Effect of the Laser Surface Treatment on Properties of the Alloy (Ni-Cu-V) Nanoparticles Prepared by Powder Metallurgy Method

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Abstract

In this research, an alloy with a nanostructure was prepared using a metallurgical technique. To prepare an ideal alloy, three nanoscale powders were used (70 percent Ni, 25 percent Cu, and 5 percent V). The dried alloy was stored under 8 Tons of cold pressing at 80°C for 30 minutes. After that, a surface treatment of the prepared alloys with different laser energies (0, 200, 260, 300) mJ was carried out with a pulse time (10 seconds) at a distance of (100 cm). and hardness (Rockwell method) is studied. By immersing samples in a solution (3.5 percent NaCl) for different periods (3, 5, 7, 9, 11) days, the effect of laser surface treatment on the corrosion resistance of the alloy was investigated. Results show that porosity, water absorption ratio decreases after laser surface treatment with rising hardness values. Additionally, the wear resistance decreases as laser energy increases. Atomic force microscope images show that grain sizes increase as laser energy increases, and by increasing the laser energy, the surface of the nanoparticles is more homogeneous. Easy architecture and high nanostructure alloy consistency play a key role in improving the mechanical and physical properties.

Key Words: Laser Treatment, Physical Properties, Alloys, Nanoparticles, Powder Technology.

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Introduction

Metal-coated conductors such as Cu coated Al wires, and Ni coated Cu wires have attracted significant interest, primarily due to major power transmission applications, electrical interconnections, and micro-component connections. These conductors deliver striking advantages in comparison with conventional single-metal conductors (Wang *et al.*, 2015). Environmental conditions have a significant impact on the physical properties of engineering materials which open the door to huge applications (H Thanon, 2013; & Raghavan, 2015). Nickel and copper alloys have made significant progress in both the industrial and technological fields because it has very limited solubility and a high difference in fusion heaven, especially for nickel which does not mix with other metals. The mean objective of the related studies is to develop the mechanical and physical properties of the Nanoparticles Alloy (Ni-Cu-V). Powder metallurgy, including those with complex shapes or porosity, may produce parts that would otherwise be hard to form. However, in meteorological techniques, the mechanical and physical properties of precipitation are low mainly with those generated by plumbing, so it is necessary to add additional elements to improve these characteristics (Abdullah, *et al.*, 2020).

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One of the most interesting metal mixes is vanadium element powder, which has been added to mix nickel and copper powders to get the best alloy specification. The piston operation is carried out by a hydraulic piston following a complete mixing cycle. The sintering temperature was then carried out in an electric furnace using Arcon gas as an inert gas during the process to avoid oxidation (Huba, 2014; & Pogrebnjak, *et al*., 2012). Much of the works recently attracted attention to examining products Ni, Cu, and V. In 2011 Nathom et al. developed alloy Ni-Cu using a metallurgical technique (Nathom, *et al*., 2011). In addition, Abdullah examined Ni-Cu structural properties in (2018), Vanadium powder added with percentage (0, 1, 2, 3) percent (Abdullah, 2018).

Materials Preparation

The (Ni-Cu-V) alloy was formed from high purity powders, mixed powders (70% Ni, 25% Cu, 5% V), and dried at 80°C for half an hour. Then molds with dimensions of = 1,6 cm long, radius = 0,5 cm were used to cast the samples as shown in Fig. 1.
The sample was then pressed down under an (8 ton) hydraulic piston. A German oven style (Renfert) model (Magma) used heat treatment of samples at various laser energies (0, 200, 260, 300) mJ. The grain size and purity of prepared metal powder are shown in Table 1.

Table 1. Data of grain size and purity of metallic powder

Powder	Grain Size [nm]	Purity %	Origin
Nickel powder	95	99.99	Merck Co.-GERMANY
Copper powder	80	99.98	Buchs Fluka AG Co.-GERMANY
Vanadium powder	85	99.95	Buchs Fluka AG Co .-GERMANY

Figure 1. The moldings of the samples

Experimental Procedures

After drying for an hour using the Archimedes method (oven temperature at 100°C), the samples were weighed to determine their dry weight (Wd), and other properties of the samples such as bulk density, porosity, and water absorption were measured. The samples are then placed in a container filled with water for one day (24 hours), after which they are removed and dried with a cotton cloth to ensure sample integrity and to prevent water withdrawal from the studied samples' external pores. Following that, the sample's weight is calculated again to determine the saturated weight (WS), and the hanging weight (Wi) is calculated by placing the saturated sample on the weight grid and hanging it in water (suspended method).
The apparent density (*A.D*) was calculated by the given relationship (Jassim, *et al*., 2015):

$$A.D = \frac{Wd}{Wd - Wi} \times \rho \qquad (1)$$

ρ represents the water density (gm/cm^3), and the apparent porosity (*A.P*) can be calculated using the following equation (Yadav, *et al*., 2012):

$$A.P = \frac{Ws-Wd}{Ws-Wi} \times 100\% \qquad (2)$$

While the percentage of water absorption *(W.A)* is measured by the mathematical formula (Kocak, 2010):

$$W.A = \frac{Ws-Wd}{Wdi} \times 100\% \quad (3)$$

The samples are cleaned and weighed, then immersed in a solution (3.5% sodium chloride) for a variable period (3, 5, 7, 9, 11) days after that the sample is taken out of the solution and its weight is calculated by using balance type (Optika Level SR 6532-Italy), and through the following equation the lost weight (W) is calculated (Lajarin, 2018):

$$W = \frac{Mg-Mi}{A} \qquad (4)$$

Where Mg is the mass of the sample before immersion in the middle of the erosion and Mi is the mass of the sample after immersion in the middle of the erosion. Whereas A denotes the sample's surface area.

Results and Discussion

Physical Tests of Alloy (Ni-Cu-V)

Fig. 2 indicates the visible sample density as a function of laser power. With increasing laser energies, the apparent density of the samples is observed to increase. This is due to a decrease in the pores of the alloy and an increase in its homogeneity. This result is consistent with (Monzen et al., 2010; & Varea et al., 2012).

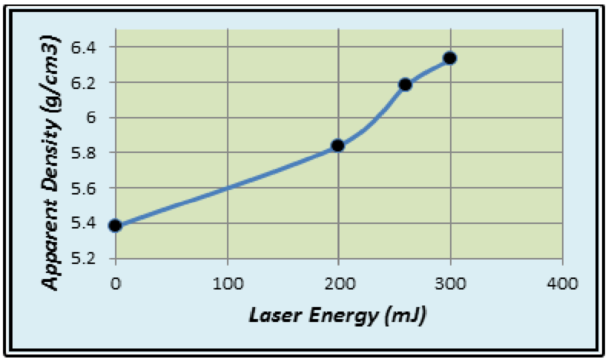

Figure 2. Apparent density versus laser energy

On the other side, Fig. 3 shows the alloy's porosity values as a function of laser energy, while Fig. 4 shows the laser energy dependency on water absorption. All statistics agree that the values of porosity and absorption decrease as laser energy increases. Rising laser energy results in increased bonding between powder grains. However, these pores decrease and shape changes. Porosity and absorption tests indicate they are in accordance with virtual density and conduct inversely.

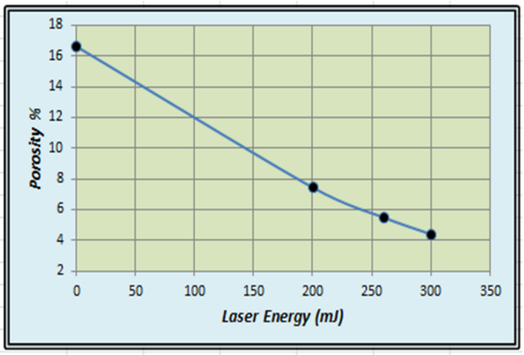

Figure 3. Apparent porosity as a function of laser energy

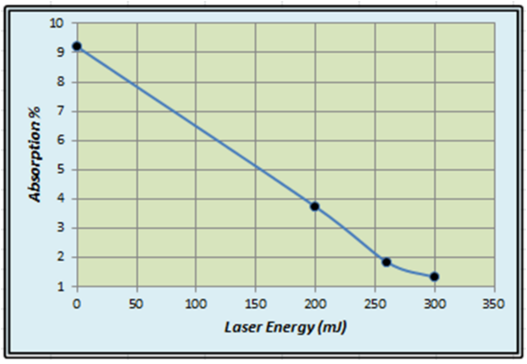

Figure 4. Absorption as a function of laser energy

From figs. 3 and 4, we note that the relationship between porosity and absorption is linear, as shown in fig. 5.

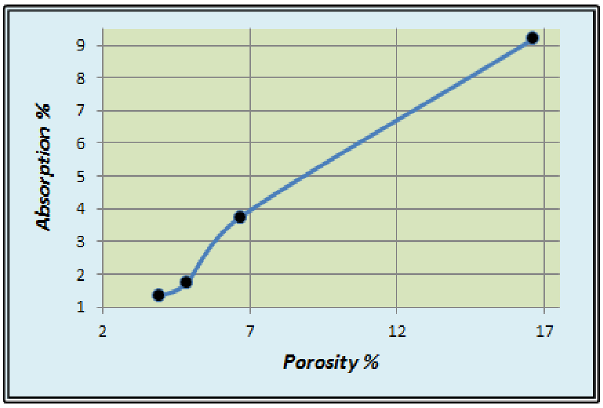

Figure 5. The relationship between porosity and absorption

In addition, Fig. 6 shows the significant amount of sample weight loss versus immersion time at different laser energy namely (0, 200, 260, 300) mJ. The result indicates that the resistance to corrosion decreases each time the immersion time increases.

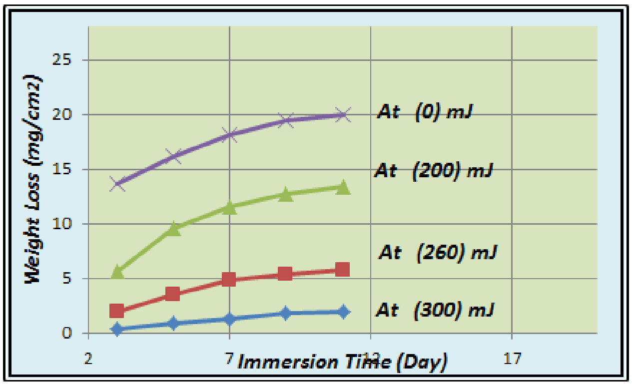

Figure 6. Weight loss versus immersion time at different laser energy

Fig. 7 depicts the hardness values (HRC) (gm / mm2) for the investigated samples at different laser energies. From this chart, it is apparent that the hardness values increase with laser energy, resulting in harmony with work (using heat treatment instead of laser treatment) (Rahimian, *et al.*, 2009).

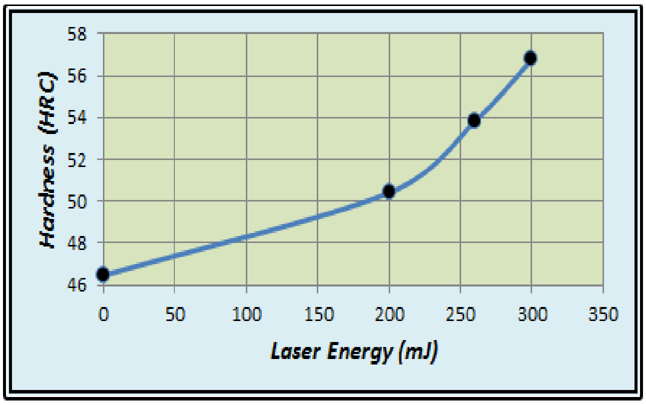

Figure 7. Plot of hardness versus laser energy

Surface Morphology of Alloy (Ni-Cu-V)

Fig. 8 displays Atomic Force Microscope (AFM) nanoparticles of the alloy (Ni-Cu-V) at specific laser energies (0, 200, 260, 300) mJ. The grain size slowly increases with increasing laser energy can be seen. In addition, the surface of the nanoparticle has been smooth with increased laser energy, which leads to improved crystallization processes at (300) mJ. The nanoparticles surface thus has a homogeneous structure with laser energy, this finding is in accordance with the study (Ţălu, *et al*., 2015).

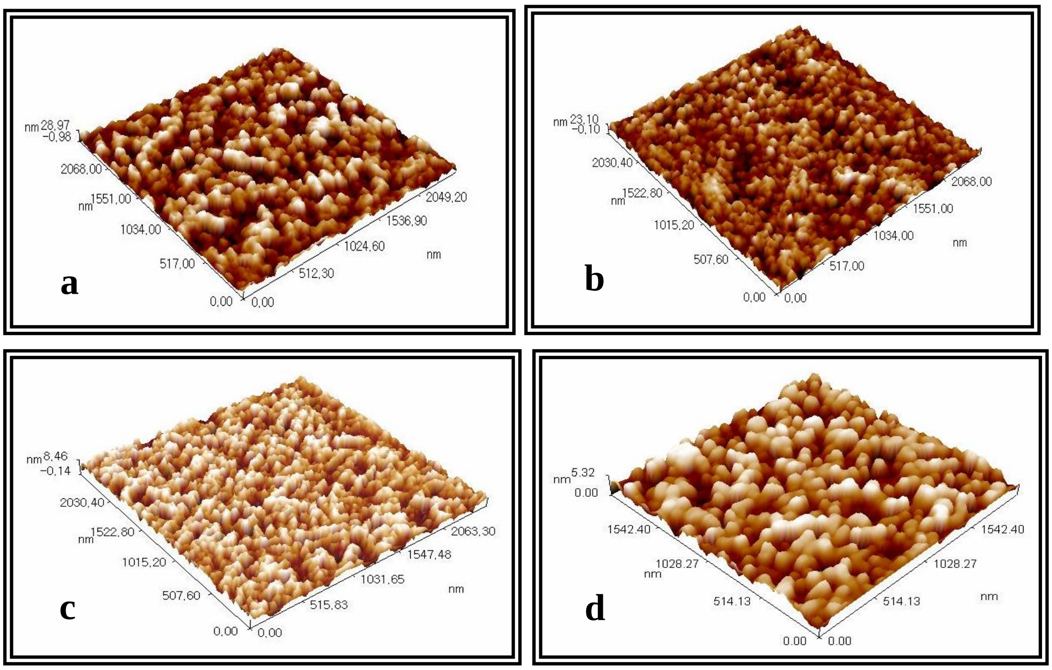

Figure 8. AFM images of nanoparticles alloy a) without laser, b) 200 mJ , c) 260 mJ , and d) 300 mJ

Conclusions

The current study found that apparent density and hardness values responded well to laser energy, due to the increased diffusion of the compound and the disappearance of pores. In addition, the porosity and water absorption can be modified by laser surface treatment by controlling the laser energy. Furthermore, increasing the laser power improves corrosion resistance, which may open up the possibility of improving sample properties for marine applications.

The surface of the nanoparticles becomes more homogeneous as the laser power increases. Furthermore, the development of sample surfaces through smoothness degree and homogeneity with an increase of laser surface treatment has been demonstrated through careful modification of experimental conditions. It has also been demonstrated that there is an inverse relationship between grain size and laser surface treatment, implying that the creation of an ideal alloy is possible.

Acknowledgments

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