Role of Alloying Additions in Microstructure and Wear behaviour of Galvannealed Coating

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Abstract— Galvannealing is a modified techniques of galvanizing in which annealing is carried out after Zn coating in order to transform the coating surface to wear resistance Zn oxides. The name is referred since galvanizing + annealing steps are carried out subsequently this kind of coatings provide better corrosion resistance as well as wear/scratch resistance there by the damages during transportation could be avoided, the annealing stage lead to the formation of intermetallic layers/precipitates which assist in enhancing the strength and hardness of the coating. Recently it is investigated that Al, Fe, Cr and other alloying elements could be added into the Zn bath during galvanizing so that they can form intermetallic layers or particles on subsequent annealing stages. Further, the annealing temperature and time need to be optimized so that a needle like/flower like morphology can be developed. The size and shape of needles/flowers control the hardness and wear resistance of the coating. Thus it is required to optimize the process parameters so as to control the morphology there by better mechanical properties can be achieved in the present investigation a galvanneled coating is developed using hot dip galvanizing and subsequent annealing. Few set of coatings are developed on mild steel substrate with addition of Al into Zinc bath the concentration of Al varied from 0, 0.1 and 0.2 weight percent respectively.

Key words: Galvannealing, Annealing, Zinc Oxides, Intermetallic, Morphology, Hot Dip Galvanizing, Concentration, Resistance

I. INTRODUCTION

Zinc coating is applied on ferrous substrate from very long time to have an improved corrosion resistance of the substrate. Sacrificial coatings of pure zinc and other type of zinc alloys having metals such as nickel, cobalt, iron, aluminium, lead etc. are applied to protect the ferrous base metal The life of zinc coatings can be improve by the alloying of elements, surface treatments', and heat treatment of the surface . There are different types of zinc coatings or we can say different ways to apply zinc coating which are generically termed "galvanizing," but each type of coating has unique characteristics. These characteristics not only affect applicability, but also economics and performance of the components in the environment. The method of applying, adhesion to the base metal, hardness, corrosion resistance, wear resistance, and thickness (*Figure 1*) of each zinc coating varies.

The reaction is get completed when coated zinc is finally transformed into Zn-Fe phases up to the top of the coating. The iron concentration decreases towards the top surface and we get different types of inter metallic phases, respectively Gamma (21-28%Fe, FeZn4), Delta (7-12%, FeZn1o), Zeta (5-6%Fe, FeZn13) and Eta (<0.03 %Fe, Pure Zn). Galvannealed coatings are reported as to have improved paintability better welding characteristic as well as better corrosion resistance as compared to hot dip galvanizing coatings. Due to these extreme properties, Demand of galvannealed coatings are continuously increasing in automobile sector, construction and other sectors of industries.

A systematic study has been performed on wear resistance behaviour of galvanized, galvannealed and uncoated iron substrate in dry condition here we get a good wear resistance in galvannealed coating for galvannealed coating we go for annealing just after the galvanizing at different temperature and time I varies the temperature 450ºc to 550ºc and for different time like 1min, 5min, 10min etc. I test the wear resistance of all coated, uncoated galvanized and galvannealed samples on the pin on disc wear resistance setup and we get that in all varying conditions the galvannealed coating perform superior than other zinc coatings.

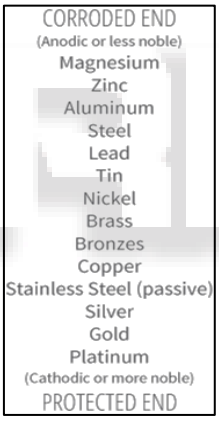

Fig. 1: Arrangement of metals in galvanic series

The inter metallic layer which formed during hot dip galvanizing, also plays an important role on corrosion resistance of galvanized coating. There is a way to effectively alter the inter metallic layer of zinc coating is called galvannealing. Galvannealing is a process in which diffusion reaction between the iron substrate and zinc coating takes place in temperature range of 500°c to 600ºc. The diffusion of iron results into the formation of columnar Zn-Fe crystal growing in the outward direction.

II. EXPERIMENTAL METHODS

A. Sample Preparation

The first step in my experimental work is to prepare the samples for Zn coating in this process following sequences are there like material selection, cutting g the material, finishing of the samples etc.

1) Material Selection

In this study I try to apply the Zn coating on steel samples, material selection is based on the requirement of the

industries and it also being considered the problem faces in day to day life. That's why I choose structural steel as a sample material and it is also of two type one is steel sheet which is generally used in automobile industries and another one is TMT bar which is mostly used in construction purpose

And in this study I have taken two types of samples

2) Plate Type

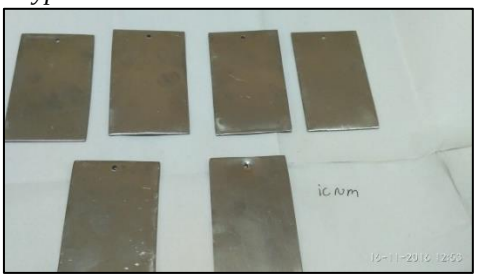

Fig. 2: Plate type sample

3) TMT Bar

Fig. 3: TMT bar sample

4) Cutting the Material in required Dimensions

For this study we required the samples in a particular dimension so we have to cut the material in particular dimensions, for cutting purpose I use hand hacksaw and grinding wheel of the MSME department.

The dimensions of the samples are as follows

5) For Plate Sample

– Length
– Breadth

6) For TMT Bar Sample

– Length: 20mm
– Diameter: 8mm

B. Finishing of the samples

When the samples was procured it was in a very bed condition the whole material was corroded but in this study for coating of Zn we required samples which are free from oxide layers so I had to remove the oxide layer from the samples, for the finishing operation I use grinding wheel and emery paper of grade 180,220,320,400.

C. Hot Dip Galvanizing

After the samples was prepared the next step is to go for Zn coating on the samples so we go for hot dip galvanizing method in this process first I put the Zn ingot in the crucible and add some alloying element and melt them in the furnace at temperature around 700ºc to 750ºc and keep at this temperature for some time so that the Zn is fully get melted and then we take it out from the furnace and dip the samples in melted Zn solution and keep it in for some period of time around 5 to 10sec so that the samples are fully get covered by Zn solution and then we take out the samples.

III. ANNEALING

For galvannealing process we have to go for annealing just after the galvanizing process here first we dip the samples in the zinc solution whose temperature is around 700-750º c and then after put the samples in the furnace for the annealing at different temperature (450ºc, 500ºc, 550ºc) and different time (1min, 5min, 10min) and examine the microstructure and appearance in different annealed sample.

A. Before Annealing

Fig. 4: Coating without annealing

B. After Annealing

Fig. 5: coating with annealing

C. Samples are annealed at different temperature and time

At 550ºc 10min 500ºc 5min 450ºc, 1min

Fig. 6: Samples annealed at different temp. And time

IV. WEAR RESISTANCE TEST

To test the wear resistance of base material and coated samples I use pin on disc wear resistance testing machine of MSME department of MANIT Bhopal , for the wear testing process I prepared five samples whose description are given below.

Procedure of pin on disc wear resistance test

– The first step in this test is to make the sample surface flat to that so that the load will act on the whole cross section of sample; this is achieved by finishing the samples with emery paper.
– In second stage we clean the disc with the help of ethanol soaked cotton and then fit the sample in given space and tight it properly so that it wears the cross section uniformly.
– The third step is to feed the necessary parameter in machine like load, speed (rpm), track radius, pin diameter, sliding distance etc. and save the file in the computer attached with the machine

– After feeding the data press start button of the machine then steady state wear of material started

A. Wear Calculation

1) Area

Cross sectional Area, $A = \pi r^2$

2) Volume loss

Volume loss = Cross sectional Area x Height loss

3) Wear rate

Wear rate = Volume loss / Sliding distance

4) Wear resistance

Wear resistance = 1/ Wear rate

5) Specific wear rate

Specific wear rate = Wear rate/load.

S. No.	Sample name	Cross sectional area (mm^2)	Height loss (mm)	Volume loss (mm^3)	Wear rate (mm^3/m)	Wear resistance (m/mm^3)	Specific wear rate (mm^3/N-m)
01	S1	44.17	0.22	9.7174	0.004858	205.85	9.72×10^{-4}
02	S2	46.32	0.18	8.3376	0.004168	239.93	8.34×10^{-4}
03	S3	45.36	0.15	6.8040	0.003402	293.94	6.80×10^{-4}
04	S4	45.36	0.09	4.0824	0.002412	414.59	4.82×10^{-4}
05	S5	44.18	0.13	5.7431	0.002871	348.31	5.74×10^{-4}

Table 1: Different wear parameters of samples

V. Results and Discussion

A. XRD Analysis

For phase identification and crystallographic analysis we have to prepare the samples for XRD so we choose the samples which having no scratches and free from any surface defects and cut it in required dimensions then we wash the sample with acetone.

The XRD results of as deposited samples showed the presence of zinc, Al and other intermetallic phases in the coating. After annealing the coating revelled the presence of zinc oxide and intermetallic phases such as Gamma (21-28%Fe, FeZn4), Delta (7-12%, FeZn1o), Zeta (5-6%Fe, FeZn13) and Eta (<0.03 %Fe, Pure Zn). The HCP zinc crystals have found to grown in 002 direction as deposited condition while zinc oxide showed a predominant plane of 200.

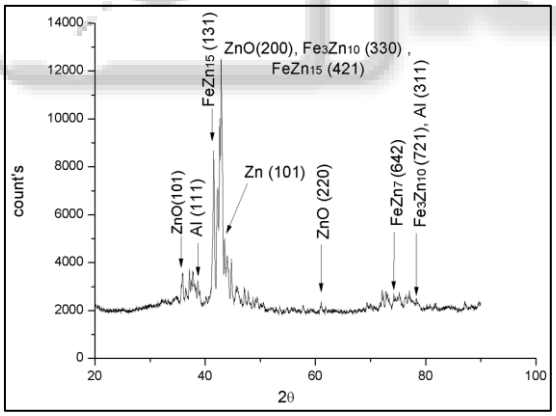

Fig. 7: XRD pattern of galvannealed sample

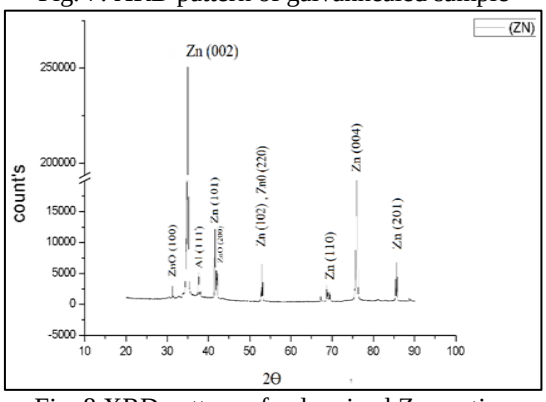

Fig. 8 XRD pattern of galvanized Zn coating

B. SEM Analysis

SEM is used for microstructure and morphological analysis of the material here I prepare 4 to 5 samples for SEM analysis I choose the samples which are free from scratches and cut them in required dimension of ideal sample of SEM

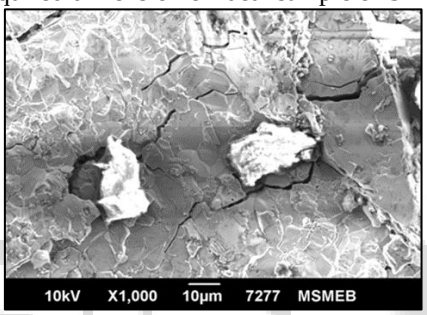

Fig. 9: SEM image of galvanized coated sample

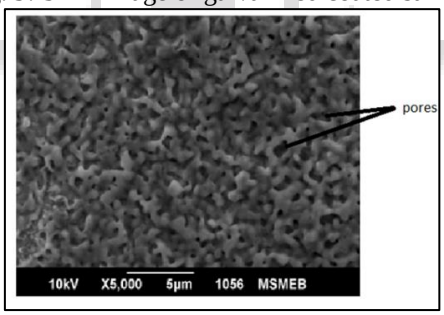

Fig. 10: Needle like structure of zinc coating

VI. Conclusion

We prepare the galvannealed coating at different temperature and time of annealing and perform several experiment on the coated sample and compare the experiments data with the base material data and the galvanized coated samples data, here we analyse the microstructure, morphology, composition, wear and corrosion behaviour of different samples.

In SEM results we analyse the microstructure of coating and here we can see that the samples which are galvannealed coated having three layer of coating gamma (Γ), delta (δ) and zeta (ζ) alloy layers which provides three layer protection of the base material from the environment and we get matte uniform surface and better surface finish of the galvannealed coated samples so, it will have good paintability and weldability as compare to galvanized coating and base material.

Where as in wear testing of samples we analyse the different parameters like weight loss, wear, wear rate, frictional force and coefficient of friction by observing all parameters overall we can say that the galvannealed coating having the highest wear resistance then after galvanized coating and finally the uncoated sample shows vary poor wear resistance, in galvannealed coating also we can optimise the result by varying the temperature and time of annealing in this study I prepare the three types of galvannealed samples one annealed at 550˚c for 10 min second one is annealed at 500˚c for 5 min and the last one is at 450˚c for 1 min, In this study I get optimised result for second type of sample which is annealed at 500˚c for 5 min.

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