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Corrosion Resistance of Nickel Weld Metal Deposited on Carbon Steel In 3.5% NaCl Solution

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Abstract

Dissimilar metal welding is frequently used to join carbon steels to other materials such as nickel metal. This approach is most often used where a transition in mechanical properties and/or performance in service are required. The power generation industry uses dissimilar metal welding extensively to reduce material costs and enhance performance in elevated-temperature applications.Anodic polarization curves for deposited as weldcondition of Ni weld metal on carbon steel in 3.5% NaCl solution having neutral pH are studying. Anodic polarization curve for thermal aging of Ni weld metal for different agingtimes50,500 and 1000 hr at 550ºCare also recorded. The results indicated that the corrosion current of the Ni weld metal on carbon steel increases as aging time increase,also the grain size of the deposited Nickel increase during thermal aging for different times 50, 500 and 1000 hours respectively

1-Introduction:

Welds between different metals are called Dissimilar Metal Weld (DMW). Dissimilar metal welding (DMW) has become a critical technology in many areas [1-2]. Nickel-based filler metal has superior corrosion resistance, thus are used frequently in applications requiring dissimilar welding. They are used in a variety of joint involving carbon steel. These welds are commonly used in plants of energy generation, chemical and petrochemical industries and nuclear power plants. In nuclear power plants DMWs are used in safety class systems of all Pressurized Water Reactors (PWR) and “Water Water Energy Reactor” WWER plants. DMWs are generally designed and fabricated to high quality standards [3-4]. However some instances of flaws and/or leakages in operation with nickel alloys have been reported[5]. It is difficult to detect the potential damage with in-service inspectionsystems because of the dendritic nature of the weld, geometric factors, component form and accessibility[6]. Investigations of potential degradation mechanisms, integrity assessment methods have been performed in many developments nuclear center [7-8]. The weld should havecorrosion/oxidation resistance equal to the least resistant base metal being joined. It is fortunate that in most all instances the weld will be of a higher alloy content (better corrosion and oxidation resistance) than the least resistant base metal being joined[9]. When a DMW is in an environment where the liquid can be an electrolyte, the weld metal should be cathode to (more corrosion resistant than) both base metals. If the weld is anodic (less corrosion resistant), it suffers accelerated galvanic corrosion due to area effects [10-11].
The aim of the present work is the study of the performance of the Ni welds deposited on carbon steel in aggressive media, namely 3.5% NaCl and the effect of its heat treatment on the performance.

2-Experimental work:

The experimental investigation was carried out to evaluate the corrosionperformance ofweldmentsmanufactured by manual shielded metal arc welding (SMAW) processes withpure Ni welding electrode.

2.1 Materials:

2.1.1 Material of plates:

The chemical composition of the used plate of carbon steels are givenin Table (1).

Table(1) Chemical composition of the used plate of carbon steel

Element %	C	Cr	Ni	Mn	Si	P	S	Mo	Fe
Carbon Steel (CS)	0.2	0.01	0.01	1.37	0.23	0.02	0.008	0.005	Basis

Figure(1) Carbon steel with Welded metal Ni [12].

2.1.2 Weld metal:

The type of coated electrodes of class AWS (American Welding Society) was used in the welding experiments, thetype is E-Ni, with diameter ϕ =4 mm. The chemical composition of the used electrode is shown in Table (2).
The (SMAW) process was used to prepare acladded–carbon steel with Ni layers, which were welded to form dissimilar joints with Ni filler metal as shown in Figure (1).

Table(2)Chemical composition of the Ni electrode

Element%	C	Ni	Fe
Ni Electrode	0.5	Basis	1

2.2 Thermal aging procedure:

Weld metal specimens (both cladded and welded joints) were subjected to an aging temperature of 550ºC for various holding times ranging from 50 to 1000 hr followed by aircooling, in order to simulate working conditions. The effect of this isothermal thermal aging on microstructure was investigated for the cladded carbon steels and compared with as welded condition.The thermal aging process was performed in a muffle furnace which is automatically controlled with an accuracy of ± 5°C. Ni-NiCr thermocouple attached to a digital thermal indicator was used to check the temperatures at the furnace throughout the holding time.

2.3 Metallographic examination:

Metallographic examination was carried out for the weld deposits (Ni layers).The specimens were prepared by grinding under water on rotating disc, using abrasive paper with grades ranging from 180 to 2000. Then polished to mirrored surface by using diamond paste with grades 3 and 1 micron.Nickel was etched with 30 ml HNO_3 and 70 ml H_2O by immersion at room temperature for 5 to 20 second, Specimens were rinsed with alcohol and dried with hot air. An optical microscope (OM) was used for microstructural examination.

2.4 Microhardness test:

A Vickers microhardness testing machine was used to measure at least five-hardness values on the studied weld deposit specimens(cladded) and the as weld and after heat treatment conditions.Tests were carried out, also for thesurface Ni layer welded specimens.The applied load was 300g and the indentation time was 30 second according to ASTM E92-72.

2.5 Electrochemical Corrosion testing:

Prior to corrosion behavior studies, the samples were ground on SiC grinding papers from 240 till 1000 grade, followed by polishing on polishing lapped cloth using 1μm diamondsuspension. Then the polished samples were degreasing with ethanol before immersion in thetest solution.The electrochemical corrosion behavior of the samples was studied by applying thePotentiodynamic polarization technique using a potentiostat (Electrochemical ImpedanceAnalyzer, Model 6310) interfaced to a computer and a three-electrode cell with the sample asa working electrode of exposed area 100 mm2, a saturated calomel reference electrode (SCE), carbon electrode as counter electrode. The testing media was 3.5% NaCl prepared from duple distilled water and reagent grade salt.The carbon steel part was covered with plastic tap to avoid the galvanic action.

3-Results and discussion:

The microstructure of nickel metalwelded-carbon steel in the as weld condition, aging times 50,500 and 1000 hr are shown in Figure (2).It reveals austenitic matrix with the presence of fine precipitates within the austenite matrix. The microstructure of nickel alloys shows as-solidified dendritic microstructure with recrystallisationfeatures [12]. C.R. Das, et al [13] found that the microstructure of ERNiCr-3 weld shows as-solidified dendritic microstructure with recrystallisationfeatures. It also shows that in the multipass weld the dendritic microstructure has changed to recrystallisedequiaxed grains. The role of carbides in super alloys is complex and dynamic. Most investigators believe that carbides do exert a significant and beneficial effect on rupture strength at elevated temperatures. In addition, it is quite clear that carbide morphology can influence ductility, and also that carbides can influence the chemical stability of the matrix through the removal of reacting elements. The three main types of carbides found in nickel-based alloy are MC, $M_{23}C_6$ and M_6C. Cr_7C_3 can also be present but is rare [14].Since M_6C carbides are stable at higher temperatures than $M_{23}C_6$ carbides, M_6C is more beneficial as a grain boundary precipitate to control grain size in the wrought alloy [14].The microstructure of weld metal structure has no major changes after 50 hr aging the zone of retained austenite increased with increasing aging time, this in agreement with R. Anand et al [15], it is clear as that as the aging time increasethe grain size of the Ni part increase, Nickel base exhibit a complex precipitation behavior at elevated temperatures, during welding, furthermore, the precipitation behavior will depend upon the nickel content and the final temperature [16].

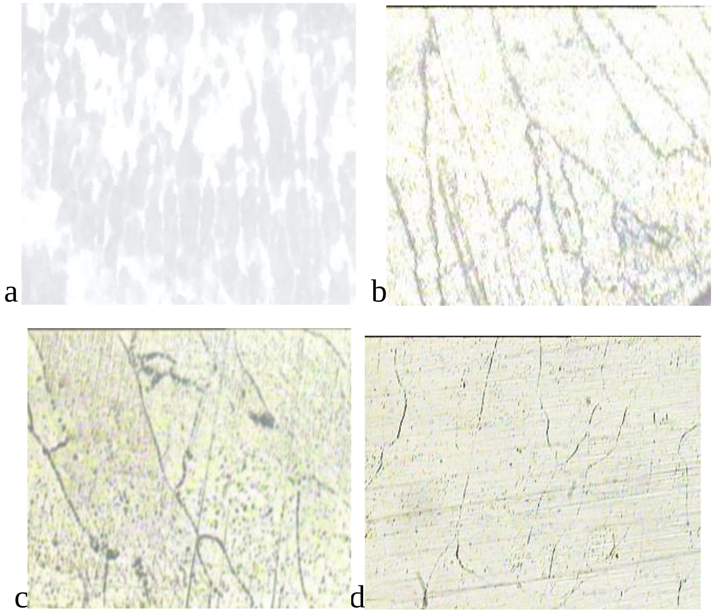

Figure (2) Optical micrograph showing the microstructure features of Ni weld metal deposited on carbon steel after aging (x200) (a) as weld (b) aging time 50 hr (c) aging time 500 hr and (d) aging time 1000 hr.

Microhardness testing machine was used to measure at least five -hardness values on the weld deposit specimens in the as weld and after agingconditions [12].

Figure(3) show the microhardnessprofiles of the mean value forfive measuringsmicrohardness at welded deposits on the as-welded condition and after various aging at 550 °C times for the Nickel weld metals. The curves show the following results the minimum microhardness at 50 hr and the maximum microhardness at 500hr aging,this increase inmicrohardness may be attributed to the strain hardening that produces large amount of deformation twins as shown in Figure (3)

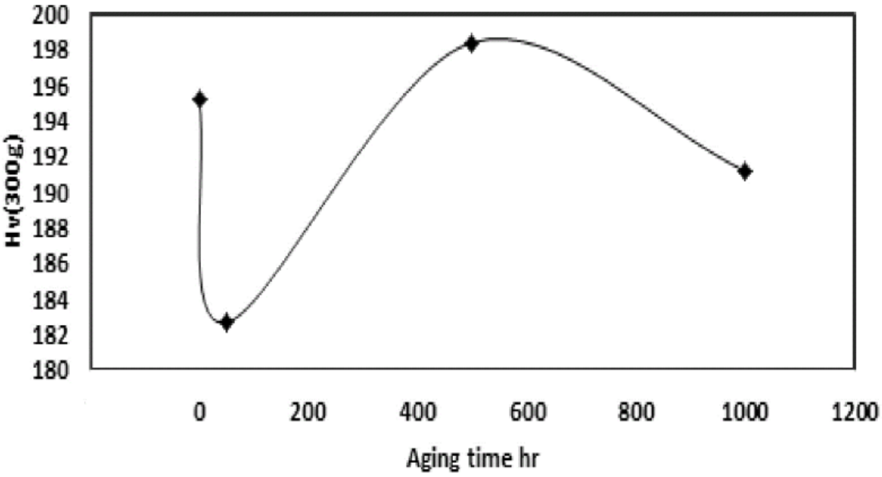

Figure (3) Relation between hardness and aging time hr

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Table 3 Corrosion potential E_{corr} and corrosion current density I_{corr}

Aging condition	E_{corr} (mV)	I_{corr} (μAcm-2)
As weld	-181	38.68
50 hr	-473.2	20.78
500hr	-469	7.6
1000hr	-473.6	8.922

The corrosion current density I_{corr} and corrosion potential E_{corr} of the steel tested,which were determined (Table3) by potentiodynamic technique. From these data, one maygenerally evaluate the corrosion properties of Ni at different conditions ofaging.
The electrochemical tests were established by usingPotentiodynamic technique. Anodic polarization curves for deposited as weld and heat treated Ni weldmetal in 3.5% NaCl solution having never neutral pH are shown in Figures (4-7).

In Figure (4) the as weld Ni weldmetal the corrosion current density was 38.7μA/cm^2. The anodic polarization curve shows some irrigators after corrosion potential and the current density increases as potential increases till 50mv, after this potential there is an abrupt increases in current density, which may be due to pits formation then the current density increases till the end of the run. The hardness value of weldmetal was 195.2 HV measured at 300g load.

Figure (5) shows the anodic polarization curve for Ni weld metal heat treated for 50 hr at 550 ºC, the corrosion currentdensity was 20.8 µA/cm2, the current density increases moderately till -300 mv, after that the current density increases abruptly till the end of the run.The corrosion current which is lower than that of as weld Ni, but the potential is more negative. The hardness of this weldmetal is 182.67Hv at 300g load.

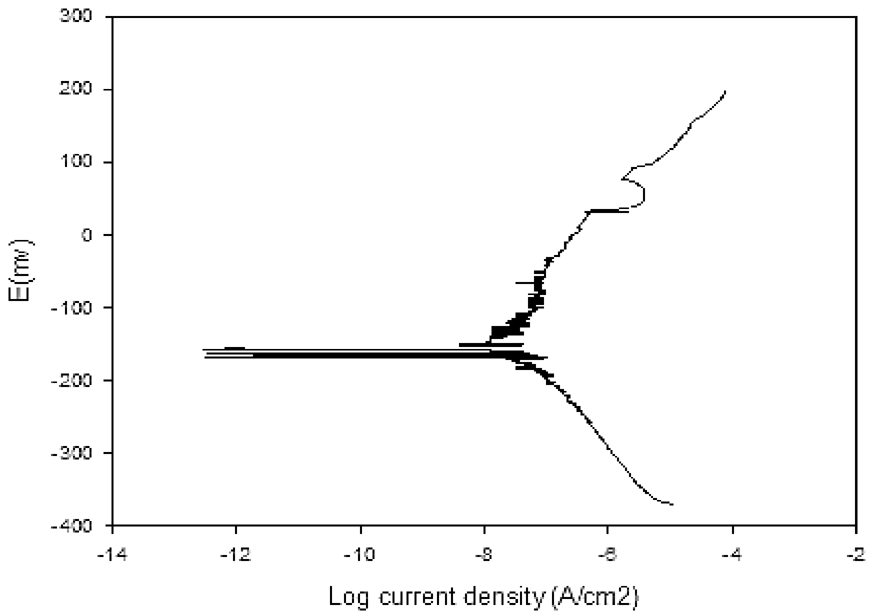

Figure (4) Anodic polarization curve of deposited Ni weld metal as weld condition

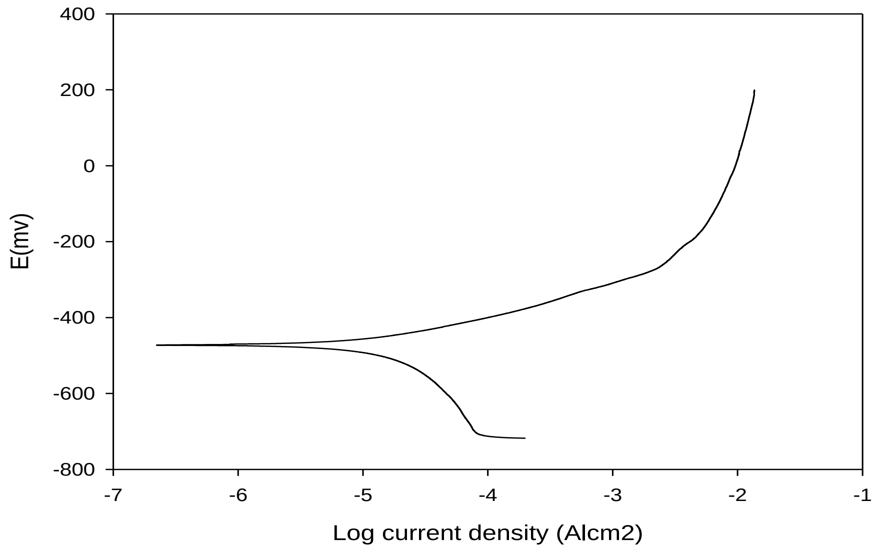

Figure (5) Anodic polarization curve ofdeposited Ni weld metal aging for 50hr at 550 ^{o}C

Figure (6) shows the anodic polarization curve for Ni weld metal heat treated for 500 hr at 550 ºC, the corrosion current density was 8.9 µA/cm 2in this case, and the current density increases steadily with content rate to the end of the experiment the hardness in this case was 198.4 Hv.

Figure (7) shows the anodic polarization curve for Ni weld metal heat treat for 1000 hr at 550 ºC, the corrosion current was 7.6 µA/cm 2. In this case the current density increases after corrosion potential with high rate. The hardness was 191.175.

For all heat treated Ni weld as the heat aging increases the corrosion potential become more negative as compared to as weld one.

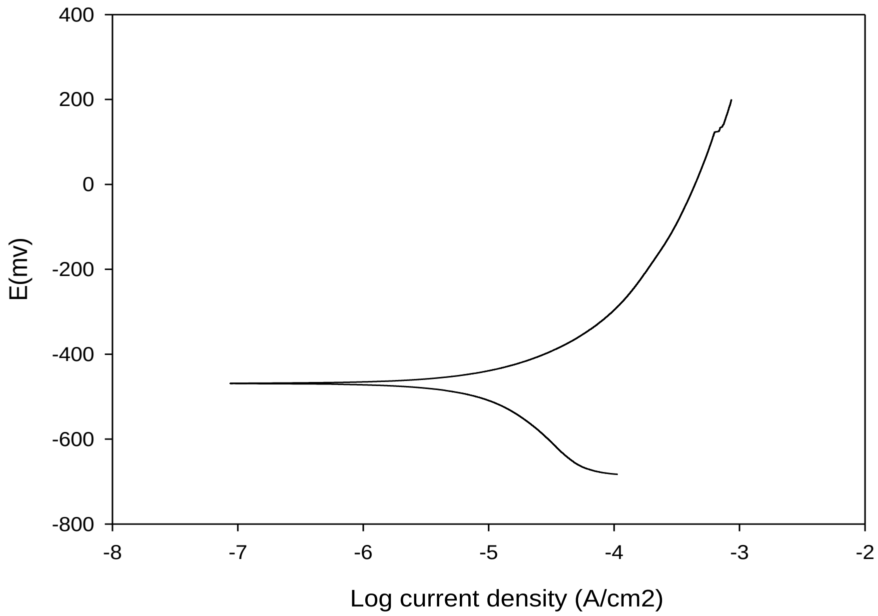

Figure (6)Anodic polarization curve ofdeposited Ni weld metal aging for 500 hr at 550 ^{O}C

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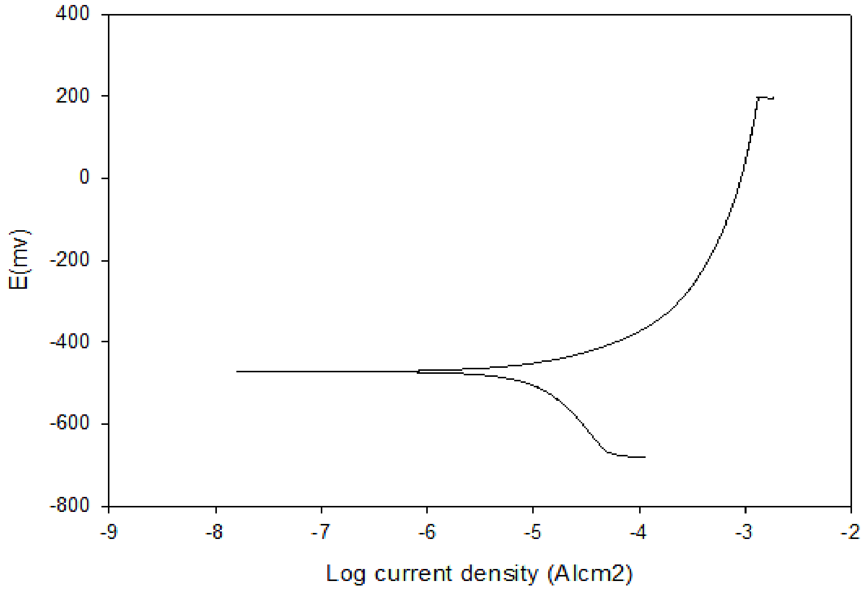

Figure (7) Anodic polarization curve of deposited Ni weld metal aging for 1000 hr at 550 ^{O}C

Conclusion:

The study of the corrosion performance of the as weld and heat treatment of deposited Nickel showed that with aging time increases the grain size of the deposited Nickel increase.Also, as the aging time increases the corrosion current density decreases after 50hr and 500hr, and the potential shifts toward more negative values.

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