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Increasing The Properties of Steel by Diffusing Intermetallic Substance

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***Abstract*— Surface coating is an efficient and cost-effective way to achieve desirable surface properties. Among the surface modification techniques diffusion is the most cost-effective way incorporate desired properties to surfaces. Current investigation is focused on This study investigated aluminizing the steel surface through hot dip coating technique. Experiments were carried out on mild steel substrates with a thickness of 5mm. The substrates were immersed in molten aluminium kept at 750˚C for a duration of 30, 60, and 90 minutes. This investigation included hardness survey across the specimen. The hardness of the steel found to vary with the change in the depth, dipping temperature and time. As a result of this treatment improved surface properties were observed in the specimens after treatment.**

Keywords: Diffusion, Surface coating, Intermetallic, Fe-Al, Microstructure

I. INTRODUCTION

Steel is a versatile Engineering material preferred by the design engineers because of its strength, ductility, ease of fabrication and low cost. Even though new advanced materials have been developed nowadays, steel remains preferred choice in construction, automobiles, appliances, industrial machinery as well as in the nuclear industry. The limitations of Steel are low corrosion resistance, hardness and wear characteristics. These properties can be improved by expensive alloying additions. Most of the Engineering failures do originate from the surface, so these surface properties play a vital role in deciding the durability of the components used in the aggressive environments like earth moving equipment and agricultural equipment. In this context, it has been proposed to modify the surface alloy content to meet the necessary service requirements demanded in the aggressive environments. Surface coating is another avenue to impart desirable surface properties like hardness and corrosion resistance economically. Various methods adopted to modify the surface properties are classified into thermal, thermomechanical, ion implantation, plating and coating. Some of these processes result in increased material build also, need to be considered when dimensional stability is an important criterion. Diffusion based surface alloy modification techniques offers attractive alternative over plating and coating techniques. It is important to identify the element to diffuse ranges from Carbon (Carburizing), Nitrogen (Nitriding), Carbo nitriding, Chromizing, Aluminizing, Boronising etc., In which, Aluminizing offers comparatively low cost and better surface characteristics over other materials [4]. In hot dip aluminizing, when steel is in contact with a molten aluminium maintained at a temperature for a specific period, diffusion occurs to form a brittle interlayer of intermetallic compounds. The intermetallic layer develops between the steel substrate and the coated aluminium [3]. The intermetallic layer grows and dissolves concurrently into the molten aluminium, which is directly associated with the loss of the steel substrate [5-7]. The growth and dissolution rates of the intermetallic layer determine the thickness of the layer. The rates are closely related with the temperature of the molten aluminium and dipping time of the steel. The thickness of the layer also varies depending on chemical composition of the molten aluminium [2]. Aluminium is very successful as a protective coating for steel because of its self-healing passive layer. Any improvement in the wear and corrosion properties will result in significant cost saving. However, the adhesion between coating and substrate by formation of the intermetallic phase is important to be investigated to produce strong and durable coating. The wear behaviour of the Fe-Al intermetallic coating was found to vary significantly with temperature and load [1].

II. OBJECTIVE

The properties of low carbon steel meets most of the strength-based requirements except wear and corrosion resistance. The objective of this investigation is to improve the surface properties like wear and corrosion resistance. The hard intermetallic layer produced through diffusion It will result in the improvement of durability of the component by coating intermetallic coating using diffusion method.

III. METHODOLOGY

A. Material Selection

Specimens were made from low carbon steel substrate (IS:2062). This has high tensile and good yield strength, good mechanical strength, flexibility, hardness and toughness. This is the most common substance that used in construction, automobile industry and in nuclear industry. The composition of the substrate material is presented in the table 1.

Table 1 Substrate composition

Material	**Elements (% wt.)**									
	C	**Mn**	**Si**	**S**	**P**	**Cr**	**Ni**	**Mo**	**N**	**Fe**
Base metal (IS: 2062. GR. B, ASTM A36)	0.196	1.12	0.293	0.011	0.0044	0.128	0.336	0.275	--	Balance

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B. Specimen Preparation

The specimen preparation is described as follows. The specimens were annealed at 750⁰C to remove any residual stresses and refine the grain structure. The surface oxide layer is removed by grinding and followed by polishing by abrasive papers of coarse, medium and fine grades. At the end of surface preparation,

Figure 1. Specimen

the surface roughness was measured and presented in the table 2. The figure 1 and figure 2 shows the specimens before and after grinding. The holes were made in specimens for the purpose of immersion and retrieval during diffusion process. Also, the specimens were numbered for the identification during post diffusion characterization.

Table 2: Surface roughness measurement details

Specimen No	Direction	Surface roughness (μ)
1	Longitudinal	0.12
	Transverse	0.17

TABLE 3 Specimen dimensions

Length	55mm
Breadth	30mm
Thickness	5mm
Volume	8250mm^3

Figure 2. Specimen after surface grinding

IV. HARDNESS TEST

The hardness of the specimens was tested before the diffusion. It is required to compare hardness values before and after the diffusion process. Rockwell and Vicker's hardness tests were performed before diffusion treatment of the specimens.

Hardness of each specimen was taken at three different locations and average value is for better understanding of the hardness value. All those values were tabulated below in table 4.

TABLE 4 Rockwell Hardness Values before Difussion

Specimen No	Average hardness HR_C
1	61.3
2	60.3
3	61.3
4	60
5	59
6	59
7	60.3
8	57.6
9	58.6
10	60
11	59

The graphical representation of the hardness test of the specimens is shown in the figure 6. It is observed seen that the overall average of the hardness is 59.6.

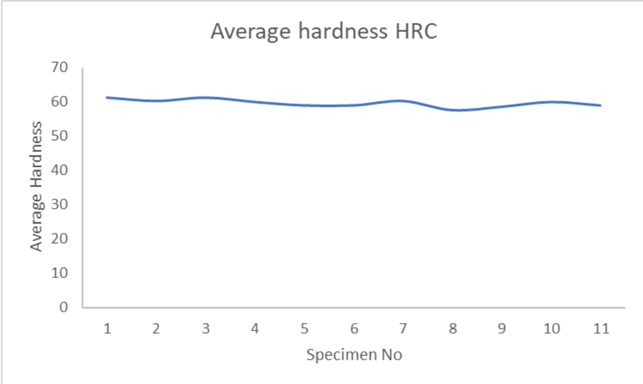

Figure 6. Graph of hardness test values

V. DIFFUSION

Diffusion is carried out using STIR CASTING FURNACE. The aluminium is placed inside a crucible and melted at 750˚C using the furnace. Once the aluminium is melted the steel specimen is placed inside the furnace and the diffusion is conducted at three different timings 30, 60 and 90 minutes at 750˚C. Once the diffusion is finished the specimen is quenched in water. The unwanted aluminium coatings were removed by SiC sheets.

VI. VICKER'S HARDNESS TEST

The hardness test is performed by using vicker's hardness testing machine**.** The diffused specimen hardness values are tabulated in table 5.

TABLE 5 Vicker's Hardness Values after diffusion

Specimen	Position	Scale	VHN
Untreated	1	0.718	17.99209154
	2	0.742	16.84700598
	3	0.695	19.20263961
	4	0.689	19.53853948
	5	0.736	17.12280504
30 min	1	0.436	48.79300459
	2	0.553	30.33054946
	3	0.652	21.81902546
	4	0.6	25.764875
	5	0.424	51.59395581
	1	0.3	103.0595
	2	0.563	29.2626566

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60 min	3	0.7	18.92929592
	4	0.618	24.28586577
	5	0.3	103.0595
90 min	1	0.3	103.0595
	2	0.323	88.90485867
	3	0.621	24.05178651
	4	0.523	33.90995105
	5	0.287	112.6073523

The formula used for calculating the VICKER'S HARDNESS NUMBER is,

$$VHN= (2P \sin 136^{\circ}/2)/d^2$$
$$VHN= 1.8544 (P/d^2)$$

Where,

P= load applied,

d^2=square of total scale value.

From the table we can able to understand that the hardness improves with more dipping time of diffusion and the hardness is diffused specimen is greater than that of untreated specimen. This proves that the properties of steel is improved by diffusion.

VII. ELEMENTAL ANALYSIS

Element analysis is done by using **SPECTROMAXx .** The result shows that the aluminium has diffused into the steel by the means of diffusion. The composition of diffused specimen is presented in the table 6.

TABLE 6 Composition of diffused specimen

Fe	Al	C	Cu	Mg
98%	0.58%	0.012%	0.214%	0.0190%

The presence of Aluminium in Steel is 0.58%.

VIII. RESULT AND CONCLUSION

The hardness value for the specimens after diffusion is greater than that of before diffusion. This will prove that the diffusion coating of FeAl intermetallic coating improves the surface properties. The elemental analysis shows that the Aluminium is merged with the Steel forming a stronger bond.

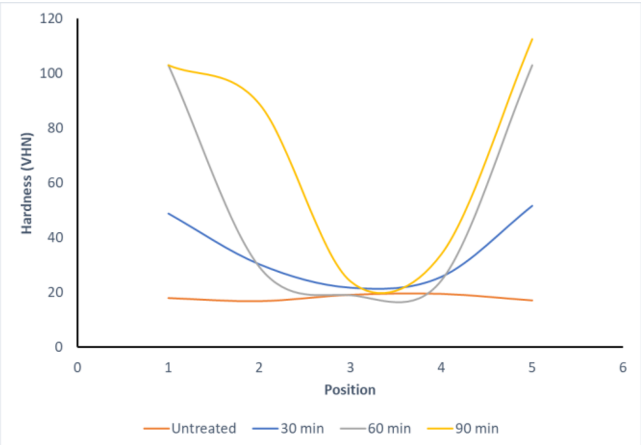

Figure 7. Graph of Vickers Hardness Number

It is found that the surface properties of the steel specimens are improved by diffusing FeAl intermetallic coating. The purpose of this project is to incorporate this method into the industry. This mainly focuses on agricultural equipments where the wear and tear are more which needs to be replaced over and over. By implementing this technique, the life span of the equipments are improved.

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