THERMAL CYCLING EFFECT ON DIFFERENT TWO WAY SHAPE MEMORY TRAINING METHODS IN NiTi SHAPE MEMORY ALLOYS

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1. Introduction

The two-way shape memory effect (TWSME) is the reversible and spontaneous shape change of the alloys subject to thermal cycling. The TWSME is not an intrinsic property of a shape memory alloy (SMA): it is only observed after some training procedures [1]. The TWSME developed by the alloy depends on its previous thermomechanical history, the training method applied and the training parameters used. Several training routes have been reported to be associated with the B2→B19' transformation, but little work has been done on training methods that consider R-phase transformation to be an essential part of the training process. In fact, different opinions are published [2, 3] concerning the influence of R-phase on the TWSME. The aim of this work is to study experimentally the influence of R-phase on the development of the two way memory strain (ε_{tw}) and on the transformation temperatures (TTs). Constant load thermal cycling (L) and tensile deformation below M_f (D) are used as training procedures.

2. Materials and Experimental procedures

A binary near-equiatomic NiTi wire (diameter 1 mm) manufactured by Euroflex (SME 495) is used. Two different thermomechanical treatments (A, B) are applied in order to ensure different R-phase presence on the alloys. Treatment A consists of a heat treatment at 500ºC for 1 hour, and subsequent quenching in water. Treatment B consists of the same heat treatment as A, but the R-phase is then enhanced and stabilized by a repeated thermal cycling at zero stress in the temperature transformation range. The TTs (M_S, M_f, R_S, R_f, A_S, A_f) are obtained by measuring the changes in electrical resistivity (ER) due to temperature. The A and B samples trained by L are A_L and B_L; the A and B samples trained by D are A_D and B_D. To perform L training, a constant training stress of σ_{tr}=103.7 MPa is applied to the sample in the martensitic state, and then it is repeatedly thermally cycled through the transformation range. D training is carried out in three subsequent steps: (a) tension test at a training strain of ε_{tr} = 4.5% in the martensitic state, (b) the sample is completely unloaded, (c) the sample is heated to above A_f. These σ_{tr} and ε_{tr} guarantee the complete martensite reorientation in accordance with [2]. Then, repeated thermal cycling is performed on A_L, B_L, A_D and B_D to measure the ε_{tw} and determine the evolution of TTs. A small force of 5 N is applied to keep the samples stretched during TWSME tests.

3. Results

Figure 1 presents the TTs measured for treatments A and B, (showing R-phase); the TTs after L training (A_L, B_L) and the TTs after D training (A_D, B_D). Taking temperatures A and B as initial reference values, the R-phase transformation does not appear in all the trained samples because the M_S increases considerably during the training cycles. ER profiles during training have not resistivity peaks associated with the R-phase. L training increases both martensitic temperatures and decreases A_S. D training decreases M_f but increases M_S, and decreases A_S and A_f for both samples equally. Figure 2 shows the TWSME behavior for samples A_L and B_L, trained by the L method. The evolution of the reversibility of the deformation (ε_R) during training illustrates that, after an initial rise, ε_R reaches a fairly constant rate after four cycles. Thermally cycled sample B_L develops ε_{tw} values that are similar to those of A_L, but the accumulation of plastic strain (ε_P) is lower, suggesting that the dislocations introduced by prior thermal cycling can help the formation of preferentially oriented martensite [3], which is an essential factor to obtain a substantial ε_{tw}.

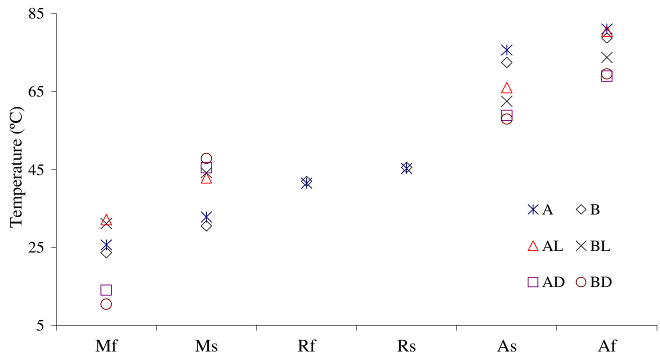

Figure 1. Effect of thermal treatments and training methods on the transition temperatures.

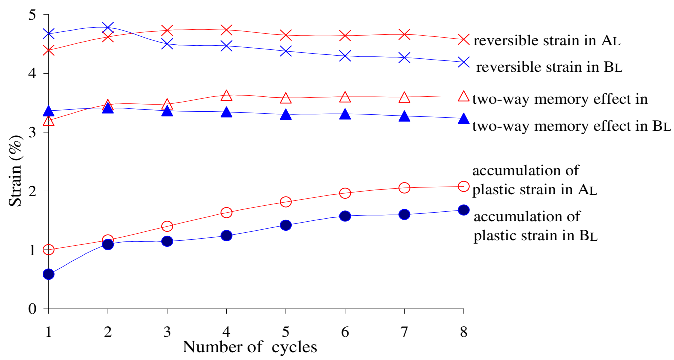

Figure 2. ε_R, ε_P and ε_{tw} evolution for constant load training (L).

4. Conclusions

D and L training enlarge TT intervals. The increase in M_S and decrease in A_S narrows the hysteresis width, and this effect is stronger in the B samples. A_L and B_L show resistivity peaks on ER curves measured after thirty TWSME tests, suggesting that the applied training parameters do not help to make the complete R-phase vanishment. Prior thermal cycling leads to lower ε_P for values of ε_{tw} similar to A_L. L training shows similar ε_{tw} than D.

5. References

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