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ROUGHNESS DETERMINATION OF MILD STEEL SURFACE COATED WITH ALUMINIUM

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ABSTRACT

Mild steel is an important engineering material used in major engineering industries like construction, chemical plants, power production, automobile and electrochemical industries due to its remarkable mechanical properties such as good strength, toughness, ductility, formability and weld ability in conjunction with its abundance and relative low production cost but it is also susceptible to ravage and failure depending on the environmental condition causing its surface deterioration, a phenomenon called corrosion. This call for coating of the material surfaces so as to improve its hardness, wear, fatigue and corrosion resistance to suit many applications. Therefore, in this research work, aluminum has been used as a coating material to improve the surface quality of mild steel due to its better wear resistance and fatigue strength and can equally be used at an elevated temperature. The study therefore determines the effect of roughness on the surface of coated mild steel with aluminum. Experimental works were performed at difference temperatures of 650^{o}c,750^{o}c, and 850^{o}c,indentation discovered were 4mm, 3.9mm and3.6mmwith brinell hardness of 763650.091, 80522.206 and 95156.997 kgf, showing a deflection at peak in (mm) to be0.837,1.075and 0.714 respectively for the various temperature values. It was therefore concluded that the lower the temperature of the coating the higher the roughness of the surface of the specimen.

Keywords; *Mild steel, Aluminum, Coating and corrosion.*

1.0 INTRODUCTION

Mild steel remains an important engineering material frequently applied in construction, chemical, power production, automobile and electrochemical industries due to its abundance at relatively low production cost (Thiraviyam et al, 2013).Above all, mild steel possesses unique and remarkable mechanical properties such as good strength, toughness, ductility, formability and weld ability which confirm its suitability as a better construction material in comparison to other engineering materials (William and David, 2009).

Mild steel has been widely used in many chemical industries due to its low cost and easy availability for fabrication of reaction vessels, tanks and pipes, etc. mild steel also finds some mechanical, structural application in industries.

In other words, mild steels are sometimes susceptible to ravages and failure depending on the environmental conditions causing deterioration of material surfaces, a phenomenon called corrosion. Corrosion causes gradual weakening and failure of material properties which can sometimes lead to human injury, loss of life and collateral damage (Philip, 2010)

In fact, most fabricators and machinists consider mild steel as a favorite raw material in the production of engineering components such as gears, cams, shafts, keys, hand tools among others. Some of these engineering components must have strong and hard surface along with soft and tough core for their durability, reliability and safe operations depending on the operational conditions. These aforementioned properties are however lacking in mild steel, thus causing simultaneous wear at the surface and subsequently breakage upon impact during operation.

On the other hand, several metals and non-metals, ceramics, including polymers have been applied as coating on mild steel to improve their hardness, wear, and fatigue and corrosion resistance in order to suit many applications.

Apart from classical bearing materials, Aluminum alloys are used as bearing materials these days because of their superior quality. Wear resistance and fatigue strength of aluminum based bearing materials are higher than classical bearing materials and they can be used at elevated temperatures. The alloys based on aluminum have superior qualities like corrosion resistance, higher thermal conductivity, high fatigue strength, co-adaption with steel shafts, light in weight, low cost, and workability. But, apart from the advantages mentioned above, the engineering applications for some aluminum alloys are restricted because of their poor surface properties and low resistance to abrasion. However the required tribological and mechanical properties are developed by adding alloys and applying heat treatment (Math van and Patnaik, 2016)

The biggest consideration about bearing material is its wear resistance. Current developments in engine technology have seen the launch of advanced materials. So, aluminum-based alloys are introduced in bearing industry because of its high wear resistance. Aluminum based bearing materials are used in several applications like crank shaft bearings in automotive industry, internal combustion engines etc. Advancement in the efficiency of internal combustion engines has caused growth in the consumption of aluminum alloys like Al–Si. The main objective of the study is to determine the effect of roughness on the surface of a coated mild steel with aluminum.

Mild steel has been widely used in many chemical industries due to its low cost and easy availability for fabrication of reaction vessels, tanks and pipes, etc. Mild steel also finds some mechanical, structural application in industries. (Thiraviyam, K. Kannan, MildSteel, 2013). Steel is being used everywhere in world due to its broad application. Steel has inherent mechanical properties to a proper extent, but there are some problems related to corrosion, especially in aqueous, dry and atmospheric conditions. The atmospheric corrosion of steel is a serious problem and different types of organic and inorganic coatings have been developed to extend the service life of structures made from steel. Besides coatings on structural steel, stainless steel is being used in infrastructure but is not economical. (Edigaryan,L.N. Vykhodtseva A. A steel *Metals,* (2001). Consequences of wear are many, Wear usually cost money, in the form of energy loss and material loss, as well as in the social system using the mechanical devices. (Thiraviyam et al, 2013).Wear can decrease national productivity, can affect national security can affect quality of life and can even cause accident. To prevent all these anomalies mild steel plated with aluminum are used as materials these days because of their superior quality but thorough surface preparation of steel is essential if the coating scheme applied is to perform well. (Edigaryan,L.N, 2001). The coating of steel with aluminum metal is found to provide protection in industrial and marine environments. (Jandin et al, 2003; Guilemany et al, 2001). To protect bridges, strobes, pipelines and other large steel structures for long-term protection in industrially polluted, saline and open atmospheres, the use of Al coating with the thermal spray process had been reported about a century ago (Rhys-Jones, 1990).

Li *et al.* (2006) and Muhamad *et al.* (2013) have carried out research into the protection of steel by means of Al coating through an arc thermal spray process with a filler; they reported enhanced corrosion resistance properties for coating after eight years of exposure in a coastal environment.

1.2 MATERIALS AND METHOD

The materials used for this work are; Mild steel, Aluminum rod, Furnace, The spruce is a tapered cylindrical type with cup at the top to facilitate easy purring into the die. The preheating of the die cavity was achieved using the involving heat from the furnace during melting and considerable reduction in operational time and heating was achieved by performing the melting and preheating simultaneously to 200^0C. Melting of charged material was done using Tap fired Crucible furnace.

i. From a commercial grade bar (15 mm diameter) of UNI mild steel (nominal composition: C% < 0.17, Mn% < 1.40, P% < 0.045, S% < 0.045 and Fe balance), two different series of sample were prepared. For the electrochemical tests thin coupons were cut (4 mm thickness) and polished with SiC paper down to 1200 grit in order to achieve a smooth and reproducible surface. Just before the aluminum electroplating, the coupons were chemically polished to remove the oxides and the organic impurities eventually present on the surface. The second series of samples was made in the form of cylinders (about 80 mm length and 15 mm diameter) were used for the salt spray test. After machining and cleaning, these samples were aluminum plated for about 3/4 of their length. The parts left unplated were covered with epoxy resin The average roughness of the surfaces was measured using a Homme Tester W55. The measurements were obtained performing five different and independent tests in randomly chosen areas of the sample. The measures were performed scanning 4.8 mm surface at 0.2 $^{mm}/_{s}$ scan rate. The parameters employed were kc = 0.8 mm and kc/ks = 300 using a filter ISO 11562(MI), for every type of sample the Ra (dipping rate), Rz (specimen) and Rt (dipping time) values were calculated. The plating process was carried out inside a nitrogen filled glove box (Iteco mod 10A), where the water and oxygen content was kept below 5 ppm. The galvanic bath was constituted by 1- butyl-3methyl-imidazolium heptachloroaluminate ([BMIm] Al2Cl7), supplied by Merck and used as received without further purification. The deposits were obtained in current controlled (galvanostatic) conditions at room temperature using as anode a pure aluminum foil (Good fellow 99.9%). The morphology of the coatings was investigated by optical (Nikon Eclipse LV150) and scanning electron microscopy (ISI 100B), while the chemical composition and the surface phases were obtained, respectively, by energy dispersive X-ray microanalysis (EDX) (NORAN NSS 300) and X-ray diffraction analysis (Bragg–Brentano configuration, Cu Ka radiation). The spectra were analyzed by means of a fitting program based on the Riveted method (Rietquan 2.3). The electrochemical characterization was performed using a Model K47 corrosion cell from Princeton Applied Research. The potentiostat was a PAR model 2273 controlled by PowerSuite2.58 software. The classical three electrode set-up was employed using two high-density graphite counter electrodes and a SCE reference electrode separated from the solution with an ion conducting glass frit, the working electrode surface was $1.0 cm^2$. The experiments were carried out at room temperature (19–23℃) in a saline solution obtained dissolving NaCl (>99.5% from Merck) in deionised water. Every sample was kept in the saline solution for at least 14 hours in order to allow the stabilization of the system. During this time the open-circuit potential (OCV) was recorded. After this time, electrochemical impedance spectroscopy (EIS), and potentiodynamic (PD) experiment were performed. The EIS spectra were measured in the frequency range between 100 kHz and 5 MHz, sampling 20 frequencies per decade, at the free corrosion potential, applying a sinusoidal perturbation of ±10 mV. The PD curves were recorded starting from _0.250 V respect to the free corrosion potential at the scan rate of 0.3 mV s_1. Free corrosion tests were conducted in a salt spray cabinet (Angelantoni model DCTC600 P) spraying NaCl solution (50 ± 5 gr dm_3) at 35±2_C (NSS test). The evolution of the corrosion phenomena was monitored by visual investigation up to 21 days.

In the design for surface roughness of mild steel coated with Aluminum, The length of the coating (L) was estimated to be 103 mm using equation (1)

$$L=L_1+M_1+S_1 \quad (1)$$

Where, L = length of the coating, L_1= length of the mild steel test piece which is 100mm, S_1= shrinkage allowance is 0.16mm, M_1= machine allowance is 2.30mm. Diameter of coating was calculated to be 12.50mm, using equation (2)

$$D = D_1 + S_1 + C_1 \quad (2)$$

Where, D = diameter of the coatingD_1= diameter of test piece= 10mm

C_1= Coating cavity allowance=2.3mmS_1= shrinkage allowance=0.16mm

3.2.3 Draft Allowance

Draft angle of internal surface for metal with length between 100mm to 200mm was (1^o). Figure 3.2 below represent the tapered size of the coating cavity

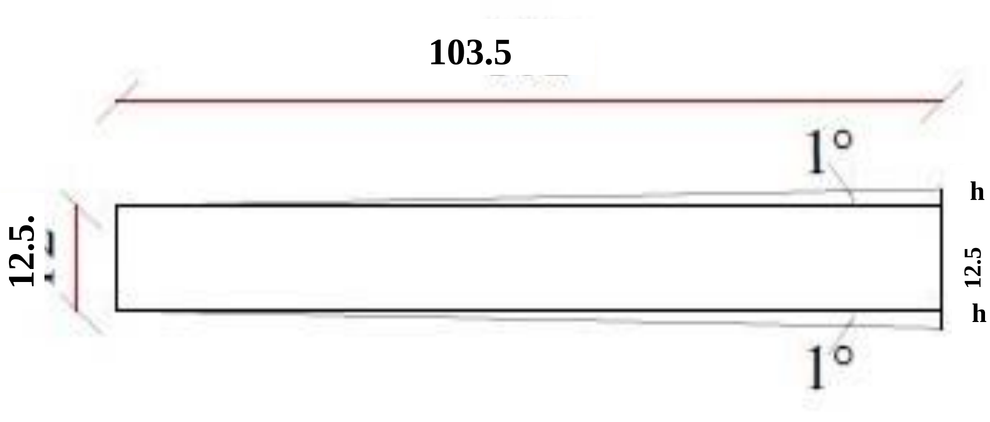

Figure 1.0: draft angle of the mild steel specimen

The larger diameter was estimated to be16mm

Using

$$\tan 1 = \frac{h}{103} \qquad (3)$$

The dipping rate was estimated to be 0.0037kg/s using equation (4)

$$R = b\sqrt{w} \qquad (4)$$

Where: R = dipping rate. b = Constant with a value of 0.47.

W which is casting weight for aluminum specimen is 0.000063

Adjusted dipping rate R_a

Was estimated to be 0.0044kg/s using equation (6)

$$t = \frac{w}{R_a} \qquad (6)$$

Where t is dipping time estimated to be 0.0143s

Effective spruce height H_P was estimated to $118mm$ using equation (7)

$$H_P = H - 0.5\frac{{h_i}^2}{h_2} \qquad (7)$$

Where; Spruce height$H = 120$, height or the casting in the cope $h_i = 20mm$

Total height of the casting $h_2 = 102$

The cross sectional area of the mold cavity was estimated

The following equation was use

$$A_c = \frac{w}{p + c\sqrt{2gHp}}$$

Where Ac is choke area (mm^2) W is casting weight (kg)

ρ is density of coating metal (kg/m^3) Hp = effective spruce height (mm) C is discharge coefficient 0.8 g = acceleration due to gravity (9.81m/s)

$$A_c = \frac{0.00063}{2500 + 0.8 \times \sqrt{2 \times 9.81 \times 118}}$$

= $279.621mm^2$

To calculate the spruce inlet area, since spruce inlet – A spruce exit = Chocked area AC

Continuity Equation

$$Area\ of\ sprue\ inlet = \frac{A\ sprue\ exit\ \sqrt{H\ sprue\ exit}}{\sqrt{H\ sprue\ inlet}}$$

$$\frac{\pi d^2}{4} = \frac{\pi \times 16^2}{4}$$

A spruce exit = 2.79

$$H_{sprue\ inlet} = 11.53$$

$$H_{sprue\ exit} = 11.53 + 102 = 113.53$$

$$A_{sprue\ inlet} = 201.08 \times \sqrt{\frac{113.53}{11.53}} = 630.96\ mm^2$$

Radius of the spruce inlet

$$R_{inlet} = \sqrt{\frac{A\ sprue\ inlet}{\pi}} = \sqrt{\frac{630.96}{3.142}} = 14.17\text{mm}$$

Radius of the spruce exit

$$R_{exit} = \sqrt{\frac{A\ sprue\ inlet}{\pi}} = R_{inlet}$$

$$= \sqrt{\frac{630.96}{3.142}} = 14.17\text{mm}$$

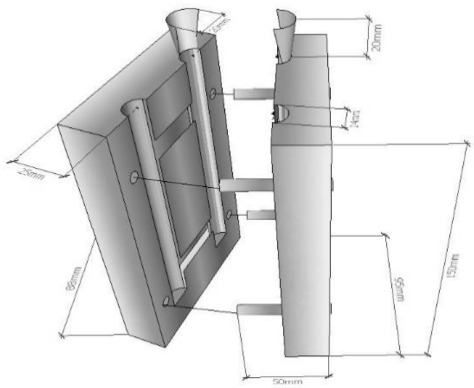

Figure 2.0 Exploded view of the metallic mold

Table 4.5 Roughness test of the coated test piece with pouring temperature of 650^0c, 750^0c, 850^0c.

Test No	Ball diameter (mm)	Indentation diameter (mm)	Treatment	Brinell Hardness (kg/m²)	Force@ Peak (kgf)	Def. @ Peak (mm)
1	10	4	A	76305.091	1000.648	0.837
2	10	3.9	B	80522.206	1001.565	1.075
3	10	3.6	C	95156.997	1002.177	0.714
Min				76305.091	1000.648	0.714
Mean				83994.764	1001.463	0.875
Max				95156.997	1002.177	1.075
S.D.				9894.068	0.770	0.184
C. of V.				11.779	0.077	20.967
L.C.L.				59416.266	999.551	0.419
U.C.L.				108573.262	1003.376	1.331

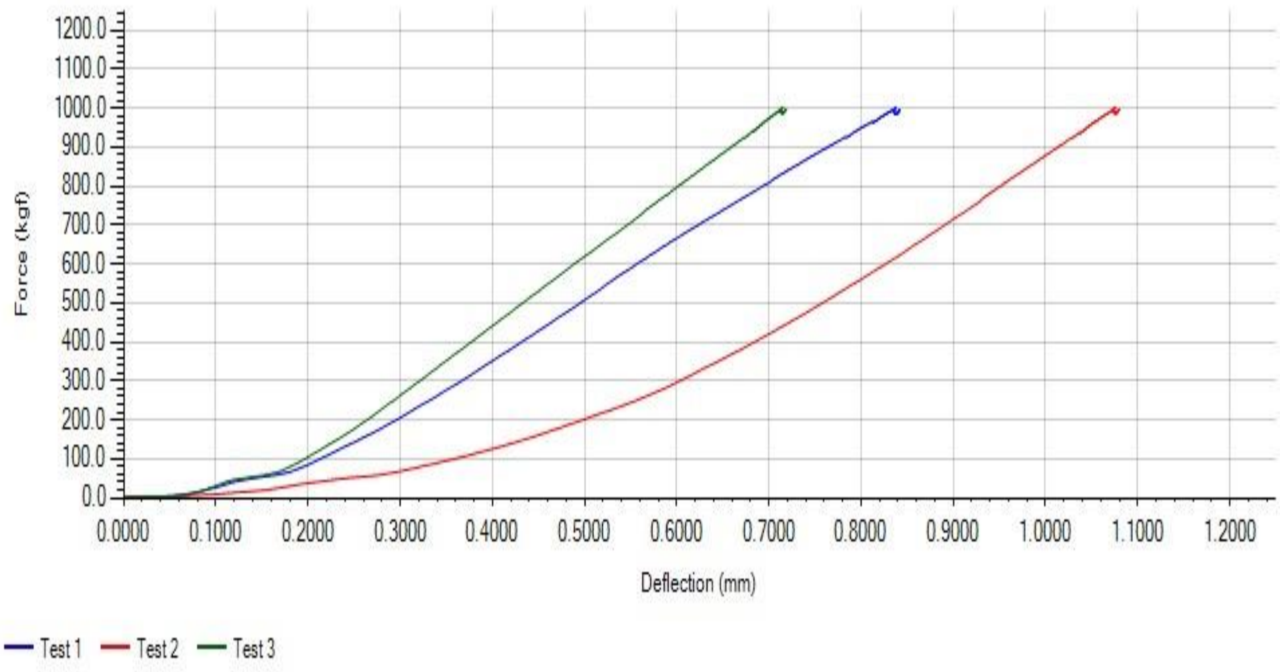

fig 4.4 The graph of roughness of the three specimen at 650℃, 750℃,850

CONCLUSION

The following conclusions can be drawn from the above results:

1. The corrosion characteristics of the Aluminum coating applied on the specimen in the presence of stimulants provide enhanced corrosion resistance properties to the steel substrate with exposure periods in the SAE J2334 solution;
2. The enhanced corrosion resistance properties of the Aluminum coating is due to presence of NaCl, CaCl2 and NaHCO3 in the solution, which reduces the anodic surface area of the coating and the cathodic reduction of oxygen by forming a thin layer of protective passive film;
3. Kinetics and the mechanism determined by EIS and potentiodynamic studies suggested the passivation nature of the Aluminum coating in the presence of carbonate and chloride ions of the SAE J2334 solution with exposure periods;
4. The morphology of passive films is very dense, layered, thick, compact and adherent to the specimen coating surface;

5. The concluded investigation revealed that the lower the temperature of the coating the higher the roughness of the specimen.

5.0 RECOMMENDATION

It is therefore recommended that the aluminum should be melted above their upper critical temperature to enhance a better coating and high corrosion resistance. Temperature approximately above 800℃.

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