Optimization of Corrosion Factors for Locally Manufactured Fe – Ni Alloy Used in Oil Refining Equipments

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Abstract—**Purpose: This research focuses on studying some mechanical and corrosion resistance of Fe – 10%Ni alloy (which is fabricated in Iraq) for the purpose of use it in many oil industries applications.**
Design of Experimental work: Ingot samples were prepared from steel scrap with addition of alloying element (Ni pellets).
The mixture were heated to 1650ºC and the Argon gas were pumped into molten steel. The molten metal were cast into graphite tool and cooled to room temperature. Hot rolling process were applied to produce plate with thickness 40 mm and sheets with thickness 10 mm.
Mechanical properties such as impact energy, microhardness and wear were evaluated depending on the carbon percent and the Ni ratio. Corrosion test was performed to evaluate corrosion rate and probability of pitting corrosion.
Results: The value of impact energy increase with decrease of carbon ratio in the alloy. It was found that the alloy with 0.1% C has high impact value. The corrosion resistance increase with increase the percent of Nickel addition, from which it has been shown that the alloy Fe – 10% Ni has good resistance against general and pitting corrosion.
Originality: Production of Fe – Ni alloys from steel scrap contribute to decrease the cost of parts and plates used in different equipments in oil industries such as storage tanks, distillation towers, and pipe lines. It is possible to produce such alloy in Iraq, with economy quantities and low cost.
The results obtained from study were applied to produce plate which used in distillation tower.

Keywords -Optimization, Corrosion Factors, Oil Refining Equipments, Corrosion Resistance, Microhardness, Weight Loss.

I. INTRODUCTION

Energy is a key component in our everyday lives. A secure energy future requires a balance between environmental impact and affordable supply. Petroleum and gas systems engineers are able to address and solve important issues that will lead to energy security and thus are in high demand.[1]
steel finds extensive applications as a construction material in various aggressive environments such as in chemical, and in the petroleum industry due to its adequate mechanical properties, good fabricability and weldability. Corrosion resistance of steel can be improved by alloying the metal with some elements such as nickel, chromium, molybdenum.[2]

Mechanical properties are not only a function of the chemical composition, but also of the conditions during the solidification (ingot casting, continuous casting, and moulding) and further hot and cold treatment of the steel (like rolling, reheating, quenching, drawing, pickling, etc.). Chemical elements can be divided into sub-groups based on their role in process metallurgy and how they relate to mechanical properties:[3]
1-Alloying elements – These elements have a positive effect on the mechanical and the following processing properties
2- Impurity elements – These elements have a negative effect on the mechanical properties, and the following

3- Trace elements – These elements have no or negligible effect on mechanical or processing properties either because the concentration is too low or that they are very similar to iron atoms in every aspect.

4- Tramp elements – Elements that can not be easily removed by any known metallurgical refining process. They accumulate during remelting of steel scrap and pose a long term threat to steel scrap quality.[4]

In Iraq there are large quantities of steel scrap can be recycled and benefit them in manufactured steel alloys used in many petroleum applications such as plate in storage tanks, different parts in distillation units and pipes.

Manufacturing of some parts used in petroleum industries and study their mechanical and corrosion properties was investigated in this research, by using steel scrap as a base component. Steel scrap may divided into two main groups: The first group is, wrecked vehicles beds and different structural steel wastes, while the second group is steel wastes which are a by product from various mechanical operations such as machining, piercing and blanking operations.

II. EXPERIMENTAL WORK

Chemical analysis of steel scrap was performed by using Nova 350 atomic absorption spectrophotometry, in Ibin Sina Company for chemical industries / ministry of industry and minerals. the chemical composition of steel scrap are shown in table I.

The process were performed by using electrical furnace as shown in Fig. 1. The process basically starts with melting steel scrap and then ferronickel pellets were added to the liquid steel. the argon gas tube was immersed inside the crucible. The liquid steel is then stirred using argon gas. This is to insure homogeneous composition and uniform temperature. In addition the gas bubbles float out the impurity which are absorbed into the slug. The slug is removed and liquid steel poured into graphite tool to obtain steel ingot as shown in Fig 2.

Hot rolling process were performed to improve mechanical properties of the steel ingot. This process was performed by heating the steel ingot to 1021 C^0 (30% above the recrystallization temperature) and then hot rolled.

Two types of samples were produced; samples for mechanical tests (for hardness and impact tests) and samples for corrosion tests (weight loss method) as shown in Fig. 3 and Fig. 4 respectively.

The dimensions of weight loss method samples are 25*50*2mm.

In order to manufacture alloy from steel scrap, the experimental work of this research includes some operation starting from steel scrap melting and refining with nickel addition. Three types of alloys were manufactured according to nickel percentage. The percentage of added nickel were (6 %, 8 %, and 10 %).

In order to evaluate some mechanical properties of manufactured alloys, Mechanical tests which includes micro hardness and impact energy using charpy methods were performed. Corrosion tests were carried out using weight loss method. Design of experiment using Taguchi methods was used to optimize the results. Three samples were tested in H_2SO_4 solution for each experiment.

The Minitab 16 program was used in the current research to create design of the experiment. Three types of alloys were studied with different parameters (Ni%,acid concentration, time, temperature and circulation speed). Table II. illustrate types of alloys , parameters and their levels.

III. DISCUSSION OF RESULTS AND DIAGRAMS

The chemical composition of the alloys were evaluated by using atomic absorption spectrophotometry, the chemical composition of the Fe-Ni alloys are shown in Table III.

Mechanical tests were performed represented in charpy impact energy and hardness to evaluate some mechanical energy. The results are shown in Tables IV. and VI. respectively.

The results of Charpy test shows that the impact energy decreases slightly in alloys B, and C because of increased hardness of these alloys due to hot rolling process. Where samples were heated to 1021 C^0 and hot rolled at room temperature, besides, When Ni % increases the hardness increase because of the strong influence of nickel by the ferrite solid solution strengthening. Table VII illustrate results of Vickers hardness for samples before and after hot rolling process, from which it has been shown that the alloys after hot rolling have high values of micro hardness than the other samples. This is because hot rolling processes increase surface hardness of the samples Besides whenever alloying element (Ni) increases, the ability of hardening increase as was mentioned above.[5]

Corrosion tests were performed to evaluate corrosion resistance of manufactured alloys. Taguchi method L 27 orthogonal arrays was used to evaluate the results, and in order to quantify influence of each level of all parameters, mean and S/N ratio for experiments 1-27 were calculated, as shown in the Table VIII.

The data shown in Table VIII were used to create response table for S/N ratio as shown in Table IX.. The data in such table were used to create main effect plot for S/N ratio which is illustrated in Fig. 5.

The response table for S/N ratio shows the average of each response characteristic (S/N ratios) for each level of each factor. The tables include ranks based on Delta statistics, which compare the relative magnitude of effects. Response table for S/N ratio assigns rank based on delta values. Percentage of nickel addition (rank1) to the highest delta values (9.3129) at level 3 gives the lower corrosion rate. Rank values of concentration, temperature and time signifying second, third and forth contribution to low corrosion rate. and circulation speed observed to be insignificant. Analysis of main effect plot Fig. 5 and Interaction plot Fig. 6 suggested that the arranging of parameters to be perform as A at level 3, B, C,D, and E at level 1.

Analysis of variance:

Design parameters were investigated by using analysis of variance.[6] In this analysis sum of squares and variance were calculated. F- test value at 95% confidence level was calculated to prove significant factors affecting the corrosion rate.[7] ANOVA table 4 showed that the factors A (Nickel content could accelerate the formation of the films, which can be very stable, passive and could increase the alloy resistance to corrosion),C,B and interaction (B*C) are statistically significant.

The H_2SO_4 concentration (B) is directly proportional to the corrosion rate. It is observed that the higher is the solution concentration the higher is the corrosion rate. This is related to the increased electrical conductivity of the solution facilitating the cathodic reaction (oxygen reduction) and anodic reaction (iron and nickel) dissolution. Testing time is associated with concentration that leads to increase corrosion rate.

Predictive corrosion rate

According to factors setting as A at level 3, B,C,D, and E at level 1 predicted corrosion rate (mean) is (0.287432） and predicted S/N ratio is (10.3201）

Confirmation Experiments

Confirmation experiments were run using factors settings to test the accuracy of the experimental conclusions. Three tests were conducted to verify the corrosion rate at the optimum level of each parameter (A at level 3, B,C,D AND E, at level 1). The values obtained were 0.284912, 0.29.0026, and 0.287213 respectively with an average of 0.287383.

Conclusions:

The manufactured alloys exhibit good impact energy and the values are adequate for many industrial applications. Percentage of nickel addition has significant effect on mechanical and corrosion properties of the manufactured alloys, and the value of corrosion rate was 0.287383 for the alloy with 10% nickel. The concentration of tested solution (H_2SO_4) and time have significant effect on corrosion rate.

The conclusions of this study were applied to manufacture some parts which are used in petroleum industry, and these parts exhibit good mechanical properties and excellent corrosion resistance during work, and the parts are shown in Fig.7.

TABLE I. Chemical Composition (Wt %) Of Steel scrap

Composition %								
C	Si	Mn	P&S	Cr	Ni	Mo	W	V
0.2	_	0.3	0.035	0.2	0.4	0.1	0.08	0.1

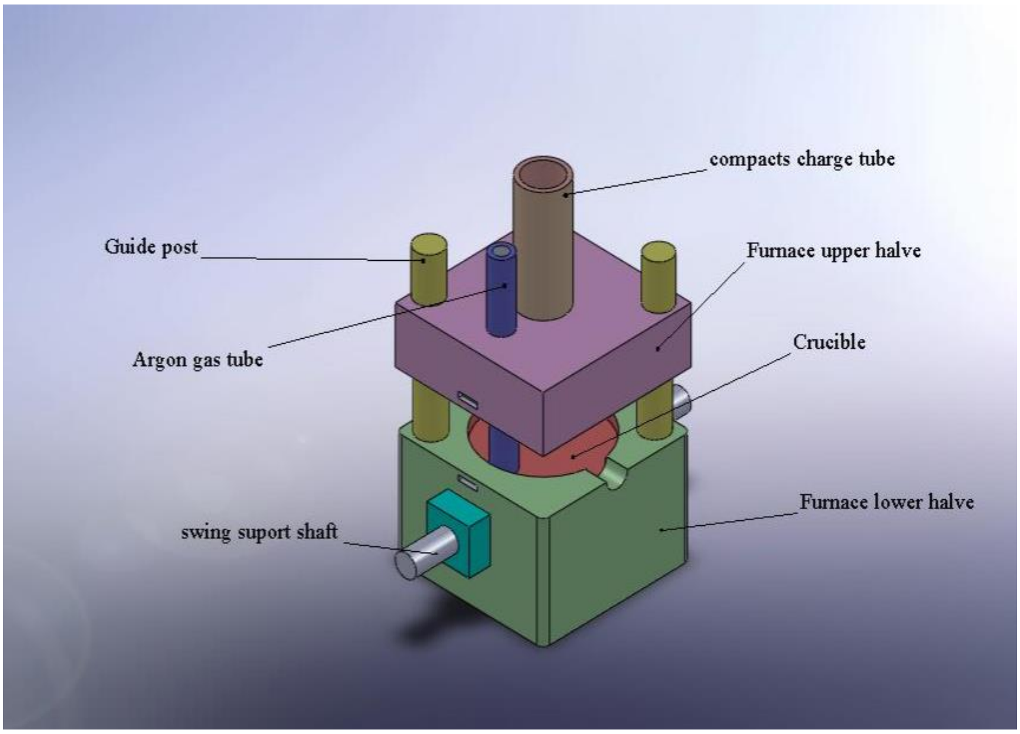

Figure1. Electrical furnace

Figure2. Steel ingot

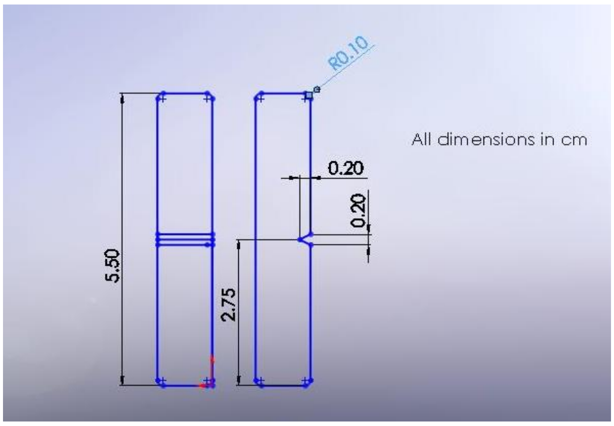

Figure 3. Samples for charpy impact test

Figure 4. Sample for weigh loss tests

TABLE II. The parameters of Fe-Ni alloys and their levels

parameters	Symbol	Level 1	Level 2	Level 3
Ni %	A	6	8	10
Concentration (M)	B	1	2	3
Time (days)	C	25	35	45
Temperature (C^0)	D	25	35	45
Circulation speed (r.p.m)	E	250	500	750

TABLE III. Chemical composition of Fe-Ni alloys

Alloy No.	Ni %	Steel scrap %
A	6.2	Bal.
B	8.1	Bal.
C	10,1	Bal.

TABLE IV. Impact energy values for Fe-Ni alloys

Alloy	**Impact energy (after hot rolling and tempering) J**
A	36
B	34
C	33

TABLE VI. Results of Vickers hardness

Alloy	(Hv Kgf.mm^{-2}) before hot rolling	(Hv Kgf.mm^{-2}) after forging
A	244	310
B	253	331
C	270	345

TABLE VII. Results of L27 OA of the Corrosion Rate for Fe-Ni Alloys

↓	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
	Ni %	Concentration M.	Time days.	Temperature C	Circulation speed r.p.m	Trial 1	Trial 2	Trial 3	Mean	S/N
1	1	1	1	1	1	0.893	0.891	0.892	0.892000	5.7639
2	1	1	1	1	2	0.894	0.893	0.895	0.894000	5.7444
3	1	1	1	1	3	0.896	0.898	0.896	0.896667	5.7186
4	1	2	2	2	1	0.901	0.903	0.902	0.902000	5.6671
5	1	2	2	2	2	0.908	0.907	0.909	0.908000	5.6094
6	1	2	2	2	3	0.911	0.912	0.910	0.911000	5.5808
7	1	3	3	3	1	0.945	0.946	0.943	0.944667	5.2657
8	1	3	3	3	2	0.948	0.949	0.947	0.948000	5.2350
9	1	3	3	3	3	0.965	0.957	0.956	0.959333	5.1318
10	2	1	2	3	1	0.689	0.686	0.684	0.686333	8.0405
11	2	1	2	3	2	0.688	0.690	0.693	0.690333	7.9901
12	2	1	2	3	3	0.696	0.698	0.697	0.697000	7.9065
13	2	2	3	1	1	0.687	0.681	0.680	0.682667	8.0871
14	2	2	3	1	2	0.688	0.689	0.691	0.689333	8.0026
15	2	2	3	1	3	0.693	0.695	0.694	0.694000	7.9440
16	2	3	1	2	1	0.702	0.704	0.707	0.704333	7.8156
17	2	3	1	2	2	0.712	0.716	0.714	0.714000	7.6972
18	2	3	1	2	3	0.718	0.719	0.721	0.719333	7.6327
19	3	1	3	2	1	0.302	0.301	0.300	0.301000	15.1998
20	3	1	3	2	2	0.304	0.308	0.309	0.307000	15.0284
21	3	1	3	2	3	0.312	0.316	0.318	0.315333	14.7960
22	3	2	1	3	1	0.323	0.321	0.320	0.321333	14.6321
23	3	2	1	3	2	0.318	0.312	0.310	0.313333	14.8511
24	3	2	1	3	3	0.309	0.302	0.309	0.306667	15.0377
25	3	3	2	1	1	0.320	0.321	0.322	0.321000	14.6411
26	3	3	2	1	2	0.318	0.317	0.312	0.315667	14.7868
27	3	3	2	1	3	0.324	0.322	0.326	0.324000	14.5603

TABLE VIII. Response table for S/N ratio

Level	Ni%	Concentration M	Time (days)	Temperature C^0	Circulation speed r.p.m
1	0.7529	4.8053	4.6614	4.7009	4.6858
2	3.1306	4.7190	4.6491	4.6762	4.6671
3	10.0658	4.4250	4.6388	4.5722	4.5964
Delta	9.3129	0.3802	0.0226	0.1287	0.0894
Rank	1	2	4	3	5

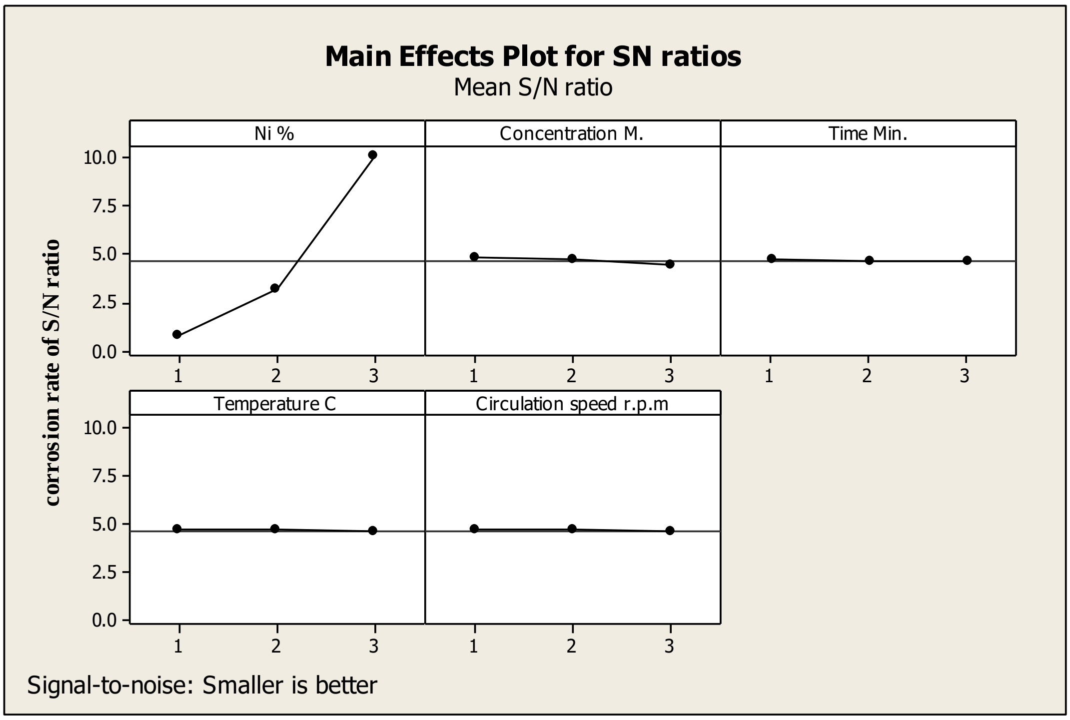

Figure 5. main effect plot for S/N ratio

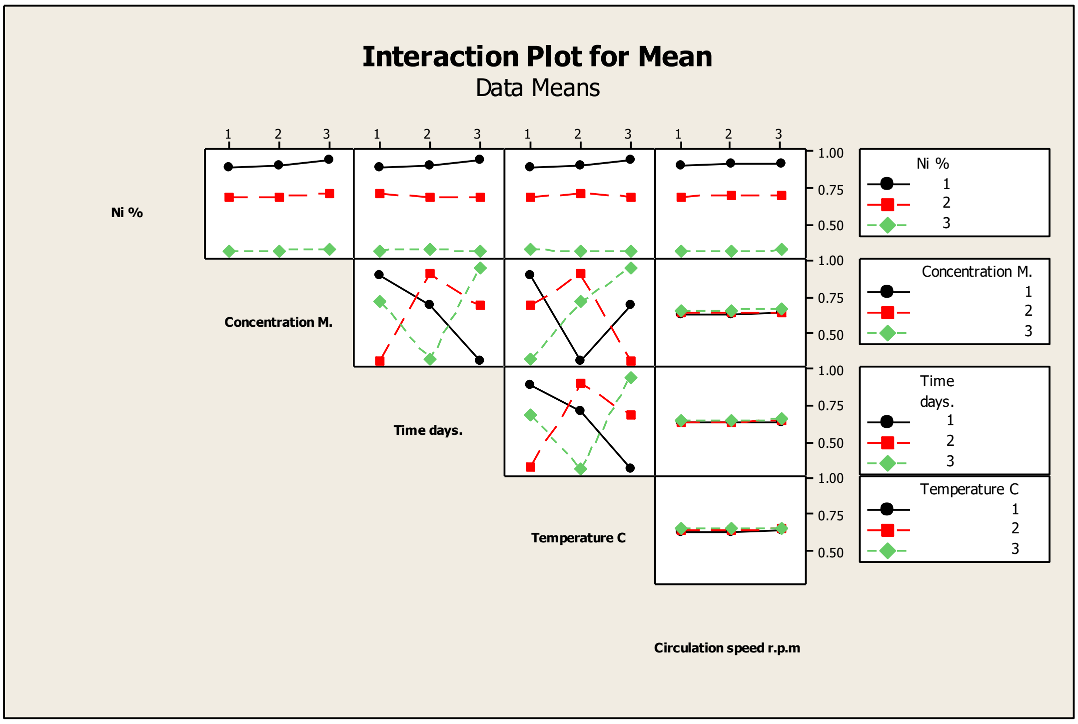

Figure 6. Iinteraction plot

TABLE IX. ANOVA table

Analysis of variance				
Source	DF	Seq SS	F	P
A	1	1.63825	10.4278	0.006058
B	1	0.00407	0.4197	0.527563
C	1	0.00035	3.7566	0.073033
D	1	0.00138	0.1499	0.704492
E	1	0.00026	0.0034	0.954388
A*B	1	0.00006	1.4793	0.243999
A*C	1	0.00018	0.9003	0.358788
A*E	1	0.00005	0.0277	0.870216
B*C	1	0.01317	6.6446	0.021906
B*E	1	0.00000	0.0004	0.984756
C*E	1	0.00010	0.0525	0.822120
D*E	1	0.00001	0.0029	0.957676
Error	14	0.02776		
Total	26	1.68565		

Figure 7. Some parts used in petroleum refining

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