Al-Bahir Journal for Engineering and Pure Sciences
BJEPS

Volume 2 | Issue 2 Article 3

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ORIGINAL STUDY

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Abstract

The gloss properties can be improved by repeated additions of carbides or ceramic materials, where in the current research, Nano-zirconia was mixed as a support material for the system (Ni−3%SiC) and the reinforcement percentages were (0,3,6,9,12)%. The process of manufacturing the samples was carried out by the powder method. Where the support and foundation materials were mixed by the volumetric method. The resulting samples were heat treated at 900 °C for two hours, after that the scanning electron microscope was studied to find out the topography of the surface formed, and it was found that the best ratio that gives a surface with a distinctive structural structure and structural homogeneity after the sintering process is at 12%, and some mechanical properties were also studied. At all different ratios, through the results obtained, it was found that the best reinforcement percentage is 12% of Nano-zirconia after the sintering process.

Keywords: Nano zirconia, Micro vickers hardness, Thermal sintering, Porosity

1. Introduction

Powder metallurgy is an important technology for metal-based composites (MMCs) because it reduces segregation of stiffeners that occurs in metal casting processes [1]. The effect of isolation is reversed on the properties of MMCs, so the homogeneous distribution of reinforcing materials is essential. Powder metallurgy technology (solid phase processes) can produce mineral-based composites (MMCs) in which the particle distribution is homogeneous with a density close to the theoretical density values [2]. Composite materials have been used since ancient times, as the Mesopotamian civilization was the first to use composite materials. They built ziggurats by reinforcing layers of masonry with reed fibers to stabilize the structure [3]. As well as building houses by strengthening the mud with sawdust. Examples found in nature of overlapping materials are cellulose fibers with wood. Composite materials consist of two phases: the matrix phase, also called the floor, and the reinforcement phase [3]. The main phase works to link the particles of the reinforcing phase, as well as to distribute the stresses between the particles of the reinforcing material when under the influence of load [4]. Thus, powder metallurgy technology has many advantages, where the parts produced by powder metallurgy method are of accurate or semi-accurate dimensions and do not need removal operations or other operations. Powder metallurgy processes have very little loss in metal compared to other processes such as casting processes. In this technology, metal parts with specific porosity (with a qualitative level of porosity) can be produced, such as filters, oiled mechanical bearings and gears. Powder metallurgy technology is of high productivity and in time It is economical. In powder metallurgy technology, products that are difficult to form by other traditional methods can be produced, for example the production of tungsten filaments or filaments used in lamps. The microstructure of the materials produced by powder metallurgy method is relatively regular and homogeneous, as well as the possibility of controlling the particle size of the products produced by metallurgy technology. powders. There is a possibility to change the chemical

Received 14 February 2023; revised 24 February 2023; accepted 24 February 2023.
Available online 27 March 2023
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https://doi.org/10.55810/2313-0083.1020

composition of the products by controlling the proportions of mixing the powders, and then obtaining dissimilar properties and a decrease in product defects such as gas pockets and segregation inherent in traditional casting processes, and then improving the properties in general, the possibility of mixing the reinforcement particles at higher rates than the mixing ratios used in casting processes [5]. The research aims to study the effect of adding nanoparticles of zirconia to the base material of zirconia through structural and mechanical properties.

2. Practical part

1. Materials Used in the Project:

The matrix material used in the article is metallic nickel (Ni), grain size (400 mish.) from India, manufactured by CDH company, with a purity of 99.5%. In addition, a fixed ratio of silicon carbide (SiC) with a grain size (500 mish.) from Germany was used. The place of origin is from (Fluka) company, the purity is 99.5%, nano-sized zirconia ZrO2, the particle size is (25 ± 5) nm, originating in Germany, from the company (Changasha Santech Co.), the purity is ≤ 99.94%.

2. Method of prepared materials:

In the current work, a base metal of nickel was used, and the support was made with a fixed amount of SiC a rate of 3%, while and the second reinforcement material was nano-zirconia at rates of (0, 3, 6, 9, 12)%. The process of mixing the materials was carried out in a volumetric manner as a result of the difference in densities, and the materials were dried to get rid of any moisture. As for during the pressing process, at this stage the homogeneous powder was pressed after the mixing process using the Uniaxial pressing technique in a steel mold made of tool steel. And a load of (5 tons) was applied for a period of (30 s) to ensure that elastic return did not occur [6]. The prepared samples were pressed by a press with the highest capacity of 20 tons, of Turkish origin (HALIM USTA). Then, the resulting samples After two hours at 900 °C in a Korean-made muffle furnace, the samples were ready for physical inspection.

3. Physical examinations

1- Vickers hardness:

The Hardness is a mechanical property by which a material's durability and ability to scratch are identified, where the hardness test was carried out for the models coming out of the kiln by Vickers method. A load of (100 g) was used for (10 s). Then the equation below was applied for the purpose of finding the result of the micro hardness [7]:

$$HV = 1.854\,P / d_{av} = (2P\sin(136^{\circ})/2) / d_{av} \quad (1)$$

where: HV: Vickers, hardness, P: impact, load, d_{av}: mean impact, diameter.

2- True Porosity:

Porosity is an important and effective indicator within the physical tests, where the real porosity was calculated, which represents the sum of the closed, open pores within the prepared samples, and it was calculated with the following equations:

$$T.P = \frac{TD - BD}{TD} \times 100\% \quad (2)$$

As if:
T.P. = Is the percentage of the total porosity in the sintered body.
T.D. = Theoretical sintered compact density (g/cm^3).
B.D. = Sintered almost by bulk density (g/cm^3).

3- Compressive Yield Strength Test:

In this test, the universal testing machine (Microcomputer Controlled Electronic Universal Testing Machine) was used, connected to a computer (Chinese) of origin, according to ASTM E9-89, knowing that the maximum capacity of the machine is 180 KN. The sample was placed on the examination platform, and then we start to load the diameter of the sample until failure occurred. And through the computer screen we read the maximum load. We calculate the diagonal compressive strength from the relationship below [7].

$$\sigma_D = \frac{2F}{\pi d h} \quad (3)$$

Since
σ_D Compressive strength (MPa).
F force applied (N).
h sample thickness (mm).
d sample diameter (mm).

4- Wear Rate Test:

Wear was measured with a home-made slip wear device. Which consists of a flat metal arm containing a clamp to fix the sample, a rotating steel disk connected to an electric motor, the speed of the disk is (500 r.p.m) and the hardness of the disk is (269 HB), smoothing paper to clean the disk after each test, different loads, level to level the sample face to face. The applied vertical load was (1 Kg) and the sliding distance was (70 mm). The test was conducted at three different times (5, 15 and 30) minutes cumulatively. The wear rate is calculated by following the weighting method with the following steps, sample preparation, Weigh the sample before testing (w_1) using a sensitive scale with four decimal places, Smoothing the disc with smoothing paper (500 grain/cm^2) before testing for each time, Clean the disc with alcohol, The sample is attached to the device holder so that the sample is identical to the disk, The arm shall be leveled in a horizontal state by means of a level before the load is placed on it. The required load is placed [8,9]. The time is set with a stopwatch and the machine is started. The sample is weighed after turning on the device (w_2) to determine the weight loss. The relationships below were used to calculate wear [10,11]:

$$Wear\ Rate = \Delta w / S_D \left(\frac{gm}{cm}\right) \tag{4}$$

$$\Delta w = w_1 - w_2 \tag{5}$$

$$S_D = 2\pi \mathrm{rnt} \tag{6}$$

where:

Δw = The difference is the weight of the sample (g).

w_1 = It represents the weight of the sample before testing (g).

w_2 = It represents the weight of the sample after the test (g).

S_D = The sliding distance (cm).

r = Radius from sample, center to disk center (cm).

n = The number of disk, revolutions (r.p.m).

t = Test, time (min.).

5- Scanning Electron Microscope (SEM):

The scanning electron, microscope is one of the necessary microscopes in structural examinations, and these electron microscopes rely on smearing the surface of the sample for several thousand times, as the surface of the sample is examined by scanning with a focused electron beam, the electron beam is scanned in general using point scanning and the location of the beam is combined with The signal to produce an image. The best image can be achieved from 1 nm and above [12].

4. Results and their discussion

1. Effect of Adding Reinforcement on Porosity:

The figure(1) below shows the inverse relationship, between the porosity and the addition percentages of nano-zirconia before and after the heat treatment at 900 °C of 2 h, as the percentage of porosity decreased from % (26) to 0% and gradually decreased to reach at The lowest is when the percentage of zirconia is 12%, which is (14)%. After conducting the heat treatment process. It is noted from the figure that the increase in the added volumetric ratios has led to a decrease in porosity, as the percentage of porosity decreases from (20)% at (0%) content to (8) % at a content of (12%), The increase in the support material of nano-zirconia works to reduce the porosity, and the reason for the decrease in the porosity is due to the decrease in the voids inside the model. Also, the large increase in the reinforcement particles leads to a sufficient degree of sintering (900 °C) to obtain an integrated sintering process, so a significant decrease in the proportion of Porosity, while their decrease with

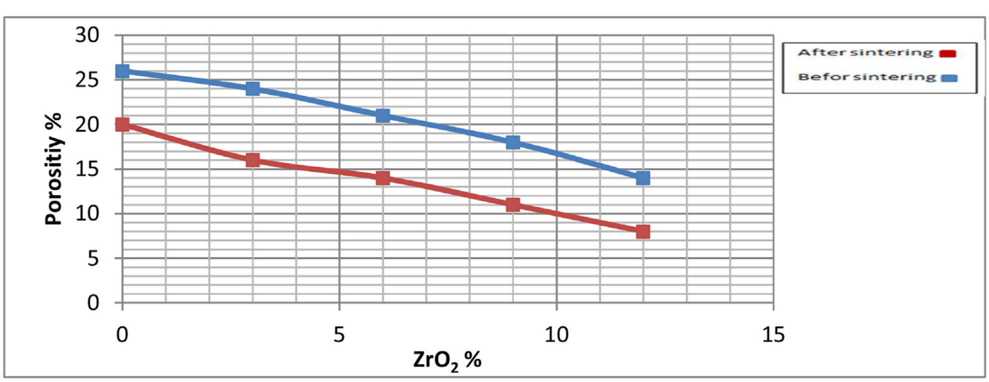

Figure 1. The inverse relationship between porosity and zirconia nanoparticles before and after heat treatment.

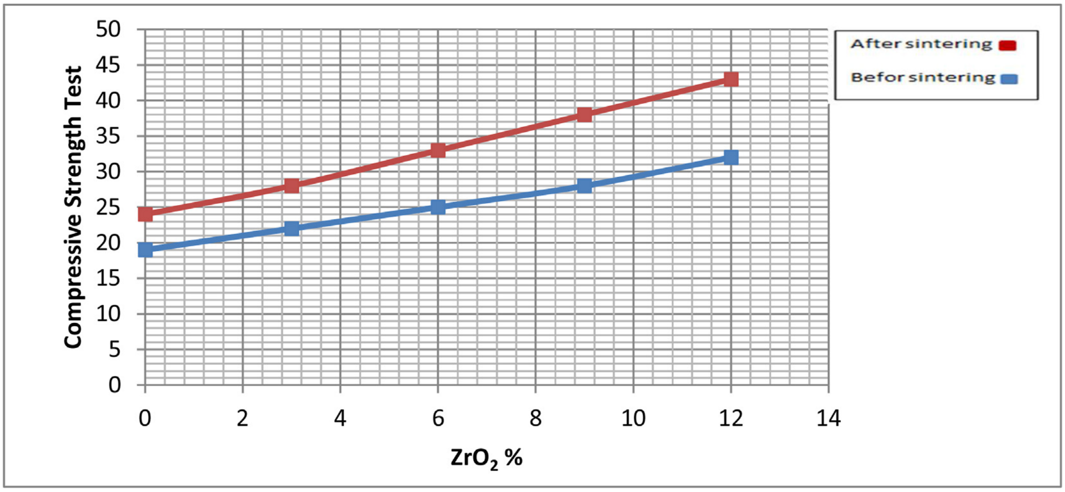

Figure 2. The relationship of compressive strength and zirconia nanoparticles before and after heat treatment.

increasing sintering temperature is attributed to the increase in the closeness of the sample granules to each other and the filling of the voids between them [13,14].

2 Effect of Adding Reinforcement Material on Compressive Strength (Compressive yield stress):

Figure (2) clearly gives the positive relationship between the zirconia nanoparticles and the compressive strength, as we notice before the heat treatment process and at a strengthening ratio of 0–12%, the diameter of the compressive strength is from 19 to 32 N/mm^2, but after the heat treatment process at 900 °C and with a strengthening rate of 0–12%, the value of the diagonal compressive strength is from 24 to 43 N/mm^2, and the amount of the obvious increase in the diagonal compressive strength with each addition of nano-zirconia is attributed to the effect of nanomaterial on the high hardness that is directly proportional to the resistance diagonal compression, and the spreading of the reinforcement material on the base material in a consistent manner contributes significantly to increasing the hardness and compressive resistance [15,16].

3. The Effect of Adding Reinforcement on the Wear Rate:

Figure (3) clearly gives the inverse relationship between the zirconia nanoparticles and the wear rate, as we notice before the heat treatment process and at a strengthening rate of 0–12%, the value of the wear rate ranges from (7.22*10^{-7}) g/cm to

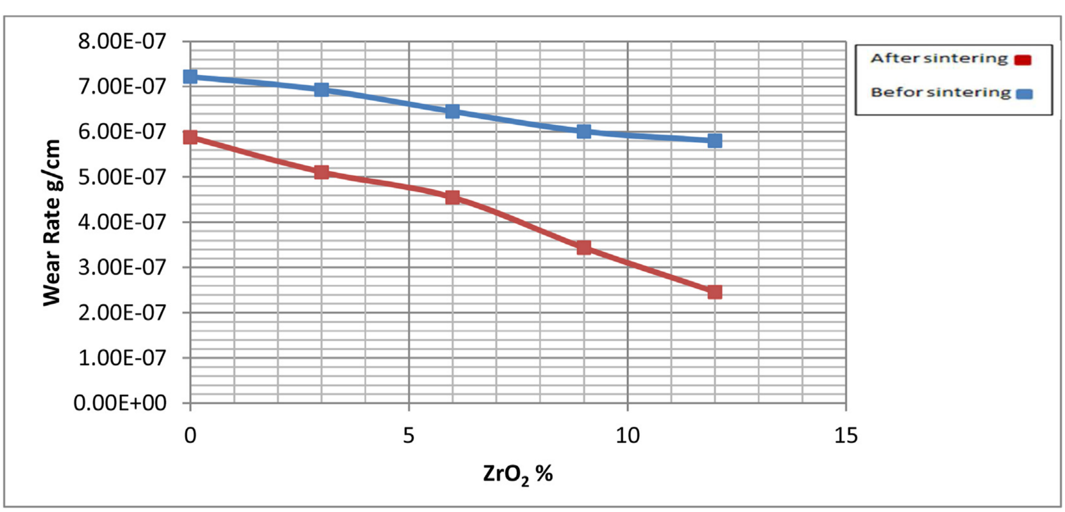

Figure 3. Clearly shows the inverse relationship between zirconia nanoparticles and wear rate before and after heat treatment.

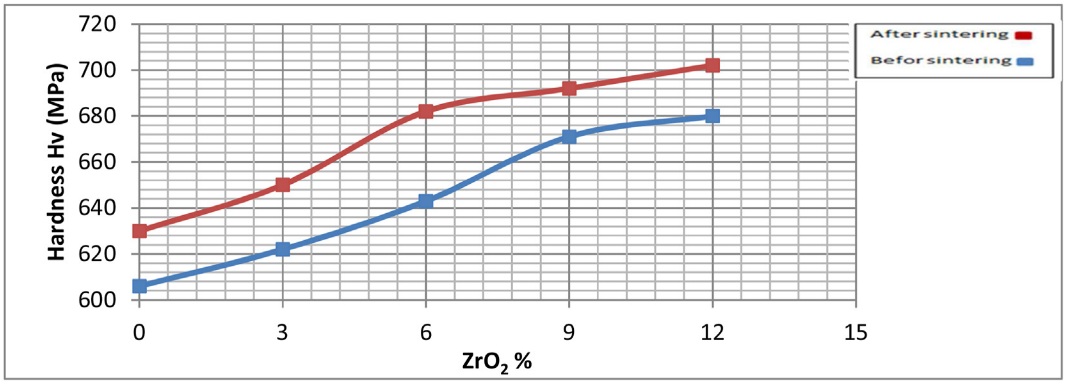

Figure 4. Clearly shows the positive relationship between zirconia nanoparticles and Vickers micro hardness before and after heat treatment.

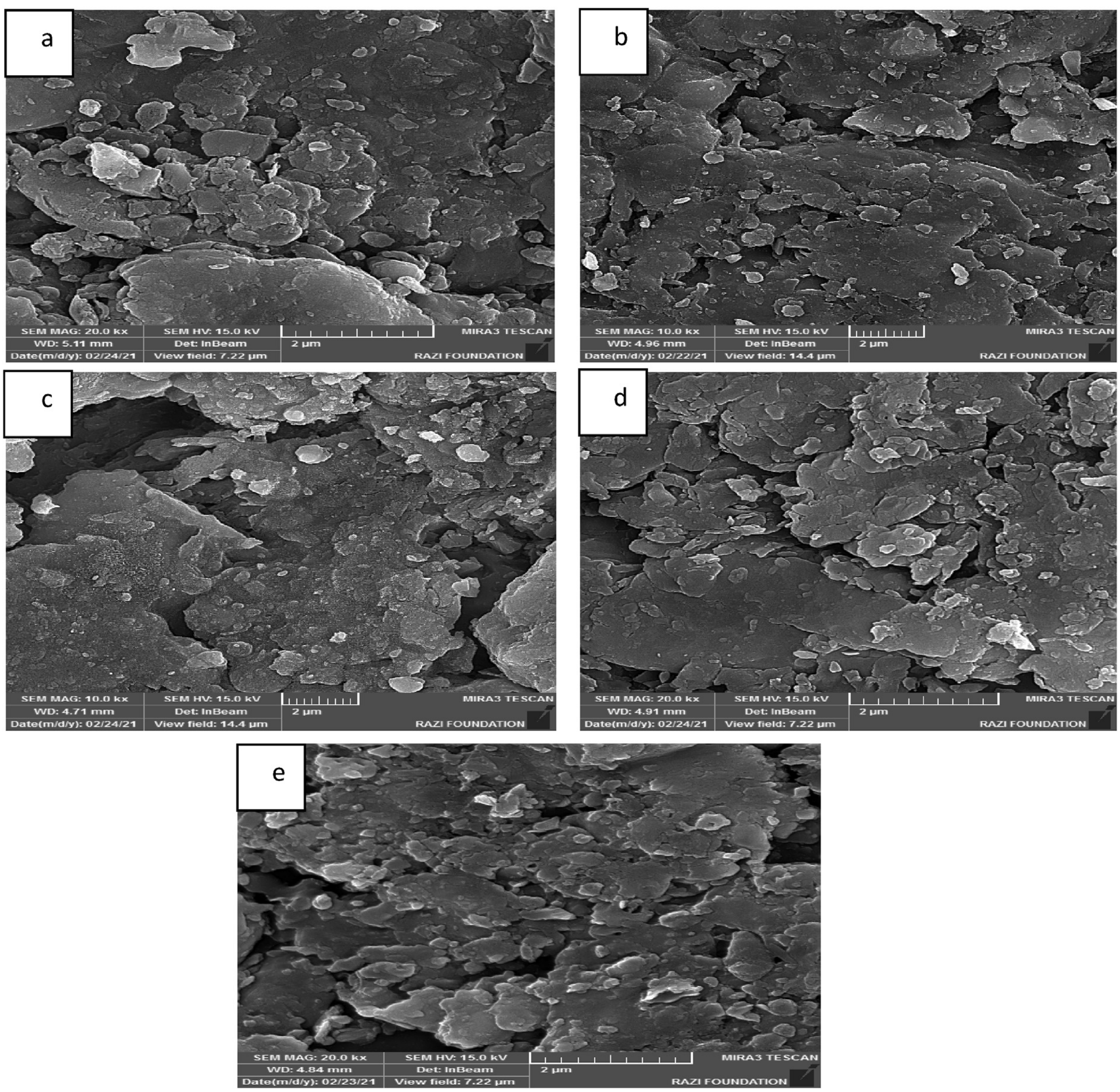

Figure 5. SEM images of the composite (Ni–3%SiC–ZrO_2) before sintering with mixed support ratios (a-0%, b-3%, c-6%, d-9%, e–12%).

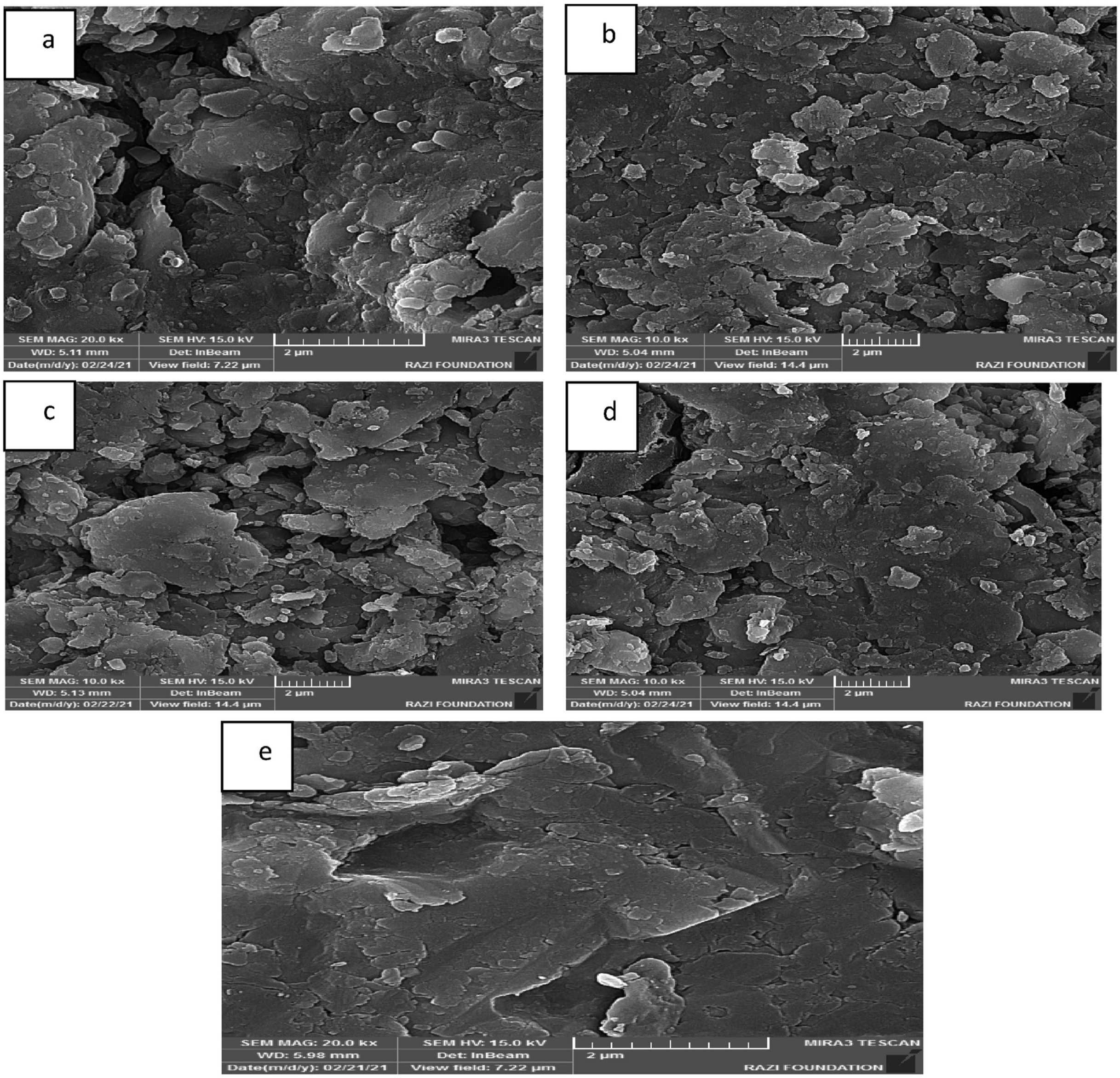

Figure 6. SEM images of composite (Ni–3%SiC–ZrO_2) after sintering with different support ratios (a-0%, b-3%, c-6%, d-9%, e–12%).

($5.80*10^{-7}$) g/cm, but after conducting the heat treatment process at 900 °C and with a strengthening rate of 0–12%, the value of the wear rate ranges from ($5.88*10^{-7}$) g/cm to ($2.46*10^{-7}$) g/cm And that the amount of the apparent decrease in the wear rate with each addition of nanoparticles of zirconia is attributed to the effect of nanomaterial on the high hardness that is directly proportional to the compressive strength of the diagonal, and the spreading of the reinforcement material on the base material in a consistent manner contributes significantly to the decrease in wear. The cause of wear and tear is due to the deformation that occurs between the surface of the sample and the disc, which leads to an increase in the density of cracks and defects. Small cracks gather together leading to scraping or removing surface layers, forming wear debris in the form of thin sheets. The reason for the low wear rate is that the nickel overlays are more solid when reinforced with ceramic particles, which in turn impedes the progression of dislocations, as the weight loss is small as a result of strengthening the base material with these particles. In addition, in addition to that the hard particles such as silicon carbide and nano-zirconia resist the stresses that are generated and then generate dislocation density, And because of the high hardness of the reinforcement particles, these particles will be embedded in the wear tester disk that scratches it, and as a result, the surface of the press will need large frictional forces in order to slide on the surface of the wear tester disk, so most of the energy will be consumed on the friction between the particles Reinforcing and tweaking the test device when the content of the reinforcing particles is increased [17,18]:

4. Effect of Reinforcemen t Addition on Vickers Micro Hardness:

The experimental tests confirmed that there is a correlation between the addition and the spread of surface defects affecting the hardness. It has been observed that the best value of hardness is when the surface is free from defects, as Figure (4) shows the, relationship between Vickers, hardness and the percentage of adding nano-zirconias before and after sintering. Before sintering, it is (680Hv) at an addition rate of (12%), while the Vickers hardness after sintering was (702Hv) at the same addition rate (12%). The addition acts on the bonding of nickel and carbide to each other, which increases the mechanical properties of both hardness and compressive strength and improves the crystalline structure of the prepared samples [19].

5. SEM Examination of the Prepared Samples:

Fig. 5: [a,b,c,d,e)], which represents scanning electron microscope images at (2 μm) and with a magnification of (20Kx) for the superimposed pistons before the sintering process, where we find in figure (a,b) that there is a distribution of particles. The zirconia nanoparticles are homogeneously within the nickel ground, forming an interconnected metal network. As for the form (c), we find that increasing the addition rates works to strengthen the basic surface, and the zirconia nanoparticles are centers for polarizing porosity, whether before or after sintering. It is noted from the electronic images that the process of The diffusion is clear and homogeneous in the solid state, and there is a good correlation between the elements of the superimposed as in the sample (d) i.e. at (9% ZrO_2), but in figure (e) we notice that there is a large degree of homogeneity, crystal entanglement and lattice consistency between the components of the three elements. As for after Performing the sintering process and at all the images in Fig. 6 [a, b, c, d, e]. We note that after conducting the heat treatment process for all samples, we find that there is a clear change in the surface topography of the prepared samples. Increasing the ceramic reinforcement ratios contributes effectively to increasing the consistency of the surface, as well as the interaction at the interface between the added proportions and the base material. Which contributes to increasing the surface hardness and crystallinity. What was observed was 12%, which is the best mixing, which gave clear synthetic results [20,21].

5. Conclusions

The best results were obtained through the addition percentages of nanocrystalline zirconia, which were in percentages (0–12)%, and it was found that the results ranged between the reinforcement percentages from the lowest percentage to the largest percentage, and after thermal sintering, the lowest percentage is 14%, while the diameter compressive strength was between (24–43) N/mm^2 at a reinforcement ratio of (0–12)%, while the micro hardness was between (630–702) MPa at a reinforcement ratio of (0–12)%, while the wear rate was (($5.88*10^{-7}$) g/cm to ($2.46*10^{-7}$) g/cm) at a reinforcement ratio of (0–12)%. As for the synthetic results, it was clear using electron microscopy that the best ratio obtained was 12%, where it gave distinctive and encouraging physical, mechanical and structural results. The main and important conclusion from the results as a whole is to obtain alloys with high cohesion and hardness and excellent surface consistency that appeared through the obtained results.

Conflict of interest

None.

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