PRELIMINARY BENDING ROTATION FATIGUE TESTS IN NiTi WIRES

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Abstract. *The aim of this study was to evaluate preliminary bending rotation fatigue (BRF) tests conducted on the Ti50.33at%Ni SMA wire that was produced at the Institute. The rotational speed, the number of cycles and time to wire rupture of BRF test machine is automatically controlled by microcomputer using* C^{++} *language. The preliminary results indicate that the wire fabrication is quite feasible and the wire failed with low cycle fatigue with maximum number of cycles of 1462 turns.*

***Keywords**: fatigue failure, fatigue resistance, NiTi wires.*

1. INTRODUCTION

The NiTi alloys known since 70’s have one the best performance among Shape Memory Alloys (SMA), presenting shape recovery up to 7% with applications at several areas including medical and dentistry. At dentistry emphasize the orthodontics wires to correct dental arc and the endodontics files for root canal treatment. Superelasticity property are used for these applications (Otubo *et al*. 1997; Otubo *et al*. 1998).

The scientific and technological progress permitted great improvement in the endodontics instruments mainly in terms of mechanical properties. It made possible to produce endodontic files machined from superelastic NiTi SMA promoting a fast and uniform biomechanical preparation of the root canal. The major concern in the use of NiTi rotary instrument is the possibility of the occurrence of unexpected failure. Usually, the file does not show visible indication that the failure will occur especially when misused (Sattapan *et al*. 2000; Lopes *et al*. 2001). Therefore, the fatigue loading is an important aspect of mechanical properties study for the final file and also for the wire from which the file is produced.

The objective of the present article is to verify the effectiveness of a device especially manufactured for the BRF test controlling parameters such as the wire curvature radius, wire diameter and rotational speed and relating those parameters to fatigue behavior in terms of number of cycles up to failure. Also brief analyses related to wire fabrication is presented.

2. MATERIAL AND METHODS

The experimental procedure could be divided in three steps: wire fabrication, BRF machine construction and fatigue test itself.

The starting material was a hot forged 2.2mm in diameter superelastic Ti50.33at%Ni which was cold drawn down to 1.37mm with 15% area reduction per pass with intermediary annealing at 773K per 10 minutes in a box furnace. Before drawing, the surface defect as shown in figure 1 (a) and (b) were removed by milling machine. The drawing machine is shown in figure 2.After drawing the wire was straightened (memorized) by pulling it apart in a gas flame jet.

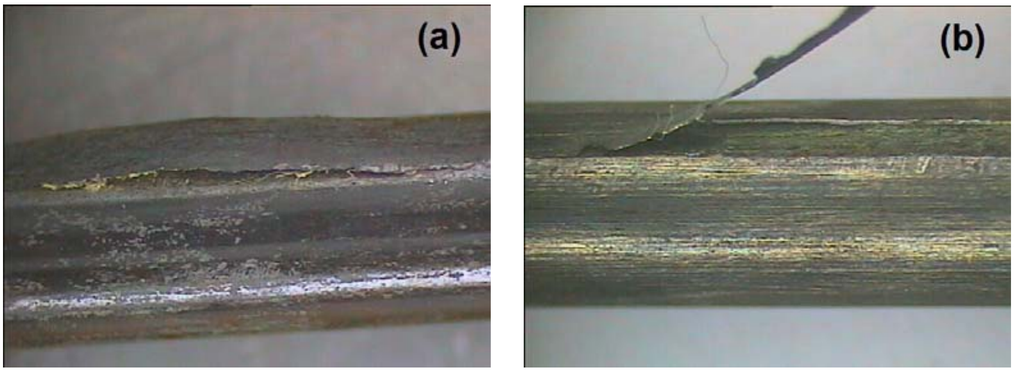

Figure 1 The defects of surface was removed by milling machine before the wire drawing; (a) 6,4 x magnification (b) 10 x magnification.

Figure 2 Drawing machine

A BRF device was constructed especially for fatigue tests as shown in figure 3 (a) and (b), which indicates the bent wire forced into rotation by the loading grip connected to a driving motor. A low-friction nylon® bearing was used to keep torsional load of the wire at a minimum. Three lubricants were evaluated to minimizing the friction: glycerin, silicon and graphite grease. The number of cycles, speed rotation and the time to failure of the test is automatically controlled by computer which is programmed in C^{++} language. The final presentation is the Windows® format.

The amount of deformation, ε_a, was evaluated through the equation 1 in which *d* represents the wire diameter and *R* the curvature radius of the wire.

$$\varepsilon_a = \frac{d}{2 \cdot R} \qquad (1)$$

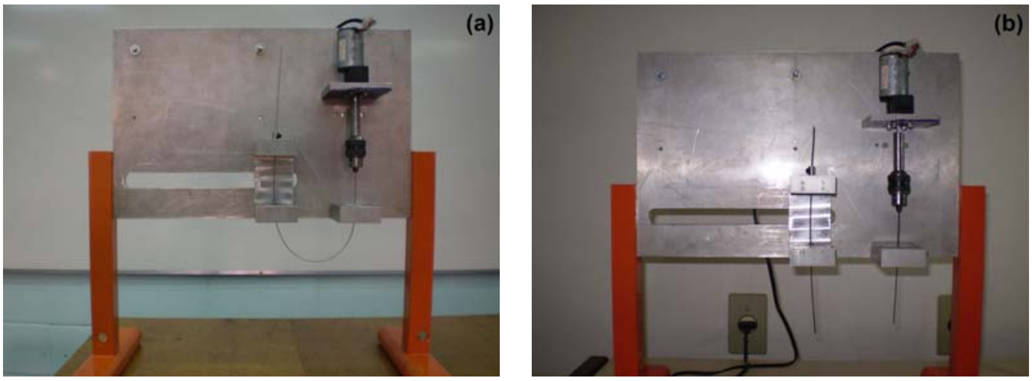

Figure 3 Wires mounted in the device, (a) before test (b) after test

In the BRF test performed in the present study the curvature radius was R was 50 mm with rotational speed of 430 rpm. The tests were conducted at room temperature.

3. RESULTS AND DISCUSSION

The as drawn wire before the straightening is shown in figure 4. Besides some pointing problem of the wire, no major problem could be seen up to final diameter of 1.37 mm.

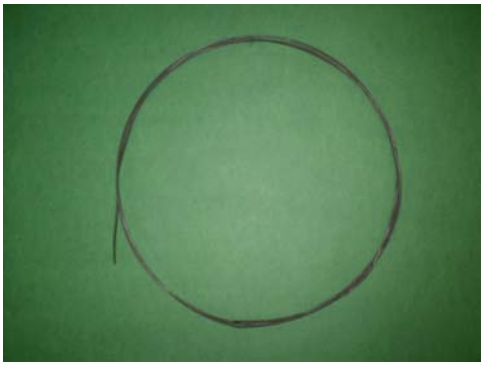

Figure 4 The as drawn wire

As can be seen in table 1 from the DSC (Differential Scanning Calorimeter) results the wire is martensitic below 275.8K. Therefore, the wire is superelastic at test temperature which is done at room temperature.

Table 1 Transformations temperatures; M_S martensite start, M_P martensite peak, M_F martensite finish, A_S austenite start, A_P austenite peak, A_F austenite finish.

M_S (K)	M_P (K)	M_F (K)	A_S (K)	A_P (K)	A_F (K)
275.8	268.1	256.8	279	290	300.2

The table 2 shows the results of BRF tests which were obtained from three samples taken from same wire diameter 1.37 mm. According to equation 1 the strain amplitude was 1.37 %.

Table 2 Number of cycles in the fatigue rupture

Samples	*R (mm)*	*ω (rpm)*	N_f
1	50.0	430	860
2			1462
3			695

The preliminary results show that the number of cycles up to rupture is not high and varied from a minimum of 695 to a maximum of 1462. The result is similar to Sawaguchi *et al* (2003) results that show that for a strain amplitude larger than 1% the fatigue rupture occurs in the early stage (small number of cycles). This is considered low cycle fatigue. Other factors such as microstructure, presence of R phase, wire thermomechanical treatment could affect its fatigue performance (Bahia and Buono, 2005). Also macroscopic parameters such as wire diameter, radius of curvature and wire surface finishing are important on the fatigue performance.

The results shown here is preliminary insight and more experiment is underway to better understand the relationship between the above mentioned parameters

4 CONCLUSIONS

The preliminary results show that:
The NiTi wire fabrication is quite feasible;
The constructed apparatus could be used for rotary bending fatigue test and
The NiTi wires failed as low cycle fatigue with a maximum N_f *of 1462* cycles.

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