. Clean technology is being enhanced by the use of these wastes for useful products. The clean technology procedure includes planning, pre assessment, assessment, feasibility study and implementation of the various meaningful uses of agro waste. Agro waste can be used in the production of biofuel to replace fossil fuels and in turn, reduce the amount of environmental pollution [12]. It can also be implemented to produce enzymes that are needed industrially. It can be used for production of citric acid, pigment production, and bio active compounds that can be used to treat illnesses [13-14].

Mishra *et al.* [15], studied the strength of the joint between two different metals, mild steel and stainless steel. The study was carried out because of the need for maximum output in the

manufacturing industry [16], when joints are being made between different metals for the benefit of resistance to corrosion and strength [17]. Due to the different properties (chemical and physical) of the metals, finding a suitable joining process is hard. It was concluded that MIG welding gave more favorable results for the joints, as opposed to TIG welding [18]. The welds done with TIG welding were faced with cracking during welding, which demanded for more effort being put into the process [19]. It also showed that properties like resistance to corrosion, strength and plasticity was enhanced because of the presence of low free carbon [20]. Galvanized, mild and stainless steel have variety of applications in various industries and one of the major welding system use is MIG [21]. Welding which is limited by low weld penetration and weld bead shape of the weld joint [22]. But this research is aimed at increasing weld penetration and increase the quality of weld bead shape of a welded joint using MIG welding through the use of flux powders [23]. Also to check the comparative

performances of commercial flux powder with Nano flux powder developed from banana peels (agro-waste)

2.0 METHODOLOGY

2.1 Preparation of the metals

Galvanized, mild and stainless steel were chosen because they commonly used metals in industries for manufacturing, fabrication, construction and reinforcement frames. Before welding takes place, the metals had to be prepared. Sixteen (16) pieces each galvanized and mild steel plates of 60 x 60 x 10 mm, stainless and mild steel rods of 17 x 56 mm length were prepared. Also the stainless and mild steel rods were cut to 50 mm long 16 mm diameter rods and machined into 5mm bell shape respectively as shown in figures 1 and 2 for the purpose of tensile test.



Figure 1: Mild steel rod



Figure 2: Stainless steel rod

2.2 Application of Flux Powder

The faces to be welded were grinded to be very smooth for the best results. The welding fluxes selected includes; developed Nano-flux powder from banana peel (agro -waste) and imported flux powder (control) were introduced using MIG welding. The samples used were welded under three categories; without flux, with control and Nano-flux welding powder.

2.3 Welding

The setup was for MIG welding. The equipment used in welding are shown below in Figure 3. The samples were

divided into two batches (Rods and plates) of which undergone MIG welding (Chauhan and Monika 2017). The joint chosen was butt joint as it is very commonly used. The joints were for similar metals, so it included GS-GS plate as shown in Figure 4, MS-MS plate as shown in Figure 5, MS-MS rod and SS-SS rod as shown in Figure 6. The samples were categorized into three, control (without flux powder), control with commercial flux and Nano-flux powder respectively. The MIG welding parameters used are shown in Table 1.

Table 1: MIG Welding Parameters for the Experiment

METALS	CURRENT (A)	VOLTAGE (V)	ARC GAP	GAS-FLOW RATE
STAINLESS STEEL	40	54	5	8
GALVANIZED STEEL	36	56	5	8
MILD STEEL	42	55	5	8
STAINLESS ROD	35	60	4	7
MILD ROD	34	40	4	7



Figure 3: MIG Welding Equipment



Figure 4: Mild Steel Weld joint



Figure 5: Galvanized Steel



Figure 6: Mild steel rod

2.4 Experimental Analysis

The experimental test was carried out on both the welding flux powder and welded joints of all the samples. The flux powder was firstly subjected to surface morphology test using Scanning Electron Microscopy and Elemental Dispersive X-ray to analyze its composition. The second categories of the test on

the welded joints were tensile and impact using universal testing machine (UTM). Also hardness test using Monsanto hardness testing machine shown in figure 7 to measure the welds resistance to indentation of the three zones; base metal, weld joint and heat affected zone.



Figure 7: Monsanto Testing Machine

3.0 RESULTS AND DISCUSSION

3.1 Scanning Electron Microscopy Test

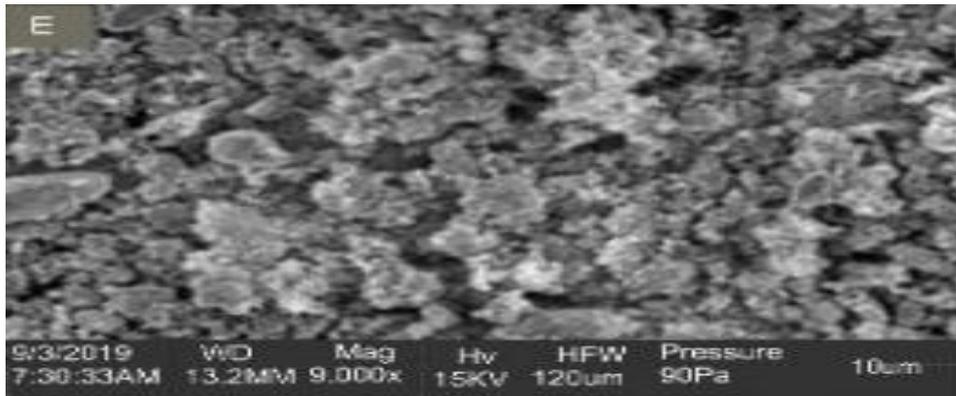


Figure 8: Image of Nano flux welding powder (Banana peels)

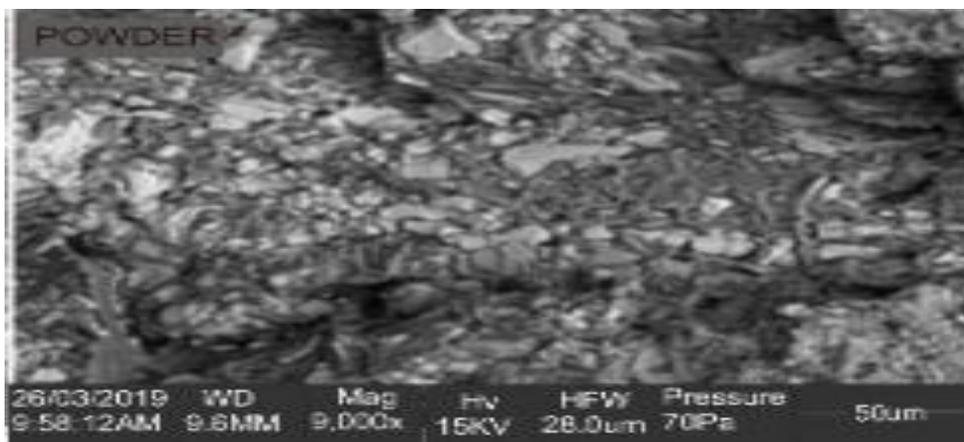


Figure 9: Image of commercial flux welding powder (control)

The figures 8 and 9 showed the image of Nano flux and commercial flux welding powder respectively. The SEM Image presented a lot of coarse and charged particles in both images which is the combination of manganese oxide and iron oxide. However, there are dispersed quartz coupled with some Mn and

Fe based structures in the Nano and commercial flux powder. This confirmed the traits morphological structure of a welding flux powder. This can affirm the suitability of the samples powder as a flux for the welding.

3.2 Elemental Dispersive X-ray

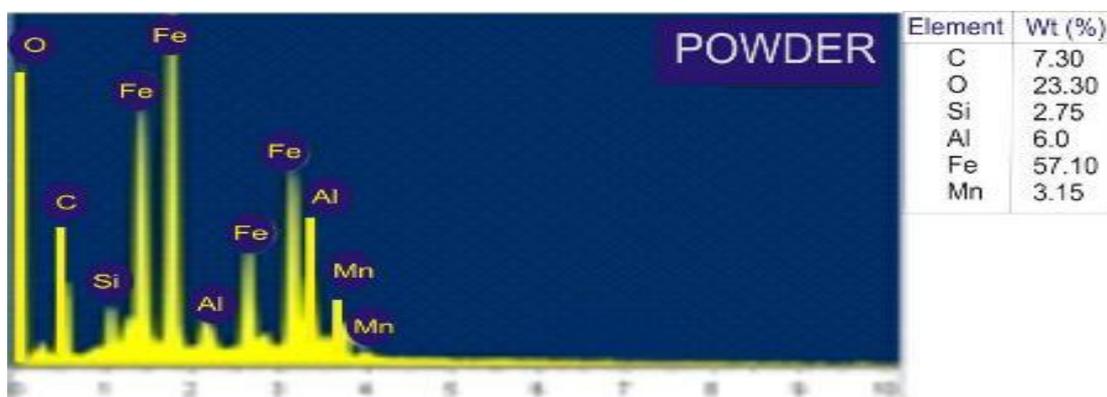


Figure 10: EDS graph of commercial flux welding powder (Control)



Figure 11: EDS graph of Nano flux welding powder

The Energy Dispersive Spectrometer was engaged to analyze the compositional elements as shown in figure 10 and 11. It was observed from the results that the two fluxes both Nano and commercial have high peaks of 23.3% and 38.70% oxygen respectively. The high volume of 57.10% Iron and 29.45% Manganese respectively confirmed that the flux in Figure 10 is Iron oxide (FeO) type of flux while Figure 11 indicated that the flux is Manganese Oxides (MnO) type of flux powder

3.3 Hardness Test

The results show how the weld joints were affected by the variables they were subjected to. Specimen 1 is welded joint for galvanized steel while specimen 2 is welded joint for mild steel.

Table 2: Hardness test for MIG – Specimen A (Galvanized steel)

Samples	Base metal (BHN)	Welded joint (BHN)	Heat affected zone (BHN)
Nano- flux	267.72	181.36	118.56
Commercial flux	247.91	159.91	101.22
Without flux (control)	200.48	131.36	81.67

Table 3: Hardness Test for MIG – Specimen B (Mild steel)

Samples	Base metal (BHN)	Welded joint (BHN)	Heat affected zone (BHN)
Nano- flux	125.76	151.67	156.76
Commercial flux	111.26	112.75	120.50
Without-flux (control)	83.70	86.89	94.22

The results in Tables 2 and 3 show the hardness test using Monsanto hardness testing machine shown in figure 7 to measure the welds resistance to indentation of the three zones; base metal, weld joint and heat affected zone for Specimen A - galvanized steel and Specimen B- mild steel. Considering Table 2 for Samples A-The application of Nano-flux powder gave the best hardness results in all the three zones; base, weld joint and affected zone with 267.72, 181.36 and 118.56 hardness values respectively followed by the samples with commercial flux application of 247.72, 159.91 and 101.22 hardness value respectively. But for the samples welded without flux has 200.48, 131.36 and 81.67 hardness value respectively.

Also in Table 3 Sample B; application of Nano-flux powder gave the highest hardness values in all the zones; base, weld joint and affected zone with 125.76, 151.67 and 156.76 hardness values respectively followed by the samples with commercial flux application while without flux have the least hardness values

The results confirmed that the developed Nano flux powder has the highest value of hardness which enhanced the high hardenability of the welded joints in all the three zones of the mild and galvanized steel and it was also affirmed that the welded joints was harder than the heat affected and base metal zones

3.4 TENSILE TEST

The results show how the weld joints were affected by the variables they were subject to. Specimen 1 (mild steel) is a weld joint between two rods, while specimen 2 (stainless steel) is a weld joint between two rods.

3.4.1 Stress and Strain Graphs

These are the stress and strain graphs for the various weld specimen

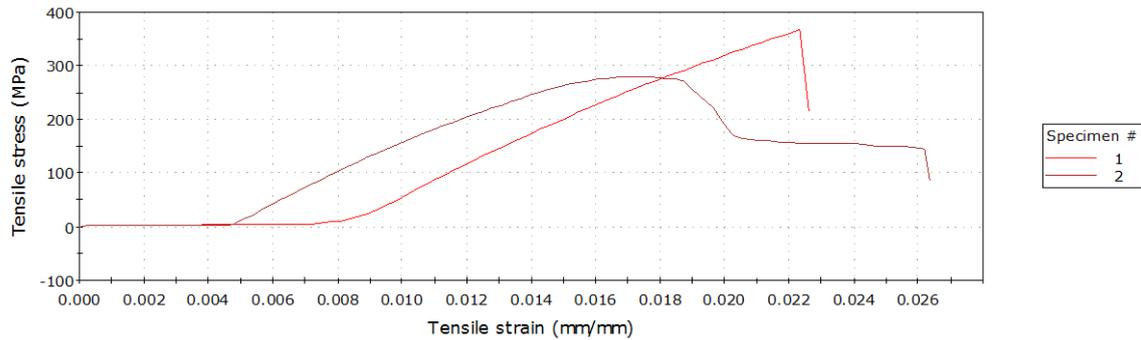


Figure 12: Strain and Strain curve of MIG welding with Specimen 1 and 2 with Nano- flux powder

Figure 12 shows the behavior of joints between two (2) each of mild steel rods (Specimen 1) and stainless steel rods (specimen 2). Specimen 1 possesses a relatively high yield strength closely related to Specimen 2. Specimen 1 experiences a longer phase of no elastic deformation than Specimen 2 does. The constant straight line at the beginning of the graph confirmed it. The yield strength of specimen 1 was slightly higher than that of specimen 2 and it necks with little tensile strain in the joint before fracturing. Specimen 2 experienced 2 phases of necking before fracturing and it mean that specimen 2 was more ductile even with the high yield strength. Specimen 1, due to the high yield strength and little to no plastic deformation can be said to be brittle in nature.

Figure 13 shows the behavior of joint between 2 mild steel rods (specimen 2) and 2 stainless steel rods (specimen 1). Specimen 1 has a high yield strength and little plastic deformation before it necks and then fractures. The quality of high yield strength and little plastic deformation shows that the joint is brittle. Specimen 2 has a high yield strength also, but it undergoes a large phase of plastic deformation before it reaches ultimate strength and then necking begins. This phase of plastic deformation shows that specimen 2 was more ductile than brittle in comparison to specimen 1.

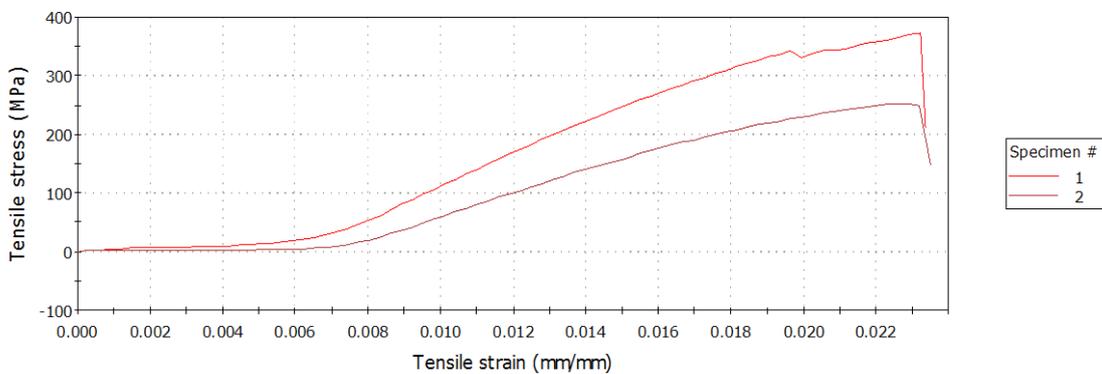


Figure 13: Strain and Strain curve of MIG welding with Specimen 1 and 2 with imported flux

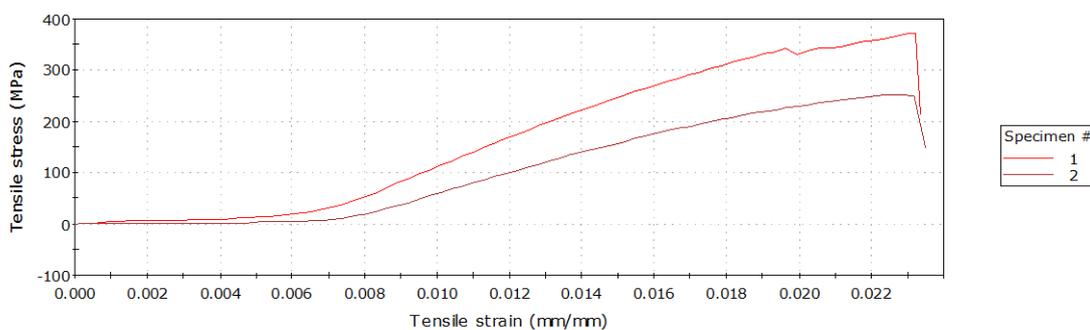


Figure 14: Strain and Strain curve of MIG welding with Specimen 1 and 2 without flux

The behavior of joint between 2 mild steel rods (specimen 1) and 2 stainless steel rods (specimen 2) is shown in Figure 14. Both specimen have similar behaviors on the graph, but the yield strength of specimen 1 is higher than that of specimen 2,

so it means it is more brittle than specimen 2. The two specimen have a small plastic deformation before necking, which shows that they are more brittle than ductile. They experience necking with little increase in tensile strain towards fracture.

3.4.2 Maximum tensile stress

Table 4: Maximum Tensile Stress at the welded joints

Sample (s)	Max Tensile Stress (MPa) Sample A	Max Tensile Stress (MPa) Sample B	Max Tensile Stress (MPa) Sample C
Mild steel	372.58473	366.84846	136.56328
Stainless Steel	278.67173	252.14050	125.95011

The sample A represent welding with application of Nano-flux, Sample B represent welding with application of commercial flux and Sample C represents the welding without any flux. It is shown from the Table 4 that the maximum tensile stress of the joint when Nano flux powder was used in MIG welding were 372.58473 and 278.67173 MPa. The maximum tensile stress of the joint when no flux was used were 136.56328 and

125.95011 MPa. The maximum tensile stress of the joint made using the Nano flux powder was greater than that of when no flux was used. It can also be deduced from the results, that the joint made using Nano flux powder in MIG welding has higher maximum tensile stress than the joint made with commercial flux powder. It can be said that when using the Nano flux powder, it is more efficient with MIG welding.

3.4.3 Maximum tensile strain

Table 5: Maximum Tensile Strain at the welded joints

Sample (s)	Max Tensile Strain Sample A	Max Tensile Strain Sample B	Max Tensile Strain Sample C
Mild steel	0.02323	0.02232	0.01813
Stainless Steel	0.02262	0.01785	0.01697

Table 5 presented the tensile strain results at the welded joint when subjected to tensile test. The sample A represent welding with Nano-flux application, Sample B represent welding with commercial flux application and Sample C represents the welding with no flux. It can be seen that the elongation before

failure was more pronounced in Sample A than any others. Also when no flux was used, the maximum tensile strain was very low compare to others. The experiment has validated that the introduction of flux during MIG welding will increase the elongation of joints rupture when subjected to tensile load.

3.5 Impact Test

Table 6: Maximum loads at the welded joints

Sample (s)	Max Load (J) Sample A	Max Load (J) Sample B	Max Load (J) Sample C
Mild steel	4225.53904	4160.48318	4110.37754
Stainless Steel	3160.45769	2859.56301	1428.4189

As shown in Table 6, Sample A represent welding with application of Nano-flux, Sample B represent welding with application of commercial flux and Sample C represents the welding without any flux. From the results sample A gave the maximum load of 4225.53904 and 3160.45769 J respectively while the Sample C without flux gave the lower impact loads of 4110.37754 and 1428.41898 J respectively. It can be

deduced that the maximum load in specimen A (mild steel) with Nano-flux was highest among the samples during impact test. Also confirmed that the application of flux increased the toughness of the welded joints resulted to high impact for Energy storage at the welded joints of the metals. This shows that application of fluxes during MIG welding has significant impact on the strength and life span of the loading materials.

3.6 SEM Test Results

3.6.1 SEM Image of Galvanized Steel joint with MIG Welding

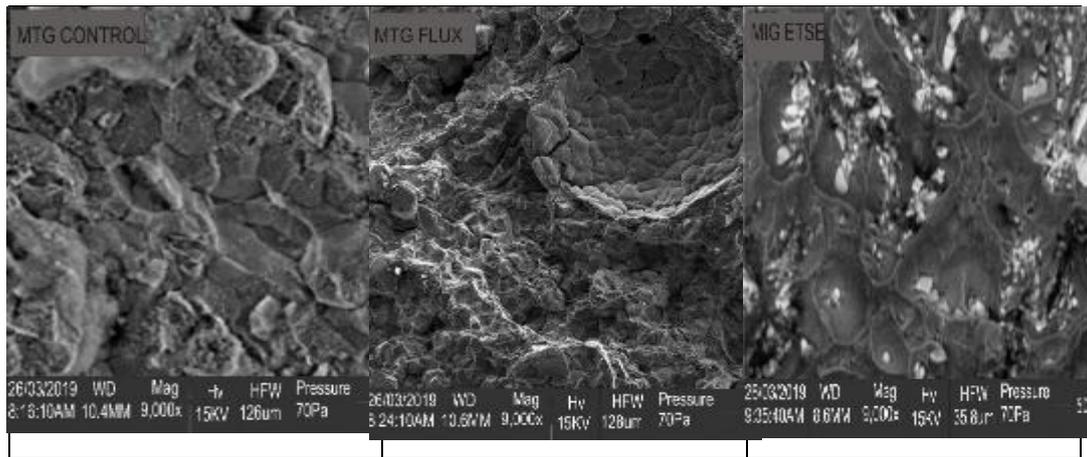


Figure 15: SEM image of galvanized steel joint a) without flux b) with commercial flux and c) with Nano- flux

Large size particles in Figure 15 interlocked together which may be pearlitic and ferritic structures distributed in the matrix uniformly in the control sample. There are coarse particle structures with some degree of alignment within the SEM image of the MIG fluxed sample and it could be cementite. The SEM image of the MIG sample from the Nano flux shows a scattered martensitic phase laced with scattered silicon carbide/silica/ Mn_3C . The joint made with the Nano flux have

a smoother surface with less holes and deep contours than the weld done with the commercial flux. The developed flux weld shows deposits of particles which may be as a result of the use of the flux. The weld done without the use of flux shows a coarse non uniform surface. This confirmed the fine and crystalline arrangement of the internal structures of the welded joint when flux was applied. This in return gave a firm and tight strength.

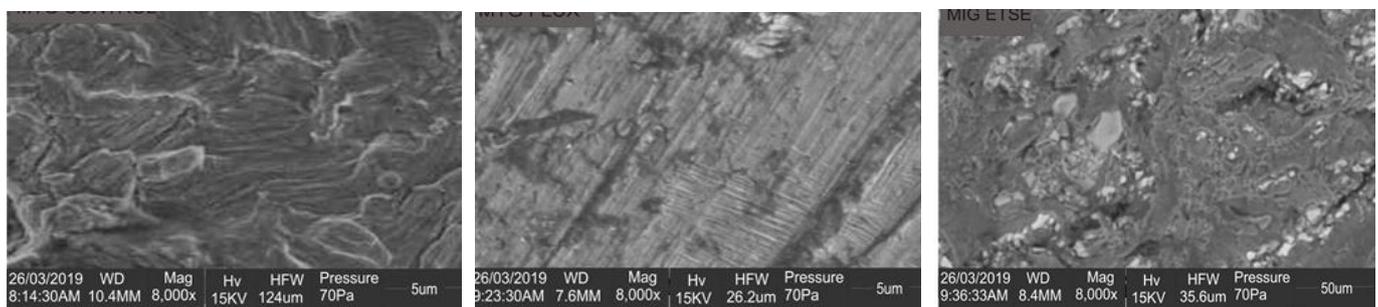


Figure 16: SEM image of mild steel joint a) without flux b) with commercial flux and c) with Nano flux

The microstructure of the control is different from that of the fluxed samples. It can be observed that the grain structure primarily non-epitaxial growth like bridges which may be ferritic structure. According to Figure 16 there were no air holes in the SEM image for commercial flux sample and it was

dominated with more ferritic structure which was the influence of the flux used. The weld done with Nano flux however was smooth and it has some lightly colored deposits and it has overall composition of the weld quality behaviour.

4.0 CONCLUSION

- ❖ The microstructural analysis of Nano and commercial flux powder with the use of Scanning Electron Microscope showed some dispersed quartz sum of Oxygen, Manganese and Iron respectively. This confirmed the traits morphological structure of a welding flux powder and also affirmed the suitability of the samples powder as a flux for the MIG welding.
- ❖ The mechanical properties of the characterization of the produced welds has proven the flux to have better effects in MIG welding of galvanized and mild steel and these effects were more in the Nano flux than the commercial and when no flux applied.
- ❖ It was also observed that application of flux on mild steel joints showed more ductility than brittleness in MIG welding while stainless steel joints showed to be more ductile than brittle when Nao flux was used. This is because of the short phase of plastic deformation for mild steel joint samples in comparison with the stainless steel joints sample.
- ❖ The Morphological analysis results with the use of Scanning Electron Microscope have revealed the microstructural properties of the weld with the application of the Nano flux to have improved the structure, surface and pattern of the welded joint as compared to when flux are not used.

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