International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161

Available at http://inpressco.com/category/ijcet

Research Article

Study the Effect of Cold Working and Heat Treatment on the Mechanical Properties of Copper Nickel Alloys

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Accepted 14 July 2015, Available online 25 July 2015, **Vol.5, No.4 (Aug 2015)**

Abstract

Copper nickel alloys are widely used in differential industries due to their special mechanical and chemical properties, today copper and its alloys remain on of the major groups of commercial metals ranking, third behind only steel and aluminium in production and consumption. The present work was attempt to study and investigate the effect of cold working and heat treatment on the mechanical properties of copper nickel alloys reaching to estimate the effect of these work conditions on the copper nickel alloys performance. . The results indicated that cold working increase the mechanical properties, while it's been controlled if the cold working applied tighter with the heat treatment. The experimental result show the effect of cold working and heat treatment and on the tensile strength and Brinel hardness of the three grade of copper nickel alloys (90%Cu: 10%Ni), (80%Cu: 20%Ni), and (70%Cu: 30%Ni).

Keywords: *Copper nickel alloys, cold working, heat treatment, etc.*

1. Introduction

Copper-nickel alloys are widely used in different industries due to their special mechanical and chemical properties, they are highly resistance to corrosion in different media, present excellent electrical and thermal conductivity and are easily manufactured (ASM 2001).

For this reasons, they are widely applied in the building of ships, pipes and other seawater-related structures as well as in the building of equipment's for chemical processes , heat exchangers, pumps, valves, etc.(Wilhelm Schleich 1994).

Studying the influence of cold working on microstructure and properties of annealing Cu-Ni-Ti alloys, to investigate the effect if of cold plastic deformation of the super saturation on the structure and properties of the CuTi4 alloy aging. On the basis of conductivity, the influence of cold plastic deformation and subsequent aging on the hardness and electrical conductivity of the alloy CuTi4. (J. Konieczny 2012)

Two type of heat treatment solutionizing and aging were employed to nick l- aluminium bronze, heat treatment was done to access their effect on the mechanical properties e.g. tensile and compressive strength and strain. (Praveen Kumarand 2013)

The effect of corrosive solution motion on copper-nickel alloy pipe in presence of Naphthylamine as a corrosion inhibiter, the corrosion of copper nickel is hydrochloric acid was investigated at different temperature, inhibitor concentrations and corrosive solution velocities.

Corrosion rate increased with both temperature and acid velocity was at level of temperature. (Anees A.Khadom 2014)

During machining, the surface and immediate subsurface of the material become harder due to work hardening (Goutam D.R. *et al*, 2014).

A series of experimental was carried out in seawater at different temperatures in order to investigate the correlation between the modification of the composition of the passive layer linked to temperature change and the resistance of the alloy against generalized or localized corrosion. (Y.Z.Wang 2015).

In this study tensile strength, hardness and corrosion rate were predicted to develop and improve the work quality of the copper nickel alloys in three grade. The effect of cold working (% hardening) and heat treatment time and temperature on the tensile stress, Brinel hardness, and the corrosion rate, of the copper –nickel alloys.

2. Experimental Work

Three groups of copper nickel alloys were used in the present study, the 1st is (C70600), the 2nd is (C71000), and the 3rd is (C71500). The chemical composition are according to the ASTM E08. As shown in table 1

All the required alloys were brought from Wisdom heating alloys (Shanghai) co. Ltd. Chemical composition analyses are done to ensure that the alloys

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are meet the requirement of this study , the test were done according to ASTM E55, using spectra metal analyser model (txg 25 , Germany).

Table 1: Chemical Composition Results of copper nickel alloys

Cu/Ni alloys	C71500	C71000	C70600
Cu%	69.5	79.5	90.1
Ni%	29.6	20.4	9.87
Zn%	0.015	0.015	0.015
Pb%	0.020	0.020	0.020
Fe%	0.039	0.023	0.020
Mn%	0.82	0.0040	0.004
P%	0.029	0.018	0.011

2.1 Material

Around 450 specimens prepared to cover this work, the required design (shape), 150 specimens design from each copper nickel grade. All of these specimens are machined as a circular cross section of 12.5 mm diameter and 75mm length which satisfy in tensile test machine according to ASTM E8. Same number of specimens used to cover Brinel Hardness test, and the corrosion rate test.

2.2 Specimen preparation

To remove all the machining and stress history, all the specimens were heat treated (full annealing) at approximately (600°C). After solid solution has been recognize, the specimens is cooled to the room temperature slowly by leaving the specimens inside the closed furnace.

To cover the requirement of the experimental work part, the work conditions are divided as follow:

1-Cold Working Rate

The cold working rate will be in four rate's (5%, 10%.15%, and 20%) from the total extension occurred in the tensile test.

Tensile test are used to supply the required rate of cold working, depending on ϵl,

Cold working (CW) is the measure to the degree of plastic deformation and it usually calculated as below

$$\%CW=\left(\frac{Ao-Ad}{Ao}\right)*100 \quad (1)$$

2- Heat Treatment Temperature and Time

The specimens are heat treated by three temperature stage (350°C, 400°C,and 450°C), all of these temperature applied and kept to the periods (1hr. and 2 hr.) time.

Three specimen were used to each case and we depend on the most satisfied two value.

3. Mechanical tests

The experimental tests are included the following

1- Hardness test measurement

The Hardness test measurements are set to determine the resistance of penetration and are occasionally employed to obtain a quick approximate tensile strength.

In this study a Brinel hardness test machine was used to measure the hardness values, by determining the depth of penetration of hardness steel ball into specimen under certain fixed conditions.
Hardness test were done according to ASTM E18.
The mean value of three readings for each specimen were calculated.

2- Tensile Test Measurements

The experimental procedure and the dimensions of the specimens were done according to ASTM (E08).
Tensile machine (Instron) was used to carry out this test.

Each tensile test was carried out three times, and the main value of the results was calculated, depending on the best and closest values.

3- Corrosion test Measurements

Corrosion test was carried out on the specimens to estimate the effect of cold working and heat treatment on the corrosion rate of copper nickel alloys. Around 150 specimen prepared in 40 mm length and 10 mm diameter. All specimens were cleaned carefully to release all the machining effect, and then weighted to found the exact weight before corrosion, using 5 digit electronic balance.

The specimens are immersed in artificial sea water (3.5%NACl) using a standard glasses, sea water used are the worst corrosion condition, by adding 35G from NaCl to each one litre water.

Leaving the specimens in these conditions for 72 hours to reach the corrosion level required, and then all the specimens are released to calculate the corrosion effect using the loss weight method, by checking the difference in weight as per equation(2) below:

$$\text{Mpy} =\frac{\Delta w(g)}{72hr}*\frac{24hr}{1day}*\frac{365day}{year} \quad (2)$$

4. Results and Discussion

The experimental results of the three types of copper-nickel alloys included: (1) Tensile test, to determine the exact values of yield and tensile strength; (2) Hardness test, to determine the strength of copper nickel alloys to the working ;(3) Evaluate the corrosion test result give clear indicator about the corrosion of copper nickel alloys in sea water and room temperature.

4.1 Tensile test results

The experimental results of the tensile test to the three different alloys of copper nickel were mention in three figures as below, each figure actually mention a seven curves of the relation between the tensile strength with the cold working rate and the time/temperature of the heat treatment to each grade of copper nickel alloys.

Figure (1) shows the effect of the cold working and heat treatment on the tensile strength of (70%Cu-30%Ni) alloys , cold working increase the tensile strength , while the heat treatment decrease it, if they applied separately , in this study we are applying both together and shown the effect on the tensile strength.

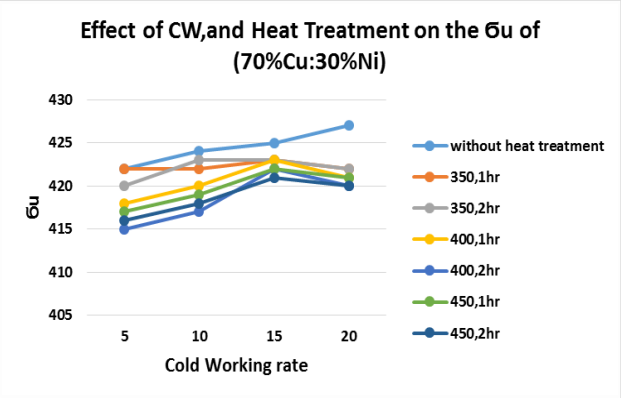


Figure (1) Effect of cold working and heat treatment on the tensile strength of C71500

Figure (2) shows the effect of the cold working and heat treatment on the tensile strength of (80%Cu-20%Ni) alloys.

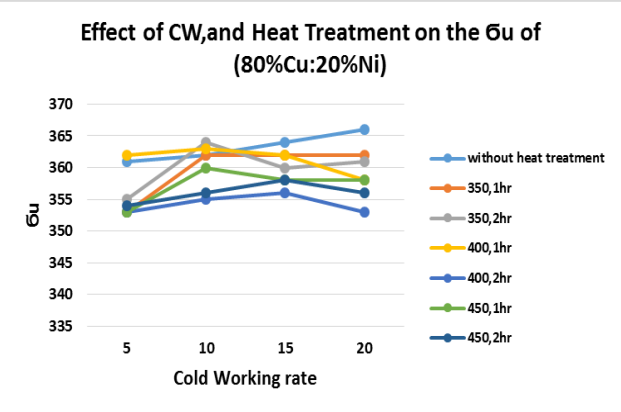
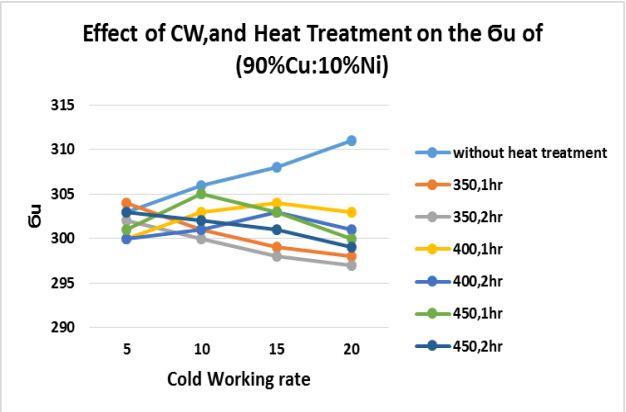


Figure (2) effect of cold working and heat treatment on the tensile strength of C71000

Figure (3) shows the effect of the cold working and heat treatment on the tensile strength of (90%Cu-10%Ni) alloys.



These figure a comparison between the values of the tensile strength in each heat treatment temperature and time, depending on the cold working rate.

From these three figures it was observed that the tensile strength were increase by the cold working due to the work hardening , and then its controlled by the heat treatment which is reduce the tensile strength due to softening the material,

These figure indicate that its very useful to heat treat the alloys to temperature less than 400°C because of in all the experimental work the tensile strength decrease after this temperature.

The tensile strength value increase with increasing the Ni concentration in the alloys as mention in the figures.

Therefore its can recognized that Figure (3) is more clearly indicate the increasing of tensile strength with increasing of cold working till (15%) and then decrease occur with the (20%) which is mean it's not useful to hardening the copper nickel alloys more than 15% cold working.

4.2 Hardness test Results

The experimental results of the Brinel Hardness test to the three different alloys of copper nickel were mention in three figures as below: each figure represent a seven case of Hardness and cold working rate with a time/temperature of the heat treatment.

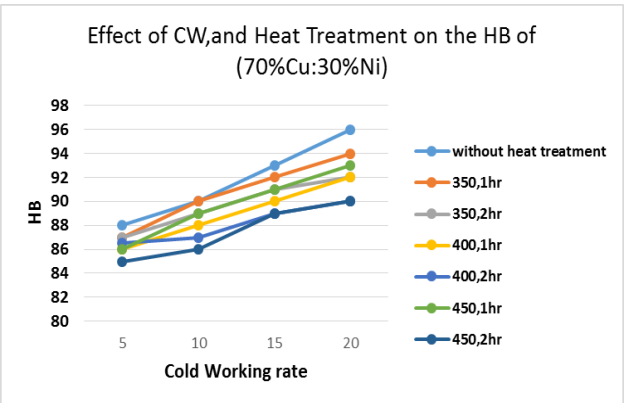


Figure (4) Effect of cold working and heat treatment on the Hardness value of C71500

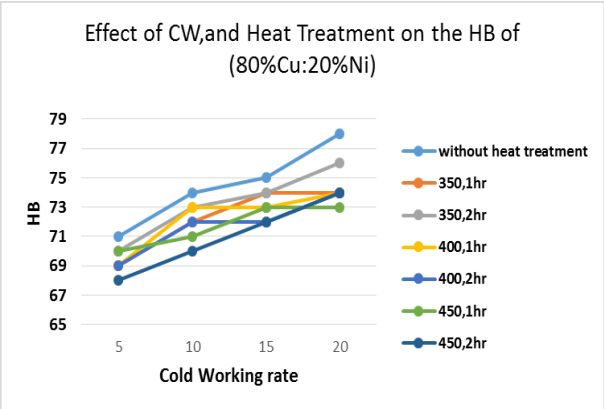


Figure (5) Effect of cold working and heat treatment on the Hardness value of C71000

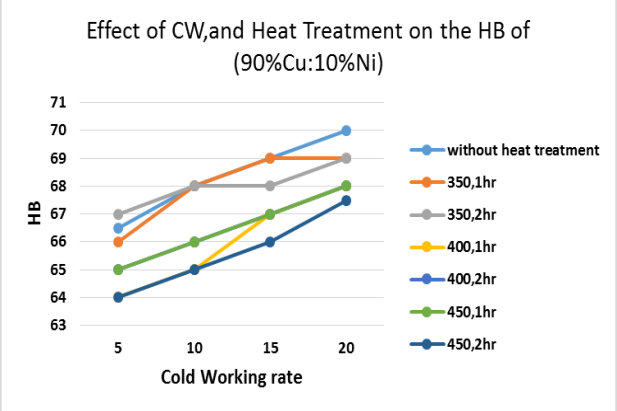


Figure (6) Effect of cold working and heat treatment on the Hardness value of C70600

Figure (4) show the effect of the cold working rate and heat treatment conditions, on the hardness value of the alloys (70%Cu: 30%Ni), it can be observed that the effect of heat treatment increases with increasing the time and temperature, therefore the decreases with increase the time and temperature of the heat treatment with increasing the cold working rate. And this alloy record the highest value of the hardness than the other alloys.

Figure (5) show the effect of the cold working rate and the heat treatment conditions, on the hardness value of the alloys (80%Cu: 20%Ni).

The hardness value was increase with the cold working and then controlled by the effect of the heat treatment. And also mention a clear different between the 1hr and 2hr heat treatment time

Figure (6) Show the effect of the cold working and heat treatment conditions on the hardness value of the alloys (90%Cu: 10%Ni), it can be observed a little different on the effect of the work conditions on the hardness value because of the decrease on the Ni % concentration

Therefore this alloys record the least values of the hardness than the other alloys.

The largest different between the hardness value for each cold working case was record to the C70660 alloys.

It's recognise that the hardness is little effected with the work condition than the tensile strength value therefore its continue increases with increase the cold working.

4.3 Corrosion Rate Results

The experimental results of the Corrosion rate test to the three different alloys of copper nickel were mention in three figures as below: each figure represents a seven case of corrosion rate with the cold working rate and a time/temperature of the heat treatment.

These figures shows the effect of cold working and heat treatment conditions on the corrosion rate of copper nickel alloys , it can be observed that the corrosion rate increases with the cold working rate while return controlled with the heat treatment conditions , which give a useful point to the best work hardening rate and heat treatment procedure.

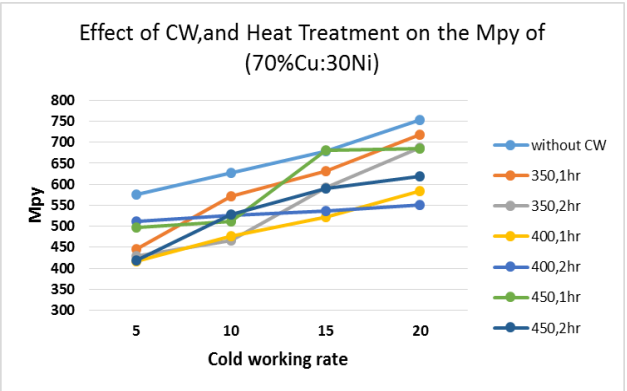


Figure (7) Effect of cold working and heat treatment on the Corrosion rate of C71500

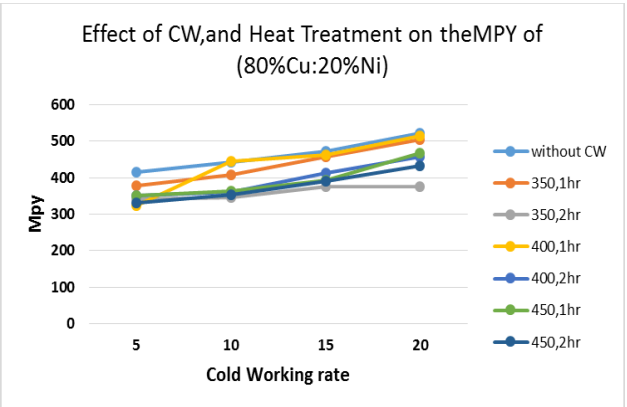


Figure (8) Effect of cold working and heat treatment on the Corrosion rate of C71000

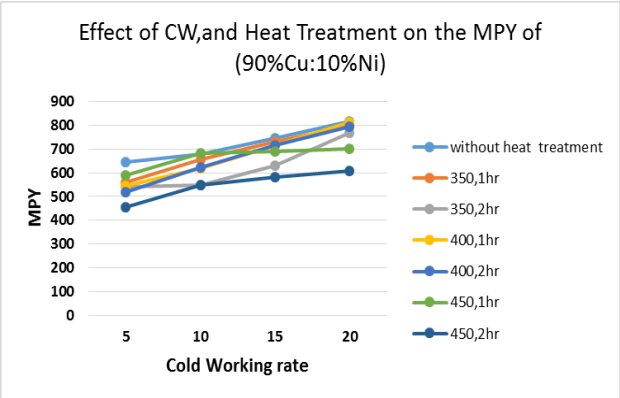


Figure (9) Effect of cold working and heat treatment on the Corrosion rate of C70600

In order to compare with the behavior of the copper nickel alloys without the effect of cold working and heat treatment , table (2) provide the values of the tensile strength , hardness , and corrosion rate of the copper nickel alloys as received (annealing specimens)

Table 2 Results of experimental work for the as Received copper nickel alloys

Alloys	Tensile Strength Mpa	Hardness	Corrosion Rate(Mpy)
C71500	420	84	312
C71000	360	66	375
C70600	296	64	486

Conclusions

The present work provide with an experimental data to the copper nickel alloys mechanical and manufacturing process, under a sever work conditions.

From this work, the following conclusions could be reached:

- There are no study related with the prediction of mechanical properties of copper nickel alloys under cold working and heat treatment together.
- Most of studies occurred to cover the C71500 and C70600 alloys while there is no satisfy studies to cover the properties and behaviour of C71000 alloys.
- Increasing the tensile strength, hardness, and corrosion rate due to the work hardening controlled by the heat treatment conditions.
- The (70%Cu: 30%Ni) mention the best values of the mechanical properties because of the highest amount of Ni% in this alloys.
- It can be seen that 1h heat treatment better than the 2hr in all work cases and alloys.
- The 15% cold working is the better work hardening rate to increase the tensile strength, therefore it's not useful to effect the specimen more than this rate.
- It can be recognize that the 400 °C heat treatment temperature is the best temperature for heat treated the copper nickel alloys.

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