# THE EFFECT OF STRESS RATIO ON FUNCTIONAL BEHAVIOR AND STRUCTURAL FATIGUE OF PSEUDOELASTIC NITI ALLOY

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**Abstract.**The influence of stress ratio on functional behavior and structural fatigue of pseudoelastic NiTi alloy are studied. With the change of the stress ratio from 0 to 0.5 the residual strain in the first and next cycles increases significantly even at lower values of maximal stress. The fatigue life of NiTi alloy increases with the decrease of stress ratio from 0.5 to 0 in the case of presenting the results depending on the stress range.

## 1. Introduction

Pseudoelastic SMA due to their unique properties [1] are used in the structural elements [2], machines [3] and other [4] which operate under cyclic loading. In contrast to traditional materials, pseudoelastic SMA lose both structural and functional properties under the influence of cyclic loading. Therefore, for such materials it is important to study the functional and structural behavior under cyclic loading with regard to stress ratio.

## 2. Experimental setup and material

The influence of stress ratio on functional properties was studied on pseudoelastic $Ni_{55.8}Ti_{44.2}$ alloy at 0°C which is above the austenite finish temperature ($A_f$ = –38.7°C).

Material has the following mechanical properties at 0°C ($A_f$ = –38.7°C): yield strength, $\sigma_{0.2}$ = 447 MPa, ultimate tensile strength, $\sigma_{UTS}$ = 869 MPa [5,6]. Chemical composition of material is given in following paper [5].

Cylindrical specimens with the diameter of 4 mm and gauge length of 12.5 mm were tested under uniaxial cyclic loading at temperature 0°C and stress ratio $R = \sigma_{min}/\sigma_{max} = 0$ and $R = 0.5$ (here $\sigma_{min}$ and $\sigma_{max}$ are the minimum and maximum stresses). Tests were carried out under displacement–controlled mode at stress ratio $R = 0$. In this case, the maximum stress, except for the first twenty loading cycles, remains constant [6,7].

Fatigue tests were carried at stress ratio $R = 0.5$ under stress–controlled mode. Thus, it can be assumed that during testing the maximum and minimum stresses were constant.

## 3. Results and discussion

For the same maximum stress and different stress ratios a typical hysteresis loops of loading cycles ($N$ = 1, 10, 20 cycles) are presented at Fig. 1. For both stress ratios a significant reduction of the hysteresis loop area after first ten cycles and its stabilization after twenty cycles could be observed (Fig. 1 a, b) [7].

The functional properties of the pseudoelastic SMA can be characterized by residual strain. The increase of the initial stress range from 509 MPa to 605 MPa augments the residual strain that leads to degradation of pseudoelasticity. However, with the further increase of the initial stress range to 740 MPa, the dependence of residual strain on the number of loading cycles shifts down to the same dependence for $\Delta\sigma_1$ = 605 MPa. The indicated inversion from the general law is due to the fact that the initial stress range is 8.7% at $\Delta\sigma_1$ = 740 MPa in the first cycle that exceeds the maximum deformation under which the super-elastic effect is still visible [7].

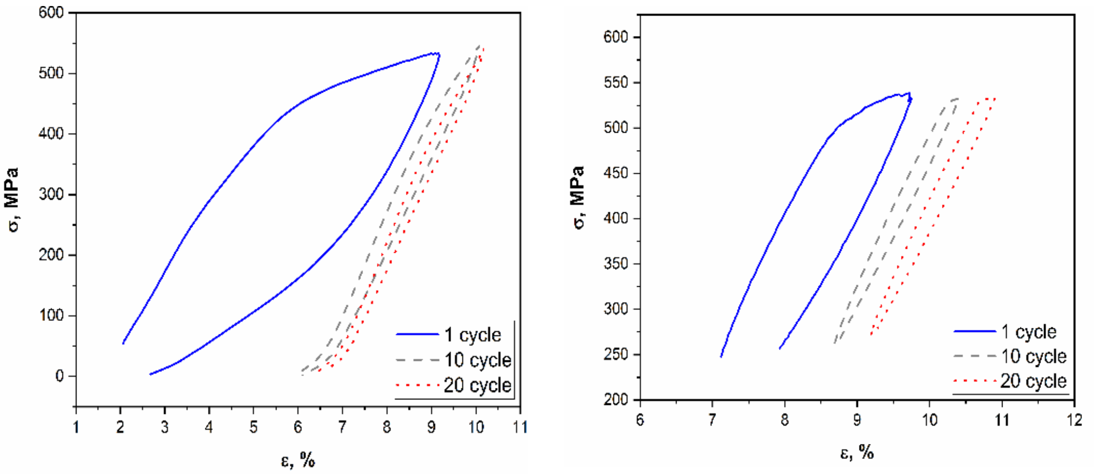

Fig. 1. Stress-strain curves: maximum stress $\sigma_{max}$ = 538 MPa and stress ratio $R = 0$ (a), $\sigma_{max}$ = 530 MPa and stress ratio $R = 0.5$ (b) [7].

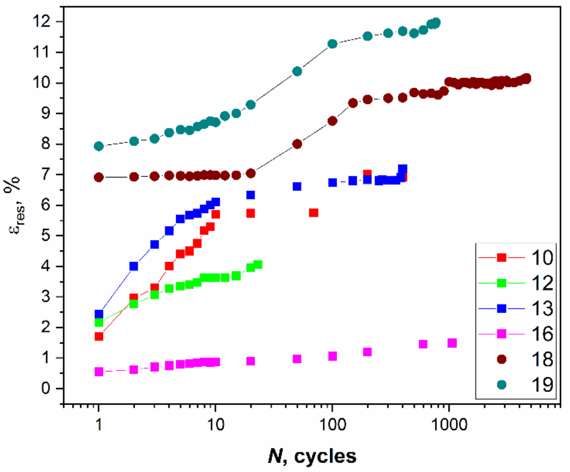

Fig. 2. Dependences of the residual strain – a) and strain range –b) on the number of loading cycles. Δσ = 492 MPa (16), 539 MPa (13), 580 MPa (10), 727 MPa (12) at stress ratio $R = 0$, Δσ = 243 MPa (18), 305 MPa (19) at $R = 0.5$.

The dependences of the stress range Δσ on the number of cycles to failure $N_f$ for NiTi alloy in ice water at stress ratio 0 and 0.5 are presented in Fig. 3. Stress range was determined at the number of half-cycles to failure. The increase of stress ratio from 0 to 0.5 decreases the fatigue lifetime under low-cycle fatigue as well signigicantly decreases the angle of relationship between lgΔσ and lg$N_f$.

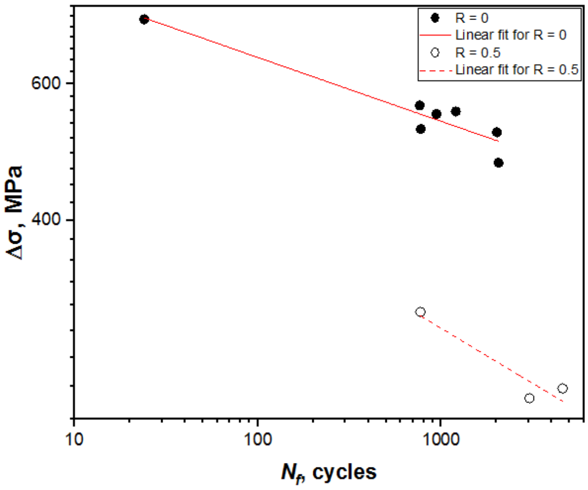

Fig. 3. Dependence of the stress range on the number of loading cycles at stress ratio 0 and 0.5

Fig. 4 shows experimental fatigue curves in coordinates strain range versus number of cycles to failure of the specimen. The strain range values were determined at the number of half-cycles to failure, in the same way as stress range. The experimental data were fitted by means of equation with the determined parameters, which are in detail described in paper [8]. In contrast to the data presented in Fig. 3, using strain range as a criterion of fatigue failure, fatigue lifetime of pseudoelastic Ni55.8Ti44.2 alloy at at stress ratio 0 is almost the same that at $R = 0.5$.

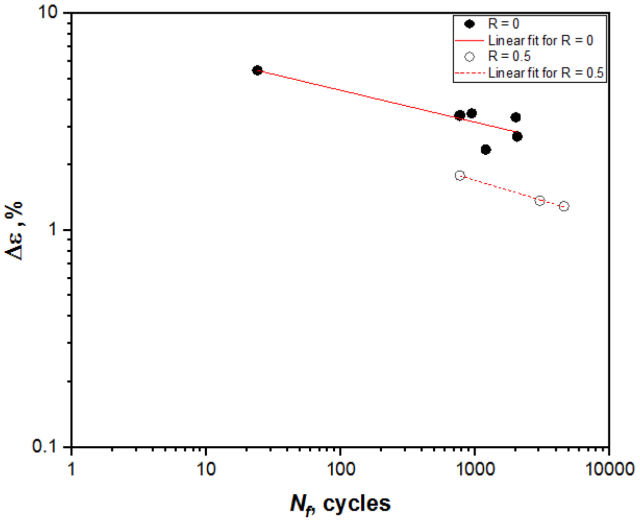

Fig. 4. Dependence of the strain range on the number of loading cycles at stress ratio 0 and 0.5

Moreover, the slope angle of both curves in logarithmic scales is also approximately the same.

## 4. Conclusions

The effect of stress ratio on functional behavior and structural fatigue of pseudoelastic $Ni_{55.8}Ti_{44.2}$ shape memory alloy was studied under the uniaxial tensile deformation at temperature of 0°C, which is above the austenite finish temperature ($A_f = – 38.7$°C).

The results show that the functional fatigue of the NiTi alloy under the stress-controlled cyclic loading is dependent on the stress range and stress ratio. With the change of the stress ratio from 0 to 0.5 the residual strain in the first and next cycles increases significantly even at lower values of stress range.

The fatigue life of NiTi alloy increases with the decrease of stress ratio from 0.5 to 0 in the case of presenting the results depending on the stress range. Nevertheless, in the case of employing the strain range the lifetime of NiTi alloy at R = 0 is is almost the same that at stress ratio of 0.5.

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