Corrosion of Dissimilar Welded Joints of Monel 400 and AISI1020 Carbon Steel

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Abstract

Nickel–copper alloys are widely used as corrosion resistant materials in electrochemical, marine engineering and many other applications. The corrosion rates of these alloys decrease sharply with increasing nickel content in the alloy. In the present work, the effect of 10% HCl solution on Monel400 and AISI 1020 carbon steel joints made by Friction Stir Welding and Shielded Metal Arc Welding was investigated. Microstructure evolutions of welds were characterized using optical microscopy and Scanning Electron Microscopy. The work has been carried out using cyclic, potentiodynamic polarization, Specimens was submerged in 10% HCl solution for 30 days and the corrosion effect was investigated. Dealloying phenomenon was observed
i.e Nickel leaching inside Monel400 through corrosion process which is denickelation.

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1. Introduction

Monel-400 is extensivelyutilized in the desalination technology industry and in other marine engineering fields [1,2]. This is because Monel-400 contains about 60-70 percent nickel, 20-29 percent copper and small amounts of iron, manganese, silicon and carbon. Monel 400 exhibits excellent corrosion resistance in atmosphere, sea water, various acids and alkaline media. This characteristic coupled with sufficient ductility and workability makes this alloy very attractive for a wide range of industrial applications.

Due to its unique properties, Monel 400 is widely used in reducing and oxidizing environments, marine industry, power and chemical plants as well as for manufacturing valves, pumps, sensors, boiler feed water heaters and other heat exchangers,,, etc [1-8].

In terms of present work Joints between Monel 400 and AISI 1020 are exposed to strong corrosive mediums such as HCl, Sadek and Abbas [9] have investigated dissimilar joints between carbon steel and Monel 400 produced by fusion welding techniques using two types of filler materials.

The aim of the present study is to analyze the corrosion resistance of Bi metal weld joints of Monel 400 to AISI 1020 Carbon steel produced by both SMAW process and Friction stir Welding.

2. Experimental Procedure

2.1 Friction Stir Welding

Dissimilar materials used in this study were 3 -mm thick AISI 1020 Carbon Steel and Monel400. The chemical compositions and mechanical properties of AISI 1020 Carbon Steel and Monel400 are given in [10]

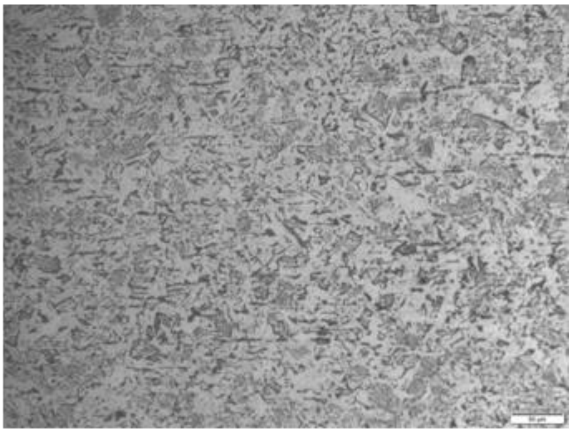


Fig. (1) Microstructure of Monel400 Fig(2) Microstructure of 1020 AISI Carbon Steel The microstructure of 1020 AISI carbon steel contained of ferrite and pearlite, while that

of Monel 400 consisted of equiaxed grains Fig.1-2.

The FSW process was carried out using the rotating speeds of 200, 250 and 400 rpm and traverse speeds of 50 and 100 mm/min. The plates were joined in a butt-weld configuration. During the FSW, plunge depth of 3 mm was applied. For microstructural observations, the specimens were cut perpendicular to the FSW direction. Specimens for the optical and SEM investigations were prepared according to ASTM E-3 [11] and ASTM E-2014 [12] then etched by 2% nital and Marbles reagents [13] for AISI 1020 carbon steel and Monel400 sides respectively, then optical microscopy (OM) were used. The micro-hardness tests were performed in order to obtain the hardness profile across the cross section perpendicular to the weld line.

FSW is based on the plastic flow of material produced by a non-consumable rotating tool inserted into the joint to be welded. The heat necessary to produce the required plastic flow for the conformation of the joint is mainly produced at the interface tool-work piece, being affected by factors such as rotational speed, welding speed, axial load and tool shoulder diameter (D), among others.

Schmidt and Hattel (2008) developed an analytical model for the heat generation in FSW.

The most important difference between this model and previous ones is that it considers the contact condition at this interface by a parameter called slip rate (δ), which varies from 0 to 1. If the slip rate is 0, the contact condition is sliding, and if it is 1, the contact condition is sticking. Moreover, although it has been reported that the heat input (HI) generated by the tool pin can become 20% of the total heat input, in this work the terms associated with the tool pin are omitted to simplify the analysis (Mishra and Ma, (2005); Mishra and Mahoney, (2007)). Therefore, based on that model,

Equation 1 expresses power (Q) generated during FSW depending on the rotational speed (ω) and the tool shoulder diameter (D), considering that the shear yield stress (τ_y), the friction coefficient (μ), the contact pressure (p) and the slip rate (δ) are uniform throughout the interface.

$$Q = \frac{2}{3}\pi\left[\omega\left(\delta.\tau_y + (1-\delta)\mu.p\right)\right]\left(D/_2\right)^3 \quad \textbf{(1)}$$

For FSW process, the heat input according to equations 1 was observed to be **177.66 watt.**

2.2 Results and discussion

Figures 3 and 4 illustrate the cross sectional area of the produced FSW. Generally speaking, there are four distinct regions after FSW. These include the nugget or stirred zone (SZ), the thermomechanically affected zone (TMAZ), and the heat-affected zone (HAZ) and the base metal (BM).

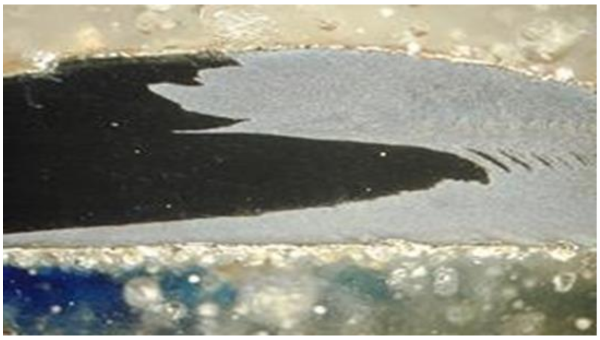


Fig (3) cross sectional area of the produced FSW showing the carbon steel inside Monel400

Fig (4) cross sectional area of the produced FSW showing Monel400 inside Carbon steel

2.3 Shielded Metal Arc Welding

Dissimilar materials used in this study were 3 -mm thick AISI 1020 Carbon Steel and Monel400. The chemical compositions and mechanical properties of AISI 1020 Carbon Steel and Monel400 are given previously. Specimens were welded using 2 electrodes (ENiCrFe-3- ENiCu-7). With the chemical composition given in table (1)

Chemical composition, %	ENiCu-7	ENiCrFe-3
Ni+Co	62	Bal
Cu	Bal	0.1
Mn	4	7.75
Fe	2.5	7.5
Si	1	0.5
C	0.15	0.05
S	0.015	0.008
Al	0.75	---
Ti	1	0.04
Nb+Ta	---	1.75
Cr	---	14

Table (1): Chemical composition for welding electrodes

2.3.1 Welding Procedure

The base metals were prepared as strips with dimensions of 30 x 20 x 3 mm. the shielded metal arc welding process was adopted in this work and the joint configuration is shown in Fig (5)

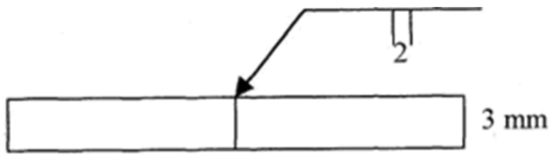


Fig (5) showing the Joint design

The joints were kept fixed until it was cooled down, and then the slag was removed.

Best welding parameters for Fusion Welding for Monel400 and 1020 AISI Carbon Steel are mentioned in table (2)

Current, A	80
Travel speed,(mm/s)	3.75
Voltage, V	12
Polarity	DCSP
Groove position	Flat

Table (2): best parameters for fusion welding:

3.2.2 Results and discussion

3.2.2.1 Microstructural evolutions

Figures (6) and (7) illustrate the cross sectional area of the produced weld.

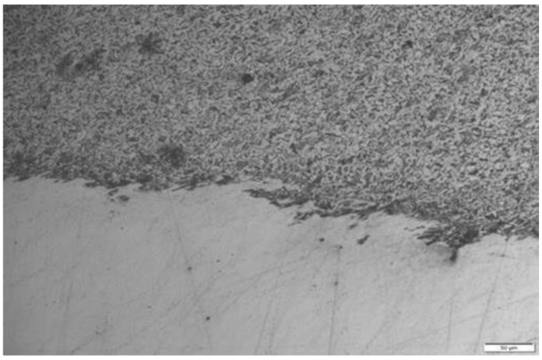


Fig (6) Microstructure of Monel in HAZ Fig (7) Microstructure of Carbon steel in HAZ For SMAW process, the heat input according to [14] was observed to be **289 watt.**

4. Corrosion Testing

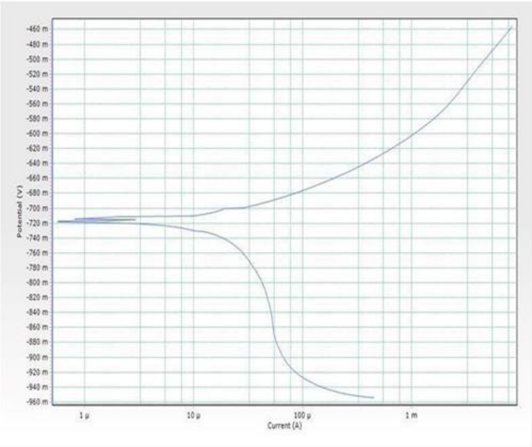
The electrochemical test of Monel 400 and AISI 1020 Carbon steel was performed with the help of Potentiodynamic method with a potentiate coupled to PC. To carry out this process. Specimen was polarized in a 10% HCl solution made of analytical grade HCl and distilled water. The specimen was fixed on mounting fixture. Fixture allowed an electrical contact to be supplied to the sample. POTENTIOSTAT has been used for the study.

Potentiodynamic polarization results and Corrosion rates for Monel400 and AISI 1020 joints in 10% HCl was shown in Table 3.

Specimen	**Corrosion rate**
Monel400-Monel400 FSW	13 mpy
Monel400 -Carbon Steel FSW	20.3 mpy
Monel400 -Carbon Steel(ENiCu-7)	26.15 mpy
Monel400 -Carbon Steel(ENiCrFe-3)	30.83 mpy

Table (3) Results for corrosion test

Polarization curves are shown in Figures 8 a and b below.



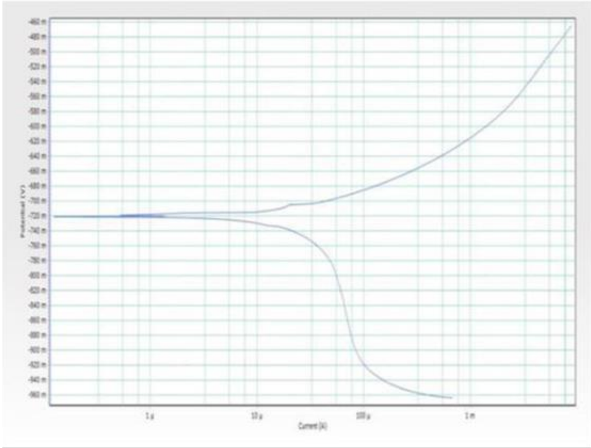
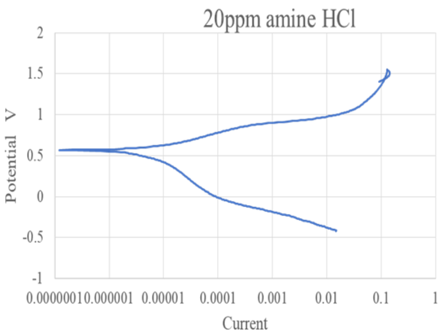


Fig (8) polarization curves

(a) For FSW (b) For SMAW

Cyclic polarization is a short-term exposure test. It provides information on both corrosion characteristics and corrosion mechanisms.

Cyclic polarization measurements are typically used to characterize metals and alloys that derive their corrosion resistance from the formation of a thin passive film.



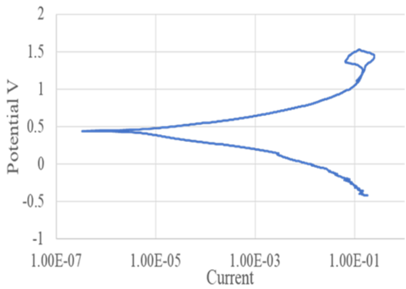


Fig 9 (a) cyclic potential of FSW specimen in 10%HCl Fig 9 (b) cyclic potential of SMAW specimen in 10%HCl Specimens were submerged in 10% HCl for 30 days and then after removing the solution Monel400 showed redish metal and a new phenomenon was observed and this was denickelation and it’s a kind of dealloying.

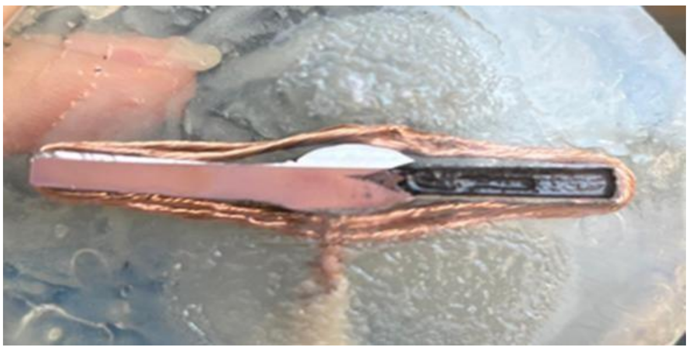
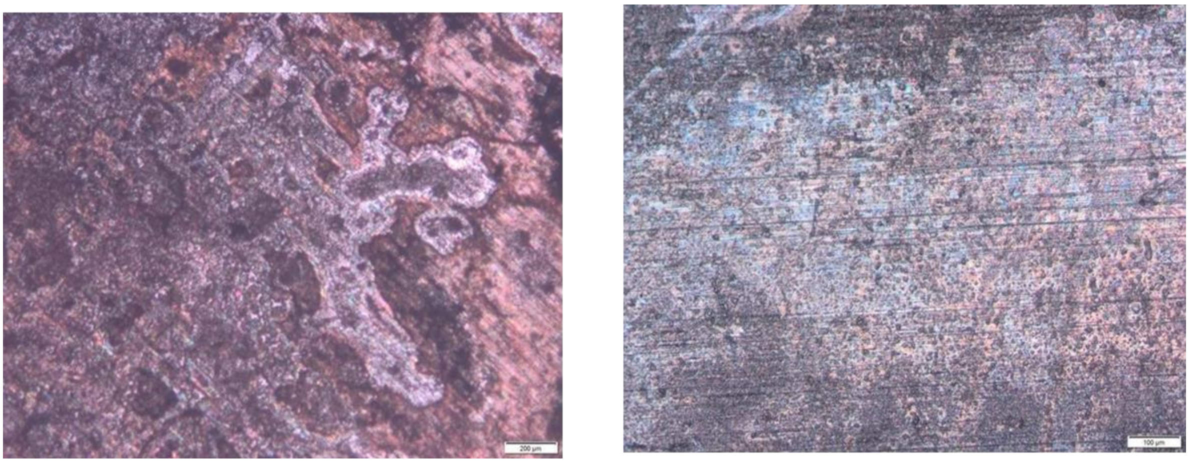


Fig 10 showing Denickelation

Denickelation refers to an occurrence of corrosion where nickel is extracted by leaching from its alloys. This process occurs in copper-nickel alloys that have undergone significant exposure to seawater or other aquatic environments.



(a) **(b)**

Fig 11 Microstrucure showing Denickelation in

(a) SMAW specimen

(b) FSW specimen

6. Conclusions

1- FSW process under the selected parameters, produced sound accepted welds without cracks and cavities between Monel 400 and AISI 1020 Carbon Steel.

2- Due to uneven weld microstructures and precipitate distribution most serious corrosion occurs at weld nugget area, forward side and lighter at the return side.

3- Pitting in Monel alloys are due to Denickelation and redistribution where oxide film breakdown during FS weld which supports anodic reaction.

4- Denickelation was observed to happen in SMAW more severe than in FSW according to the heat input.

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