Comparative Evaluation of Flux Coated Mild Steel Electrodes in Nigeria

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Abstract

This study presents comparative evaluation on the brands of flux coated mild steel electrodes available in the Nigerian market. There are little or no established scientific facts on why a particular brand of mild steel electrode is given preference to others in usage and cost. Spark, microstructural, microhardness and tensile strength tests of the resultant weldment sample of each electrode brand were comparatively analyzed. The results obtained showed the percentage compositions of the weldment constituents, micrographs and values of tensile strength of adhesion as well as the hardness tests. The comparative analyses revealed that FED electrode (made in Nigeria) weldment exhibited the closest conformity with the expected mechanical and chemical properties of an ideal mild steel electrode weldment, followed by Oerlikon electrode (made in Nigeria under license from abroad) and lastly China electrode (Imported).

Keywords: *Weldment, chemical composition, Oerlikon electrode, tensile strength, mechanical properties.*

1. Introduction

In general, a flux-cored electrode includes an external sheath which encloses a core including a wide variety of fluxes, deoxidizers, and slag-forming ingredients along with alloying metal. Kou (2002) asserted that the flux coated mild steel electrodes are the most popular type of filler metal used in arc welding. The electrode rod is made of a material that is compatible with the base material being welded and is covered with a flux that protects the weld area from oxidation and contamination by producing CO_2 gas during the welding process. The electrode core itself acts as filler material, making separate filler unnecessary. The compositions of the electrode rod contribute to the determination of usability of the electrode, the composition of the deposited weld metal, and the specification of the electrode as suggested by Hong *et al*. (1996).

The formulation of electrode core rod is very complex and while it is not an exact science it is based on well-established principles of metallurgy, chemistry, and physics, tempered with experience. In addition to the core rod basic elemental constituents, alloying elements are added to improve the strength and provide specific weld metal deposit composition.

AWS (1991) asserts that a large number of different flux-cored electrodes have been produced, even when considering only mild steel electrodes for use on mild steel. However, a vast quantity of such electrode is used by industry, particularly in heavy fabrication, the manufacture and repair of construction equipment, ship building, and for offshore structures. Consequently, with regard to various criteria, a need continues to exist for an improved form of such welding electrode by continual appraisal of the products since it is not based on an exact science.

2. Experimental Materials and Equipment

The materials used in this research include: three different mild steel electrode samples sold in Nigerian market, mild steel rod (Ø 12^{mm}), natal and resin powder.

The experimental equipments are: Lathe, grinding/polishing machine, Arc welding machine, Optical microscope, micro hardness tester, and Instron universal mechanical tester.

3. Methodology

3.1 Spark, Microstructural and Hardness Tests

Samples of the three different brands of mild steel electrode of the same diameter size (Oerlikon, FED, and China brands) in Nigeria market were collected. A set of weldment of each electrode were deposited on pieces of mild steel rod using an arc welding machine and all the samples were allowed to cool in air. The resultant weldments were then mounted with phenolic resin on the mounting press for ease of handling on the grinding/ polishing machine as suggested by Carvill (2003). The weldment surfaces were then grinded and polished to smooth mirror surface finish to enhance the microstructure, spark and hardness analysis which were examined using software driven optical metallurgical microscope, micro hardness tester and spectrometer.

3.2 Tensile Test

The tensile tests of the weldment were determined by preparing three circular test samples from a mild steel rod using a lathe. The samples were cut into two equal parts, each welded back with different electrode brands, allowed to cool in air, slightly grinded, and mounted on the Instron universal tester to perform the tensile test.

4. Results and Discussion

The spark result as presented in Table 1 shows the elemental compositions of weldments of the mild steel electrode brands. In theory, as reported by Barrett *et al*. (1973), the carbon content of mild steel is between 0.08% and 0.3%. Only the China electrode falls within this range therefore its usage is expected to be limited to welding only mild steel, interestingly the carbon content of Oerlikon and FED electrodes fall within the range of carbon content of medium carbon steel. This indicates that the usage of both is expected to span mild steel and medium carbon steel applications, because in practice, mild steel electrode is generally used in welding most ferrous metals except in some cases where there is clear understanding of the steel such as cast iron and stainless steel, and most of the steels for fabrication and construction are either mild or medium carbon steels. Increase in carbon content of steel increases the hardness and strength of the steel as suggested by Cottrell (1975), therefore, the hardness and strength values order (starting with the highest) should be: FED - Oerlikon - China. The hardness order as presented in Table 3 is China - FED - Oerlikon while the Strength order as presented in Table 4 is FED - China - Oerlikon. Assessing by amount of deviation from standard, the least deviated (best) is FED, followed by Oerlikon and lastly China.

Table 1. Spark analysis result (Authors' Estimate 2008).

	$\overline{X}_{\text{OERLIKON}}$	$\overline{X}_{\text{(FED)}}$	$\overline{X}_{\text{CHINA}}$
C (%)	0.335	0.458	0.234
Si (%)	0.0386	0.224	0.268
Mn (%)	2.07	0.354	0.84
P (%)	0.029	0.020	0.047
S (%)	0.020	0.028	0.039
Cr (%)	0.284	1.38	0.150
Ni (%)	0.046	0.042	0.068
Mo (%)	<0.0020	<0.0020	0.0051
Al (%)	0.0031	0.0033	0.0030
Cu (%)	0.0370	0.040	0.043
Co (%)	0.010	0.012	0.016
Ti (%)	0.037	0.018	0.016
Nb (%)	0.0081	0.0067	0.0044
V (%)	0.019	0.020	0.012
W (%)	<0.010	<0.010	<0.010
Pb (%)	<0.0030	<0.0058	<0.0073
B (%)	0.0007	0.0012	0.0010
Sn (%)	0.058	0.063	0.040
Zn (%)	<0.0020	<0.0020	<0.0020
As (%)	0.0090	0.0080	0.013
Bi (%)	<0.0020	<0.0020	<0.0020
Ca (%)	0.0006	<0.0001	0.0006
Ce (%)	<0.0030	<0.0030	<0.0030
Zr (%)	<0.0015	0.0016	<0.0030
La (%)	0.0011	<0.0010	<0.0010
Fe (%)	96.6	97.3	98.2

Higgins (1993) stated that alloying elements generally without exception increase the hardenability of steel as well as the strength. Therefore, as presented in Table 2 with reference to the amount of carbon content percentages, the hardness and strength values order (starting with the highest) should be: FED - Oerlikon - China. The Hardness order as presented in Table 3 is China - FED - Oerlikon while the Strength order as presented in Table 4 is FED - China - Oerlikon.

Table 2. Summary of spark analysis result (Authors' Estimate, 2008).

	Carbon (%)	Alloys (%)	Iron(Fe) (%)
$\overline{X}_{Oerlikon}$	0.335	3.065	96.6
$\overline{X}_{FED}$	0.458	2.252	97.3
$\overline{X}_{China}$	0.234	1.566	98.2

Table 3. Hardness values (Authors' Estimate, 2008).

Sample	HV
China electrode weldment	260.5
FED electrode Weldment	244.8
Oerlikon electrode weldment	204.1

Table 4. Tensile Test result (Authors' Estimate, 2008).

Sample	Tensile stress at maximum load (MPa)	Extension (mm)
FED	544.64	4.66
China	484.44	3.12
Oerlikon	355.19	1.91

Assessing by amount of deviation from standard, the least deviated (best) is FED, followed by Oerlikon and lastly China. Based on the carbon contents of the electrodes and expected effect of the alloying elements, the value of the extension (measure of ductility) order (starting with the highest) should be: FED - Oerlikon - China. The result of ductility order as presented in Table 4 is FED - China - Oerlikon. Assessing by amount of conformity with standard, the best is FED, followed by China and lastly Oerlikon.

Plate 1 shows the microstructure of the mild steel rod (core) that served as the control. It revealed the even distribution of ferrite within pearlite matrix. Plate 2 shows the microstructure of FED weldment with more proportion of ferrite than pearlite. It could be assumed to be in ratio 55%:45% as suggested by Ashby and Jones (1998). The micro-structure represents a feathery – like pattern similar to the formation of a lower bainitic structure as suggested by Brick *et al*. (1977).

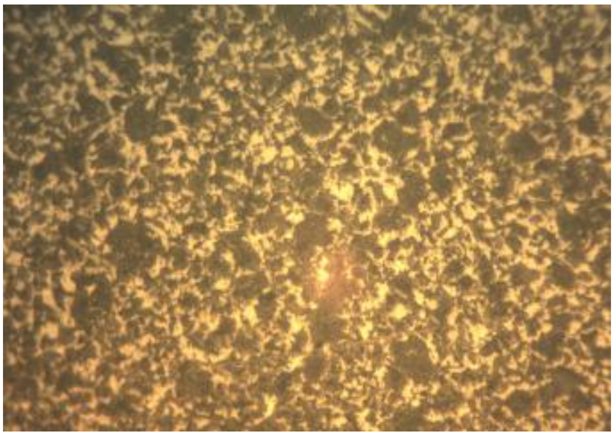

Plate 1. Microstructure of mild steel rod (Control) (X 400) (Authors' Estimate, 2008).

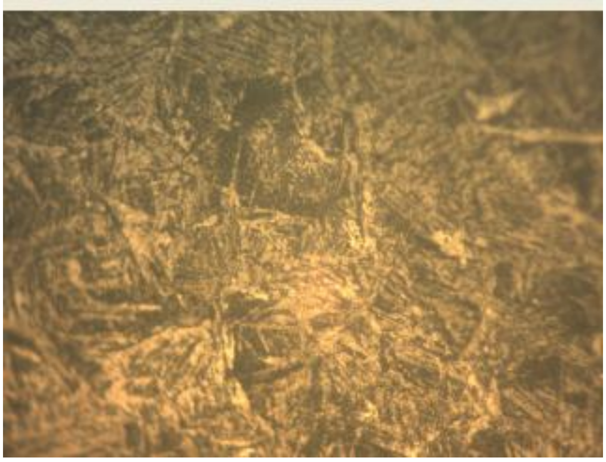

Plate 2. Microstructure of FED weldment (X 400) (Authors' Estimate, 2008).

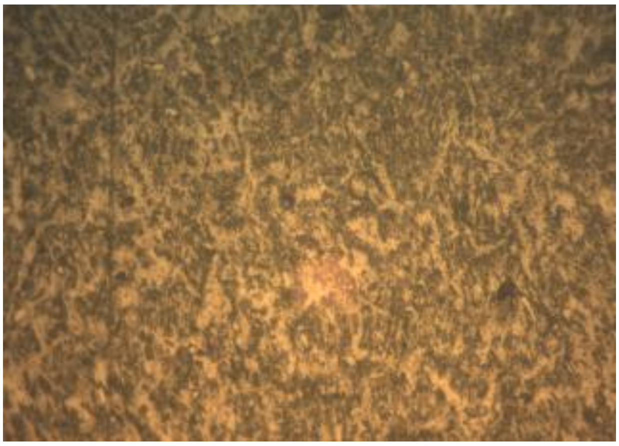

Plate 3. Microstructure of China weldment (X 400) (Authors' Estimate, 2008).

This is responsible for the moderate hardness as well as the improved ductility of the weldment. Plate 3 shows the microstructure of China weldment with more proportion of pearlite than ferrite. However, it should be noted that the proportion of ferrite in the China weldment is higher than in the control sample.

The presence of more ferrite when compared to the control (core rod) can be attributed to its relatively lower hardness value but improved ductility. Plate 4 shows the microstructure of Oerlikon weldment with predominance of pearlitic structure and little ferrite. Hence, improved hardness but low ductility was observed.

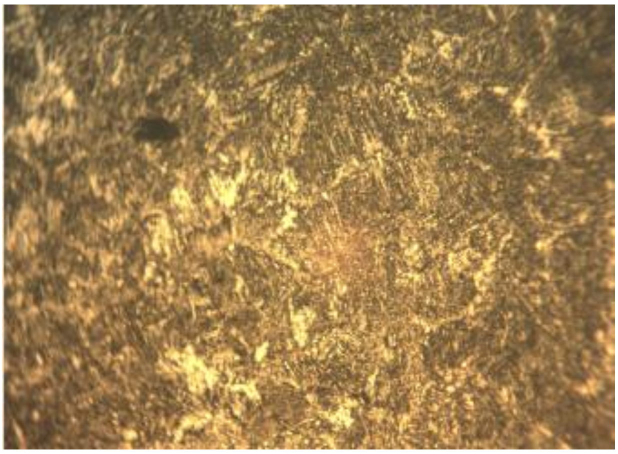

Plate 4. Microstructure of Oerlikon Weldment (X 400) (Authors' Estimate, 2008).

5. Conclusion

Relative evaluation of combination of spark test, hardness test, tensile strength of adhesion and microstructure of the weldments of the mild steel electrode brands in the Nigerian market have been assessed in this research work, and being concluded based on the tests results that FED electrode weldment exhibited the best chemical and mechanical properties in consonance with theoretical expectations and experience. This study therefore deems the FED electrode (purely manufactured in Nigeria) as the best Mild Steel electrode in the Nigerian Market, followed by the Oerlikon electrode (Manufactured in Nigeria under license from abroad) and lastly the China electrode (Manufactured in China). Interestingly, the FED electrode is less than five years old in the Nigerian market but its market price and usage is more than that of china electrode which has been in the market before it. Its market price with usage is less than that of Oerlikon electrode that has been in market for decades. Through such a scientific revelation as presented by this study and improvement/ maintenance of quality, FED electrode will soon take the market lead and make consumers believe more in made in Nigeria products.

This study is expected to kindle further significant research interest in the area of quality assurance of engineering materials as such will assist Standard Organization of Nigeria in her bid to evaluate the suitability of engineering material in Nigerian market for different engineering applications.

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7. References

Ashby, M.F.; and Jones, D.R.H. 1998. Engineering Materials. Vol. 2: An Introduction to Microstructures, Processing and Design. 2nd ed., Butterworth-Heinemann, Oxford, UK.

AWS. 1991. Welding Handbook. Vol. 2: Welding Processes. 8th ed., American Welding Society (AWS), Miami, FL, USA.

Barrett, C.R.; Nix, W.D.; and Tetelman, A.S. 1973. The Principles of Engineering Materials. Prentice-Hall, Englewood-Cliffs, NJ, USA.

Brick, R.M.; Pense, A.W.; and Gordon, R.B. 1977. Structure and Properties of Engineering Materials. 4th ed., McGraw-Hill, Montreal, Quebec, Canada.

Carvill, J. 2003. Mechanical Engineer's Data Handbook. 2nd ed., Butterworth-Heinemann, Oxford, UK.

Cottrell, A. 1975. An Introduction to Metallurgy, 2nd ed., E. Arnold, London, UK.

Higgins, R.A. 1993. Engineering Metallurgy. Part I: Applied Physical Metallurgy. 6th ed., E. Arnold, London, UK.

Hong, K.; Weckman, D.C.; and Strong, A.B. 1996. Trends in Welding Research. ASM International, Materials Park, OH, USA, pp. 399-404.

Kou, S. 2002. Welding Metallurgy. 2nd ed., John Wiley & Sons, Inc., New York, NY, USA.