Journal of Engineering and Applied Sciences 14 (Special Issue 1): 3914-3918, 2019
ISSN: 1816-949X

The Role of Ultrasonic Surface Treatment on Mechanical Properties of 50%Ni 50%Ti

Kadhim F. Alsultani, Ekbal and Raghad Abd Alkareem
Department of Metallurgical Engineering, College of Materials Engineering,
University of Babylon, Hillah, Iraq

Abstract: This research is represent the study of the influence of ultrasonic surface treatment for 50%Ni and 50%Ti alloy. The Sample was prepared by using powder metallurgy techniques; two different nanoparticles (SiC-BN) were employed. The study use of several tests were conducted such as X-ray diffraction,Vickers hardness corrosion resistant, wear behavior and Ni- Ion release obtained results showed a great improvement in hardness and wear resistant in addition significant reduction in current density and ion release.

Key words: NiTi alloy, ultrasonic surface treatment, corrosion resistant, wear behavior, hardness, Ni-ion release

INTRODUCTION

Ni/Ti systems are the most superior and popular alloy. They were found in many application and several fields such as aerospace and biomedical, etc. They also have effective corrosion resistance mainly due to TiO_2 oxide. This oxide not only protective but also it has an aphotocatalytic property which decompose the toxic organ material (Hermawan *et al*., 2011).

However, deformation structure associated with ultrasonic technique have a great interested recently (Ye *et al*., 2016). Many studies were worked ultrasonic surface treatment in different techniques.

A group of workers (Khachin *et al*., 1992; Gjunter *et al*., 2006) used Ultrasonic Impact Surface Technique (UIST) to improve mechanical properties of NiTi SMAs (Surikovaa *et al*., 2016; Zhuravlev and Pushin, 2000).

NiTi base alloys have excellent Super Elasticity (SE) and shape memory alloy effect but it is often necessary for great improvement and further increase in hardness, wear resistance, reduction in corrosion. The works showed that the micro hardness of surface layers will improved and increase because of nanostructure of plastic deformation by using ultrasonic treatment (Lindemann *et al*., 2006).

The aim of this research is to investigate the effects of ultrasonic treatment on the mechanical properties of 50% Ni 50% Ti.

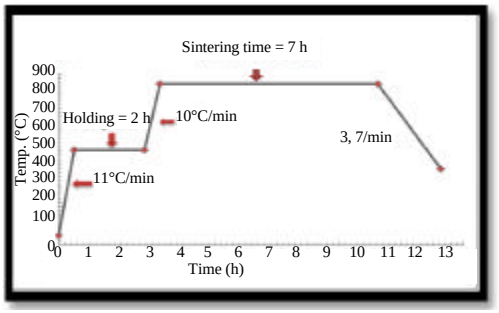

Fig. 1: Sintering cycle of the prepared samples

MATERIALS AND METHODS

Experimental work

Prepearing the samples: Specimens of (50% Ni and 50% Ti) were prepared by powder metallurgy technique. particale size of the used powder was (1.2-11μm) their purity was (99.2-99.8%). The compacting pressure was (800 MPa). Then samples were sintered in a programable vacuum furnace at 850°C for 7 h. Figure 1 specimens were discs of diameter 12.8 mm and 6 mm thickness.

However, then they were subjected to ultrasonic treatment by using a slurry composed by nano SiC particles and Boron Nitride (BN) of size (100 and 50) Nano. Different levels of power and time were used, Table 1 and 2.

Tests

X-ray diffraction: X-ray diffraction test was conducted for the samples before and after treatments to detect any phase formed during treatment.

Corresponding Author: Kadhim F. Alsultani, Department of Metallurgical Engineering, College of Materials Engineering, University of Babylon, Hillah, Iraq

Table 1: Ultrasonic surface treatment by nano SiC (A)

Samples	A_1	A_2	A_3	A_4
Power (%)	40	40	80	80
Time (h)	1	3	1	3
Temp. (°C)	50	50	70	70
Pluser	70	70	70	70

Table 2: Ultrasonic surface treatment by nano BN (B)

Samples	B_1	B_2	B_3	B_4	B_5	B_6
Power (%)	40	40	40	80	80	80
Time (h)	1	2	3	1	2	3
Temp. (°C)	50	50	50	70	70	70
Pluser	70	70	70	70	70	70

Fig. 2: Pin-on-disc wear test

This instrument used Cu ،a radiation of current 20 mA at power 40 kW, the target used was Cu tube, ،Cu =1.54060 A°, scanning was 5(2ₒ) per min.

Hardness: The hardness of surface layer before and after treatment was calculated by using Vickers hardness load 1000 g holding for 10 sec.

Wear resistance: This test was determined by pin-on-disc test. The diameter of sample was 12.8 mm and the hardness of disc (852) HV and applied load 10 N with Speed equal 350 rev/min, sliding distance is equal to (171) (Fig. 2).

Corrosion resistance: Tafel extrapolation technique was used to determine of corrosion resistance by potentio dynamic anodic polarization measurements. This test was carried out by using salvia solution at 37°C. Also, this test was carried out according to ASTM Standard (GS-94).

Ion release: On of the most improvement test for these alloys is ion release because of Ni-ion toxic in human body salvia solution was used at 37°C where sample immersion individually for 14 days Ni-ion release was determined by atomic absorption spectrometry.

RESULTS AND DISCUSSION

Figure 3-5 shown phase NiTi, Ni_3Ti, TiO_2 appears in NiTi shape memory alloy (Jiang *et al*., 2013; Man *et al*., 2001).

Table 3 and 4 shown hardness of treated samples by (SiC and BN) nano. The hardness increased in both cases, us well, the maximum hardness of nano-BN UST was 527 HV, compared with the reference untreated sample. There is an improved equal to 115% while in using nano-SiC UST maximum peak hardness was 400 HV. Compared with reference sample, the improvement is ،64%. The increasing in hardness however, maybe attribute to generation a high density of dislocation with random crystallographic in the surface layer (Man *et al*., 2005; Zhang *et al*., 2003). Also, the Table 3 and 4 shows increasing in ultrasonic power (40.80) causes decreases in the hardness, this is properly attributed to higher generated heat, Fig. 6 show comparison of samples in hardness.

Tribology behavior of these samples (treated and untreated) and as shown in Fig. 7 and 8 was carried by using pin-on-disc technique. These Fig. 7 and 8, it is obvious that there is a sharp decrease in weight loss with time (reference sample). From tribological point of view, this behavior was expected because of process of asperity smoothing (untreated sample) while for treated sample, gradual decrease in loss. This is because of the higher hardness of surface layer (Wong *et al*., 2007). Also, sample treated by nano BN UST shown lowest weight loss in comparison with sample treated by nano SiC UST, this is because of Vickers hardness, the wear rate is recorded in Table 5 and Fig. 9.

The chemical behavior of all sample (treated and untreated) was studied through using Tafel extrapolation technique, great reduction in corrosion current ($I_{corr.}$). The current density of sample treated by nano BN UST was only (0.318 μA cm^2) compared to that of the reference sample (9.409 μA/m^2. The corrosion rate of treated sample was (0.0085 mpy) compared with reference sample (2.232 mpy). This means that a higher improvement in corrosion resistance about 99.6%. on other hand current density of the sample treated by BN was greatly lower than this sample treated by nano SiC.

These treated samples improvements was due to form protective layer of (TiO_2). The temperature range was enough to produce the protective layer of (TiO_2) 50-70°C (Dawood, 2014). Ti according to electro chemical series is more nobles (less active than Ni). But nickel oxide was expected to be not formed which attributed to forming of physical and chemical barriers which acts as barriers to prevent oxidation forming of

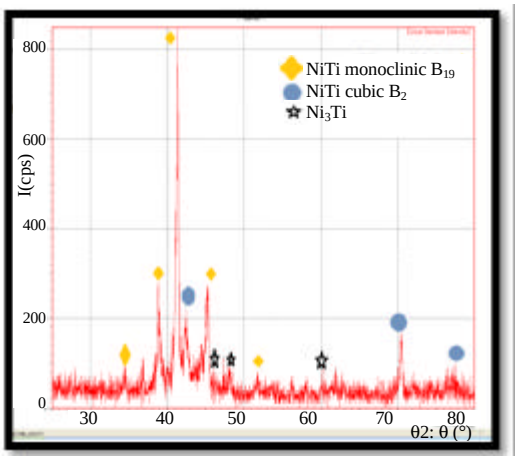

Fig. 3: XRD pattern of reference sample

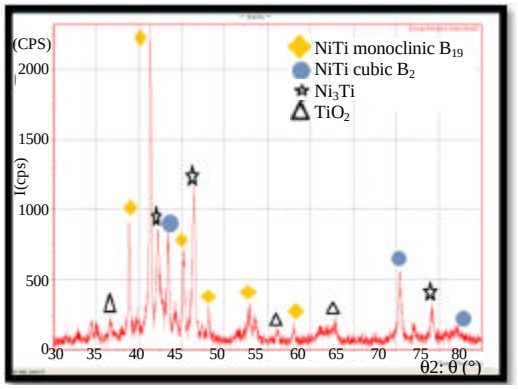

Fig. 4: XRD pattern of treated sample by ultrasonic surface treatment with nano SiC (power 40%, time 1 h)

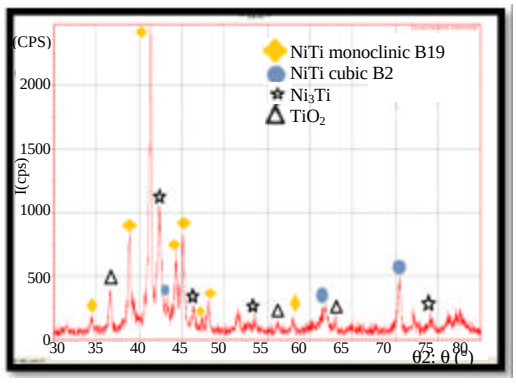

Fig. 5: XRD pattern of treated sample by ultrasonic surface treatment with nano BN (power 40%, time 1 h)

(Ni). Also, these barriers prevents the out ward diffusion paths of (Ni) (Wong *et al*., 2007; Grossmann *et al*., 2008).

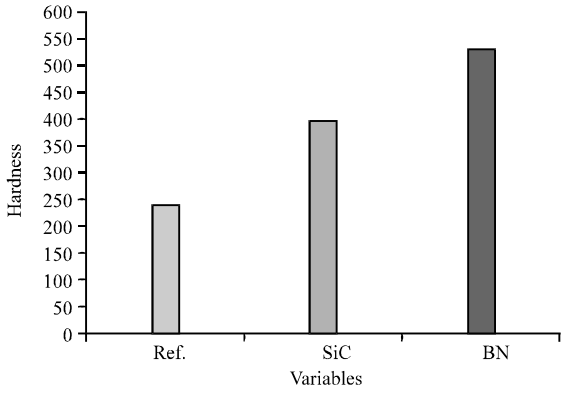

Fig. 6: Comparison of samples in hardness

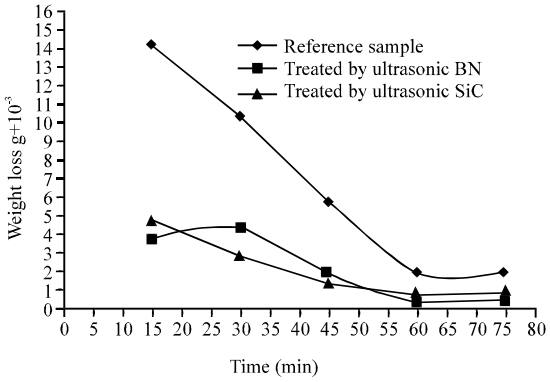

Fig. 7: Comparison of samples wear behavior

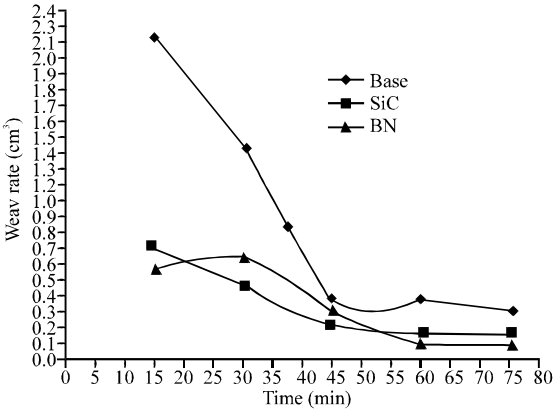

Fig. 8: Wear rate of untreated and treated sample

Table 4: Hardness value of untreated and treated sample by nano BN

Samples	Ref.	B_1	B_2	B_3	B_4	B_5	B_6
Power (%)	-----	40	40	40	80	80	80
Temp. (°C)	-----	50	50	50	70	70	70
Hardness HV	244	527	414	385	350	320	300
Hv/Hvref.	------	216	169	157	143	131	122

The temperature during ultrasonic treatment was high enough to form protective oxide film (TiO_2) Ti is very reactive metal oxide (Table 6 and 7).

Table 5: Wear rate at steady state of the examined sample

Samples	Wear rate×10^{-2} cm^3
Ref.	3.10
A1 (SiC-power:40 time:1 h)	1.39
B1 (BN power: 40 time: 1h)	0.93

Table 6: Corrosion parameters for treated samples by nano SiC in artificial Saliva solution

Sample	Ref	A_1	A_2	A_3	A_4
OPC	-298	-151	-169	-146	-197
Icorr µm	12.01	0.519	0.745	0.869	0.926
Ecorr (mV)	-272	-58	-158	-134	-150
Current density µm/cm^2	9.409	0.403	0.587	0.675	0.720
C.R (mpy)	2.232	0.096	0.138	0.161	0.172
Improvement percentage (%)	-----	95	93	92.7	92.2
$I_{corr.}$ /$I_{ref.}$ (%)	-----	4.32	6.203	7.235	7.710

Table 7: Corrosion parameters for treated samples by nano BN in artificial Saliva solution

Samples	Ref.	B_1	B_2	B_3	B_4	B_5	B_6
OPC	-298	-152	-123	-168	-159	-150	-194
Icorr (µ)	12.01	0.409	0.454	0.570	0.648	0.756	0.941
Ecorr (mv)	-272	-196	-151	-82	-75	-87	-160
Current density (µm/cm^2)	9.409	0.318	0.353	0.443	0.503	0.587	0.731
C.R (mpy)	2.232	0.0085	0.084	0.105	0.120	0.140	0.174
Improvement (%)	-------	99.6	96.2	95.3	94.6	93.7	92.2
Icorr. /I ref. (%)	-----	3.405	3.780	4.647	5.539	6.294	7.835

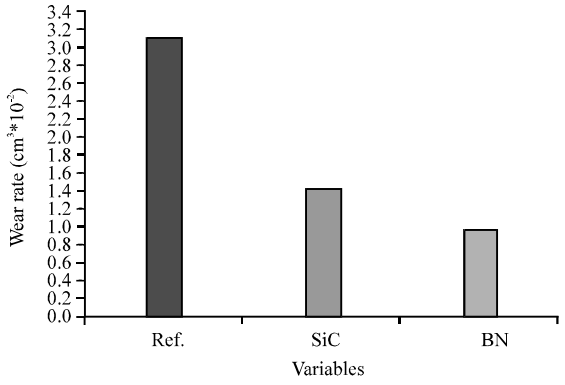

Fig. 9: Wear rate at the steady state

A comparison between the corrosion rate of the reference sample and the ultrasonic treated samples is presented in Fig. 10. The brown color of the circle represent the corrosion rate of the reference. The red vertical however indicated the corrosion rate of the BN containing slurry while the black chisel like is the corrosion rate of SiC containing slurry.

Ion release was very important test for the biomedical application in spite of importance of Ni for human body. But the presence of high level of ion nicked in the human body was very bunger because of allergic and toxicity (Wang *et al*., 2013; Ashby *et al*., 2008).

According to Table 8 and Fig. 11 were clearly that treated samples shown lower ion nickel release.

Table 8: Ni released for 14 days

Samples	Ni-release ppm
Ref.	2.016
A_1 (Sic –power:40% time: 1 h)	0.58
B_1(BN power :40% time: 1 h)	0.419

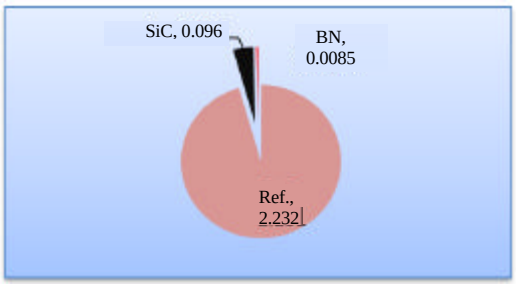

Fig. 10: Corrosion rate of reference sample and treated sample (A_1, B_1)

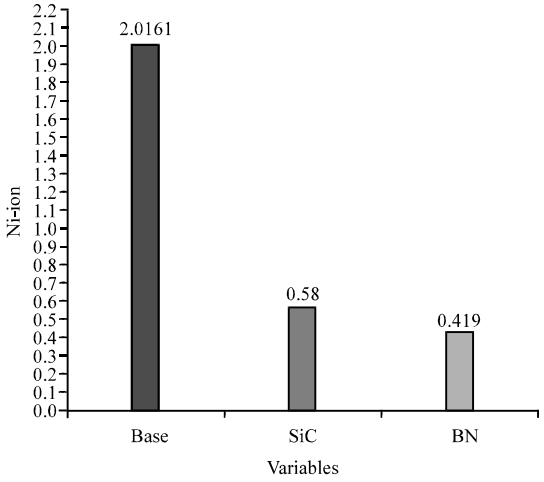

Fig. 11: Ni ion released for untreated and treated sample

This is because decrease from (2.016) ppm to 0.58 ppm and (0.419) ppm for nano (SiC, BN) UST, respectively.

The reason stand behind this behaviors were due to energy which was injected to the surface during treatment. This energy improve and increase growth rate of protective layers of (TiO_2) and decrease of nickel at surface, also, refinement of grain size and redistribution of titanium at surface (Biront, 1979).

As well the reduction in ion release in the sample treated by nano BN UST was the lowest and equal to 0.2 to the reference sample. While, the sample treated by nano (SiC) the reduction in ion release was equal to 0.28 compere to reference sample (untreated).

The sample treated by nano BN UST shows highest decrease in ion release 0.419 ppm compere to that treated by nano SiC UST (0.58) ppm.

CONCLUSION

The sample treated by nano BN (UST) was caused a higher increasing in hardness, its enhanced hardness by 115%. Also, the sample treated by nano SiC shown enhanced in hardness about 64%.

The sample treated shown a sharp decrease in the weight loss with time. The wear rate of samples treated by nano BN (UST) were the lowest value compared with nano SiC samples and reference samples, the improvement was equal to (71%) that reference sample.

The sample (UST) shows a great improvements in the corrosion resistance. The current density of the sample treated by nano BN (UST) was equal to 0.318 compared of reference sample. While, the samples treated by nano SiC was equal to (0.403) compared with reference sample is equal to 9.409.

The sample after UST show reduction in ion release for nano (BN and SiC) after immersion for 14 days compared with reference sample and improvement was equal to 80% for nano BN UST and 71% for nano SiC UST.

All the samples treated by nano BN(UST) shown higher properties (mechanical and electro-chemical) than sample treated by nano SiC (UST).

REFERENCES

Ashby, M.F., H. Shercliff and D. Cebon, 2013. Materials: Engineering, Science, Processing and Design. 3rd Edn., Elsevier, Amsterdam, Netherlands, ISBN:9780080982816, Pages: 784.

Bironi, V.S., 1979. Kinetics of ultrasonic hardening. Met. Sci. Heat Treat., 21: 195-199.

Dawood, N.M., 2014. Preparation and characterization of coated and Cu alloyed Bio Nitinol. Ph.D Thesis, Department of Materials Engineering, University of Technology, Baghdad, Iraq.

Gjunter, V.E., V.N. Hodorenko, F.Y. Jasenchuk, T.L. Chekalkin and V.V. Ovcharenko, 2006. Titanium Nickelide: Medical Material of New Generation. MITs Publishing House, Tomsk, Russia, Pages: 296.

Grossmann, C., J. Frenzel, V. Sampath, T. Depka and A. Oppenkowski *et al*., 2008. Processing and property assessment of NiTi and NiTiCu shape memory actuator springs. Mater. Sci. Eng., 39: 499-510.

Hermawan, H., D. Ramdan and J.R.P. Djuansjah, 2011. Metals for biomedical applications. Master Thesis, Faculty of Biomedical Engineering and Health Science, University Teknologi Malaysia, Johor Bahru, Malaysia.

Jiang, H.J., S. Cao, C.B. Ke, X. Ma and X.P. Zhang, 2013. Nano-sized SiC particle reinforced NiTi alloy matrix shape memory composite. Mater. Lett., 100: 74-77.

Khachin, V.N., V.G. Pushin and V.V. Kondrat'ev. 1992. Titanium Nickelide: Structure and Properties. Nauka Publisher, Moscow, Russia,.

Lindemann, J., C. Buque and F. Appel, 2006. Effect of shot peening on fatigue performance of a lamellar titanium Aluminide alloy. Acta Mater., 54: 1155-1164.

Man, H.C., S. Zhang, F.T. Cheng and X. Guo, 2005. Laser fabrication of porous surface layer on NiTi shape memory alloy. Mater. Sci. Eng., 404: 173-178.

Man, H.C., Z.D. Cui and T.M. Yue, 2001. Corrosion properties of laser surface melted NiTi shape memory alloy. Scr. Mater., 45: 1447-1453.

Surikova, N.S., N.A. Narkevich, N.Y. Surikov, I.V. Vlasov and S.V. Ovchinnikov *et al*., 2016. Effect of ultrasonic impact treatment on the mechanical properties of titanium nickelide single crystal. Phys. Met. Metall., 117: 1061-1069.

Wang, X., W. Xia, X. Wu, Y. Wei and C. Huang, 2013. Microstructure and mechanical properties of an austenite NiTi shape memory alloy treated with laser induced shock. Mater. Sci. Eng., 578: 1-5.

Wong, M.H., F.T. Cheng, G.K.H. Pang and H.C. Man, 2007. Characterization of oxide film formed on NiTi by laser oxidation. Mater. Sci. Eng., 448: 97-103.

Ye, C., X. Zhou, A. Telang, H. Gao and Z. Ren *et al*., 2016. Surface amorphization of NiTi alloy induced by ultrasonic nanocrystal surface modification for improved mechanical properties. J. Mech. Behav. Biomed. Mater., 53: 455-462.

Zhang, H.W., Z.K. Hei, G. Liu, J. Lu and K. Lu, 2003. Formation of nanostructured surface layer on AISI 304 stainless steel by means of surface mechanical attrition treatment. Acta Mater., 51: 1871-1881.

Zhuravlev, V.N. and V.G. Pushin, 2000. Alloys with Thermomechanical Memory and Their Application in Medicine. Urals Branch of the Russian Academy of Sciences, Yekaterinburg, Russia,.