PRODUCTION OF MANUAL METAL ARC WELDING ELECTRODES WITH LOCAL RAW MATERIALS

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ABSTRACT

Manual arc welding using flux coated electrodes is carried out by producing an electric arc between the base metal and a flux covered metal electrode with electric current that depends on the type of electrode, material, welding position and the desired strength. The composition of flux coated electrodes is complex and a variety of coatings were used to cater for different types of welding applications. However, in all cases, the coating is formulated to satisfy three major objectives: to form fusible slags, to stabilize the arc and to produce an inert gas shielding during welding. In the research carried out, several flux samples of various local raw materials were collected, their chemical compositions were determined and the results utilized in producing manual metal arc electrodes. The electrodes produced were used to carry out welds on mild steel sections. The basic characteristic test criteria for determining the performance of any electrode were carried out. The samples of the weld metals were analyzed to determine the homogeneity of the chemical composition as a result of the flux coating, welding rod, and base plate materials. It was observed that manganese based flux covered electrode (a local electrode) with tensile strength of 585.8 N/mm^2 was able to compete effectively with titanium dioxide based electrode (a foreign electrode) with tensile strength of 606.7N/mm^2. This research work therefore, highlights the need to maximize the use of local raw materials aimed at reducing the cost of importation and thereby help in conserving scarce foreign exchange.

***Keywords**: Arc welding, Electrode, Raw Materials, Flux, Weld Metals.*

1.0 INTRODUCTION

The objective of welding is to join pieces of metals together by means of suitable heat source (Lancaster, 1993). The heat source should be capable of providing enough heat and sufficiently high temperature to melt the metals to be joined, with additional metal (in liquid form) being added. Whereas in brazing, soldering and solid-phase welding, a bond is formed without any bulk melting of the parts to be joined, fusion welding relies upon such melting and joints are made by fusion and running together adjacent edges or surfaces. The resulting joint should have approximately the same chemical composition and mechanical properties as those of the metal being joined. The complete weld metal and metal pieces having been joined should now, to all intents, be one piece of metal (Somsky, 1986). The earliest fusion welding technique, known as flow welding has been practiced since the early bronze age. A mould was made around the two bronze parts to be joined, and the molten bronze poured between and sometimes around them. This method was used for repairing swords and it was also employed for the fabrication of a bronze chariot discovered in 1980 near the tomb of the Chinese Emperor Qin Shi Huang (Lancaster, 1993). Current fusion welding techniques rely on the use of a heat source that is intense enough to melt the edges as it transverse along a joint. Such heat source first becomes available on an industrial scale at the end of 19th century, when gas welding, arc welding and resistance welding all made their appearances, (Uzoukwu, 2000). Arc welding with a fusible electrode (the most important of the fusion process) is more complex in character and developed more slowly. Initially, bare wire electrodes were used, but the resulting weld bead was high in nitrogen and oxygen content and therefore brittle. Wrapping the wire with asbestos or paper improved the properties of the weld deposits and led eventually to the modern type of arc welding electrodes, which are coated with a mixture of minerals, ferro-alloys and in some cases organic materials, bonded with sodium or potassium silicate (Lancaster, 1993). Different types of electrodes exist, each with its own covering materials. For examples, titanium based-electrode which is also a foreign electrode is composed of 40% titanium oxide, 10% Calcium Carbonate ($CaCO_3$), 10% ferro alloys, 5% potassium, 3% feldspar, 2% mica and minute amount of nickel, silicon, chromium, sulphur, molybdenium, celluslose, starch and dextrin. Some special electrodes have metallic salts included in the flux to add alloying substances to the weld metal. A good flux covered electrode can produce a weld that has excellent physical and chemical properties (Miller, 1997).

In the arc process, the covering changes to neutral or reducing gases such as carbon monoxide or hydrogen. These gases as they surround the arc proper prevent air from coming in contact with the molten metal (Zimmer et al, 2002). For example, they prevent Oxygen which may approach the molten metal and prevent it from combining with it. The gases usually do not protect the hot metal after the arc leaves the weld point. The covering also contains special fluxing ingredients which promote fusion and tend to remove impurities from the molten metal (Somksy, 1986).

As the electrode flux coating residue cools, it forms a coating of materials over the weld. This residue coating prevents the air from the hot metal. This coating over the molten metal forms slag. In addition to the filler metal to the weld pool, electrode flux serves the following functions:

(i) It adds alloying ingredients to the weld metal and area in order to change the physical properties.

(ii) It establishes the polarity and electrical characteristic of the electrode.

(iii) It produces a gas, which shields the base metal molten pool and weld bead from oxidation during welding.

(iv) It provides fluxing agents, impurity scavengers and deoxidizers to clear the pool.

(vi) It produces a solidified covering (slag) over the hot weld area, which prevents oxidation.

(vii) The slag covering permits the weld metals to cool slowly, thus preventing a hard brittle weld.

2.0 MATERIALS AND METHODS

2.1 Materials

In the production of manual metal arc welding electrodes with local raw materials, seven flux materials were obtained. These materials were Starch, Potasium Chloride (KCl), Calcium Carbonate ($CaCO_3$), Manganese (Mn), Slag, Silicon (Si) and Iron (III) Oxide (Fe_2O_3). Starch was obtained from National Root Crops Research Institute, Umudike, Abia State, Nigeria. Others were obtained from Aladja steel complex, Aladja Delta State all in Nigeria.

Binding Material

Starch is used as the binding material for the local electrode production. The bonding is an interfacial adhesive one, which is a chemical bond across the interface between one component and another (Bosworth and Deam, 2000). The starch binds the flux materials together and also serves as a bond between the flux materials and the core wire. Starch is a carbohydrate that occurs as discrete, partially crystalline granules in the seeds, root (tubers), stems (pith), leaves, fruit and pollen grains of higher plants. Starch functions as the main storage or reserve form of carbohydrates. Cereal grains for example, maize (corn), are often steeped first to loosen the starch granules in the endosperm matrix, followed by wet grinding or milling. In other plants, roots and tubers are ground to give a suspension containing starch granules. This is then followed by sieving, washing, centrifuging, dewatering and drying.

2.2 Methods

These materials were mixed in a particular proportion without the starch as indicated in table 1. Then 25% by volume of an already prepared liquid starch (binder) was added to the dry mixture and thoroughly mixed up until a thick paste resulted. The paste was coated on a bare wire, in this case manually by means of a permanent mould casting with the wire forming the core. It is allowed to cure and the mould removed. An electrode has been formed. A regulated temperature of 27^{o}C is necessary for the drying to avoid cracking. Five different electrodes were produced by this method (table 1). The type of electrodes produced depends on the composition. The material constituent that has the highest percentage in the composition of the mixture determines the name of the electrode. For example, if in a particular mixture $CaCO_3$ has the highest percentage composition (40%, say) then the resulting electrode will be named calcium carbonate based electrode.

Table 1: Different Electrodes and their Percentage Compositions

Base flux (40%)	**Composition**	**Respective percentage composition by volume (%)**
Silicon	$CaCO_3$, KCl, Slag, Mn, Fe_2O_3, Starch	25, 3, 2, 3, 2, 25
KCL	Mn, Si, $CaCO_3$, Fe_2O_3, Slag, Starch	15, 10, 5, 2, 3, 2, 25
C_aCO_3	Si, Mn, Fe_2O_3, KCl, Starch	15, 10, 5, 5, 25

Manganese	Si, Slag, Fe_2O_3, $CaCO_3$, KCl, Starch	5, 7, 3, 5, 15, 25
Slag	Mn, Si, $CaCO_3$, Fe_2O_3, KCl, Starch	10, 5, 15, 3, 2, 25

3.0 RESULTS AND DISCUSSION

The weld metal of each of the electrodes was subjected to a tensile test using Housfied Monsanto tensiometer and the results of the test are as presented in table 2. From this table, the tensile strength of each electrode (4mm X-section) was obtained and presented in table 3. Visual inspection of the weld metals from the five local manual metal arc electrodes, four samples per electrodes indicated a good weld of manganese, silicon and potassium chloride based electrodes, while those of $CaCO_3$ and slag left behind noticeable cracks on their weld metals. This is because of their brittle nature due to high carbon content. They also have little tendency to promote fusion and removing impurities from the molten metal.

In table 2, it should be noted that for all the electrodes, their individual stresses increase from first row to the tenth row (the ultimate stresses) beyond which they decrease to their fracture stresses as represented by the twelfth row. Between row ten and twelve, the weld metal samples "neck" (reduce in their X-sectional areas). This means that the tenth row represents the highest stresses (strengths) the electrodes can withstand.

Table 2: Tensile Test Result of the Weld Metals

S/N	TiO_2 (foreign electrode)		Manganese electrode		KCl electrode		$CaCO_3$ electrode		Silicon electrode		Slag electrode	
	Stress	Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress	Strain	Stress	Strain
	(N/mm^2)	($x10^{-4}$)	((N/mm^2)	($x10^{-4}$)	(N/mm^2)	($x10^{-4}$)	(N/mm^2)	($x10^{-4}$)	(N/mm^2)	($x10^{-4}$)	(N/mm^2)	($x10^{-4}$)
1	68.9	3.3	47.9	3.2	26.8	3.1	16.5	2.9	32.8	3.0	6.8	2.7
2	137.9	9.9	116.8	6.5	53.9	6.4	32.7	6.2	101.8	6.3	22.5	6.0
3	206.8	9.9	185.6	9.4	122.8	9..3	101.9	9.0	170.6	9.6	91.8	8.8
4	275.8	13.2	254.5	12.8	191.8	12.7	170.5	12.5	239.2	12.9	160.5	12.3
5	344.7	16.5	323.4	16.2	260.7	16.1	239.2	15.9	308.5	16.2	229.7	15.7
6	413.8	25.0	393.7	24.2	329.7	24.0	308.7	23.8	377.7	24.7	298.4	23.7
7	448.0	46.0	427.1	45.5	364.0	45.3	343.0	45.1	412.1	45.7	333.0	449
8	499.9	51.0	478.6	49.6	415.9	49.4	394.5	49.2	463.6	50.7	384.1	49.0
9	551.6	86.0	530.5	85.2	467.6	85.0	446.6	84.8	515.6	85.7	436.5	84.6
10	606.7	113.0	505.8	112.3	522.4	112.1	488.7	111.9	570.8	112.7	478.2	111.7
11	594.7	161.5	573.8	160.8	510.7	160.5	475.7	160.3	558.5	161.2	465.7	160.1
12	593.0	170.0	5721.1	169.2	509.1	168.8	470.4	168.5	557.1	169.7	460.4	168.3

Table: 3 different weld metals and their ultimate strengths

Electrode	Ultimate (N/mm^2)
1. Titanium dioxide (foreign electrode)	606.7
2. manganese	585.8
3. Potassium chloride	522.4
4. calcium carbonate	488.7
5. silicon	570.8
6. slag (CaS_iO_3-Na, Mg)	478.2

4.0 CONCLUSION

The covering of an electrode affects the mechanical properties of the resulting weld metals. However, titanium dioxide based electrode (a foreign electrode) is able to yield the best performance in terms of strength and visual appearance of the weld metal because it was produced with a more ideal chemical composition than the local ones. It also has the best ability to expel atmospheric oxygen from getting in contact with the weld bead. Chances of slag inclusions, porosity and hydrogen embrittlement in the finished weld are very low with titanium dioxide. In this research work, the weld metal of manganese based flux electrode with a tensile strength of 585.8N/mm^2 has a very close tensile strength with the foreign electrode having a tensile strength of 606.7N/mm^2. Thus, the attempt to look for a local substitute for engineering materials in a developing nation is highly encouraged as it will go a long way in conserving scarce foreign exchange.

However, the unit price (x10 per electrode) of these locally made electrodes is certainly going to increase their demand compared to the foreign ones sold at twenty naira (x20) per electrode.

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