Enhancement of Ti by carbon Nanotubes addition for bone repair

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Abstract. This study involves fabricating Ti based materials reinforced by carbon nano-tubes. CNTs were added with weight percentage (1, 2, 3, 4 and 5 wt% ) to enhance the mechanical properties of titanium. Some properties were measured for nanocomposites (CNTs/Titanium) such as microhardness, elastic modulus, wear rate in addition to microstructure by SEM. Microhardness was increased for nano-composites, which increased 421 Kg/mm2. The results of elastic modulus shown the decreasing in elastic modulus from 124 GPa to 82 GPa for nano-composites. Wear rate results exhibited the lower wear rate of nano-composites compared with titanium due to the filling the vacancy in microstructure by CNTs. The scanning electron microscopy images showed that uniform distribution of CNTs in titanium and the lowest defect in microstructure. The good coherence between CNTs and base metal led to good mechanical properties.

Keywords: titanium, nanocomposite materials, carbon nanotubes, biomaterials.

1. Introduction
Titanium and its alloys matrix nanocomposites materials are suitable for bio-applications which exhibit better performance at elevated body environment because of their biocompatibility and it has good mechanical properties (especially high strength and lightweight [1]. It is used as orthopedic implants due to their better strength/weight ratio compared to other metallic materials and high corrosion resistance in various environments ( because of a passive oxide surface film on surface ), long-term diseases and non-inflammation. Titanium and its alloys have good toughness, plasticity and easy to fabricate furthermore, titanium is not attacked by body environment [2].
Numerous research has been done to enhance the properties of titanium especially wear resistance and hardnes to use it as bone repair or fixation [3]. Titanium and Titanium alloys have poor resistance to wear under erosion and abrasion conditions that limits its using particularly in applications that involving friction and wear [3,4].

Elastic modulus of (100–110) GPa, this is good above the elastic modulus of bones near (10 –30) GPa. Large difference in Elastic Modulus due to absorption of bone and premature failure of the implant during utilization as a result of stress shielding effect [5,6]. Reinforcements by carbon
nano-tubes is improving the properties of metallic matrix especially fracture toughness, micro hardness and wear resistance when the reinforcement distributed uniformly [7].

2. Experimental procedure
2.1 Materials
Titanium/carbon nano-tubes has been prepared by mixing of titanium powder and carbon nano-tubes(CNTs) by mixing using mixture in speed 100 rpm for (2 hrs.), then pressed the samples by pressing under 200 MPa and 850 °C for 6 hrs, finally sintering in a furnace at 550 °C for 4 hrs. The properties of titanium powder and carbon-nano-tubes can be shown in Table 1.

Table 1. Properties of Ti powder and CNTs.

| Ti powder | CNTs |     |    |   |    | type | company |
|-----------|------|-----|----|---|----|------|---------|
| Partial size | purity | company | diameter | length | type | company |
| 90 μm | 99.98 |     | 30 nm | 800 nm | multiwall | |

2.2 Tests and Examinations
- Micro hardness: Micro hardness Vickers test was achieved according to ASTM E92-82 by Vickers tester model HV - 1000. This apparatus was used to measure the hardness with 1000g load and holding time of 20 seconds to the surface of the specimen using a standard 136° Vickers diamond pyramid indenter combined with an optical microscope [2].
- Young Mudulas: Young modulus test was determined from universal tests according to ASTM C623–92 using tensile tester by calculation the slope of (\( \sigma - \varepsilon \)) curve [2,4].
- Wear and Coefficient of friction: The pin on disc wear tests are the most spread tests for wear behavior (sliding wear) and friction of material. The tests can be both vertical and horizontal, while vertical configuration mode enables to eliminate the debris during wear tests. The relative motions such that is a circumferential wear pathway on the disc surfaces are generated. The disc or pin can be moving.
- Scanning Electron Microscope (SEM): uses a focus beam of high electrons energy to produce a variation of signals at the surfaces of the specimens. The signal reveal information about the samples including crystalline structure, orientation, external morphology, chemical composition of the sample.

3. Results and discussion
3.1 Hardness
Figure (1) show the effect of carbon nano-tubes adding on hardness of titanium, hardness was increasing when percentage of carbon nano-tubes are increasing, these results suggests the filling of vacancies in titanium by CNTs and getting more coherent between the components in nano-composite (Ti/CNTs) [4,8]
3.2 Young Modula’s

Figure (2) shows the effect of CNTs addition on Young modulus of (Ti / CNTs) nanocomposite, it is clear that increasing in CNTs addition led to decreasing in Young (Elastic) modulus (E) of nano-composites, this can be a good advantage since this decreasing indicate to brittleness which like or tend to elastic modulus of bone. The value of E = less than 100 GPa is well above the Young’s modulus of bones [9].

![Figure 2. Effect of CNTs on Young Modulus of titanium.](image)

3.3 Wear Resistance (wear rate) mm3/Nm

Pin on disc is used to calculate the wear rate of all samples noted increasing wear rate by increasing the applied load when sliding distance and time are constant (Fig 3). Wear rate decreasing by increasing in CNTs percentage, this increasing result from high coherence between CNTs and base metal (titanium). The increasing in hardness is index to increasing in wear rate [10].

![Figure 3. Effect of CNTs on wear rate of titanium.](image)
3.4 Coefficient of friction ($\mu$)

Figure (4) shows the effect of CNTs addition on coefficient of friction of (Ti / CNTs) nanocomposite. The coefficient of friction was recorded by reciprocating tribemates. It is clear that the coefficient of friction value without CNTs is about (0.48) during the stable period, while that is (0.42 to 0.19) with CNTs. We conclude that adding CNTs as a solid lubricant in composite can significantly decrease friction and can reduce the heat generated during sliding (2,4).

![Figure 4. Effect of CNTs on coefficient of friction of titanium.](image)

3.5 Scanning Electron Microscopy

The scanning electron microscopy images (Figure 5) showed that no cracks or crystalline defects in microstructure, uniform distribution of CNTs in titanium and also showed good coherence between CNTs and base metal. The lowest defect in microstructure and good coherence between CNTs and base metal lead to good mechanical properties (micro-hardness and wear resistance) [10].

![Figure 5. a, b SEM image of CNTs / titanium nanocomposite.](image)
4. Conclusions

In the current study Ti was fabricated and reinforced by carbon nano-tubes. CNTs were added with different weight percentage as an attempt to enhance the mechanical properties of Ti. The following conclusions can be drawn

1- The addition of CNTs to titanium base metal to increase in hardness to (≈421 Kg/mm²).
2- The addition of CNTs to titanium base metal led to decrease young modulus to (≈ 82 GPa).
3- Wear rate was decreasing when CNTs was increasing (from 6.3*10^-4 to 5.11*10^-4 mm³/Nm).
4- Friction coefficient was decreasing when CNTs was increasing (from 0.48 to 0.19).
5- In microstructure the addition of CNTs spread through titanium that led to a consolidate for all the alternate properties.

5. References

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