WCEJ

WORLD CHEMICAL ENGINEERING JOURNAL

Journal homepage: http://jurnal.untirta.ac.id/index.php/WCEJ

Corrosion Rate Analysis of JIS G-3141 Steel for Automotive Inner Wheel House Production with Weight Loss Method

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ARTICLE HISTORY

Received 3 March 2022
Received in revised form 21 April 2022
Accepted 27 April 2022
Available online 25 June 2022

ABSTRACT

The growth of car sales and production has decreased since 2020, this is due to corrosion of automotive steel plates in the form of low carbon steel stored in warehouses. The purpose of this study was to obtain the value of the corrosion rate and its effect on mechanical properties and changes in the composition of carbon values. Low carbon steel plates commonly used by automotives where the material is low carbon steel JIS G-3141, with its elemental content of C 0.12%, Mn 0.5%, P 0.04% and S 0.045% with tensile mechanical properties. strength 270 N/mm^2, elongation 37%. The purpose of this study was to obtain the value of the corrosion rate and its effect on mechanical properties and changes in the composition of carbon values. Low carbon steel plates commonly used by automotives where the material is low carbon steel JIS G-3141, with its elemental content of C 0.12%, Mn 0.5%, P 0.04% and S 0.045% with tensile mechanical properties. strength 270 N/mm^2, elongation 37%.

Keywords: Carbon steel JIS G-3141, Corrosion rate, Mechanical properties

1. INTRODUCTION

Steel is the main material in the building, ship, train, weapon, automotive, and tooling industries [Ali & Fulazzak. 2020; Onyeachu & Solomon. 2020]. The biggest enemy of the steel industry is corrosion. Low carbon steels exhibit excellent mechanical properties. However, low carbon steel is prone to corrosion. One type of low carbon steel is JIS-G-3141 which is commonly used in the automotive industry [Wryosumarto and Okumura. 2012]. According to Antar News.com 2020, during the 2020 Covid-19 pandemic, steel demand was stable, but according to Gakindo data in 2021, car sales and production growth in 2020 decreased by 48%. So that the automotive industry stops its production for a while and stores its main material, namely low carbon steel plates in warehouses, when the steel plates will be used there is corrosion.

The purpose of this research is to analyze the corrosion rate on a type of low carbon steel plate JIS G-3141 so that corrosion can be detected faster and corrosion treatment can be carried out immediately. By knowing the value of the corrosion rate, the production for the automotive industry can be carried out before the corrosion occurs due to storage in the warehouse. The measurement of the corrosion rate in this study used the weight loss method.

2. LITERATURE REVIEW

According to the ASM Handbook vol. 1: 330 (1990) Low carbon steel is a steel containing < 0.2% carbon which is a carbon content below the eutectoid composition and has a completely ferrite (α) microstructure that makes low carbon steel soft and strong weak but very good tenacity and toughness. Low carbon steel is very difficult to form into martensite. This steel is usually used for sheet metal forming processes, for example for vehicle bodies and frames and other automotive components. One type of low carbon steel is JIS G3141 steel with the SPCC (Steel Plate Coiled) process.

[Fontana. M.G.1987; Onyeachu, I. B., & Solomon, M. M. 2020]

According to Steel Plate Cold Rolled Coiled (SPCC) is a carbon steel that is cold-rolled with commercial quality. SPCC Low Carbon Steel (JIS G-3141) is a low carbon steel that complies with the Japanese Industrial Standards for the SPCC steel grade. JIS G-3141 steel is a low carbon steel with a content of C = 0.12%. (Mulyanto Khaerudini, (2020).

2.1. CORROSION

Corrosion is defined as metal damage as a result of chemical reactions between metals and other elements in the surrounding environment (Prayitno & Irsyad, 2018). This is because in general, metals are always in contact with open air where humidity and pollutant content can affect metal corrosion. Atmospheric corrosion is strongly influenced by topographic and climatic or environmental conditions. Factors such as temperature, humidity and chemical content in the air greatly determine the corrosion rate.

Corrosion process will not occur only if the 4 basic components of corrosion are met, these components are [Di & Jember. 2012]:

a. Anode

The anode is the part of the metal that functions as an electrode, where an anodic reaction occurs. Anodic reactions can generate electrons. An example of an anode reaction:

$$Fe \rightarrow 2+ + 2e-$$

b. Cathode

The cathode is an electrode that undergoes a cathodic event that consumes electrons resulting from the anodic reaction.

c. Electrical circuits.

Between the cathode and anode there must be electrical contact so that corrosion can flow in the cell.d. Electrolyte Electrolyte is a medium that conducts electric current such as water and soil.

2.2. CORROSION RATE

Corrosion rate is the speed of propagation or the rate of deterioration of material quality with time, in calculating the corrosion rate the units commonly used is mm/yr (international standard) or mill/year (mpy, British standard) [So et al.2007; Wahyu 2015; Gapsari, Femiana. 2013] the corrosion rate can be defined in various ways, such as the percentage of mass loss, milligrams per square centimeter per day and grams per square inch per hour. Corrosion rate testing can use the weight loss method or the electrochemical method (potentiodynamic polarization, electrochemical impedance spectroscopy, etc.). Weight loss in mils per year is the most desirable way of expressing corrosion rates. Meanwhile, according to [Abu-Dalo et al., 2012; Arwati, I. G. A. 2017; Deni shidiq, Sagir Alva.2020] defines the formula for the corrosion rate of the weight loss method with the following equation:

$$\text{Corrosion rate (CR)} = \frac{m1-m2}{At}$$

Where:

CR = corrosion rate (mg cm^{-2} $hours^{-1}$)

m1 = mass of sample before immersion (mg)

m2 = sample mass after immersion (mg)

A = sample area (cm^2)

t = immersion time

3. 3. RESEARCH METHODOLOGY

3.1. Weight Loss Test

The procedure for testing the corrosion rate using the weight loss method is to put the test specimen at room temperature with the average mass of each low carbon steel specimen determined before and after the test.

Specimen Preparation;

In this study, the metal sample used was JIS G-3141. The work steps in preparing the JIS G-3141 metal sample are as follows Fig.1 and Fig. 2:

1. Metal JIS G-3141 is cut to size 84 x 50 mm x 1 mm.

Fig. 1. JIS G-3141 . metal sample

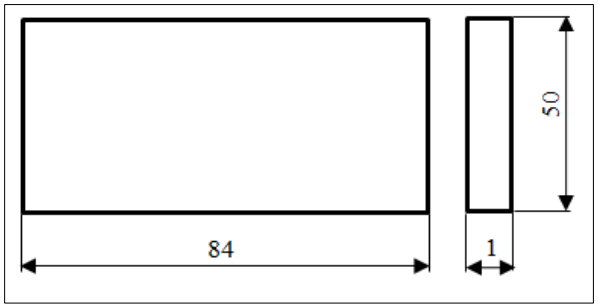

Fig. 2. Dimensions of the test specimen material

3.2 Tensile Test

Tensile testing is carried out to determine the tensile strength. This tensile test will produce the value of mechanical properties. The test process is that the test specimen is mounted on a tensile testing machine with a grip from the tensile machine at the ends and is pulled in a longitudinal direction slowly until it breaks. During towing at any time recorded by the graph available on the pulling machine, the magnitude of the pulling force acting as a result of the pulling force. Tensile testing is generally a basic stress test according to standards such as ISO 527-4, ISO 527-5, ASTM D 638, ASTM D 3039, and ASTM C 297. Tensile testing produces a stress-strain diagram that is used to determine the tensile modulus. Tensile testing

can be seen in the Fig.3.

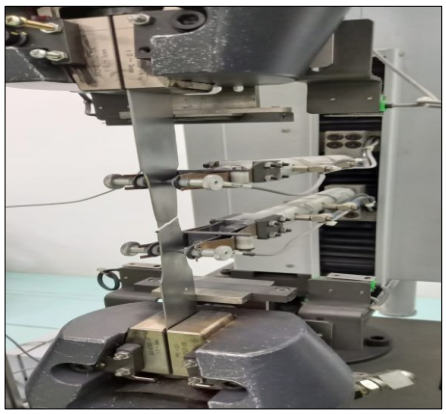

Fig. 3. Tensile Test Proces EDX SEM Testing

After testing the weight loss, the surface and cross section of the JIS G-3141 steel sample will be observed using SEM and EDS (Fig.4). In this process, it will be known more clearly about the changes in the surface elements the sample before and after experiencing corrosion.

Fig. 4. SEM testing tool (JEOL JSM)

4 PURPOSE OF OUTCOMES AND DISCUSSION

4.1 Weight Loss Test

In testing the corrosion rate using the weight loss method, the sample is placed at room temperature with time variations The results of the corrosion rate testing process using the weight loss method are presented in Table 1. Anon 19985; ASM Metals Handbook 1990; Ali, N., & Fulazzaky, M. A. 2020; Arwati, I. G. A. 2017)

Table 1. The results of the weight loss test and the calculation of the corrosion rate JIS G-3141 . low carbon steel

Sample	Time (hours)	Weigh loss (mg)	CR (mg cm^{-2} jam^{-1})
A	720	4000	0.132
		3000	0.099
		3000	0.099
B	1440	9000	0.149
		7000	0.116
		6000	0.099
C	2160	82000	0.353
		117000	0.276
		113000	0.287
D	2880	121000	0.471
		123000	0.438
		124000	0.372

Based on Table 1, it can be seen that the corrosion rate calculation data, at 720 hours, the average value of the corrosion rate of JIS G-3141 low carbon steel was 0.110 mg cm-2 hours-1, the average value of the corrosion rate of JIS G low carbon steel samples -3141 at 2 months or 1440 hours which is 0.121 mg cm^{-2} $hours^{-1}$. Then the value of the corrosion rate at 3 months or 2160 hours is 0.305 mg cm^{-2} $hours^{-1}$ and the average value of the corrosion rate for 4 months or 2880 hours is 0.427 mg cm^{-2} $hours^{-1}$

4.2 Effect of Corrosion Rate on Mechanical Properties

In the tensile test using a tensile test specimen as shown in Figure3, the test surface area is 9900 mm^2. The average Yield Force (Fy) and Ultimate Force (Fu) values obtained from the tensile testing machine are 67 kN and 99 kN, respectively. The details of the tensile test results for JIS G-3141 low carbon steel are presented in table 2.

Table 2. The results of the tensile test of JIS G-3141 steel before and after receiving treatment

Sample	Time (hours)	Tensile test value			
		TS (N/mm^2)	YS (N/mm^2)	YPEL (N/mm^2)	EL (%)
Blank	0	331	208	0,39	45,0
A	720	331	196	0,42	43,8
B	1440	331	206	0,55	42,0
C	2160	331	207	0,53	43,6
D	2880	330	205	0,60	43,0

From the test results, it can be seen that the corrosion rate of JIS G-3141 steel stored for 3 months does not affect the tensile strength, yield strength, and elongation values. However, there was an increase in the value of the YPEL value, which means the longer the difference between the elongation of the specimen at the beginning and at the end of the broken yield.

4.3. SEM and EDX Testing

Based on Figure 4a the results of the SEM and EDS testing of the sample and initial surfaces before being given treatment still look clean or normal. The results of the SEM EDS test with 500x magnification appear on the metal surface after immersion for 3 months (2880 hours) the rougher metal surface in Figure 4b, where corrosion products have formed which are characterized by reduced composition of the elements O, Fe and C as shown in table 3, the element of oxygen appears in the immersion time after 1440 hours by 12%, 2160 hours by 32.15%, and 2880 hours by 34.25%.

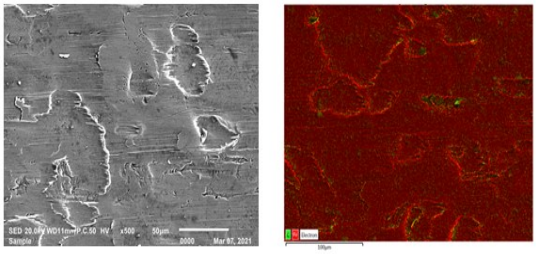

Fig. 4a. SEM and EDX display image. Observation of the surface of the initial sample before being treated with a magnification (500x)

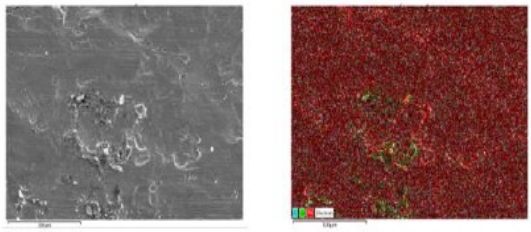

Fig. 4b. SEM and EDX Results of the 3rd lunar surface EDS SEM test with magnification (500x)

Table 3. Surface element composition of JIS G-3141 low carbon steel before and after treatment

Element	*Weight (%)*				
	0 hour	*720 hours*	*1440 hours*	*21600 hours*	*28800 hours*
C	8,05	2,70	6,04	5,24	7,45
Fe	91,95	97,30	81,96	62,61	58,30
O	0	0	12,0	32,15	34,25

5. CONCLUSION

Based on research that has been done, it can be concluded that:

1. Based on the weight loss test for 720, 1440, 2160 and 2880 hours, the highest corrosion rate was found at 2880 hours: 0.427 mg cm^{-2} $hours^{-1}$ and the lowest at 720 hours: 0.110 mg cm^{-2} hours-,
2. Based on the results of testing the mechanical properties of JIS G-3141 steel, there is no change in the large Tensile Strength, Yield Point and Elongation values.
3. The results of the SEM-EDS test on JIS G-3141 steel have not found any elemental changes at 30 days or 720 hours from before treatment

6. REFERENCES

Ali, N., & Fulazzaky, M. A. (2020). The empirical prediction of weight change and corrosion rate of low-carbon steel.Heliyon,6(9),e05050.https://doi.org/10.1016/j.heliyon.2020.e 05050

Anon. (1985). Standard Practice for Laboratory Immersion Corrosion Testing of Metals. ASTM Special Technical Publication, i(Reapproved), 534–544.

ASM Metals Handbook. (1990-1, 2005-2), "Vol 01 : Properties and Selection Irons, Steels, and High-Performance Alloys", ASM International.

Di, A., & Jember, K. (2012). Evaluasi Korosi Baja Karbon Rendah Astm A36 Pada Lingkungan Atmosferik Di Kabupaten Jember Sumarji 1. 5, 44–51.

Fontana, M.G.(1987). *Corrosion Enginnering (Third Edition).* Singapore:McGrawHillBook Company.

Gapsari, Femiana. 2013. *Pengantar Korosi*. Malang: UBMedia.

Jones, D. A. (1996). *Principles and prevention of corrosion, Prentice-Hall International, NJ, USA* (p. Prentice- Hall International, NJ, USA).

Mulyanto, B., & Khaerudini, D. S. (2020). Investigasi simulasi numeris dan eksperimen proses springback berbentuk cup silider pada lembaran baja karbon Jis-G3141. *Dinamika TeknikMesin*, *10*(1),60 https://doi.org/10.29303/dtm.v10i1.326

Abu-Dalo, M. A., Othman, A. A., & Al-Rawashdeh, N. A. F. (2012). Exudate gum from acacia trees agreen corrosion inhibitor for mild steel in acidic media. *International Journal of Electrochemical Science*, *7*(10), 9303–9324.

Ali, N., & Fulazzaky, M. A. (2020). The empirical prediction of weight change and corrosion rate of low-carbon steel. Heliyon,6(9),e05050. https://doi.org/10.1016/j.heliyon.2020.e 05

Arwati, I. G. A. (2017). Aluminum Corrosion Analysis for Environmental Acid Chloride Solution. 1(5), 65–69.

Onyeachu, I. B., & Solomon, M. M. (2020). Benzotriazole derivative as an effective corrosion inhibitor for low carbon steel in 1 M HCl and 1 M HCl + 3.5 wt% NaCl solutions. Journal of Molecular Liquids, 313, 113536. https://doi.org/10.1016/j.molliq.2020.11 3536

Ramadani, A. (2017). Analisis Perbedaan Laju Korosi Material Jari-Jari Sepeda Motor (Spokes) Pada Berbagai Media Air Yang Berkonsentrasi Asam Di Daerah

Deni ShidIq Khaerudini, https://www.sciencedirect.com/science/article/abs/pii/S025405 8419311095 - !SagirAlva .2020. Optimization strategy of Ag/AgCl thin film electrodes approached by chlorination process for electrochemical response materials , Materials Chemistry andPhysicsol.240.