Experimental Investigation of Tensile Properties of Ni-Ti Samples Prepared By Different Techniques

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Abstract
Ni-Ti alloys have been given a lot of attention mainly for their innovative use in practical medical applications. These motives led to understand deformation mechanisms, particularly tensile fracture behaviors. In this research, tensile properties will be investigated for different composition Ni-Ti alloy samples. Ni-Ti samples were prepared in different techniques with different compositions and subjected to different tensile loading. Sand casting was found to be the best technique for preparing Ni-Ti samples, where Ni-Ti samples prepared by this technique showed best tensile behavior compared to samples prepared by other techniques. Furthermore, it was found that as the percentage of Ni is increasing in the Ni-Ti samples, as their tensile strength is improving. Even though, the ductility of Ni-Ti samples with high Ni percentage is reduced.

Keywords: Ni-Ti Alloy, Implants, Nondestructive techniques

Introduction
Near equiatomic alloy had attracted Scientifics to use as functional materials long time ago [1, 2]. The first Nitinol alloy was prepared by Buhler in the Naval Ordinance Laboratory in 1962 [3-4]. The first fatigue study of NiTi SMAs was performed by Melton and Mercier [5] in 1978; pseudoelastic fatigue tests were run on wire specimens with different
temperatures. This work was soon followed by that of McNichols and Brookes [6], who studied the fatigue life of NiTi springs. It wasn’t until the early 90s, when the medical industry began to push for less invasive medical procedures and alternative implants [7]. Because of its importance in many applications, many researches [8-12] have been conducted to investigate the fatigue life of components made of Ni-Ti alloy. Abu Jadayil and Alnaber [13] investigated the fatigue life of Ni-Ti samples prepared by different techniques. Ni-Ti samples prepared by different techniques were also investigated nondestructively by Alnaber and Abu Jadayil [14].

Takeshita et al. [15] implanted a cylindrical NiTi parts in rats for 168 days in the year 1997. An electropolished NiTinol samples were implanted in a periosteum osteoblasts, for the first 26th week it showed no toxicity effects but a small deceleration in proliferation process [16]. Nickel percentage of NiTinol composition where the issue that studied by kapanen et. al. [17] in the 2002 a fabricated samples with different percentages of nickel and titanium had been investigated for in vitro studies by Bogdanski et. al. [18]. The highest biological compatibility assured to be within a maximum 50 % nickel element of the alloy weight, higher percentages of Ni have revealed nickel releases and the released nickel rapidly reached cytotoxic concentrations within one day. Also many similar researches later handled toxicity and corrosion resistance [19-20]. It was found that the “memorial” effect point of transitions from structure to another fits perfectly body temperature. Equiatomic Nitinol, with its pseudoelastic effect, was found to have several ideal properties for such aim [15-16]. Fortunately, Mcklevey & O.Ritchie [21] found that (Ni50Ti50) casted alloy samples showed a full Austenitic structure at body temperature, which means a perfect mechanical condition providing super elasticity. Mohammad E-soni and colleagues [22] investigated the mechanical behavior for 55.8 wt. % Ni-Ti samples. Thermo mechanical stress-strain relationships and deformation processes had been investigated in detail by Sittner et. al. [23]. Strengthening and enhancing the properties of the composite material by alloy it with another element like iron or copper was done by Khraisat and Abu Jadayil [24] and Khraisat et. al. [25].

Many techniques were used to prepare the composite samples, as discussed by Abu Jadayil [26], but the most widely used technique is the sand casting which were studied by Abu Jadayil [27] and Abu Jadayil [28] to determine the main factors affecting this technique.

**Sample Preparation**

Nickel and Titanium metals were used with purity of more than 99.8%. Nickel was in plates, bullets and powder forms, whereas Titanium was in powder (150 micron) form. Three techniques were followed to prepare samples as follows:
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Powder Metallurgical Samples
Three Samples of Ni50Ti50 composition were fabricated by sintering method. A stainless steel die was specially designed as in Figure 1 for the consolidation of the metal powders into a mould. The powder of Ni was mixed with powder of Ti and the powder mixture poured into steel mould and pressed at (5 tons) force with a manual pellet press and held for about 30 minutes. The pressed specimen is then carefully ejected out of the die and placed in oven at 1235°C for an hour. Figure 2 illustrates powder metallurgical sample shape and dimensions after some surface machining. Sample properties along the 120 mm length were assumed to be constant. The effect of powder-wall friction on the sample homogeneous properties was ignored especially the outer diameter of the sample was reduced by machining. The sample temperature was assumed constant too.

![Figure 1: Powder metallurgical sample preparation](image)

![Figure 2: Powder Metallurgical Sample Shape and Dimensions](image)

Powder-Casting Samples
Three samples of Ni50Ti50 composition were fabricated by melting Ni pullets first, then Ti powder is poured into liquefy Ni and irrigated regularly in order to get homogeneous mixture. This procedure was suggested such that samples are fabricated without requiring elevated furnace temperature.
Sand Casting Samples:
Three samples of Ni50Ti50 composition were fabricated by melting both Ni and Ti at a temperature of 1700°C. The mixture was irrigated regularly in order to get homogeneous, then poured into sand moulds which have a sample shape as shown in Figure 3.

![Figure 3: Tensile testing sample dimensions](image)

Samples Testing Under Tensile Loading
The nine samples prepared by the three different techniques, were tested using Universal testing machine that was used to apply tensile loading. The testing operation is started and tensile load is applied continuously to specimen till necking are noticed and failure took place as in Figure 4. Samples prepared using powder metallurgy technique showed a brittle material behavior and the samples broke fast at low level loading, as shown by the blue thin curve in Figure 5. Samples prepared using sand casting showed a ductile material behavior, as shown by the red curve in Figure 5. On the other hand, samples prepared using powder-casting technique showed better behavior than powder metallurgy samples that is between ductile and brittle behavior, it is shown by the thick green curve in Figure 5.

![Figure 4: Tension Sample Necking and Failure Points Under Tensile Loading](image)
Since samples prepared by sand casting technique showed the best behavior with the highest tensile loading before failure, six more samples were prepared using this sand casting technique. Three of these new samples were 52.8% Ni-47.2% Ti (Ni52.8Ti47.2), and three of these samples were 47.2% Ni-52.8% Ti (Ni47.2Ti52.8). These six samples were tested using the universal testing machine and samples behavior is shown and compared to 50%Ni-50%Ti sample in Figure 6.
All samples prepared by casting showed ductile behavior with different percentages, according to fracture strain of each of the three samples. Figure 7 shows the three samples after removing the threaded part of each, the first one on the left is Ni47.2Ti52.8 sample, which was the most ductile with maximum necking compared to Ni50Ti50 which is in the middle, whereas Ni52.8Ti47.2 sample showed the least necking and the lowest fracture strain.

Figure 7: Ni47.2Ti52.8 Sample, Ni50Ti50 Sample and Ni52.8Ti47.2 Sample Respectively After Fracture

Results and Discussion
Analyzing the results go through two stages, first comparing the behavior of the Ni50Ti50 samples made by the three different techniques, and the results are summarized in Figure 5. The second stage is analyzing the results of comparing the three samples of different Ni-Ti composition when all made by sand casting, and these results are summarized in Figure 6. As shown in Figure 5, the sample made by powder metallurgy behaved just like brittle material and the fracture strain was around 4. The sample made by powder-casting technique showed a behavior close to ductile material behavior, but its maximum tensile strength was around 305 MPa compared to sample made by sand casting that has a maximum tensile strength of more than 350 MPa. Moreover, the ductility of sand casting sample was 28 compared to powder-casting sample that has fracture strain of 19.

Figure 6 shows that the sample with 52.8% Ni has the maximum tensile strength, then the sample with 50% Ni and the weakest sample was the one with 47.2% Ni. On the other hand, the ductility of the 57.2% Ni sample was around 25, and so it was the least ductile sample compared to 50% Ni sample that has a fracture strain of 28 and the weakest sample with 47.2% Ni sample is the most ductile with around 30 fracture strain. The modulus of elasticity was the highest for the sample with highest Ni content and it decreases as Ni content is decreasing. One the other hand, they have all the same limit of linearity, almost 5 µm/mm.
Conclusions

- The best fabrication technique of Ni-Ti alloy is sand casting, that powder metallurgy and powder metallurgy-casting Ni-Ti samples showed lower tensile strength and brittle fracture in case it is made of powder metallurgy technique.
- Increasing Ni% in the Ni-Ti alloy composition and decreasing the Ti% provides stronger samples with higher tensile strength, and higher modulus of elasticity, but the ductility will decrease.

References


