The Effect of Adding Titanium Nanoparticle Oxide on the Physical Properties of Nickel by Powder Method

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Abstract

The study included nickel powder support by nano titanium oxide and silicon carbide (SiC) using the powder method wherein titanium oxide cementing percentages (5,10,15,20)% were taken while silicon carbide (SiC) was at a constant rate of 5% with The base material which of is nickel. Then, mixing the powders with an electric mixer for a two hours and pressing them with an electric piston at (5ton) for one minute. The resulting samples were sintered by a thermal oven at (1100°C) and using the argon gas to reduce oxidation for a period of only two hours. The structural structure of the models was studied by using a scanning electron microscope (SEM), as well as a study of mechanical properties that included hardness, compressive strength and wear. The results of the scanning electron microscope showed the homogeneity of the components of the mixed materials characteristically after the high sintering process, and the results of hardness before sintering were (90 -132) Hv, when reinforcing from (0-20) %TiO₂ while reaching the value of (110-189) Hv are reinforcing from (0-20) %TiO₂ with sintering 1100°C, researchers also find that the compressive strength before sintering is (14-.822) MPa when reinforcing from (0-20) %TiO₂, while it reached the value of
(17.8-32) MPa when supporting from (0-20) %TiO₂ and sintering 1100°C, while the wear rate after sintering was the lowest value which is at (20 TiO₂%).

**Keywords:** Wear, Powder Technology, Compressive Strength, Vickers Hardness.

1. **Introduction:**

The great industrial development has forced researchers in materials technology to find alternatives to the materials that enter important industries and resistant to shock and they do not corrode easily and cheaply they have other qualities that make them the basis for achieving the desired development. Hence, the importance of overlapping materials that possess distinct characteristics and characteristics are: A mixture of two parts of the materials, one of them is called the matrix, and the other is called the Reinforced, and the base material is called the continuous phase. The support phase is called the strengthening phase and the area surrounding the base material of the support material is called the interstitial phase. The basis and the supporting materials, make us specifications and knowledge of their properties make us determine the type of material to be produced and the field in which it can be used. For example, in the space field, overlapping materials have been developed with low density that tolerates high temperatures. Against wear and tear [1]. Product development requires the provision of new materials with distinctive properties and effective performance, and among these materials, metal-based composite materials (Metal Matrix Composites MMC) to which the composite used in the study belongs, as these compounds have gained increasing attention in many advanced technical applications. The copper-based superposed material contributed to the production of distinct types of advanced materials that possess unique properties compared to traditional alloys [2]. The superimposed material is a mixture of two or more materials that are closely related to each other, on the basis of which the material behaves as a single block so that it has intermediate properties for the properties of the components, that is, the superposition material consists of two phases, the first of which is the base phase and the second is the reinforcement phase and the phases used are either mineral materials or materials Ceramic or polymeric and the stiffening phase is either minerals, fibers, bristles or sheets [3,4]. The current research aims to study the effect of nano titanium oxide on the mechanical and structural properties of mineral-based materials such as nickel and study the possibility of their application in many parts that are exposed to stresses and withstand high temperatures.

**Experimental Work:**

1- **Raw materials used**

The base material was used from nickel (Ni) and the size of granular ≥63 of German origin from the company (Merck) with a purity of 99.95%. Also, a fixed percentage of silicon carbide (SiC) was used with the size of granular ≥53 with German origin of Fluka with a purity of 99.99% the cementing material, made from of titanium oxide (TiO₂) nanoparticle
with a size of $(30 \pm 5)$ nm, of Chinese origin from Changsha Santech Materials Co. with a purity of $\geq 99.8\%$.

2-Prepare Samples for Measurement:

Sartorius precision balance scale (0.0001g) was used for the purpose of weighing powders manufactured. After the raw materials are weighed, they are mixed well, in order to obtain a homogeneous mixture, with a fine grain size of homogeneous sizes. Then the powders resulting from the mixing are dried in an electric drying oven at $(100 \, ^\circ C)$ for half an hour to get rid of moisture. After this process, the binding substance is added, which is polyvinyl alcohol (PVA) at a rate of $(2\%)$ of the total weight of the model in order to mix the mixture during the process of removing from the mold and the absence of distortion or surface defects of the model. This ratio does not affect the main components and evaporate during the process final heating. After, completing the weight and homogeneity of the samples, a cylindrical press mold with a diameter (2cm) was prepared from stall steel. The pressing done by using a German-type (FYD-40MTI) electric press. The pressing was at $(5ton)$ and for a period of $(60sec)$ one sample. The resulting samples were cylindrical in shape with a diameter of (2 cm) and height (3 mm). After the pressing process for all samples was completed, the samples were ready for the sintering process, whereby the sintering of the samples was carried out by using an electric oven [CARBOLITE] of English origin with a temperature range up to $1200 \, ^\circ C$, and a sinter degree $(1100\, ^\circ C)$ was programmed at a rate of $(5 \, ^\circ C/\text{Min})$, keeping the pistons inside the oven for only two hours, then turn off the oven and cool the pistons inside the oven slowly to room temperature (i.e. to the next morning) it was linked to a cannula of Arkon gas (Ar) in order to reduce the oxidation that occurs through sintering.

2.1. Tests and Practical Measurements:

First: Scanning Electron Microscope Test (SEM)

The examination of the samples carried out by using a scanning electron microscope (SEM) type (TESCAN) model (Vega III). The scanning electron microscope is usually used to obtain a high-resolution image of the samples for the purpose of knowing the external shape, crystal structure, chemical composition and also the distribution of the component materials for sample.

Second: Hardness Test($H_v$)

Hardness is an important mechanical property, and defined as the surface indentation resistance [8]. The hardness was examined by using the Vickers method by inserting the instrument (quadrilateral diamond pyramid). By shedding the tool by a mass of (500 gm) and for a period of (10 Sec), and by calculating the resulting impact diameters, Vickers hardness of the compressed can be determined by applying the equation with a relationship

$$H_v = \frac{1.8544 \, P}{D^2} \, \text{Kg/mm}^2$$  \hspace{1cm} (1)
Since: P = applied load (Kg)

Dv = average diameter of the hierarchical effect resulting from the projection of the load onto the surface.

**Third: Compressive Strength.**

The anti-compression test conducted by using a Chinese-origin Universal Testing Machine (HOYTOM) as the sample was placed on the examination platform. The load was shed on the sample until the failure occurred and the maximum load was read from the device's digital screen, knowing that the device has the ability to store the maximum value of the load before the failure. The compression resistance is calculated by the relationship (2) [6].

$$\sigma_D = \frac{2F}{\pi dh} \quad \ldots \ldots \ldots \ldots (2)$$

Whereas: $\sigma_D$: compressive fracture resistance (MPa), $F$: applied force (N), $d$: diameter of the sample (mm), $h$: sample thickness (mm).

**Fourth: Wear Rate Test.**

An Amsler device was used to measure the wear and tear of the sample coating samples. The wear test device consists of an electric motor that rotates at a rotational speed (190 rad / min) connected to a gear set with the axis of fixing the paint sample. The principle of Disk on Disk was adopted to measure the wear and tear. The weighting method was also used to calculate the amount of loss in the coating material as a result of the sliding wear. The sample is weighed before and after operation with a sensitive sensor scale (±0.001 mgm), with one cuff type (Metll H311). The sample is placed instead of assigning to it in an MSLR device and in direct contact with a hard disk with a high hardness, and under the influence of the load (100 N), the test continued for a period of (30min), by applying the following equation the wear rate can be calculated [7,8].

Wear Rate \[ \frac{M1-M2}{D} \] \ldots \ldots \ldots \ldots (3)

Whereas: M1: The mass of the sample before the examination, M2: The mass of the sample after the examination, $D$: The distance covered during the examination where:

$$D = 2r^{-} \pi n^{-} \quad \ldots \ldots \ldots \ldots (4)$$

Whereas: $r^{-}$: The sample radius (20mm), $n^{-}$: The number of turns (calculated from the number of turns in the test device).

2. Results and Discussion

1- Scanning Electron Microscopy (SEM).

They show the prepared models under discussion with this technique. It is revealed that the nanoparticle (TiO₂) nanoparticle has been distributed in harmony with the base material
powder (Ni) in addition to the sintering process at (1100°C) that contributed significantly. The homogeneity and cohesion of the granulated powder where the sintering process has an important role in the fusion of the granules and their affinity with each other. So that substances are one alloy and in this process researchers try as much as possible to get rid of the pores that are present in abundance before the sintering procedure. Just, as the low melting point of nickel compared to the oxide helped greatly in melting the granules and their fusion with the various elements of titanium oxide nanoparticles while titanium oxide possesses a high melting point thus, sintering degree is a very suitable degree for the interaction of the two substances with each other, and this is shown by the forms shown below [9]. Where the increase of homogeneity is evident with the increase in the support ratios, as shown in figures (a, b, c, d).

![SEM images](image-url)

Figure (1) Scanning electron microscopy images (SEM) for samples prepared after sintering at 1100°C where (a-5% TiO₂ b-10% TiO₂ c-15% TiO₂ d-20% TiO₂)
2- Vickers Hardness Test Results:

Figure (2) shows the relationship between the Vickers hardness and the support levels of titanium oxide nanoparticles before and after sintering. As it notice through the figure that the hardness ratios increase dramatically with the increase of nano oxide ratios and the hardness increases gradually until it reaches the highest value which is (132 Hv) before sintering, and increases with increasing the cementation percentage to reach the highest value at 20% TiO₂ which, (189 Hv) after sintering. This increase can be attributed to several reasons, the titanium nanoparticle oxide has a high hardness, so its granules act as obstacles to the deformation of the material basically due to its high hardness, it will consequently impede the dislocation movement by a greater percentage when its content in composites increases. In this case, the stress should be significant in order to the dislocation pass through the granules and thus requires an increase in the projected load and this means an increase in the hardness values [10].

**Figure (2) The relationship between Vickers hardness and the titanium oxide (TiO₂) reinforcement content before and after sintering 1100°C.**

3- Compressive Strength Test Result:

Figure (3) shows the compressive strength values increase with increasing the titanium oxide nanoparticle content. It increased from (14Mpa) to (22.8Mpa) by changing the titanium oxide content from (0%) to (20%) before sintering, and also increased from (17.8Mpa) to (32Mpa) for the same nano titanium oxide content after sintering at 1100 °C. This increase in the resistivity of the diagonal compression can be attributed to the increased hardness of the composites by increasing the titanium oxide content as above, as well as the compression resistance of the titanium oxide. The phases formed after the sintering process played an important role in increasing the bonding strength between the granules of the superposition components, and these reasons contributed All of these have increased compression resistance values for overlays [11].
4-Wear Rate Test Result:

The wear and tear is one of the important properties of the material surface, which is defined as the loss of matter from the surface of the metal due to the friction of the moving parts. From the initial experiments, the amount of projected load was determined (20 N), by using different slipping speeds. The load shedding period for each test was (20 min). Figure (4) shows the relationship between slipping speed and wear rate, which decreases when increasing the slipping speed of the models. All of them are prepared. Also, a clear decrease in the wear rate is observed when the titanium oxide nanoparticle content is (20%), due to the high hardness, and the improved mechanical properties of the composite. Thus no distortion of the plastic, resulting in increased wear and tear resistance. Minutes with the surface, but when the percentage of addition is less, it leads to a reduction in the durability of the bonding between the components as a result of the occurrence of soft distortion resulting from friction. The rise in temperature, led to a decrease in the hardness values and the presence of cracks. The beginnings of a process of separation and thus increases wear and tear. As for the models that have a rate of adding (0.5,10,15) TiO₂%, the wear rate increases significantly, and there is a separation process for the coating layers and the presence of cracks. And the lack of titanium oxide content of nanoparticles from the ratio (20%) to the base material (nickel Ni) has a clear effect on the wear rate, as it is observed that the models are exposed to a relatively high wear rate. Therefore, the lowest wear rate was at (20 TiO₂%). The results obtained by the wear rate confirm that the most
Conclusions:

Conclude from the current research the possibility of composite overlay with a mineral basis of nickel and supported with titanium nanoparticle oxide, where distinct characteristics were obtained from the studied tests, which included hardness and that were before sintering is (90-132) Hv when reinforcing from (0-20) %TiO₂While it reached the value of (110-189) Hv when reinforcing from (0-20) %TiO₂ and sintering 1100 °C, we also find that the diagonal compression resistance was before sintering is MPa (14-.822) when reinforcing from (0-20) %TiO₂, while it reached the value of MPa (17.8-32) when reinforcing from (0-20) %TiO₂ and sintering 1100 °C, and the wear rate after sintering was the lowest value for it was at the ratio (20 TiO₂%) and the results obtained for wear rate emphasizes that the most important factors affecting it are hardness and that increasing it reduces wear rate, while SEM results show very clear homogeneity between the components of the materials used.

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