# Measurement of hardness and wear rate of composite materials with an alloy base Nickel-titaniumحفظه

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## Abstract

In this paper, composite materials based on nickel-titanium alloys, which are reinforced with fractions of different sizes from a solid material, were prepared. The materials are prepared by powder metallurgy method, the materials are mixed and then pressed and sintered at an appropriate temperature, hardness tests and wear rate test are carried out. The results showed the presence of a reinforcing material with increased hardness of the composite materials compared to the non-reinforced alloys. The results also showed better particle distribution and higher hardness with increasing fracture size. As for the rate of wear, it was lower for composite materials compared to the unreinforced alloy due to the increase in hardness, and the rate of wear decreased with the increase in the size of the fracture in minutes.



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This memory alloy undergoes a non-diffusing, thermally flexible ceramic phase transformation process that enables the material to instead of using the well-known conventional slip mechanism, the twinning process allows for a full stress recovery of up to 8%, in contrast to conventional metals that recover less than 1% of the stress before the plastic deforms [4,5]. The reaction of this shape memory alloy is characterized by two distinct mechanical effects: stress memory and pseudo-elasticity. When drained into a pseudoelastic or superplastic material, martensite undergoes the austenite process once more without being heated [6].

On the other hand, in order for the deformation to happen permanently in these alloys, the stress memory effect needs the initial heating to change the martensite phase to the austenite.The stress memory effect can also be induced thermally, in this well-known case, where the structure is composed of thermally mobile martensite [7,8]. Increased stiffness, yield strength, and final tensile strength are actually associated with decreased importance in structural weight, and this has led to the development of new materials that combine lower density, improved toughness, and higher resistance as an alternative to higher strength nickel-titanium alloys. Therefore, the need to improve the properties of the alloy has led to improvements in structural efficiency and overall performance either by lowering the overall weight or increasing the strength-to-weight ratio [9,10].

## 1.Introduction

NiTi alloy core composites are used in applications requiring good mechanical properties, light weight and high flexibility. The application of these materials is based on the improvement of mechanical properties at high temperatures and wear resistance. Among the important applications in which these materials are used are aircraft and air wings (vehicle and shuttle space) [1].

Because NiTi (SMAs) possesses the benefits of shape memory alloys and superior flexibility, it appears that a growing interest in NiTi has spread to many engineering disciplines. The mechanical characteristics and phase change temperature, in particular, are crucial elements for the use of NiTi in engineering and medicine. The capacity to recall and recover from significant strains without enduring permanent deformation is one of the fundamental and distinctive characteristics of shape memory alloys. Two distinct temperature-dependent crystal structures known as phases—low temperature phase (Martensite) and high temperature phase—can coexist with shape memory alloys (austenite)[2,3].

However, there is little research on the addition of graphene, especially to nickel-titanium alloys, and its corrosion properties, and this is what we will attempt to study in this paper. The aim of this research is to study the corrosion property of composite materials consisting of NiTi alloy reinforced with different volumetric fractions of graphene.

## 2-Expremantal Work

### 2.1.Basic Powders

Nickel and Titanium powders were used in this work to prepare samples of the shape memory alloys by using powder metallurgy technique. The powders specification are shown in Table (3.1) with their purity, average particle size and the original of ingredients.

Applications such as engine pistons and bearings. Although NiTi alloys have qualifications for use in such applications, they do not have the required resistance under dry friction conditions and high temperatures. Therefore, the researchers studied it and determined the possibilities through which it was possible to improve the property of resistance to friction and the wear that occurs when friction. One way to improve this property is to add hardeners and hardeners to the alloy, and there is a lot of research dealing with Hf, Mg and Zr additives [11,12,13].



**Table (3.1) Powders used to prepare samples of NiTi alloy.**

| Materials | Purity% | Average particle size(µm) | Source |
|---|---|---|---|
| Titanium powder | 99.75% | 12.06 | Changxing Galaxy international Trade CO.,LTD. |
| Nickel Powder | 99.65% | 36.80 | |

sensor scale. SAB-285DR has an error rate of 0.001 to form a base alloy of 50% Ni-50%Ti . Planetary mixing machine (ball mill) type N Q M - 0 4, Chinese origin ,Made in China , As show in the figure(2.1)

### 2.3 Ball mill

The process of preparing the alloy started by weighing each of the nickel and titanium in equal grammes, by means of a model digital



**Figure (2.1) ball milling machine**

The mechanical mixing process was repeated in the ball mill for a period of not less than an hour, the alloys were kept in special sealed containers to prevent the alloy from oxidizing.

### 1.3 Compacting Mixing powder

In a pre-made mold with a diameter of 11 mm, 4g of the mixture was taken and filled into the cavity of the mold.An electric hydraulic press, type Carver made in the USA, show in figure (2.2)

A mixture of 25g of nickel titanium powder was put into the mixing pod, The NiTi powder was mixed for ten hours at a temperature of 25 °C and at the maximum speed of the mixing machine at 35r.p.m. with equal-sized balls the weight of each ball (13.98 g), Add the fortified material After obtaining a homogeneous mixture, the mixture is divided into several groups and the fortifier is added in a different proportion to the mixture (0.5, 1, 1.5, 2, 2.5).

**Figure (2.2) The electric hydraulic press.**

was used to seal the samples with a pressure of (9.22) and it took 4 minutes to press the green samples and 2 minutes to extract the samples from the mold. The samples were numbered to prevent the mixing process.

## 2.3.Sintering

After eroding the pressure process, the samples are forbidden to sinter in a vacuum tube furnace containing helium or argon gas .

**Figure (2.3): Tube Furnace vacuum[9]**

At the beginning of the matter, helium laurel is pumped to the oven to empty the oven and at room temperature the samples are placed inside the oven for seven hours at a temperature of 950 degrees Celsius and left to cool, As shown in Figure 5499

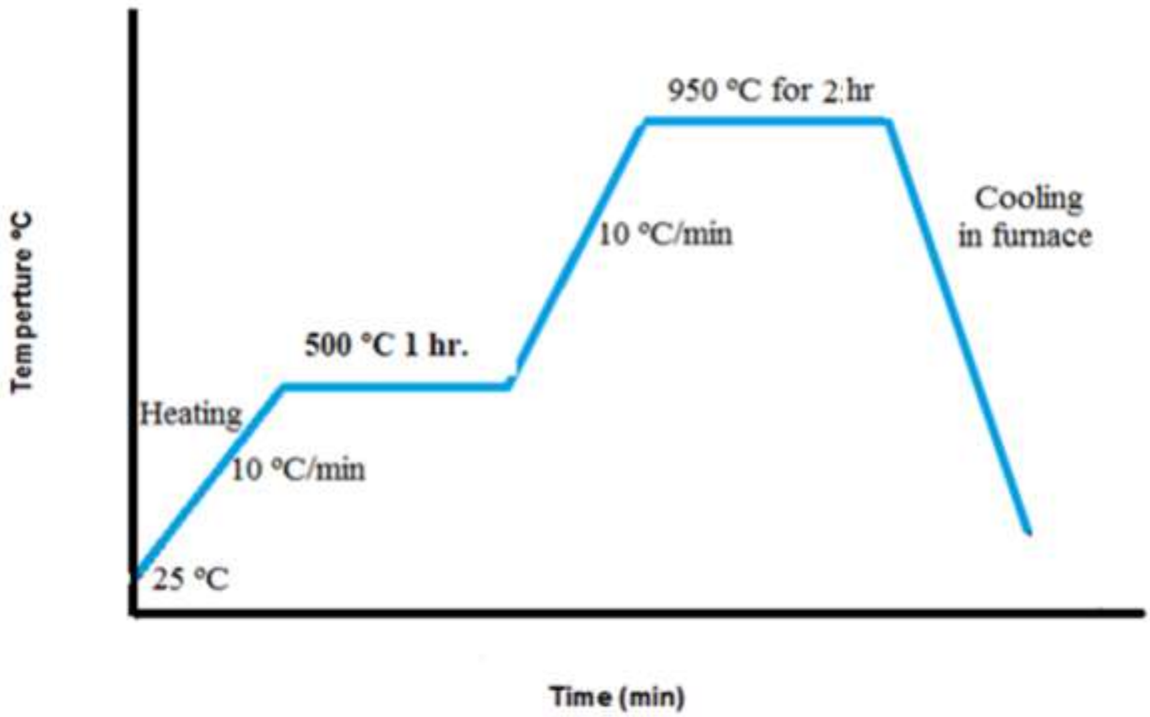



**Fig (2.4) Sintering program of compacted samples**

### 2.4 Prepare samples for testing

Grinding papers were also used on all surfaces of the prepared samples. Smoothing starts from the edges to the center of the sample, using silicon carbide papers from coarse to fine (400, 600, 800, 1000, 1500 and 2000) to obtain a shiny mirror.

Figure (2.5)Polishing and grinding machine

### 2.5 Hardness test

The shape memory effect (SME) is detected after room hardness testtemperature, the exact hardness is calculated for all samples used in the research before and aftermechanical heat treatments ,The hardness test was carried out using the Brinell device, As show in the figure (2.6)



**Figure (2.6) Hardness Test[10]**

### 2.5 wear rate test

The wear test was used in a wear test device of the type of screw on disk (Disk On-Pin) and under dry conditions after preparing its samples in the same way as for the preparation of microscopy samples, but without exposing material.

The samples were 12 mm in diameter and 5 mm in length. The values of the variables that

The amount of hardness was calculated by a computer connected to the Brinell hardness device using a load of 62.2 kPa, the diameter of the ball used for the test was 2.5 mm and for a period of not more than ten seconds, This device is located in the laboratories of the Materials / Materials DepartmentCollege of Engineering / University of Babylon. The fine hardness was used to evaluate by calculating the weight loss before and after the test, the distance from the center of the sample to the disc was taken The slip is (5 mm). as show in figure (2.7)

were adopted in these tests are: (15,10, 5 min) (T) .

The load applied to the sample - 25 N, the number of revolutions of the steel disc is 350 r.p.m per minute, the wear rate is calculated

**Figure (2.7) Wear Test devise[14]**

difference was observed through the hardness test. It was found that the lowest hardness was obtained after carrying out the test at the alloy that does not contain the reinforced substance, and the highest hardness at the highest percentage of addition of the reinforced substance.

The presence of the hardener increases gradually with the addition rate and mixing speed, as the mixing speed used was high, which leads to the distribution of particles in the mold parts. The best distribution got 2.5%. through these tests.

Figure (3.8) shows the relationship between the stiffness and the volumetric fraction of the added hardener. It is seen from the figure that the hardness of the composites is greater than that of the base alloy due to the effect of the addition particles, and the hardness also increases with the increase of the particle size because the hardness of the particles themselves is high.



Where the test samples were fixed in the holder, and a balancing process was conducted for the holder arm of the sample holder (Holder Specimen) and then to make sure that the contact between the sample surface and the facing steel disc correctly before conducting the test for each sample.

and the wear rates (Rates Wear) were calculated for the samples from By measuring the weight of each sample before starting the test and then measuring the weight of the sample after completing the test, using the sensitive balance type (AE200 Mettler Switzerland) accuracy (±0.0001 g) .

## 3. Results and discussion

The results of both the hardness test and the corrosion test showed changes in the nitinol alloy after a series of operations that took place from mixing, pressing and sintering, which is the most important process for the cohesion of the samples and their interconnection with each other. (0.5%, 1%, 1.5%, 2%, 2.5%). ), it was found that the

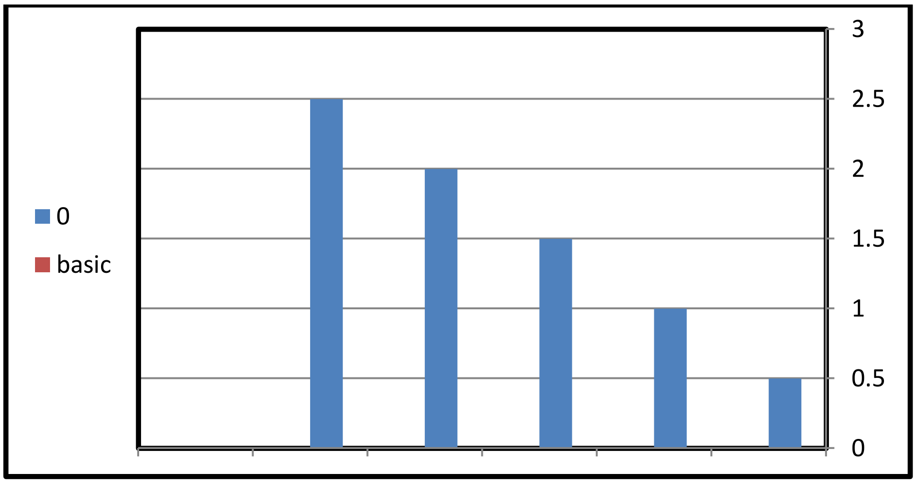
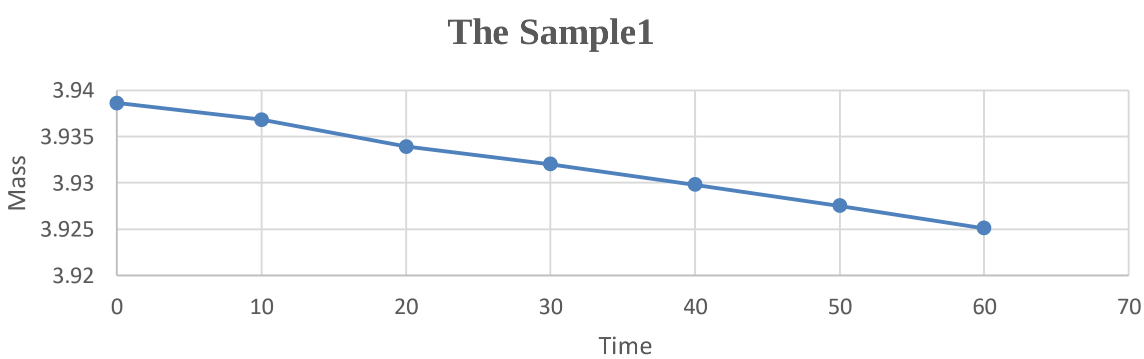
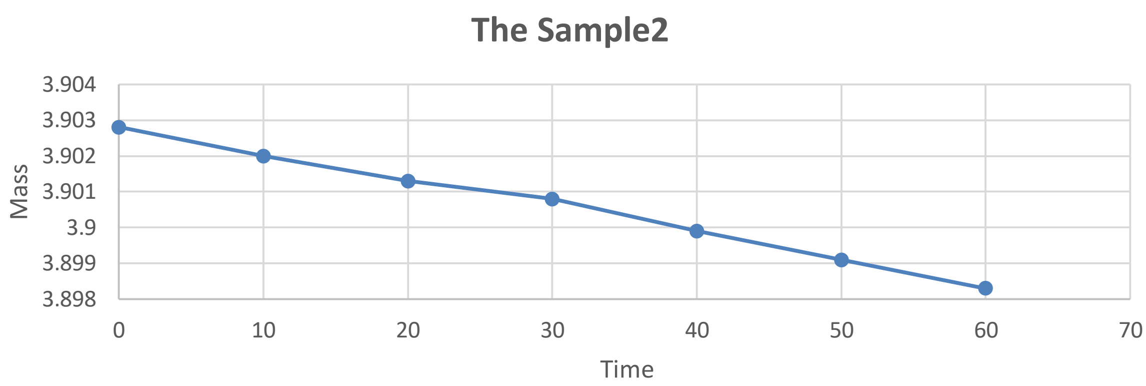


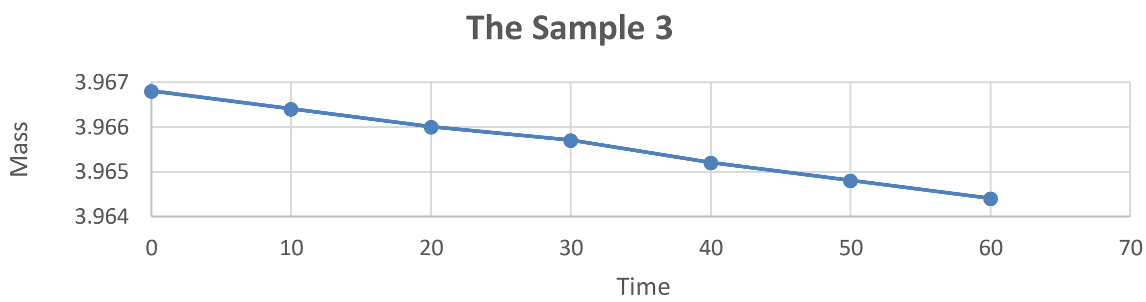

**Figure (3.8) shows the relationship between the stiffness and the volumetric fraction of the added hardener.**

It is observed that the wear rate of all overlapping materials is less than that of the base alloys and also that the wear rate decreases with the increase in the volume fraction of minutes due to the increase in hardness with the increase in the fraction size. When the sliding time is increased from (10) minutes to (60) minutes, with a stopping time every ten minutes to calculate the mass lost during the corrosion process. 5502

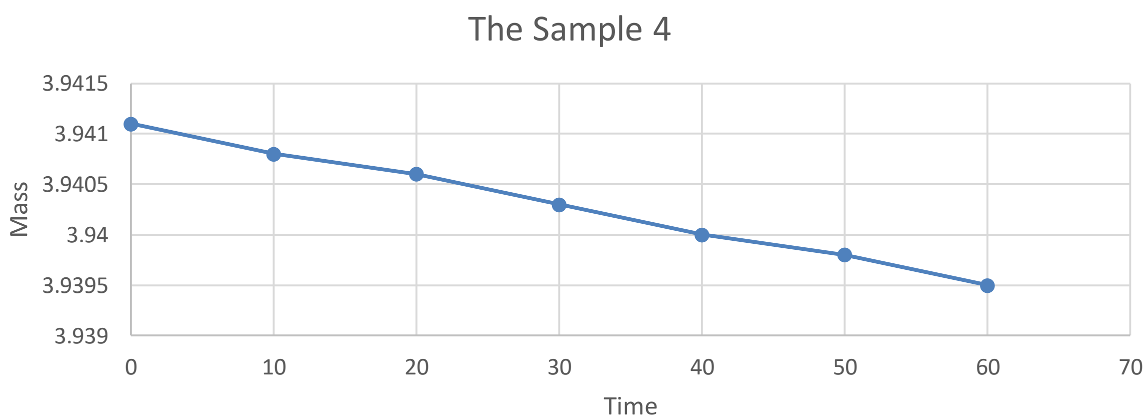
It is noted that the wear rate decreases with the increase of the fracture size of the minutes, and the wear rates decrease with the increase of the slip time to 20 minutes. The highest wear rate in the least slip time was the non-solid alloy. Figure (3.8) shows the relationship between the relationship between wear time and weight lost during the wear process.

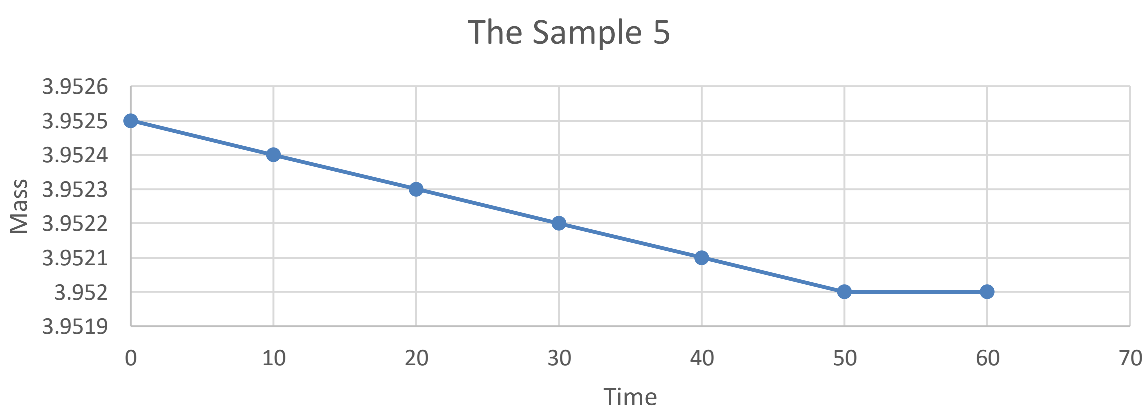



The Sample2
3.904
3.903
3.902
3.901
3.9
3.899
3.898
Mass
0
10
20
30
40
50
60
70
Time


The Sample 3
3.967
3.966
3.965
3.964
Mass
0
10
20
30
40
50
60
70
Time




The Sample 4
3.9415
3.941
3.9405
3.94
3.9395
3.939
Mass
0
10
20
30
40
50
60
70
Time


The Sample 5
3.9526
3.9525
3.9524
3.9523
3.9522
3.9521
3.952
3.9519
Mass
0
10
20
30
40
50
60
70
Time

## 4-Conclusions

In this paper, the results obtained from the hardness and wear test of a nickel-titanium alloy to which a hardener has been added, which has been prepared by powder metallurgy, were discussed. The following was obtained:

1- The cohesion of the alloy when sintered to a temperature of 950 Celsius, and the hardness of these alloys increased significantly after undergoing the hardness test and there was a difference in the hardness ratios due to the addition of the reinforced material with different reasons.

1- The wear rate decreases with the increase in the volume fraction of the addition minutes due to the increase in the resistance of the alloy to dry slip wear.

2 - An increase in the wear rate of the base alloy that does not contain a solid in a time of 10 minutes with a given load and a decrease in the corrosion rate under the same conditions of time and load used, but the decrease is due to an increase in hardening.

3- The best hardness and the lowest wear rate at the highest fracture size that was used.

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. Figure (3.9) shows the relationship between the relationship between wear time and weight lost during the wear process

The figure (3.9) shows the diagram of the relationship between the lost weight per unit area with the time exposure to the slip wear test of the manufactured alloy, and it is noted from the figure that the increase in the ratio of the reinforced material to the alloy worked to increase the dry slip wear resistance of the alloy.And by comparing the results between the prepared alloys, it was found that the increased resistance of the alloy to the dry sliding wear of the alloy,

due to the increase in the percentage of the added hardening period, which led to an increase in the hardness of these alloys due to the formation of martensite, which leads to an increase in the wear resistance of these alloy.

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