Paper from Proceeding of the National Conference on Innovative Developments in Science, Technology & Management (NCIDSTM-2015) Organized by Ganga Technical Campus, Soldha, Bahadurgarh, Haryana (India) March 1st 2015 Published by International Journal of Engineering Sciences Paradigms and Researches (IJESPR) with ISSN (Online): 2319-6564, Impact Factor: 2.20 and Website: www.ijesonline.com

A Study on SMAW by Varying the Concentration of Calcium Flouride (CaF_2) in Metal Cored Flux Coated Electrode

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Abstract

Mild steels are widely used in various structural and fabrication applications like Bridges, buildings, machineries etc. Being very common and general purpose structural steel, it is widely applied to welding all over the world. A variety of electrodes are available globally for welding of mild steel, but the development of new electrodes is always a necessity.

This paper aims to find out the influence of varying concentration of Calcium Fluoride in the flux composition on the various characteristics of metal cored coated electrodes for the purpose of developing efficient and better rutile electrodes for structural mild steel. The information about the effects of CaF_2 on the electrodes characteristics is scarce in international welding literature. In this work five rutile metal cored coated electrodes were prepared by increasing Calcium Fluoride (CaF_2), at the expense of cellulose and Si-bearing components like Mica and Calcite in the fluxes. Various mechanical properties like micro hardness, tensile properties and Impact toughness

were measured . Qualitative measurements of operational properties like porosity, slag detachability, arc stability and smoke level were also carried out.

Keywords: *SMAW, Mild steel, Metal cored flux coated electrodes.*

1. Introduction

Welding is a fabrication process that joins materials permanently, usually similar or dissimilar metals by the use of heat causing fusion with or without the application of pressure. Shielded metal arc welding (SMAW)is used in ship and various other industries due to its high deposition rate and low cost. The operation of SMAW is shown in Fig1 as below:

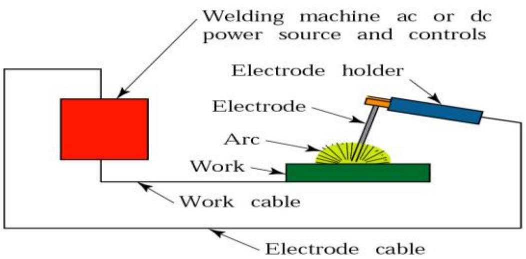

Fig. 1. SMAW Operation

The SMAW is done with the help of metal cored flux coated electrodes consisting of the core wire with a covering of coating material called flux. The diameter of electrodes usually varies between 3.15 to 12.50 mm with the intermediate standard diameters being 4.00, 5.00, 6.30, 8.00 and 10.00 mm. The length of these electrodes varies between 350 to 450 mm with bare portion ranging between 20 to 30 mm wherefrom it is held in an electrode holder. Electrode coatings can consist of a number of different compounds, including rutile, CaF_2, TiO_2 , cellulose, and iron powder. Carbon steels containing from about 0.15 to 0.30% carbon are commonly called mild steels. Under bead cracking or lack of toughness in the heat affected zone usually is not encountered when welding mild steels containing no more than 0.20% carbon and 1.0% manganese. Such steels can be welded without preheat, post heat or special welding procedures when the joint thickness is less than 1.0 in. (25.4 mm). The weldability of the mild steel is considered to be good. In general, heat treated mild steels are arc welded without preheat. However, preheat should be used when the metal temperature is below about 10 ^{o}C, and preheat of about 38 ^{o}C is used if plate thickness is over 1 inch. Although many studies have been done on the effects of varying constituents of metal cored flux coated electrodes yet an improved quality of electrodes can be produced by taking a suitable percentage of CaF_2 in the contents of these electrodes. In this experiment five different electrodes were produced with a varying percentage of CaF_2 from 2.5 to 12.5 by weight. And their effects on the weld bead were studied.

2. Experimental Procedures

The steps undertaken for the accomplishment of the experiment include the production of electrodes, extrusion of electrodes, preparation of test coupons, micro hardness testing, tensile strength testing, impact strength testing and microstructure testing of the weld beads produced by five new developed electrodes.

2.1 Process of Electrode Production

The dry coating ingredients were weighed and were mixed appropriately for around 10 minutes to obtain a homogeneous dry flux mixture. A liquid silicate binder was then added to the dry flux mixture, followed by mixing for further 10 minutes. The binder consists of a complex mixture of different alkali silicates with a wide range of viscosities.

The common flux coating ingredients are Fluxing agents (Silica, CaO3, and Calcium Fluoride), Slag formers (Rutile, Titania, potassium titanate, Asbestos, Alumina, Silica floor, iron oxide, Calcium Fluoride etc.), Arc stabilizers (potassium, Silicate, potassium oxalate, Zirconium carbonate, Lithium carbonate, Titania etc.), Gas forming materials (Cellulose, Wood Floor, Lime Stone), Slipping agents for easy extrusion (Glycerin, China Clay, Talc, Mica etc.), Binding agents (Sodium Silicate, Dextrin, potassium Silicate, Sugar), Deoxidizers and alloying elements (Ferrosilicon, Ferro-chromium, Ferromanganese, electro-nickel, Electro manganese etc.)

The flux was then extruded onto a 3.15 mm diameter mild steel core wire and coating diameter of 5 mm, coating factor of 1.58, where the coating factor represents the ratio of the core wire diameter to the final electrode diameter.

The electrodes were baked after the extrusion. The baking cycle consisted of 30-40 minutes at 120°C. These electrodes were tested by taking weld bead on plates and finally 5 types of flux coating composition were obtained by varying the Calcium Fluoride (CaF_2) from 2.5 to 12.5 wt% at the expense of cellulose, Calcite, and Si-bearing raw materials in the dry mix.

2.2 Operational Parameters

The operational behavior of the five electrodes is studied using an Inverter based-DC 400 ampere power supply set.

Table.1. Welding Parameters for the Test Specimen

Parameters	2.5% CaF2	5% CaF2	7.5% CaF2	10% CaF2	12.5% CaF2

Current(A)	**145**	**145**	**145**	**145**	**145**
Voltage(V)	**25**	**25**	**25**	**25**	**25**
Welding Speed(mm/s)	**3.7**	**3.7**	**3.7**	**3.7**	**3.7**
Heat Input(KJ/mm)	**1.1**	**1.1**	**1.1**	**1.1**	**1.1**

2.3 Test Coupon Preparation

The plates of dimension 480mmx150mmx10mm were machined on Shaper and V groove angle of 60^o and root face of depth 2mm was cut using shaper. These plates were then cleaned with acetone and then welded using the electrodes developed by varying Calcium Fluoride compositions. The weld beads with various composition of Calcium Fluoride coating were laid on the test plates of size (100mm×40mm×5mm). The transverse cut samples obtained from the weldments were etched with 5% Nital for cleanliness to examine the bead geometry. The vernier caliper gauge was employed to measure bead width and penetration of the bead.

3. Results and Discussion

3.1 Slag Properties

The slag properties by all of the flux coatings are of good quality i.e. all of them covered the bead completely. The bead was in good shape and cleans after the removal of slag. The slag produced by 12.5 % CaF2 flux was observed to interfere with the weld pool in both of the current conditions i.e. DCEP and DCEN.

On the other hand the 2.5 %, 5 %, 7.5 % and 10 % CaF2 slag did not interfere with the weld pool and the weld beads obtained by these electrodes were smooth and clean.

3.2 Spatter

The spatters produced in DCEP welding were observed to be more than in DCEN welding. Further it was observed that in DCEP 10 % and 12.5 % CaF2 electrodes produced more spatters than in other electrodes. In General, the spatters were easy to remove and were of medium size.

3.3 Weld Bead Properties

The results of bead properties showed that the bead produced with all types of electrodes for both types of current was good in shape, but the beads produced by 7.5% and 10% CaF_2 electrodes was the best in shape and penetration.

3.4 Micro Hardness Measurement

The micro hardness results obtained from all electrodes weld metals are shown in Table 5.5 and 5.6 for DCEP and DCEN respectively. The micro hardness was measured at five points on each sides of the weld bead including the weld bead itself on a specimen i.e.

1. At the center of the weld bead
2. At a distance of 3 mm from weld bead in HAZ
3. At a distance of 6 mm from weld bead in HAZ
4. At a distance of 9 mm from weld bead in HAZ
5. At a distance of 12 mm from weld bead.

In each zone, it is observed that the micro hardness is increased as the percentage of CaF_2 is increased. The variations of micro hardness w.r.t. CaF_2 are shown in figures 3.4.1 to 3.4.5. This may be due to the increase in carbon and silicon with increase in CaF_2

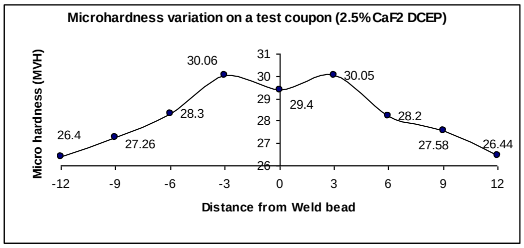

Fig.3.4.1 Micro hardness variation along the test coupon 2.5% CaF_2

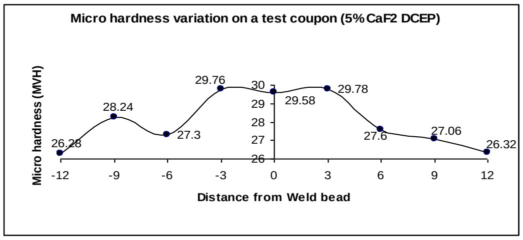

Fig. 3.4.2 Micro hardness variation along the test coupon 5% CaF_2

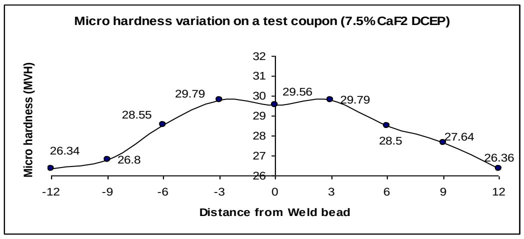

Fig.3.4.3 Micro hardness variation along the test coupon 7.5% CaF_2

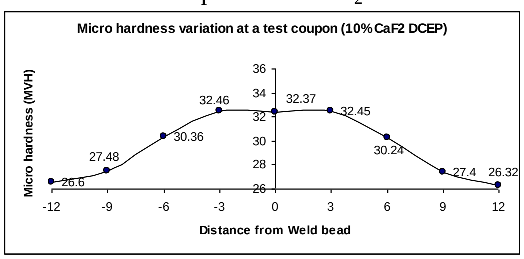

Fig.3.4.4 Micro hardness variation along the test coupon 10% CaF_2

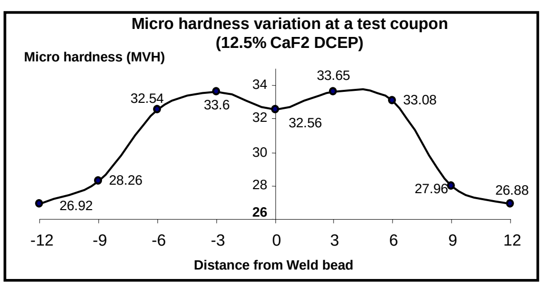

Fig. 3.4.5 Micro hardness variation along the test coupon 12.5% CaF_2

3.5 Tensile Properties

An overall reduction in tensile strength is noticeable as the percentage of CaF_2 is increased with an increase in micro hardness.The elongation is also decreased with decrease in tensile strength.

The variations of tensile strength w.r.t. percentage of CaF_2 are shown in figure 3.5.1

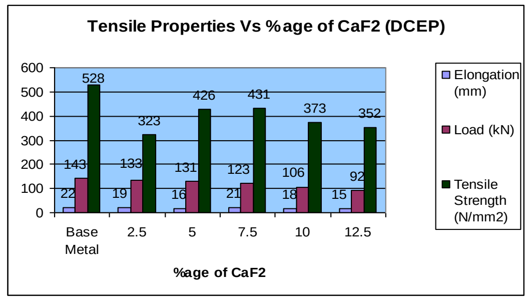

Fig. 3.5.1 Histogram for Tensile Properties

3.6 Charpy V Notch Impact Test Results

Charpy V notch test samples were prepared for the impact strength measurements. These test coupons were dipped in liquid nitrogen to drop their temperature from room temperature to -30°C, -20°C,-10°C and 0°C by varying the dipping time of test coupons in the liquid nitrogen.

The results showed that the toughness of the weld coupon increases as the percentage of CaF_2 is increased. The variations of impact energy with temperature for DCEP is shown in figure 3.6.1. Toughness is related to the hardness and tensile properties of the material. The toughness of the weld metal is reported to be increased with a reduction in tensile strength of the weld coupon and an increment in toughness is also observable with an increment in micro hardness of the weld coupon.

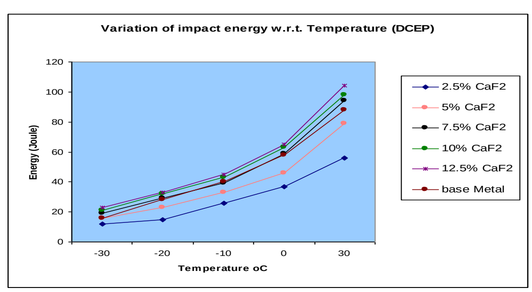

Fig. 3.6.1 Energy Vs Temperature graph of impact Test Results

3.7 Smoke Test Results

All the five electrodes are tested for smoke level produced during the welding process. As the CaF_2 is generally known as the smoke reducer among the coating ingredients; it is observed that the coatings having 10% and 12.5% CaF_2 produce lesser smoke as compared to that of coatings containing 2.5%, 5% and 7.5% of CaF_2.

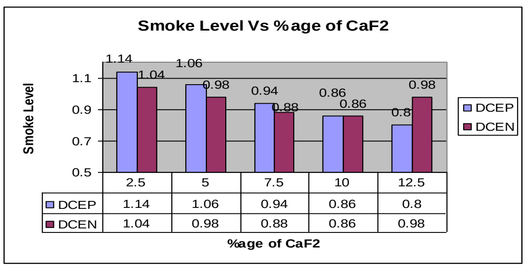

Figure 3.7.1 Smoke Level Vs Percentage of CaF_2

4. Conclusions

The composition of an electrode was modified by varying the percentage of Calcium Fluoride (CaF_2) in the flux coating. The study of the weld metals produced by these electrodes was made. Following results are observed during the above study:

1. The penetration and bead width was increased with increase in CaF_2 percentage in general for all types of electrodes and for both types of current conditions.
2. The arc stability is observed to be good for 5% and 7.5% CaF_2 electrodes. For all electrodes, DCEN welding shows better arc stability. Smoke level was seemed to be reduced at higher percentage of CaF_2. Slag detachability was generally good for all electrodes.
3. An overall increase in the Micro Hardness at the weld bead was observed with the increase in the amount of CaF_2. The same is also observed to be reduced when measured from the weld bead through the HAZ to the base metal for all types of electrodes and welding currents. The micro hardness is observed to be increased due to the increase in percentage and migration of carbon and silicon.
4. An overall decrease in the tensile strength was observed with the increase in CaF_2. The increment in silicon resulted in reduction in the tensile strength of the weld metal. Tensile strength is related with the hardness of the material in a way that the increase in hardness of the weld metal results in decrease in tensile strength.
5. The toughness of the weld metals was observed to be increased with an increase in the percentage of CaF_2. However, the same is seemed to be reduced with the decreasing temperature for all electrodes and welding currents.
6. A reduction in smoke level was observed with increase in amount of CaF_2. This reduction was due to the reduction in the percentage of cellulose. Coatings with 10% and 12.5% CaF_2 produce lesser smoke as compared to that of coatings containing 2.5%, 5% and 7.5% of CaF_2.

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