J. Basic. Appl. Sci. Res., 2(4)4109-4114, 2012
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ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Effects of Heat Treatment Time and Temperature on Corrosion Properties in Weld Area of SS 347

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ABSTRACT

This research studies welding area of austenitic alloy steel 347 from Intergranular corrosion point of view. The welding steps were done as per ASTM using E-347-15. Welded pieces were divided into 4 groups based on heat treatment time and temperature. Corrosion tests were carried out using Etch test, Exilic acid, Nitric acid, and metallographic studies were carried out using light and electronic microscopes (SEM) and micro hardness devices together with (XRD) reviews. Consequently, the best process for resisting intergranular corrosion can be done with selection of suitable temperature and time for heat treatment.

KEYWORDS: austenitic alloy steel 347, intergranular corrosion, heat treatment.

INTRODUCTION

The presence of elements like Ti, Nb, Ta, in austenitic ss, causes to create resistance type of this alloy such as 347. Negative free energy of these elements to organize for their carbides is more than corium and thus the existence of these elements leads to fast combination with carbon and the corium will remain as solid solution thereupon. The Possibility of formation of Titanium carbide(TiC) and Niobium carbide(NbC), will be prepared at near zone to weld line in austenitic resistance stainless steel and due to resolution of carbides during next welding passes or during stress relief heat treatment, necessary condition will be provided again to create Chromium carbide($Cr_{23}C_6$) at heat affected zone(HAZ).The region in which chromium carbide ($Cr_{23}C_6$) deposit, will be observed after welding of SS 347, is very thin. The presence of this narrow zone containing $Cr_{23}C_6$ adjacent to the weld line, causes to create sensitivity in narrow area and creation of special corrosion which is named "Knife line attack"[1]. There are different methods to prevent knife line attack among which special heat treatment for welding process can be mentioned In commercial alloys which include austenitic stabilizers, the reaction of $\gamma + M_{23}C_6 \rightarrow \gamma + \alpha + M_{23}C_6$ will be done very slowly in normal cooling rates. The carbide phase of $M_{23}C_6$ is stable at temperatures below 900'c and when it is heated to temperature from 1000 to 1150'c, solved in the steel and after rapid cooling, austenite-free deposit can be obtained

Sigma phase (σ) like all intermetalic compositions causes the steel to be brittle. The sigma phase which is rich in chromium and molybdenum commonly can be seen in high alloy variety of this group of austenitic stainless steels. Typically the austenitic steels have some Delta ferrite (δ) in their structure. This amount, particularly, may reach to 30 percent if the steel contains Molybdenum and Titanium. Sigma phase (σ) is produced through the decomposition of ferrite and as a result the adjacent regions will be depleted of the chromium and molybdenum formation. Although this phase does not create any acute problems in point of corrosion because of lack of continuity, due to produced brittleness it makes problem, therefore, the creation of this phase should be really avoided. Selection of appropriate chemical composition or required heat treatment will remove this phase from the structure. Existence of silicon accelerates the formation of this phase even in low amounts [2]. In general all ferrite stabilizing elements facilitate the formation of this phase, but the presence of carbon ,due to creation of chromium carbide, will delay the sigma phase (σ). The CHI & LAVES are the probable phases of intermetalic compositions in stainless steels which can be seen in rich variety of chromium, molybdenum and titanium. The CHI phase can be produced in high molybdenum alloys because of exposure to high temperature environment and it is able to resolve the carbon and make the carbide of M_3C. Also the LAVES phase is formed after the exposure of austenitic stainless steel for a long time to high temperatures in alloys containing Mo, Ti and Nb which are more liable to that formation and the reduction of molybdenum will decrease the resistance to corrosion.[3] The weld metal must be heated for several hours at 1000-1100'c temperature and then quenched after welding. Heat treatment at high

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temperature solves chromium carbide which was deposited during welding ,and quenching prevents its reformation. However stabilized stainless steel such as 347 are not sensitive to welding decay, but they are liable to another type of intergranular corrosion which is called “Knife line attack”. The reason for the Knife line attack is the deposit of chromium carbide at intergrains. Knife line attack can be distinguished from welding corrosion by two methods [4]:

1- Knife line attack occurs immediately in a narrow area adjacent to weld metal.
2- Knife line attack occurs in stabilized stainless steels [38 & 42].

RESEARCH METHOD AND MATERIAL

1. Consumables

The stabilized austenitic stainless steel of 347 with specified chemical composition in table 1 is presented in this study. The welding of specimens has been done with electrode E-347-15 as per chemical composition in table 2:

Table 1: Chemical composition of consumable austenitic stainless steel 347

Element	V	Ti	Nb	Cu	Mo	Cr	Ni	Mn	P	S	Si	C	Fe
Precent	0.1	0.01	0.41	0.25	0.31	16.1	13.8	1.5	0.03	0.03<	0.37	0.047	66.31

Table 2: Chemical composition of E-347-15

Element	C	Si	Mn	Cr	Ni	Nb
percent	0.03<	0.8	0.7	20	10	0.4

2. Specimens Welding procedure

Pipes with 14mm thickness were used as welding specimens. Shielded arc was selected as type of welding procedure (Shielded Metal Arc Welding-SMAW). Joint design specifications in welding process is shown in table 3

Table 3: Bevel dimensions and specifications

Thickness - T	Root Opening - R	Groove Angel - α	Root Face – F
14mm	2.5mm	75	2.5mm

Welding process specification is presented in table 4

Table 4: used welding process specifications

Current	Ampere	Electrode diameter
DCEP	70-80	2.5mm

Welded specimens were divided into 4 groups according to type of heat treatment which was used in:
the sample (a): 1130’c temperature and 2 hours time,
the sample (b): 1070’c temperature and 2 hours time,
the sample (c): 1130’c temperature and 4 hours time,
the sample (d): 1070’c temperature and 4 hours time.

RESULTS AND DISCUSSION

Before heat treatment, boiling nitric acid test data were obtained for welded samples according to table 5.

Table 5: The sample test results of boiling nitric acid before heat treatment

Test steps	1	2	3
Weight of sample (gr)	33.8139	33.7553	33.727
Reduction of weight (Gr)	0.0251	0.0837	0.112
Corrosion rate (mpy)	**13.8925**	**23.1633**	**20.6634**

Corrosion rates based on test procedures for the sample is given in Figure 1:

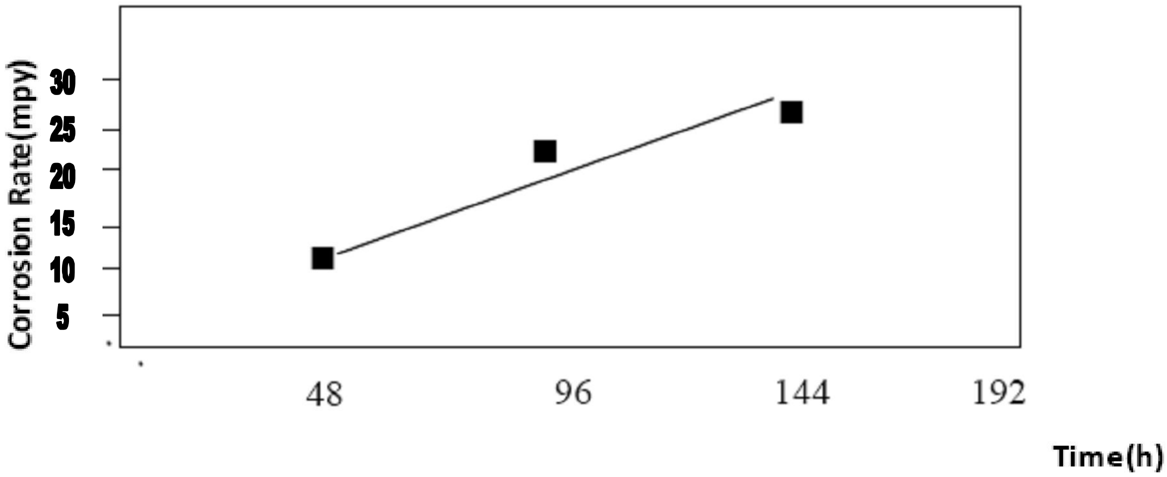

Figure 1: Various curve of corrosion rate based on test steps

The sample (a) which was selected for boiling nitric acid test, has 9.889 weight, 1.56 × 1 × 0.86 dimension, 7.5232 cm^2 total area and 8.03 gr/cm^3 density after heat treatment.
Data obtained from above mentioned test are presented in table 6:

Table 6: test results of boiling nitric acid after heat treatment for sample (a)

Test steps	1	2	3	4	5
Weight of sample (gr)	9.881	9.8734	9.8674	9.8633	**9.8609**
Reduction of weight (Gr)	0.008	0.0156	0.0216	0.0257	**0.0281**
Corrosion rate (mpy)	9.4929	9.2556	8.5436	7.624	**6.6688**

Corrosion rate is given in figure 2 according to test steps of the sample (a):

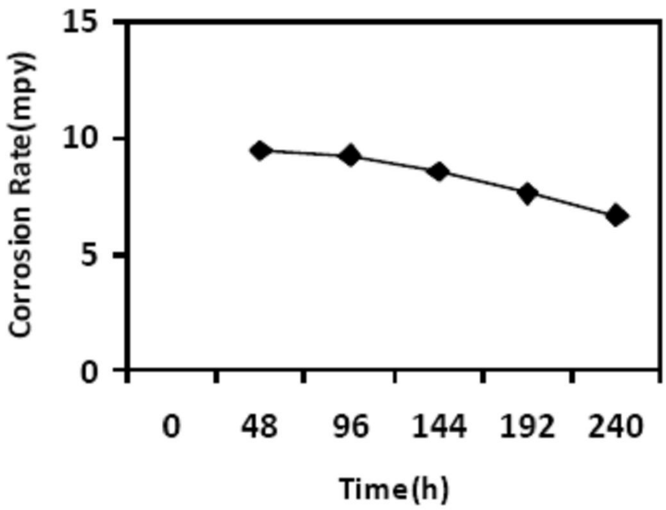

Figure 2: Various curve of corrosion rate based on test steps

The sample (b) which was selected to boiling nitric acid test, has 7.9935 weight, 1.12 × 0.88 × 1.01 dimension, 6.0012 cm^2 total area and 8.03 gr/cm^3 density after heat treatment.

Data obtained from above mentioned test are presented in table 7:

Table 7: test result of boiling nitric acid after heat treatment of the sample (b)

Test steps	**1**	**2**	**3**	**4**	**5**
Weight of sample (gr)	7.9862	7.98	7.9739	7.9697	**7.967**
Reduction of weight (Gr)	0.0073	0.0135	0.0196	0.0238	**0.0265**
Corrosion rate (mpy)	10.8864	10.1034	9.7464	8.8976	**7.898**

Corrosion rate is given in figure 3 according to test steps for sample (b):

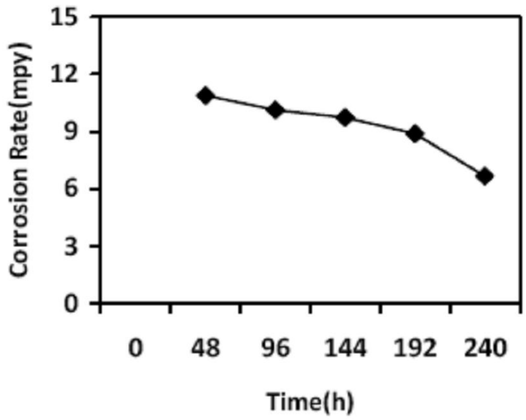

Figure 3: Various curve of corrosion rate based on test steps

The sample (c) which was selected for boiling nitric acid test, has 6.3492 weight, 1.09 × 0.93 × 0.78 dimension, 5.17 cm^2 total area and 8.03 gr/cm^3 density after heat treatment.
Data obtained from above mentioned test are presented in table 8:

Table 8 test result of boiling nitric acid after heat treatment for sample (c)

Test steps	**1**	**2**	**3**	**4**	**5**
Weight of sample (gr)	6.3431	6.3375	6.3294	6.3243	**6.319**
Reduction of weight (Gr)	0.0061	0.0117	0.0198	0.0249	**0.0302**
Corrosion rate (mpy)	10.5764	10.1287	9.8954	8.198	**7.4356**

Corrosion rate is given in figure 4 according to test steps for sample (c):

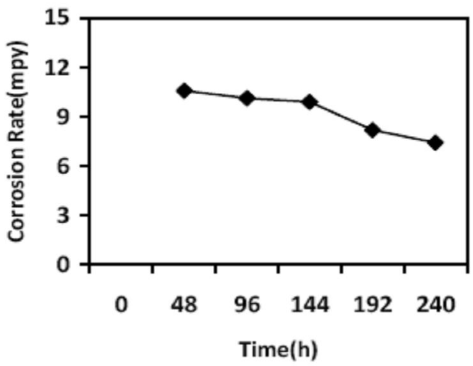

Figure 4: Various curve of corrosion rate based on test steps

The sample (d) which was selected to boiling nitric acid test, has 8.1307 weight, 1.19 × 1.21 × 0.72 dimension, 6.873 cm^2 total area and 8.03 gr/cm^3 density after heat treatment.
Data obtained from above mentioned test are presented in table 9:

Table 9: Test result of boiling nitric acid after heat treatment for sample (d)

Test steps	**1**	**2**	**3**	**4**	**5**
Weight of sample (gr)	8.1223	8.1134	8.1073	8.1004	**8.098**
Reduction of weight (Gr)	0.0084	0.0166	0.0234	0.0303	**0.0337**
Corrosion rate (mpy)	10.9274	10.8107	10.1578	9.8794	**8.7854**

Corrosion rate is given in figure 5 according to test steps for sample (d):

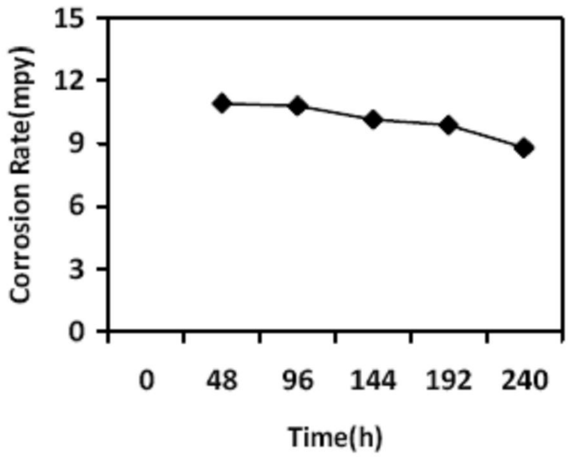

Figure 5: Various curve of corrosion rate based on test steps

Heat treatment result of 4 samples is explanatory of corrosion rate in figure 6:

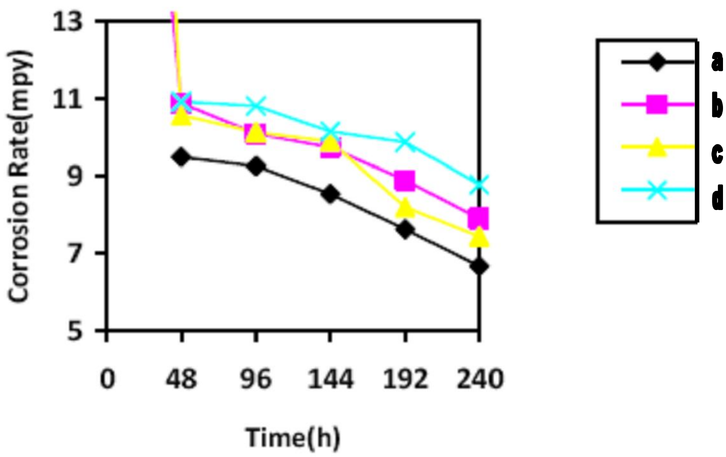

Figure 6: Various curve of corrosion rate based on test steps

The obtained result of 4 heat treated samples indicates that corrosion resistance of sample (a) is more than other samples and sample (d) is less than all samples. Regarding corrosion resistance (a), (c), (b) and (d) are rated respectively.

Conclusion

1) Generally the use of austenitic welding electrode “stabilized or not stabilized” creates intergranular corrosion in multi pass welding.

2) Niobium carbides solution due to welding heat input provides the required options for deposition of chromium carbide in Heat Affected Zone(HAZ).

3) Applying the appropriate heat treatment after welding of austenitic stabilized alloy steel is more important in comparision with choosing the optimum electrode.

4) For this operation temperature of 1130’c is more recommended for heat treatment in comparison with lower temperatures in limited range.

5) Time of 2 hours is sufficient for heat treatment and the longer times will cause the hardness to decrease of.

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