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Effect of Time and Temperature on Annealing of AISI 1040 Steel for Better Corrosion Resistance

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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 inter metallic 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 inter metallic 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 galvanised 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 is 0.1% by weight.

Keywords Galvannealing, Annealing, Zinc Oxides, Intermetallic, Morphology, Hot Dip Galvanizing, Concentration, Resistance.

I. INTRODUCTION

Zinc coating is applied on the ferrous substrate for very long time to have an improved corrosion resistance of the substrate. Sacrificial coatings of pure zinc and other types of zinc alloys having metals such as nickel, cobalt, iron, aluminum, lead, etc. are applied to protect the ferrous base metal The life of zinc coatings can be improved 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 of each zinc coating varies.

Galvannealed coatings are reported as to have improved paint ability better welding characteristics as well as better corrosion resistance as compared to hot dip galvanizing coatings. Due to these extreme properties, the Demand of galvannealed coatings is continuously increasing in automobile sector, construction and other sectors of industries.

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 material selection, cutting g the material, finishing of the samples etc.

(1) Material Selection

In this study we 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 we choose structural steel as a sample material and it is also of two types one is steel sheet which is generally used in automobile industries, Plate Type sample.

(2) 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 purposes we use a hand hacksaw and grinding wheel of the

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Mechanical department. The dimensions of the samples are as follows:

For Plate Sample

Length: 25 mm

Breadth: 20 mm

A. 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 we had to remove the oxide layer from the samples, for the finishing operation we use grinding wheel and emery paper of grade 180,220,320,400

B. Hot Dip Galvanizing

After the samples were prepared the next step is to go for Zn coating on the samples so we go for the hot dip galvanizing method in this process first we put the Zn ingot in the crucible and add some alloying elements and melt them in the furnace at a 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 10 sec so that the samples are fully get covered by Zn solution and then we take out the samples.

III. ANNEALING

For gal annealing 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 temperatures (500ºc, 550ºc, 600ºc) and different time (10min, 15min, 20min) and examine the microstructure and appearance in the different annealed sample.

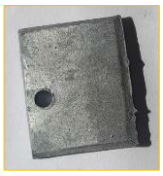
1. before Annealing

Figure 1: Coating without annealing

2. after Annealing

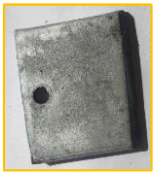
Figure 2: Coating without annealing

IV. SAMPLES ARE ANNEALED AT DIFFERENT TEMPERATURE AND TIME

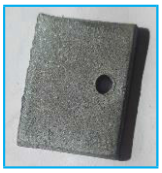


500°C & 10 min

500°C & 15 min



500°C & 20 min



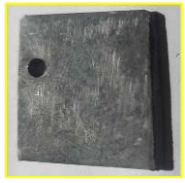
500°C & 10 min

550°C & 15 min

550°C & 20 min

600°C & 10 min

600°C & 15 min



600°C & 20 min

Galvanized

Uncoated

IV. CORROSION RESISTANCE TEST

To test the corrosion resistance of base material and coated samples we use the weight loss method for corrosion test in the Chemistry lab of Mandsaur university, for corrosion testing we prepared 11 samples in which one id uncoated and one is galvanized coated and other nine samples is galvannealed coated at different temperature and time, according to different temperature and time combination following samples are prepared

Table 1: Annealing of different samples at variable time and temperature.

Sample ID	Annealing temperature(°c)	Annealing time (min.)
S1	500	10
S2	500	15
S3	500	20
S4	550	10
S5	550	15
S6	600	20
S7	600	10
S8	600	15
S9	Galvanized coated	Galvanized coated
S10	Uncoated	Uncoated
S11		

The procedure for corrosion test is as follows

The first step is to prepare the samples of AISI 1040 steel sheet with dimension 19×14 mm followed with sample preparation for which we use emery paper of 120 grade to remove previously formed oxides and followed with acid pickling to remove any dirt and oil traces then samples are dipped into flux solution of zinc ammonium chloride and then let the sample dry and the next step is to go for hot dip galvanization in molten Zn bath with 1% Al concentration by weight

And the next step is to go for annealing of samples at different temperature and time.

After preparation of samples we go for corrosion testing for this research work we use acidic medium electrolyte to dip the samples here we prepared 5% concentrated solution of HCL. Dip the samples in the corrosive environment for a particular time interval and ensure that the samples are fully dipped in the solution and cover the beaker with Al foil. The samples are taken out from the solution at different interval of time and measure the weight of the samples and note it down and put back the sample to solution.

For this research work we measure the change in weight of samples after 5 days, after 11 days, after 20 days, after 30 days, after 40 days, after 50 days, after 60 days

A. Corrosion Calculations

Corrosion Rate (CR)

$$(CR) = 87.5 \times \frac{\Delta W}{A \times t \times d}$$

Where

Δw - Change in weight (in grams)

A – Surface Area of samples (in mm^2)

t - Time interval (in hours)

d - Density (gm/cm^2)

V. RESULTS AND DISCUSSIONS

The corrosion test shows the comparative study of uncoated samples, galvanized samples, and gal annealed samples also it shows the optimum temperature, and time in gal annealed coated samples, the corrosion test results are as follows

Table 2: Effect of annealing on the weight of different samples with time.

SampleId	Description	Weight (gm)	Changein weight (gm)
S1	500 °C for 10Mins.	10.86	0.10
S2	500 °C for 15Mins.	12.84	0.07
S3	500 °C for 20Mins	10.32	0.08
S4	550 °C for 10Mins.	11.47	0.07
S5	550 °C for 15Mins.	10.11	0.04
S6	550 °C for 20Mins.	12.46	0.05
S7	600 °C for 10Mins.	09.80	0.06
S8	600°C for15Mins.	12.23	0.07
S9	600 °C for 20Mins.	10.87	0.06
S10	Galvanized	13.26	0.10
S11	Uncoated.	12.20	0.18

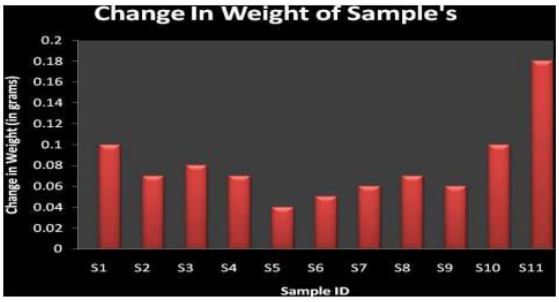


Figure 1: Graph for Change in weight of Samples after 60 days

Table 3: Corrosion rate of Different samples after 60 days.

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Sample Id	Change in weight (milligram)	Corrosion rate (mm/y)
S1	10.00	0.06295
S2	70.00	0.044064
S3	80.00	0.050359
S4	70.00	0.044064
S5	40.00	0.025179
S6	50.00	0.031474
S7	60.00	0.039209
S8	70.00	0.045744
S9	60.00	0.039209
S10	100.00	0.065349
S11	180.00	0.113307

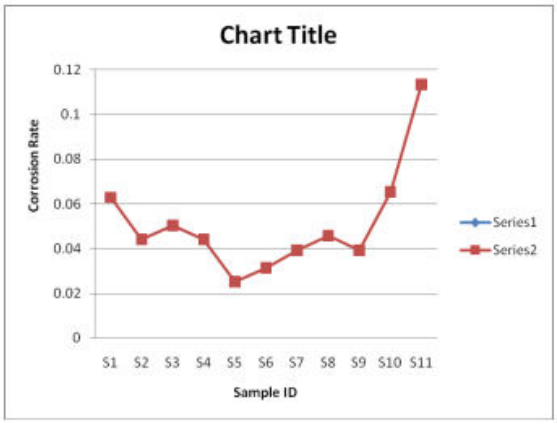

Figure 2: Graph of Corrosion Rate graph after 60 days

VI. CONCLUSIONS

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 analyze the corrosion behavior of different samples. The corrosion test shows that the galvanized sample has less corrosion rate compared to uncoated samples but higher than galvannealed coated samples, in galvannealed coated samples also the sample 5 (S5) which is treated at 550 °C and for 15 min. Has lowest corrosion rate which is 0.025179 mm/y, so on behalf of this corrosion test we can say that the optimum temperature and time for more resistive galvannealed coating is 550 °C and 15 min.

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