

Corrosive Wear of Aluminized Steel

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ABSTRACT: Mild steel is vulnerable to corrosion and often wears out at high rates due to combined effects of wear and corrosion. The annual maintenance costs of mild steel parts for prevention of corrosion are huge. Automobile parts like the exhaust manifold are being aluminized to prevent corrosion. Mild steel specimens are aluminized using hot dip aluminizing method by varying certain parameters involved in hot dipping. The dipping time and the diffusion times are kept constant while the dipping temperature is varied. The coated samples are then subjected to corrosive wear test by using 5% sulfuric acid as a lubricant in Pin-on-disk wear testing setup. Difference in wear rates between mild steel specimens and the hot dip aluminized specimens are studied.

KEYWORDS: Hot dip aluminizing, corrosive wear, Aluminized steel, diffusion.

I. INTRODUCTION

Steel has a number of desirable physical properties such as high strength, toughness, elasticity, ductility, and it is also easy to process steel, which makes it a preferable material for numerous structural applications. Steel has some disadvantages too, properties like low fatigue strength, susceptibility to brittle fracture and buckling, low corrosion resistance in addition to low strength at high temperatures especially for low carbon steel. As a result of these limitations there are costs associated with maintenance by continuous painting and thermal proofing in some cases. Hence it is important to coat steel with a superior metal that will help enhance the surface properties to lower annual maintenance.

Aluminizing is a process through which the surface of a metallic component is coated with a layer of aluminum. Steel and its alloys are the most common metals that are aluminized for commercial applications. Corrosive wear is a common occurrence in marine engines and various other mechanical parts. Steel parts are often aluminized to improve resistance to corrosion as well as wear. Aluminizing plain carbon steel or steel alloys increases their resistance to oxidation at high temperatures (773-1073K) and also increases the corrosion-resistance of steel in hydrocarbons and sulfurous atmospheres. Various techniques are available for coating aluminum over steel, these include; electrolytic coating, cladding, pack, gas, spray (metalizing) and hot-dip aluminizing. Hot dip aluminizing is an effective technique due to its various merits and cost effectiveness.

II. MATERIALS AND METHODOLOGY

2.1 Materials used

AISI 1018 steel is the base material used in this study. The chemical composition of AISI 1018 steel is listed in table 1

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Table 1: Chemical composition of base metal

ELEMENT	CONTENT
Carbon, C	0.14-0.20%
Iron, Fe	98.81-99.26%
Manganese, Mn	0.60-0.90 %
Phosphorous, P	0.040%
Sulfur, S	0.050%

2.2 Specimen surface preparation

The surface of the mild steel specimen has to be prepared before the aluminizing process. All kinds of dirt and impurities must be removed and also the specimen should have optimal surface finish for good wetting.

Acid cleaning: The mild steel surface is cleaned with 5% sulfuric acid for 3 minutes. This helps in removing the dirt and other foreign particles from the specimen surface.

Water rinsing: After acid cleaning, the specimen surface is rinsed in water for 1 minute to make sure the surface is free from sulfuric acid. It is then dried.

Shot blasting: The dried specimen is shot blasted in alumina grit for 5 minutes.

2.3 Hot dip aluminizing

The hot dip aluminizing process is done by melting pure aluminum and raising the temperature to 900° C to improve the fluidity of the molten bath. Then the temperatures are adjusted for each specimen. The dip time is kept constant for all the specimens at 2 minutes.

TABLE 2: Process details

S.NO.	TEMPERATURE (in °C)	DIP TIME (in min)
1.	700	2
2.	725	2
3.	750	2
4.	775	2

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2.4 Diffusion

In order for the hot dip aluminized coatings to bond to the base metal at atomic level, the coated specimens must be diffused. Without diffusion the coating will be weak and will perform poorly in a scratch test or adhesion test. The coated samples were diffused at 800 °C for 1 hour in a closed induction furnace. Diffusion plays an important part in formation and characteristics of the intermetallic layer which is made of Fe-Al alloy phase. Diffusion treatment of the coated aluminum samples will directly influence the coating characteristics like the thickness of the intermetallic layer and overall coating thickness. A very thick intermetallic layer will make the coating very brittle and it will easily fail the bend test. A very thin intermetallic layer will often lead to weak adhesion between base metal and the coating. An optimal range between these two is the desired thickness. Diffusing at high temperatures increases the porosity of the coating and diffusion below 660° C will not yield atomic level reactions.

III. RESULTS AND DISCUSSIONS

The coated specimens were tested using a pin-on-disk wear testing machine. Here the pin is the coated sample. The pin-on-disk wear machine parameters are held constant for all the coated and uncoated mild steel specimen. The ISO standards suggest that a wear test should have a minimum sliding distance of 1000 m. accordingly the track diameter, and speed were set. A load of 2kg is applied.

TABLE 3: Wear test parameters

Load (kg)	Speed (rpm)	Track diameter(mm)	Sliding distance (m)
2	400	50	1000

Running time calculations:

Sliding velocity, $V = \frac{\pi DN}{60 \times 1000}$, m/s

60×1000

D - Track diameter

N - Speed in rpm

By substituting the values we get,

$V = 1.04$ m/s

Velocity, $V = \frac{\text{Distance (sliding distance)}}{\text{Time}}$

Time

By substituting we get,

Time = 16.02 min

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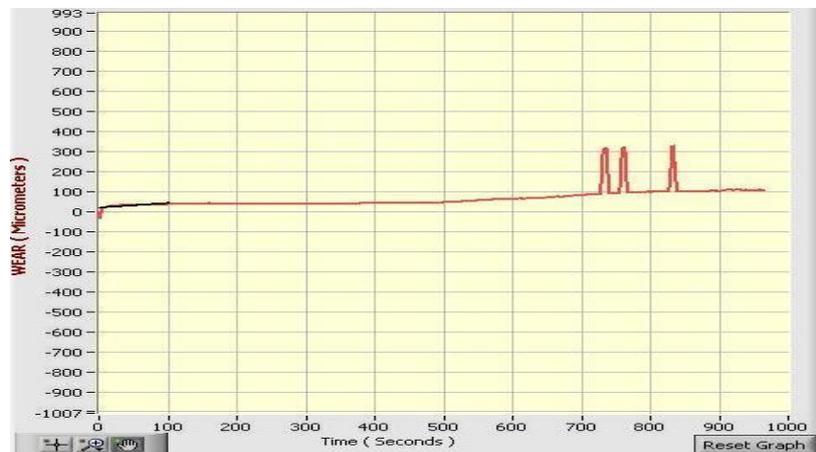
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All the parameters (load, track diameter, sliding distance, speed) were set and a running time of 16.02 minutes was taken as a minimum running time to meet the ISO standard recommendation of minimum sliding distance of 1000m. All the specimens were tested in the pin-on-disk machine under same conditions. A cast iron disk of hardness HRC74 was used for all the specimens. Mass of the specimens were taken using a digital precision weighing machine before and after the test to compute material loss.

Wear Vs Time graphs (Generated by Pin-on-disk machine software Winducom)

Graph 1: Wear of Mild steel



Graph 2: Sample coated at 700° C



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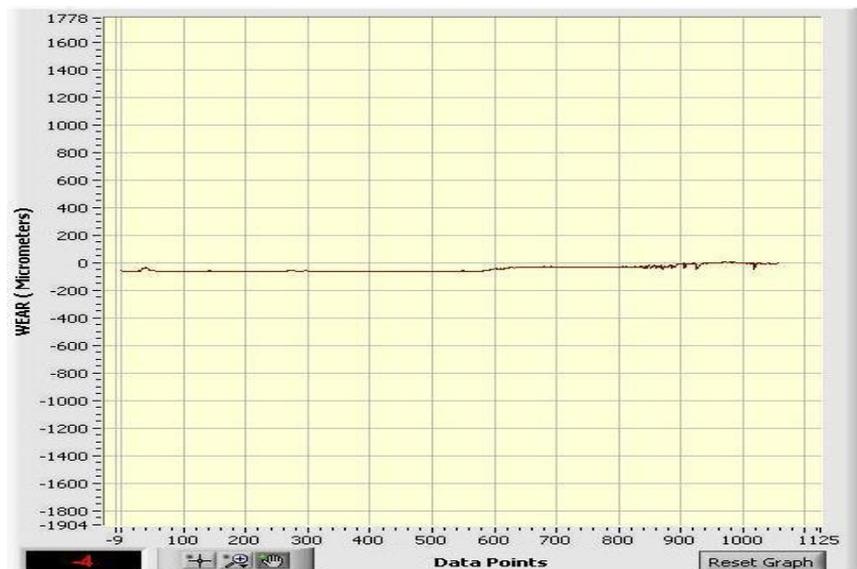
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Graph 3: Sample coated at 725° C



Graph 4: Sample coated at 750° C



Graph 5: Sample coated at 775° C

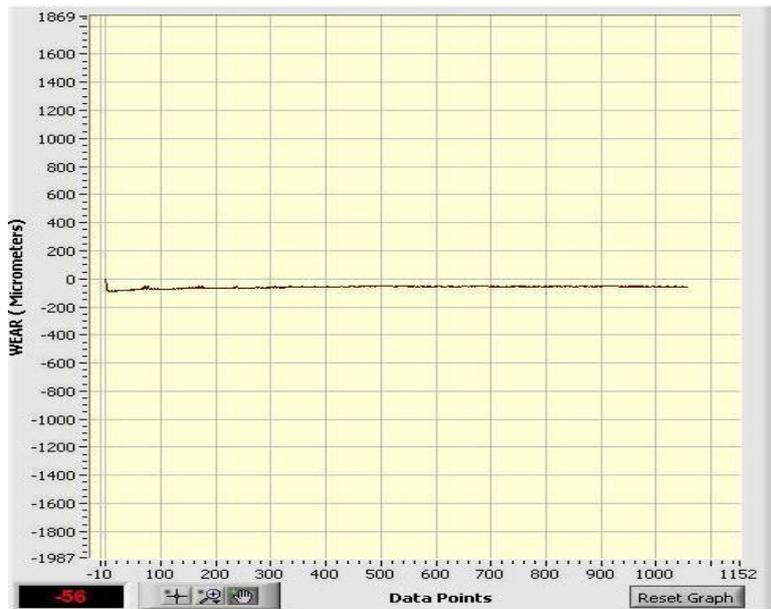


Table 4: Specimen mass before and after wear test

Specimen	Mass before wear test (g)	Mass after wear test(g)
Mild steel	24.79688	24.49244
Coated at 700 ° C	24.24990	24.11718
Coated at 725 ° C	24.69425	24.64280
Coated at 750 ° C	24.48305	24.45212
Coated at 775 ° C	24.48916	24.43002

IV. CONCLUSION

Prior to aluminizing the mild steel sample showed comparatively less resistance to corrosive wear and it can also be seen that the material loss after wear test for the mild steel sample is higher than their coated counterparts. Aluminizing the mild steel samples using hot dip aluminizing technique has very clearly resulted in a distinctive increase in resistance to corrosion and wear which is a well known fact. This study also shows the minor differences in wear rates between the samples coated at different dipping temperatures. The thickness of the coating increases with dipping temperature and time and diffusion plays an important role in the intermetallic layer formed. Optimal thickness of both coating as well as the Fe-Al intermetallic layer is important for a good coating. Sample coated at 700° C performed poorly compared to other samples, which clearly shows that a dipping time of 2 minutes and a dipping temperature of 700 ° C is not sufficient enough for the formation of intermetallic layer which is important for the coating strength.

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REFERENCES

1. P.T.Stroup and G.A.Purdy, Aluminium Coating of steel – A comparison of various processes, Aluminium Research laboratories, New Kensington, Pa. January 1950.
2. M.L.Hughes and D.P.Moses, Hot Dip Aluminising, volume 48, metallurgia, September 1953.
3. S.G.Denner and R.D.Jones, Kinetic interactions between aluminium and iron/steel for conditions applicable to hot-dip aluminizing, The metals society, 1977.
4. S.C.Kwon and J.Y.Lee, Interface Morphology between the aluminide layer and iron substrate in the hot-dip aluminizing process, Canadian metallurgical quarterly, vol .20, No.3, pp. 351-357, 1981.
5. H.R. Shahverdi, Microstructural analysis of interfacial reaction between molten aluminium and solid iron, ministry of mines and metals, Iran, april 2002.
6. Jon Martin Andersson, Controlling the formation and stability of alumina phases, thesis, Linkoping University, 2005.
7. Tomohiro Sasaki and Takao Yakou, Effects of heat treatment conditions on formation of Fe-Al alloy layer during high temperature aluminizing, Yokohama National University, April 2007.
8. H. Glasbrenner and K.Stein-Fechner, Scale structure of aluminized manet steel after HIP treatment, Institute for materials research III, 2000.
9. XIA Yuan, Effect of diffusion on coating microstructure and oxidation resistance of aluminizing steel, Chinese academy of science,2001.