Corrosion Behavior of Friction Surfaced 314 Stainless Steel Over 1018 Mild Steel

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Abstract - The principal objective of this experimental diligence was to incorporate friction surfacing to create a solid-state 314-Stainless steel coating over 1018 mild steel substrate. The 314-Stainless steel is coated with mild steel with an objective to enhance its corrosive resistance of the substrate. The solid-state surface coating overcomes the complicated problems brought on by liquid-based coating procedures. The three most essential parametric combinations for bonding integrity in frictional surface coating process are axial force, rotating speed, and feed rate (travel speed). After the coating, the micro structure analysis is done through SEM test and immersion corrosion test is conducted for both the coating material (314 -Stainless steel) and for the substrate (1018 mild steel) to evaluate the corrosion rate of the material.

Keywords - Friction Surfacing, 314 Stainless Steel, 1018 Mild Steel, Corrosion Test, pH Medium.

I. INTRODUCTION

Mild steel has wide range of application in marine, automobile, construction and industrial area because of its good mechanical properties but its poor corrosion resistance limits its applications especially in marine environment [1]. However, mild steel's corrosion severely reduces its strength, security, and appearance, which can lead to catastrophic failure or other negative effects [2]. By using atmospheric plasma spraying techniques, Fe-based nano crystalline composite coatings were created on a mild steel substrate, revealing porosity on the coated surface [3]. The austenitic stainless steels of various grade was investigated for corrosion test in NaCl solution. The samples were repeatedly heated in the furnace for 650oC and after cooling for 15 minutes, they were submerged in a 3.5% NaCl medium. Finally the corrosion test shows that AISI 314 stainless steel have lower level of weight loss compared to other steel grades [4].

A practical and affordable way to enhance the characteristics of mild steel surfaces is done by friction surfacing, which is a plasticized metal deposition process. It is a potentially useful technology for a range of metal joining application, due to its capacity to connect incompatible metals and enhance corrosion, wear and thermal resistance [5]. The Friction Surfacing (FS) tactic, which is able to join interchangeable materials and enable the creation of functionally graded materials, has recently gained popularity in the field of material joining. Friction surfacing which uses a consumable rod to apply a layer over the surface of the substrate. A spinning consumable rod (mechtrode) that is subjected to a downward axial force while contacting a base material (substrate) is typically involved in the friction surfacing process. This produces frictional heat at the point of interaction between the two-opposing stuff. Deposition takes place on a backing plate after a specific dwell time and while the consumable shaft is moving transversely [6,7]. Advanced micro structural design is made possible by these deposition technologies, which also augment and alter the substrate material's desired properties. The bonding strength is often determined by applied force and the heat created to enhance diffusion over the interface region [8]. The best materials for this coating process are those that are consumable and have greater thermal conductivity. The FS technique had a number of key advantages including coating uniformity, superior adhesion (boding strength), very minimal dilution, and a uniform heat-affecting zone at the interface [9-10]. The use of metallurgical alloy incompatible materials with some special properties is made possible by friction surfacing and is not possible with conventional coating techniques. By using the friction surfacing method, a wide variety of material combinations can be deposited [13]. The novel approach of better corrosive resistance material 314 stainless steel is friction surfaced over 1018 mild steel substrate for the application in corrosive environment under various pH levels. Finally the corrosion behavior of the coated and uncoated surface is examined [11, 12].

II. MATERIALS AND EXPERIMENTAL METHODS

Substrate Material

The base metal 1018 Mild Steel with dimensions of (150 x75x10)mm was chosen as the substrate material for the friction coating procedure [14]. The percentage of the chemical constituent of substrate material is shown in the **Table 1.**

Table 1. The Chemical Constituent Percentage of 1018 Mild Steel [13]

Material	**Elements Weight Percentage**					
1018 Mild steel	C	P	S	Si	Mn	Fe
	0.2	0.04	0.05	0.003	0.6	Balance

Tool Material

The 314 stainless steel rod of diameter 20mm is use as a tool material and is made to deposit on the surface of 1018 mild steel substrate through friction process. **Table 2** show the chemical composition of the coating material.

Table 2. The Chemical Constituent Percentage of AISI 314 Stainless Steel [3]

Material	**Elements Weight Percentage**								
AISI 314-	Cr	Ni	Cu	Mo	Mn	Si	Co	Sn	Fe
Stainless Steel	16.95	9.9	1.9	2.1	1.53	0.37	0.15	0.11	Balance

Friction Surfacing Process

In this research work a CNC vertical milling machine is used to complete the friction surfacing process by varying the three different process parameters such as tool rotation speed in (r.p.m), tool travel speed(mm/minute) and forging force (kN) [15-18]. The substrate was surface-ground and milled to guarantee flatness. Prior to surfacing, the consumable shaft and the plate must be cleaned with acetone to reduce impurities during the process [19,20]. The consumable rod was vertically moved after being clamped into the motor's spindle in order to make contact with the substrate plate. A fixed speed (measured in rpm) was set for the consumable rod's rotation. The end of consumable tip became plasticized due to the frictional heat produced at the interface between it and the substrate plate. The plasticized rod tip was given a dwell time of 30 seconds. Then the coating process is carried out with the ambient operating parameters in controlled mode [21]. As the consumable rod length reduced down as the spindle gradually moves downward under the influence of the applied downward force. Thus the thin layer of plasticized 314-stainless consumable rod is deposited over the mild steel substrate due to frictional heat formed between the two contacting surface.

Fig 1. Friction coating process of 314 steel on 1018 steel substrate.

The parameters for friction surface processing are determined by the number of trial experiments. The list of the parameters chosen for friction surfacing of 314- Stainless steel over substrate is shown in **Table 3**. The **Fig 1** shows the friction coating process of 314 steel on 1018 mild steel substrate. The **Fig 2** displays the ready samples with friction coated surfaces.

Table 3. FS Process Parameters

Consumable Travel Speed (mm/min)	3
Axial load(kN)	2
Spindle speed (rpm)	1800

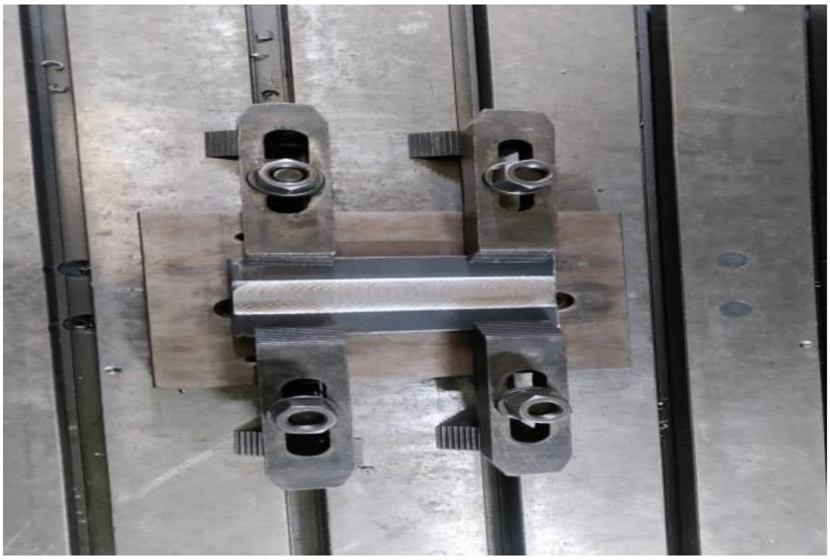

Fig 2. 314-Stainless steel deposit on 1018 Mild steel.

SEM and Immersion Corrosion test

The scanning electron microscope technique is preferred to characterize the friction surfaced microstructure and to examine the existence of coating defects such as porosity and surface crack. Then immersion corrosion test is done using four various pH levels (pH3, pH5, pH7, pH9) as the test medium in this investigation. By combining 10 ml of concentrated hydrochloric acid with 1000 ml of distilled water, the pH value of 3 was created. The same process was used to create the pH value of 5. NaCl solution and NaOH solution, correspondingly, were used to prepare the test medium for pH 7 and pH 9, respectively [13].The coated and uncoated samples are immersed in this test medium for various time duration and the weight loss as well as corrosion rate is examined.

III. RESULT AND DISCUSSION

SEM Analysis

The surface of the overlaid materials displays extremely thin martenstic characteristics similar to those of mild steel substrate and the interface region between the coating and the substrate is shown in **Fig 3**. On both the advancing and receding sides of the coating surface, it is observe a very fine martensitic structure. In this process neither the substrate nor the coating is melted, there is a very little base material dilution producing a coating of excellent quality. The SEM picture clearly shows that the coated surface was free of pores and micro cracks.

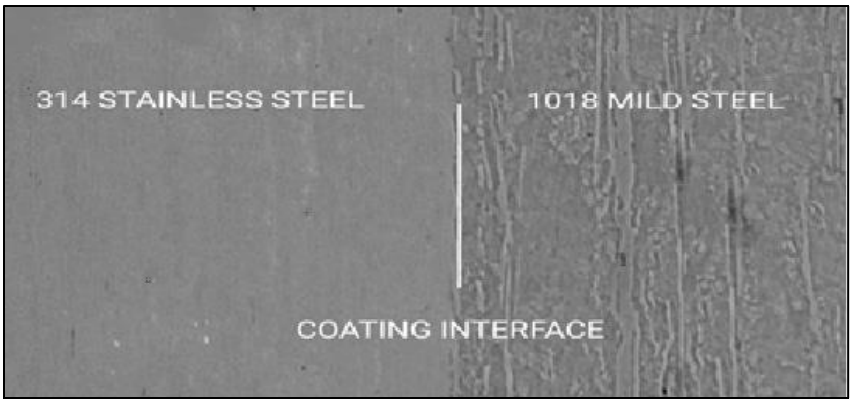

Fig 3. SEM images of Coating and Substrate Interface.

Surface Morphology

From the visual inspection it is clearly found that the coating has continuous, uniform width and excellent deposition towards width and evenly distributed bead. The width of the coating deposit measured as 21.5mm and the thickness is measured as 1.2mm. The deposition's width is found to be reduced at the end of the coating due to the reduced load and the automatically separation of consumable rod from the substrate by moving upward.

Immersion Corrosion test

Following the preparation of the coated and uncoated test specimens (20x20mm), the samples are specimen is tested by immersing in each pH solution for 24 hours as shown in **Fig 4**. Then the materials were allowed to be treated for a number of hours by gradually lengthening the time says 24 h,48h,72 h and 96h [13].

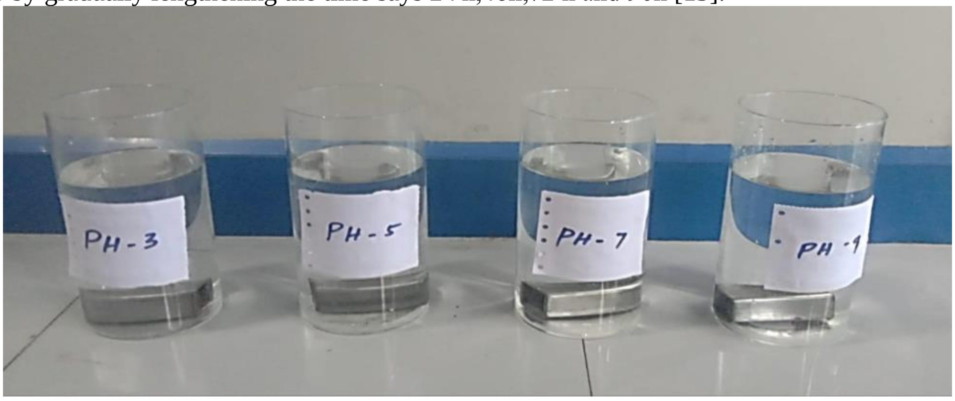

Fig. 4. Immersion Test for varying pH values.

Then the samples weights are calculated before and after immersion, finally their average weight losses measured in grams for every 24 hours' time of immersion and the same is recorded in **Table 4**. The weight loss observed for the coated and uncoated mild steel substrate immersed in different pH solution and the relationship between weight loss and pH levels is depicted in **Fig 5**.

Table 4. Weight loss for different pH solution

S.No	pH value	Weight loss (grams) Uncoated	Coated
1	3	0.0006	0.00032
2	5	0.00052	0.00024
3	7	0.00043	0.00015
4	9	0.00038	0.00011

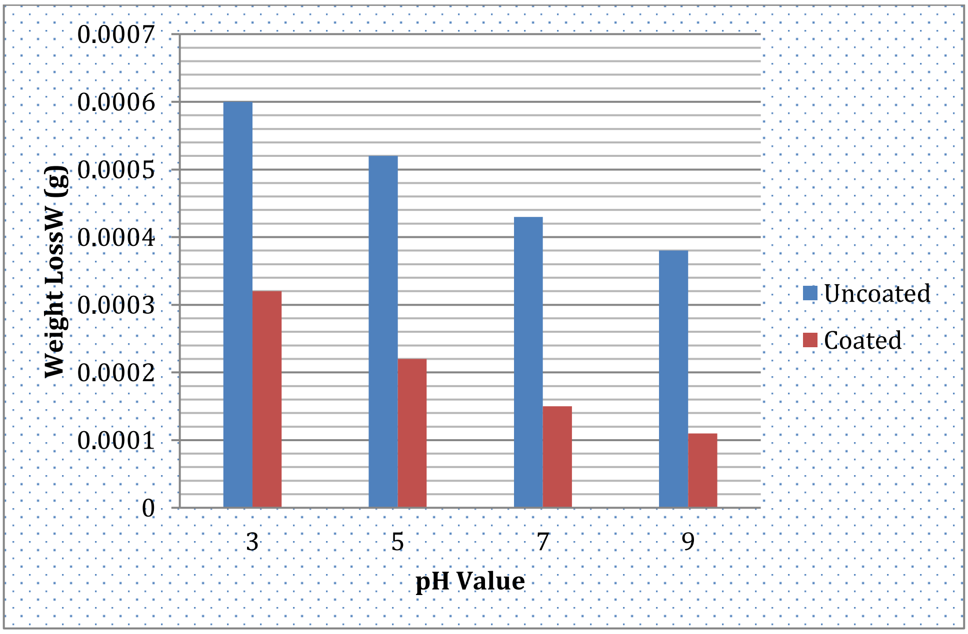

Fig 5. Weight loss for various pH values.

In pH 3 the weight loss observed for uncoated mild steel sample is 0.0006 grams and for the coated sample the weight loss measured as 0.00032grams (i.e) 47% of weight loss is reduced for the coated samples. In case of pH 5 the weight loss observed for uncoated sample (mild steel) is 0.00052grams and for the 314 stainless steel coated surface the weight loss observed is 0.00024grams, it shows that the coated material has higher corrosion resistance efficiency than the base material and it shows that53% weight loss reduced for the stainless steel surface in comparison with mild steel sample. Similarly for pH7 and pH9 the corrosion resistance is increased for the coated surface it clearly shows that the weight loss measured for coated surface is three times less compared to the uncoated surface.

The calculated corrosion rate was plotted from the obtained weight loss as shown in **Fig 6**. It also shows that for a given number of hours, mild steel samples exhibit higher corrosion rates than coated samples. The corrosion rate gradually increase with respect to increase in the time of immersion is observed. For 314 stainless steel coated sample the corrosion rate which is approximately two time less than that of uncoated mild steel sample. In an aquatic medium, the mild steel base lost a significant amount of weight, but the AISI314- Steel coatings has very low impact. Due to its acidic nature, low pH solutions have a greater rate of corrosion.

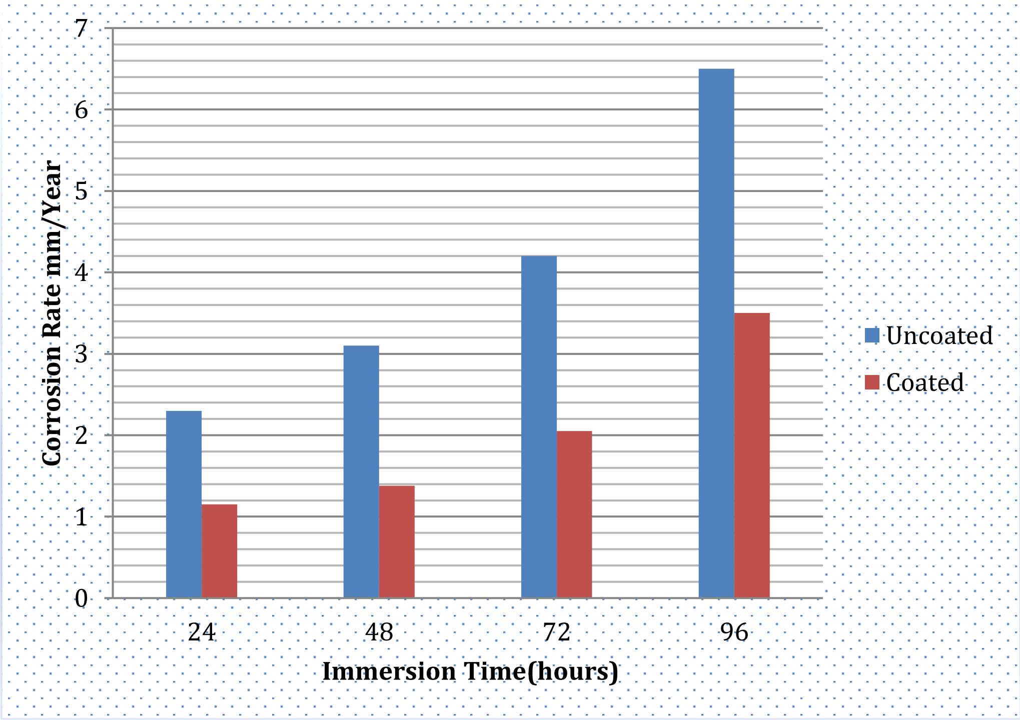

Fig 6. Corrosion Rate for Various Time Duration.

IV. CONCLUSIONS

It was found that the friction-coating growth was highly susceptible to surface property enhancement. The materials selected have produced excellent overlaying. Friction surfacing increases the cohesiveness and adherence of the coating by creating a metallurgical link between the substrate and the coated substance. The SEM image clearly indicates that the coated surface was pore-free. The conclusion have been drawn from the immersion corrosion test for coated and uncoated sample is stated as follows,

- From the immersion corrosion test it is observed that for pH 3 and pH 5 the weight loss reduced is 47% and 53% respectively for 314 stainless steel coated surface in comparison with uncoated mild steel substrate.
- For pH 7 and pH 9 it is observed that the weight loss in coated surface is reduced to 65% and 71% respectively in comparison with uncoated mild steel surface.
- 314 stainless steel coating is more suitable for all the four above tested pH environment. Further it is observed that in case of base and alkaline environment (i.e) pH7 and pH9 the weight loss observed for coated surface is predominantly lower in comparison with pH3 and pH5 immersion this is due to acid nature which has greater corrosion rate.
- In comparison to the base material, the surfaced material demonstrated a better corrosion resistance with respect to all the four pH medium tested

V. SCOPE OF FUTURE WORK

- Regarding the physical properties of the coatings, the individual parameters and their interactive effects which forms scope for future work.
- It is possible to research alternatives to fusion-based metal joining and cladding procedures to make them more energy-efficient and environmentally beneficial.

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