



Analysis of Corrosion Rate of Carbon Steel Galvanized by Weight Loss Method to Thickness and Micro Structure of Steel

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ABSTRACT

This study aims to determine the effect of hot dip galvanizing on steel with different carbon content on mechanical properties of steel. The research method used in this research is an experimental method, The method used was that the metal was coated with hot dip galvanizing media using zinc. From the hardness test results, SAE 1085 produced the highest average of hardness 95.1 HRB. The results of the thickness test showed that the highest AISI 1020 was 131.8 μm . The results of the corrosion rate test showed that the highest corrosion rate is AISI 1020 was 0.36385 mmpy. The microstructure test results showed SAE 1085 has a smaller grain size. Zn layer which is not too thick due to lack of diffusion and movement of Zn atoms due to high carbon content which has a close layer distance and small grains. So that the corrosion rate that occurs is lower than steel which has a low carbon content.

Keywords: Carbon Steel, Hot Dip Galvanizing, Corrosion, Corrosion Rate, Weight Loss Method

INTRODUCTION

Corrosion is a decrease in quality caused by chemical reactions of metals with other elements that are present in nature. As a result of its reaction with the environment as a metal it will become a form of oxide, sulfide or another form of reaction contained in its environment, therefore this event is also called an event that the metal material returns to a stable equilibrium with the surrounding conditions[1], [2], [3].

Corrosion control measures have many types and ways, such as coating other metals that are more anodic. The metal coating process with other metals that are more anodic, for example, coating steel with zinc, aluminum, cadmium or magnesium. This coating process can be done by electroplating, spraying or Hot Dip Galvanizing[4], [5].

Hot dip galvanizing is a coating process in which the coating metal is heated first until it melts. Then the metal to be coated, which is usually called the base metal, is dipped in a galvanized bath that has been filled with molten metal, so that in a few moments the metal will be coated with a layer of The alloy layer between the zinc coating metal and the base metal is in the form of a strong metallurgical bond and is arranged in layers called phases. Coating with the Hot Dip Galvanizing method is widely used because it is relatively easy to control the quality of the coating, is durable and resistant to impact. Protection on the galvanized layer has two advantages, namely as a barrier and a

thickened anode. Barrier protection will protect the metal from the outside environment while as anode which is thickened it will corrode zinc before the metal or its substrate[6].

To get good and long-lasting results, many factors influence, including the composition of the material, the composition of the solution, the temperature of the solution and the duration of immersion. The result is an even layer thickness and a good appearance of porosity in the metal coating, increases metal resistance to corrosion and extends the service life of the metal[7].

Carbon steel is a structural steel that is often used for construction purposes and the manufacture of machine components. This carbon steel is an alloy of several elements to obtain mechanical properties suitable for its intended use[8].

The use of steel as a component of machining and construction often experiences damage before a calculated time and is not supported by adequate wear and corrosion resistance. This corrosion process occurs for a long time, it depends on the environment. that the higher the carbon content of a steel indicates that its strength against corrosion is getting better, in other words that the less carbon content of a steel, the more iron content (Fe). With the occurrence of the corrosion, the iron atoms were released from their bonds by the corrosion process, especially by the HCL acid. Therefore we need a method that is sought to overcome corrosion and wear by performing

a surface treatment process, namely by providing protection to the metal surface with other metals[9], [10].

Based on the reasons and thoughts above, what is of concern is that the carbon content of different steels affects the quality of the steel in the hot dip galvanized process at a temperature of 450° To Knowing the effect of carbon content in Galvanized steel on the value of the corrosion rate.

RESEARCH METHOD

The research method used in this research is an experimental method, in which the researcher buys 3 types of steel with different carbon content (low carbon steel, medium carbon steel, and high carbon steel). Then the hot-dip galvanized process was carried out on the three carbon plates of steel and carried out 4 tests, namely galvanic thickness test, hardness test, corrosion rate test, and metallographic test.

The corrosion rate test is based on the ASTM G31-72 standard and uses the weight loss method to determine the value of the corrosion rate. Testing begins with the initial weighing of the specimens that have gone through the hot dip galvanizing process with an analytical balance. After initial weighing, each specimen was immersed in a beaker containing 10% HCL acid solution and 90% Aquades with immersion time of 14 days.

After immersion in an acid solution, the specimens were cleaned using water and alcohol to remove any residual HCL acid

solution and a final weighing was carried out for each specimen using an analytical balance.

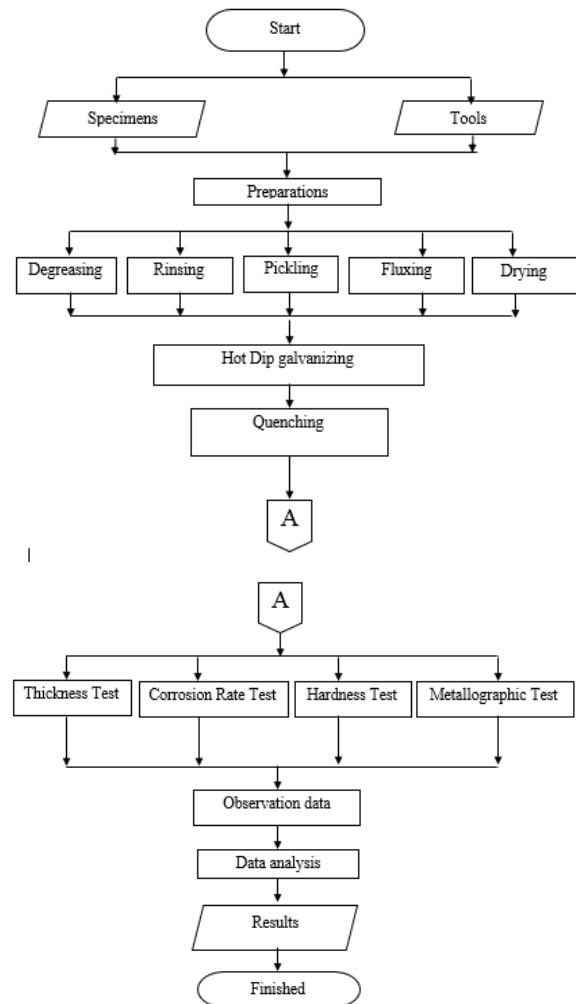


Figure 1. Research procedure

The calculation of the corrosion rate in this study uses the weight loss method with the formula for calculating the corrosion rate as follows:

$$CR (mpy) = \frac{W \times K}{D \times A \times T} \tag{1}$$

Information:

CR = Corrosion rate (mmpy)

W = Weight Loss (gram)

K = Constant

D = Specimen Density (g/mm³)

As = Surface Area (mm²)

Before testing the carbon steel with different carbon content Low carbon steel AISI 1020, medium carbon steel 1045, and high carbon steel SAE 1085 were prepared, the carbon steel was cut using a cutting machine with dimensions of 30x10x10 mm.

Preparations are carried out before galvanizing, including:

Degreasing

The specimen to be galvanized is slaughtered first immersed in an oil removal solution (NaOH).

Rinsing Degreasing

Rinse with water to remove the remaining solution in the Degreasing process.

Pickling

Specimens that have gone through the Rinsing Degreasing process are immersed in a bath filled with HCL acid solution for 10-15 minutes. aims to remove oxidation or rust stains on the specimen.

Rinsing Pickling

Specimens that have gone through the Pickling process are cleaned by being immersed in a tub filled with water. Aims to remove the residual acid solution from the Pickling process.

Fluxing

Specimens that have been through the Rinsing Pickling process are immersed in a bath containing a solution of ammonium chloride in water and heated to 60°C. This is intended so that heat transfer to the specimen takes place slowly and gradually to avoid plastic deformation that can interfere⁴

with the zinc adhesion process on the workpiece during the galvanizing process.

Drying

is a process of drying and preheating using hot gas with a temperature of approximately 150°C, the aim is to remove any liquid that may be present on the surface of the specimen which can cause a steam explosion during the galvanizing process.

After the specimens went through the preparation stages, the specimens were immersed in a bath filled with hot zinc at a temperature of 450°C with an immersion time of 5 minutes. After the specimens go through the process of immersing into a bath filled with hot zinc, then the specimens are immersed in a tub filled with sodium bichromate solution to cool the specimens.

RESULT AND DISCUSSION

Rockwell Hardness Test Results

Rockwell hardness test results can be seen in Table 1. The table is the test results of 3 types of specimens, namely low carbon steel, medium carbon steel, and high carbon steel specimens that have gone through the hot-dip galvanized process.

Table 1. Rockwell hardness test results

No	HARDNESS (HRB)		SAE 1085
	AISI 1020	AISI 1045	
1.	42.9	72.7	90.6
2.	46.9	74,4	97.6
3.	55.5	82.5	97.1
4.	50.9	77.8	99.7
5.	51.8	83.1	90.5
Average	49.6	78.1	95.1

Rockwell hardness testing was carried out 5 times the point of emphasis in a straight

line from the tip of the specimen with a distance of 0.5 cm from each point.

Microntest Thickness Test Results

The results of the Microntest thickness test can be seen in Table 2. The table is the test results of 3 types of specimens, namely low carbon steel, medium carbon steel, and high carbon steel specimens that have gone through the hot-dip galvanized process. Microntest thickness testing was carried out 5 times the point of emphasis in a straight line from the end of the specimen with a distance of 0.5 cm at each point.

Table 2. Microntest thickness test results

No	Thickness (µm)			SAE
	AISI 1020	AISI 1045	1085	
1.	121	101	56	
2.	129	105	60	
3.	130	119	78	
4.	139	120	79	
5.	140	122	80	
Average	131.8	78.1	70.6	

Corrosion Rate Test Results

Microntest thickness testing was carried out 5 times the point of emphasis in a straight line from the end of the specimen with a distance of 0.5 cm from each point using the Microntest type DualScope MP0D thickness tester.

The calculation of the corrosion rate in this study uses the weight loss method.

Table 3. Calculation Results of the corrosion rate using the weight loss method

No	Corrosion Rate (mmpy)			SAE
	AISI 1020	AISI 1045	1085	
1.	0.36385	0.34815	0.32603	

Metallographic Test Result

In metallographic testing, 100x magnification for a small scale and 400x magnification for a large scale was carried out for each carbon steel specimen.



Figure 2. AISI 1020 low carbon steel specimen 100x magnification

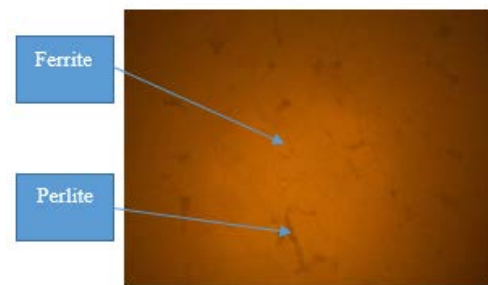


Figure 3. AISI 1020 low carbon steel specimen 400x magnification

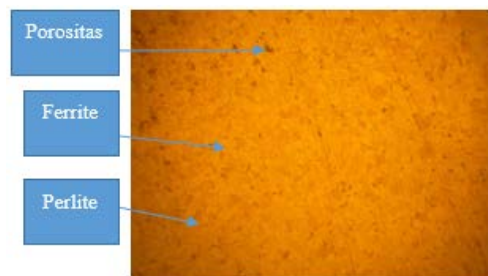


Figure 4. AISI 1045 medium carbon steel specimen 100x magnification

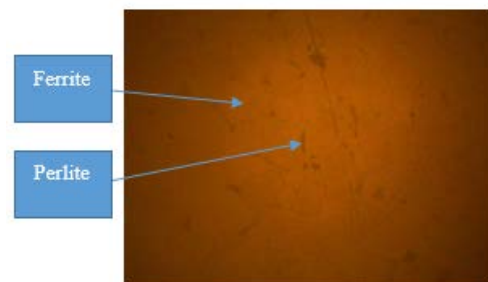


Figure 5. AISI 1045 medium carbon steel specimen 400x magnification

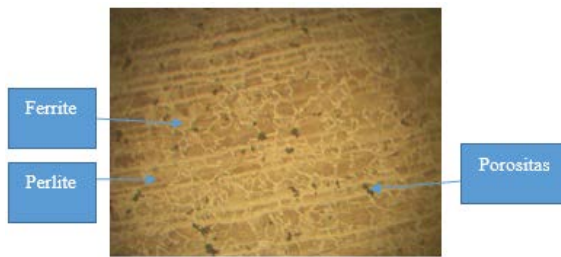


Figure 6. SAE 1085 high carbon steel specimen 100x magnification

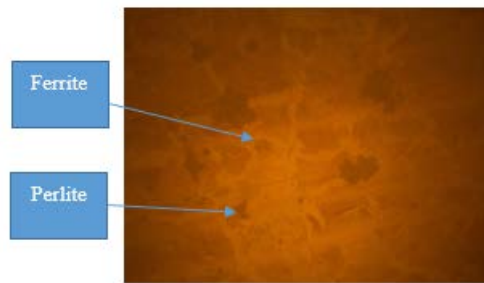


Figure 7. SAE 1085 high carbon steel specimen 400x magnification

Discussion of Rockwell Hardness Testing Results

From the results of the Rockwell hardness test in Table. 1, it can be seen an increase in the hardness value of the specimens that have gone through the Hot Dip Galvanized process with different levels of carbon steel, namely Low Carbon Steel AISI 1020, Medium carbon steel AISI 1045, and high carbon steel SAE 1085. Where in the specimen Low carbon steel has an average hardness value of 49.60 HRB. Among the 3 specimens with high carbon content, SAE 1085 had the highest hardness value, namely 95.1 HRB. This is because the zinc (Zn) layer that coats the raw material is not too thick so that when the hardness test is carried out, the indenter is slightly on the surface of the raw material where the high carbon content causes the material to become very hard [7]. And the AISI 1020 low carbon steel specimen

which has the lowest average hardness value of 49.6 HRB, this is because when testing the hardness, the indenter on the test equipment only touches the Zn layer and a little about the raw material where the hardness level of the zinc layer (Zn) is softer compared to specimens[7].

Discussion of Galvanized Thickness Test Results

From the results of the galvanic thickness test using the microntest in Table 2, it can be seen that the highest average thickness is the low carbon steel specimen, which is 131.8 μm , this is because the low carbon content results in the zinc layer getting thicker this is due to the increasing movement and diffusion of Zn atoms. to form a layer on the surface of the specimen so that the adhering layer is thicker [11] And high carbon steel specimens that have a low average thickness of 70.6 μm . This is due to the lack of movement and diffusion of Zn atoms to form a layer on the surface of the specimen so that it only forms the Eta layer where this layer is composed of 100% zinc (Zn)[12].

Coating with the Hot Dip Galvanizing method will produce an intermetallic layer that can bind well between the zinc and steel layers, but if the bond is too thick it will cause it to become brittle [12], [13], [14].

Discussion of Corrosion Rate Testing Results

The results of the corrosion rate test using the weight loss method with 5% HCL corrosion media in Figure 4.3, it can be seen

that the corrosion rate value of each carbon steel specimen has a positive linear magnitude. It is shown that the value of the lowest high carbon steel corrosion rate is 0.32603 mmpy, while the highest low carbon steel has a corrosion rate value of 0.36385 mmpy, this is because the higher the carbon content of steel shows that its strength against corrosion is getting better[10],[14].

Discussion of Metallographic Testing Results

The results of the metallographic test on the low carbon steel specimen AISI 1020 Galvanized, it is clear that the phase formed is perlite which is the content of carbon dissolved in ferrite ($\text{Fe}_3\text{C} + \alpha$) (dark or black) and ferrite which is a phase of iron or α iron (light-colored)[15]. When viewed from the constituent phases of Perlite and Ferrite, the long layer distance produces a softer strength and hardness which is malleable and has a lower strength than steel with a higher carbon composition.

Observations to see the microstructure of specimen 2 Medium carbon steel AISI 1045. The phase formed is perlite which is the content of carbon dissolved in ferrite ($\text{Fe}_3\text{C} + \alpha$) (dark or black) and ferrite which is a phase of iron or α iron (light-colored)[15]. Close layer spacing and small grain size result in higher strength and hardness when compared to longer lamellar spacing.

Observations to see the microstructure of the specimen 3 High carbon steel SAE 1085 The phase formed is perlite which is the content of carbon dissolved in ferrite ($\text{Fe}_3\text{C} +$

α) (dark or black) and ferrite which is a phase of iron or α iron (colored light)[15]. The close spacing of the layers and the small grain size results in

Higher strength and hardness when compared to longer lamellar spacing. A material with a small grain size will have a larger grain boundary. Grain boundaries are an obstacle to dislocation movement. This is because the dislocation has to change the direction of motion due to the different orientation of the grain, so it becomes difficult for the dislocation to move again. With the inhibition of the dislocation movement, it produces higher strength and violence[15].

CONCLUSION

After doing research and analyzing it, the following conclusions can be drawn:

1. The results of the Rockwell hardness test show an increase in the hardness value of different carbon steel specimens that have gone through the hot-dip galvanizing process. Where in the low carbon steel specimen AISI 1020 the average hardness value is 49.60 HRB. Among the 3 specimens with high carbon steel SAE 1085 which had the highest average hardness value, namely 95.1 HRB. This is because the zinc (Zn) layer that covers the raw material is not too thick so that when the hardness test is carried out, the indenter is slightly on the surface of the raw material where the

- high carbon content causes the material to be very hard.
2. From the results of the corrosion rate test using the weight loss method on 3 carbon steel specimens, it can be seen that the corrosion rate value of each carbon steel specimen has a positive linear magnitude. It shows that the value of the corrosion rate of high carbon steel is the lowest, which is 0.32603 mmpy, while the highest for low carbon steel has a corrosion rate of 0.36385 mmpy, this is because the higher the carbon content of steel indicates that its strength against corrosion is getting better.
 3. From the results of testing the thickness of the galvanic layer using a microntest thickness test tool on each carbon steel specimen, it can be seen that the highest average thickness is the low carbon steel specimen AISI 1020 which is 131.8 μm , this is because low carbon content results in a thicker zinc layer. this is due to the increasing movement and diffusion of Zn atoms to form a layer on the surface of the specimen so that the attached layer gets thicker. And the high carbon steel specimen SAE 1085 has a low average thickness of 70.6 μm . This is due to the lack of movement and diffusion of Zn atoms to form a layer on the surface of the specimen so that it only forms the Eta layer where this layer is composed of 100% zinc (Zn).
 4. From the results of the microstructure test using the metallographic test on each

carbon steel specimen with different phases formed, ferrite and perlite. Low carbon steel specimens have a long layer distance resulting in softer strength and hardness which are malleable and have lower strength than steels with a higher carbon composition. And on high carbon steel specimens, SAE 1085 With a close layer spacing and small grain size results in higher strength and hardness when compared to longer lamellar spacing. A material with a small grain size will have a larger grain boundary. Grain boundaries are an obstacle to dislocation movement. This is because the dislocation has to change the direction of motion due to the different orientation of the grain so that it becomes difficult for the dislocation to move again. With the inhibition of the dislocation movement, it results in higher strength and violence.

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