

Study On The Effect Of Corrosion Behaviour Of Stainless Steel Before And After Carburizing Heat Treatment

S. A.Sulaiman^{1,a*}, S.K. Alias^{1,b}, S.Ahmad, ^{1,c}, M.H.Mohd Fauzi², N.N.Ahmad¹

¹Faculty of Mechanical Engineering, UiTM Caw.Johor, Kampus Pasir Gudang, Jln Purnama,81750, Masai, Johor

²Faculty of Mechanical Engineering, UiTM Shah Alam,40450 Shah Alam, Malaysia
Universiti Teknologi MARA, 40450 Shah Alam, Malaysia

Email: ^{a*}syidatul_akma7091@johor.uitm.edu.my, ^bkhadijah_alias@johor.uitm.edu.my, ^csamsiah.ahmad@johor.uitm.edu.my.

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Abstract.

This study investigates the effect of corrosion behaviour of stainless steel before and after carburizing process. All samples were prepared based on the testing specification requirement and the chemical compositions of the stainless steel were obtained using spectrometer tester. Samples were then undergoing pack carburizing process by adding 50g of carbon powder as the carburizing agent. Then the samples were heated at 900 °C and 950 °C for 8 hours. To obtain corrosion rate, weight loss test was conducted and the samples were immersed in three different solutions which were distilled water, hydrochloric acid and sodium chloride. Hardness and density test were employed to measure the physical properties of the ASTM 304 stainless steel. The microstructures of all samples were observed using Olympus BX41M optical microscope. The resulting phases after each heat treatment were tested by x-ray diffraction (XRD) tester. The percentage of corrosion values, determined from this technique, showed fairly good agreement. Carburizing process produced a carburizing layer improved mechanical properties and corrosion resistance abilities

1. Introduction

Stainless steel is one of the metals that have a good corrosion resistance market nowadays. This material is widely used in many industries for its strength and corrosion resistance behavior. However, stainless steel still suffers from corrosion in some environment [1]. Corrosion is a process of deterioration or degradation of metals. Corrosion not only cause deterioration on the surface of components but also reduce it strength. This process occurs when metals make contact with water or moisture, bases, salts, acids and other solid and chemical liquids. Exposure to gaseous materials like ammonia gas, acid vapor and sulphur containing gas can also cause corrosion on the material [2]. There are many types of corrosion occur on material. First is uniform corrosion, where the metal loss is uniform on the surface. Second is pitting corrosion. This type of corrosion character is where the metal loss of the material is randomly located on the surface. There are also galvanic corrosion, occurs when two metals with different electrode potential is connected in a corrosive electrolytic environment [3]. In extreme cases of corrosion, repair and replacement of component structure need to be done at very high cost due to delay cost and repair cost. It is important to find a solution of corrosion to able prolong the life span of material or structure. Carburizing is one of the methods used to control corrosion for stainless steel metal. [4] Carburization of steel involves a heat treatment of the metallic surface using a source of carbon. Carburization can be used to increase the surface hardness of low carbon steel. [5] As metals are made up of atoms bound tightly into a metallic crystalline lattice, the carbon atoms diffuse into the crystal structure of the metal and either remain in solution or react with elements in the host metal to form carbides (normally at higher temperatures, due to the higher mobility of the host metal's atoms). If the carbon remains in solid solution, the steel is then heat treated to harden it. Both of these mechanisms strengthen the surface of the metal, the former by forming pearlite or martensite, and the latter via the formation of carbides. Both of these materials are hard and resist abrasion [6]. The aim of research work



is to improve the mechanical properties of the 304 stainless steels applicable by pack carburization using carbon powder as a carburizer and by optimizing carburizing temperature.

2. Experimental method

In this study the stainless steel ASTM 304 cylinder was used as the samples. First the samples was cut using lathe machine to the specific dimension before it is placed on the Optical Emission Spectrometer (OES-550). This spectrometer was used to find the chemical composition of the 304 stainless steel by sparking the samples on its surface. The element composition was then recorded using computer which connected to the tester.

2.1 Pack Carburizing:

The samples then have undergone carburizing process by heating the samples at two different temperatures. In this process, pack carburizing method was employed and 50g of carbon powder was used as carburizing media to conduct the process. The samples were then heat treated at 900°C and 950 °C for 8 hours. After the treatment done, the samples left in room temperature to cool it down (normalizing).

2.2 Hardness Test:

In present experimental work Rockwell hardness was measured on carburized 304 stainless steel samples which are carburized under different temperature range of 900 and 950°C. For each of the sample, test was conducted for 3 times and the average of all the samples was taken as the observed values in each case.

2.3 XRD procedure

This test was done using monochromatic copper Ka radiation at 40 KV and 100mA. Angular 2 θ range 42-46° was scanned using Rigaku rotating head anode diffractometer at scanning speed of 0.25° /min and 72-92° at a scanning speed of 1°/min. The rp file then analyzed on computer to obtain peak positions.

2.4 Weight Loss Test:

Corrosion behaviour was measured using weight loss test where 0.1M Hydrochloric Acids (HCL) and 25 g of NaCl was diluted and dissolved with 250 mL distilled water. The samples were then tied using aluminium wire and attached to wooden stick to make sure the whole body of specimen is immersed in the solution. The samples were immersed in three different solutions for 7, 14, 21, and 28 days.

Weight before and after immersion was taken and used in the formula at final stage to obtain corrosion rate.

$$\text{Density} = \frac{\text{Weight in Air}}{\text{Weight in Air} - \text{Weight in water}} \times \text{Water Density} \quad (1)$$

2.5 Microstructure Observation:

The grinded and polished samples were then etched by using Kailing's No 2. The microstructures of all specimens were photographed using Olympus BX41M optical microscope.

3. Result and discussion

3.1 Spectrometer Test:

The chemical composition of 3 samples of pure stainless steel is shown in Table 1 having a chromium compositions of in between 18.33 to 18.51 wt% and nickel content of 8.43 to 8.82 wt%.

Table 1: Chemical composition of pure stainless steel

Sample	C	Mn	Si	P	S	Cr	Mo	Ni	Fe
1	0.10	1.23	0.91	0.0058	0.002	18.33	0.133	8.82	69.5
2	0.08	1.22	0.67	0.010	0.0041	18.51	0.146	8.52	70.3
3	0.08	1.31	0.75	0.045	0.030	18.42	0.152	8.43	70.3

3.2 X-Ray Diffractometer Test

This test carried out to find out the detailed composition of element of pure stainless steel and carburized steel. The detailed composition of element for pure stainless steel and carburized steel are presented in Table 2

Table 2: Detailed composition of element for pure stainless steel and carburized steel

	2-theta (deg)	Phase Name
Pure Stainless steel	43.660(13)	Copper Nickel, (1,1,1)
	44.575(15)	Iron, sym, (1,1,0)
	50.78(4)	Copper Nickel, (2,0,0)
	74.73(3)	Copper Nickel, (2,2,0)
Carburized steel at (900°C)	42.27(2)	Cementite, (1,2,1), α -ferrite, (2,0,0)
	53.56(6)	Iron, syn, (1,1,0) cementite, (0,2,3)
	61.37(6)	α -ferrite, (1,1,4)
	81.10 (8)	Cementite, (2,3,3), α -ferrite, (1,4,1)
Carburized steel at (950°C)	42.284 (19)	Wustite, syn, (2,0,0), cementite (1,2,1)
	43.26(3)	Martensite, (1,0,1), Cementite, (2,1,0)
	61.19(5)	Wustite, syn, (2,2,0), Martensite, (0,0,2)
	81.03(6)	Cementite, (2,3,3), Iron, syn, (2,1,1)

3.3 Microstructure 304 Stainless Steel

Figure 1(a) shows the microstructure pure stainless steel containing austenite structure. After carburizing, there are presences of carbon layer in dark form, shown in Figure 1(b) and 1(c) respectively.



Pure Steel



Carburized steel (900°C)



Carburized Steel (950°C)

Figure 1: Microstructure of pure stainless steel and carburized steel magnified at x200 magnification

3.4 Hardness test

From Figure 2, the computed average hardness values for pure stainless steel are 92.7 HRB. While for carburized stainless steel heat treated at 900°C is 106 HRB and at 950 °C the average hardness is 106.2 HRB. These hardness values proved that pack carburizing did improve the mechanical properties of stainless steel. The differences of hardness value occur due to the difference case depth for each temperature as temperature and time play a major factor in carburizing process. Keiro Tokaji, stated that carburized depth depend on treatment time for constant temperature [7]

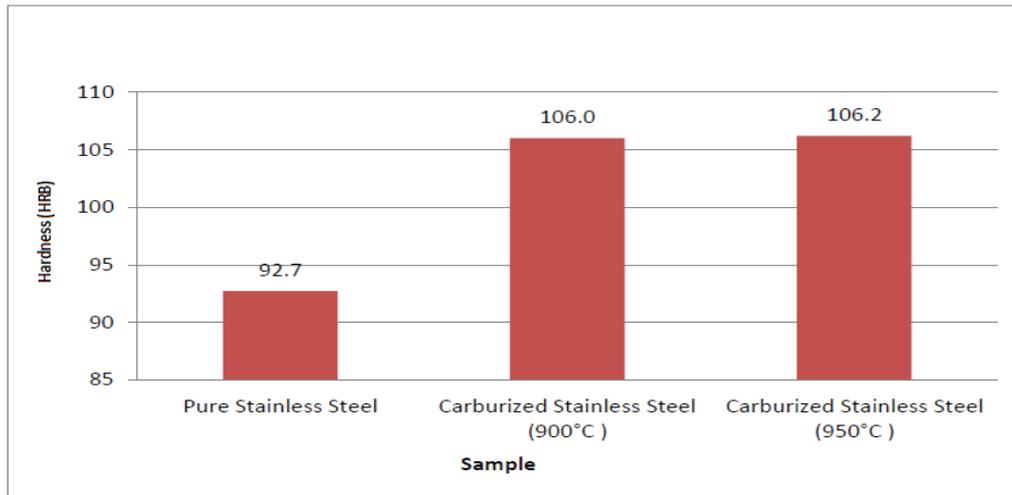


Figure 2: Hardness value for pure stainless steel and carburized steel

3.5 Corrosion Behavior

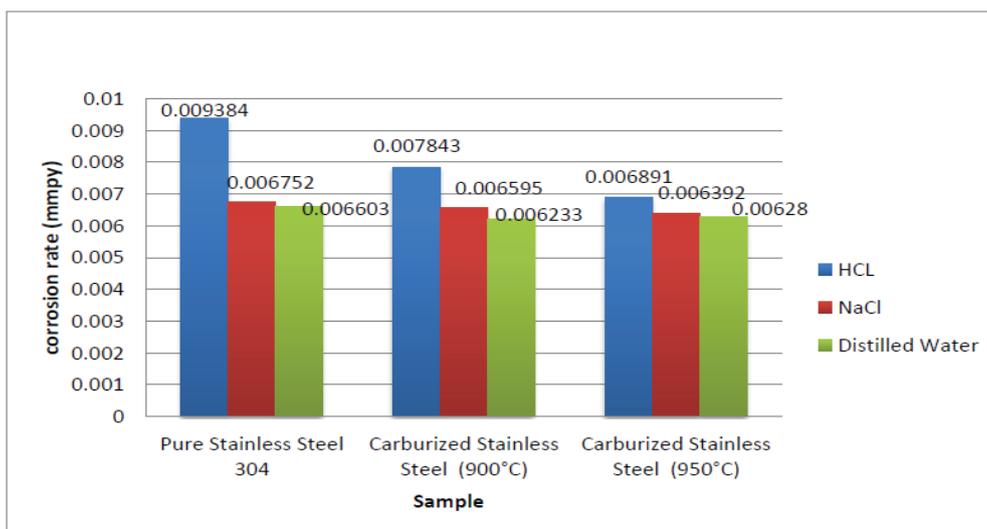


Figure 3: Weight loss for pure and carburized steel immersed in three different solutions

For HCL, there are obvious decreases in the corrosion rate of the sample as shown in Figure 3. At 900 °C corrosion rate recorded is 0.007843 mmpy, which was slightly higher than 950 °C sample which is 0.006891 mmpy. In NaCl and distilled water, there are no significant changes in the corrosion rate. There

are only a slight decrease value for the untreated sample and treated sample. This proves that carburizing process improved the corrosion resistance of stainless steel at all 3 conditions as the weight loss of carburized steel is much lower than pure stainless steel. Increasing the carburizing temperature resulted in thicker carbon layer, thus further improve the corrosion resistances by reducing the weight loss values. This is because the precipitation of carbides in the carburizing layer can cause the corrosion resistance of the material to deteriorate [8].

3.6 Macroscopic Observation

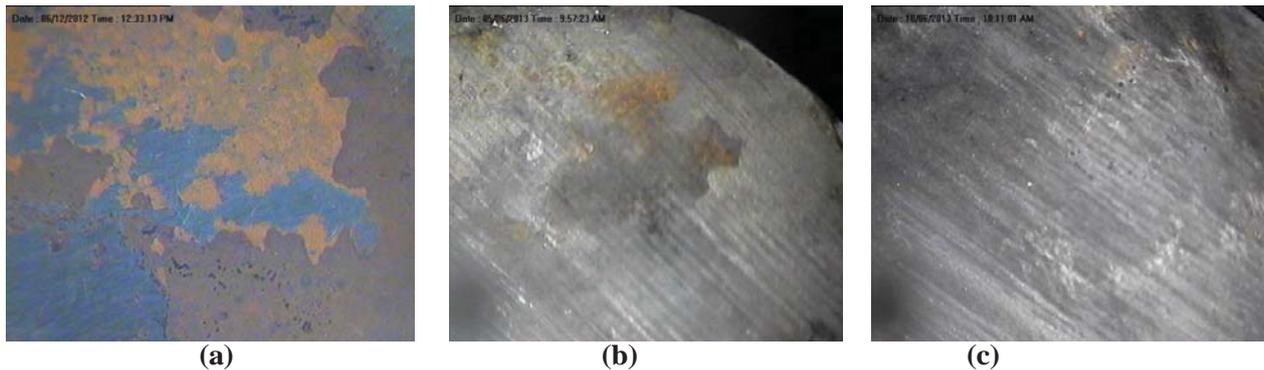


Figure 4: Macroscopic images of corroded a) Pure Stainless Steel, b) carburized 900°C c) carburized 950°C

Figure 4 shows the macrostructure of pure stainless steel, carburized stainless steel at 900°C and 950°C after undergoing weight loss test. It could be seen that the macroscopic image of pure stainless steel reveal visible corrosion marks in blue and brown color indicating that the surface was badly affected by corrosion attack. After carburizing, the mark was less visible and increasing the carburizing temperature reduces the corrosion marks, which could be seen in Figure 4(c). This indicated that carburizing is an effective method in protecting the surface from corrosion attack.

4. Conclusion

Experiment were carried out to study the influence of carburizing process on corrosion resistance for stainless steel metal. The percentage of corrosion value showed fairly good agreement.

1. Carburizing process produced a carburizing layer improved mechanical properties and corrosion resistance abilities.
2. There are slight improvements in terms of corrosion resistance of the stainless steel after carburizing process especially in HCL medium as shown in macrostructure image. The corrosion rates for treated sample also have a small improvement than untreated sample.
3. From microstructure observation, it can be seen that differences between untreated stainless steel and treated in terms of layer in the surface of the sample. For treated sample, it shows that difference temperature affect the thickness of carburizing layer.

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