Investigation of Fecraly Coating on Corrosion Behaviour of Mild Steel

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Abstract

Steel has found wide application in hot rolling equipments in the steel industry and the oil rig structures in sea water. These equipments are frequently subjected to corrosive and temperature condition which causes severe damage to them, hence the need to develop steel suitable to withstand these conditions in terms of surface treatment. This research work investigates the effect of FeCrAlY coating on mild steel under high temperature and aggressive environment. Iron based coatings are used due to low cost among other properties such as good corrosion resistance, ease of machining and high ductility when compared to hard metals.

Thermal spraying of the specimens was carried out using high velocity oxygen fuel (HVOF). Corrosion test was carried out on both coated and uncoated samples. All samples were subjected to the same high temperature treatment for oxidation test.

Keywords

Steel, Corrosion, Environment, Thermal spraying, Coating.

Introduction

Degarmo et.al. (2002) stated that plain-carbon steel should not be used in excess of 250°C while high yield strength steel can only withstand a temperature limit of 550°C. To enhance the service life of these materials at such high temperature and aggressive environment, surface engineering such as coating through thermal spraying are being adopted. Thermal spraying is a process of deposition of molten or semi-molten droplets of powder onto a substrate to form a coating. There are three stages involved in thermal spraying: generation of thermal kinetic energy, interaction of energy with spray material and interaction of spray particles with substrate.

Melted material hits the target at very high velocity thereby changing the profile of the particles to lamellar structure. There are four theoretical considerations while making coating designs: They should form a thermodynamically stable protective oxides hence the main reason for adding aluminum and chromium. There should be slow growing of the protective oxide so as to keep the rate of surface depletion low. There should be interdiffusion between the substrate and the coating at a slow rate in other to avoid distortions which may lead to residual stresses. The coefficients of thermal expansion of both the substrate and the coating material should be close to each other to avoid distortion.

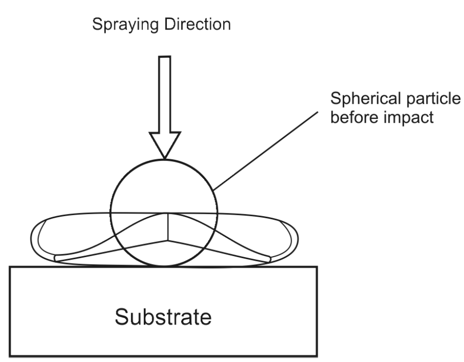

Figure 1. *Schematic diagram of thermal spraying*

Materials and Methods

Material preparation

The specimen used is mild steel of dimension 60mmx40mmx6mm thick. Surface contaminants include initial rust, oil and grease, dirt and miliscale. The specimen were all washed with detergent and later degreased with alcohol. This was followed by grit blasting using grit blaster and brown alumina (SiC) as the blasting material. This will give the required mechanical interlocking for the coating on the substrate.

The powder used for this work is FeCrAlY with the composition and dimension stated in the table 1.

Table 1. Showing composition of the powder

Element	Iron	Aluminum	Chromium	Yttrium
Composition (%)	76.7	7.4	15.5	0.44

The assembly contained the following units: spraying gun and stand, carousel for holding the specimens, the control unit and the powder feeder.

The liquid fuelled gun uses kerosene as the fuel which is mixed with oxygen in the combustion chamber and ignited by hydrogen. The converging/diverging throat of the gun provides the mixture with higher velocity through the nozzle which is about 100-200mm long. The estimated gas velocity and temperature are 1700m/s and 2500k respectively. It has high pressure, high flow rate which atomized the kerosene which is metered by electronic pump. The combustion process gives energy which is converted into hot high-pressure as well as the acceleration required. Because kerosene is difficult to burn, the combustion chamber was designed to be long for complete combustion. The powder feeder has a threaded screw bar which meters the amount of powder flowing into the flame and the powder meets the flame at the exit of converging nozzle. The particles are characterized by high velocity, low pressure and low temperature. Average coating thickness is 100 microns.

Experimental Methods

Salt Spray Test

The apparatus consists of salt spraying chamber, a salt solution reservoir, a supply of compressed air, nuzzle, specimen rack made of plastic material, heating chamber and control system. The specimens were suspended at angle 15-30° to the vertical according to ASTM standard as shown in fig.3. The specimens were positioned on the rack in such a way that they do not contact each other to avoid galvanic corrosion.

The specimen both coated and uncoated were all masked with lacquer except the 20x20 mm surface to be exposed in order to avoid crevice and galvanic corrosion mechanism. The lacquer was allowed to dry properly before putting it in the salt bath. The solution used is 5wt% in deionised water (500g in 10 litres of water).

$$NaCl_3 + H_20 – Na^+_{(aq)} + Cl^-_{(aq}$$

Digital pictures of the specimens were taken before introducing it into the aggressive environment and also after an interval of 30mins to observe the deposition of red rust on the exposed area. The time for first set of red rust was noticed for each of the specimen while the time taken for the exposed surface to be covered with the red rust was also noted. Image analysis was used to analyze the number of spots and area fraction covered by corrosion product at a particular time. The condition of this specimen after 1, 2, and 3…12, 24, 48 and 100hour were also recorded. The samples after 100 hours were characterized using SEM to check for any crack in the coatings.

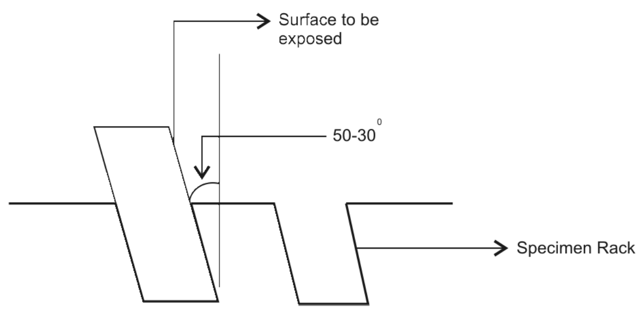

***Fig. 2**. Schematic diagram of the specimen in the rack according to ASTM B117-03 standard*

Potentiodynamic test

The test was carried out on non coated and thermally sprayed mild steel. The experiment was set up according to ASTM standard G5-94. The cell was made of three electrodes: reference calomel electrode (RE), auxiliary electrode (AE) and working electrode (WE). The surface to be exposed to the environment were prepared by cutting to a square shape of dimension (>12mmx12mm). This was mounted on a blue no-conducting resin in order to avoid galvanic corrosion during the experiment. Few microns of coating were removed from the surface during polishing of the samples. This was done to remove oxides which may accumulate on the surface of the un-melted material during solidification. 3mm threaded of brass rod was connected to the specimen from the back with the brass rod touching the specimen forming a brass electrode. Thread was made on the resin by using

Issue 14, January-June 2009
p. 140-146

drilling machine and 3mm tap. The surface of the specimen was masked with lacquer to avoid crevice corrosion mechanism with area approximately equals 1.21cm^2 being exposed to the corrosive medium. The as-sprayed coatings were not polished because thin coating was used for this research work. Nitrogen gas was used to de-aerate the electrolyte for about 30min before controlling the nitrogen gas to the surface of the electrolyte so that the experiment will not be disturbed due to stirring. 0.5M H_2SO_4 in one litre of distilled water was prepared by dissolving 27.2ml of H_2SO_4 (with concentration reagents grade of 19% and density 1.84g/ml) in 972.8cm^3 of water. The electrolyte was placed in water bath controlled to a temperature of 30^0 C. Sweep rate of 20mv/min from – 200mv to 1500mv was used to observe the corrosion of the samples. The current flow between platinum counter electrode and work piece electrode were recorded against the voltage. The experiment setup is shown in Figure 3.

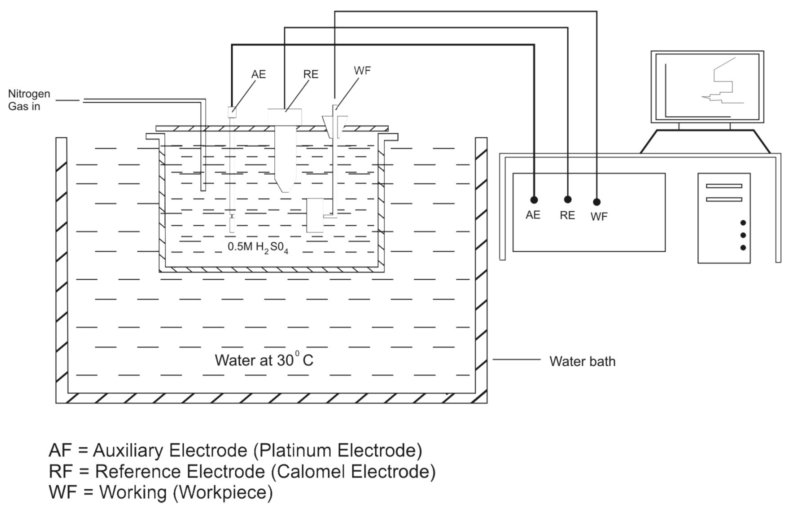

Figure 3. *Schematic diagram showing experimental set up of Potentiodynamic test*

High temperature / oxidation test.

Isothermal test was carried out by heating the furnace to a temperature of 800°C for about 1hour before the specimens were introduced. Specimens were cut to 12x12mm and arranged in a crucible before placing in the furnace. 5 samples each of uncoated mild steel and thermally sprayed ones were used for this experiment. Each of these was removed after 5,10,20,50 and 100 hours. The thickness of the oxidation formed on all the samples were measured using SEM.

Results and discussions

Salt spray test result

The formation of corrosion products on exposed surface of specimen were observed at regular interval. The number of spots and area fraction of the rust on the exposed area was analyzed. Thermally sprayed samples showed better corrosion resistance results with smaller values of area fraction and number of spots of corrosion product. The uncoated samples have more than half of its surface covered by corrosion product in less than 1 hour. After 5 hours the surface of the uncoated samples was covered with the rust products (Iron oxide), while the thermally sprayed ones were completely covered after 12hours. It took about 30mins in salty solution for light brown spot to appear on the sprayed samples which became visible after 1hour.

Potentiodynamic Test Results

After series of test on each sample under the same condition, the result revealed that the thermally sprayed samples has better corrosion resistance than the uncoated ones because there was more formation of passive oxides in sprayed ones than the uncoated ones. The values of current density reduced from a value of about 0.1A/cm^2 in uncoated ones to 0.0005A/cm^2 after thermal spraying.

High temperature /Oxidation test result

Clearly seen on the uncoated mild steel is a thick layer of oxide of iron. About 170m was deposited after 5hours while this value increased to about 325m after 20hours and reduced to about 170 m after 100hours. The deposits in the sprayed ones were characterized to be combination of aluminum and iron. After 20 hours in the furnace, about 2.6m of oxides was deposited on the coating.

Conclusion and Recommendation

The research work gave useful information on the performance and behavior of FeCrAlY coating. The coating brought about improved corrosion resistance at high temperature and corrosive environs.

Future research work should look into improvement of HVOF spraying process to reduce the amount of oxides associated with the process so that corrosion path can be reduced.

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