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A Study of Thin TiNi Fibers Superelasticity

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Abstract

Thin TiNi fibers which having superelasticity with diameter from 90 to 30 μm obtained from medical application alloy TN-10 by traction across dies with interval annealings are researched. Fine TiNi alloy fibers diameter of 90 to 30 microns having superelastic properties, obtained from TN-10 alloy for medical purposes by traction through dies with intermediate annealing. Availability superelastic properties allow thin fibers to function long in the body as the implant material. The optimum temperature superelastic properties of thin fibers with a diameter 90-30 μm was determined. It has been shown that with decreasing fibers diameter from 90 to 30 μm maximum temperature manifestations superelastic properties without residual deformation is shifted to higher temperatures, reaching values of 93 - 95 °C for 30 μm diameter fibers.

1 Introduction

Metals and alloys are used in many cases in medicine as implant material. Metal implants in the body tissues are subjected to alternating large deformation overtopping ability of implant material is deformed without introducing distortion in the material structure. Metals and their alloys allow alternating change in shape without residual deformation in the range of 0.1-0.3% [1]. Tissues are deformed up to 5 - 15%, so a implant can be plastically deformed even at the first cycle of the alternating deformation and break well before the end of working mode of the implant.

Task prolonged functioning of metal materials in biological tissues can be solved, if as element of implant is used superelastic fibers or products (cloth, mesh) obtained from alloys based on nickel-titanium. NiTi-based alloys is characterized by high level of superelastic properties and can withstand alternating deformation of up to 8% [1]. Deformation of implant from this alloy does not cause plastic deformation of internal structure of alloy, because Internal stress relaxation of alloy is not due to the formation of defects, but due to phase transition and formation of a martensitic structure [1]. Ultra-thin fibers of NiTi can be used in various fields of medicine, and the area of their application over time will expand.

2 Experimental

Thin fibers of TiNi alloy were obtained by traction through dies with intermediate annealing, carried out for internal stress relief. Superelastic properties were studied on Instron 3369 installation. We used in the study of thin fibers from 90 to 30 microns.

3 Results and discussion

A study of superelastic properties of thin NiTi-based alloy fibers diameters from 90 to 30 μm was carried out. During the experiments established that fine fibers on the basis of NiTi with diameter of 90 to 70 μm exhibit superelastic properties at strains up to 6%. The most complete superelastic deformation behavior of NiTi fibers d = 90 μm is realized at a temperature of 37° C (Fig. 1, a). At a temperature of 23.5° C and lower observed growth of residual deformation, which is associated with the presence of the martensite plates as the sample has a two-phase state. Upon further heating the residual strain can be completely removed, because martensite phase transformed in to B2-phase. There is a single shape memory effect. At temperatures above 70° C in the residual deformation adversely is affected plastic deformation, so the superelastic behavior above 70° C temperature is not realized. In this case, heating may only partial reduction in the amount of residual deformation. The dissipative loss on martensitic transformations in thin fibers of d = 90 mm, according to the value of the hysteresis (≈300 MPa) on the stress-strain caver, are high. The temperature of the most complete manifestation of superelastic properties of nickel titanium alloy thin fibers with a diameter of 90 μm is close to 37° C. Thin fibers diameter of 60 to 50 μm exhibit superelastic properties as well. Moreover, in fibers with a diameter of

60 μm superelastic properties are seen in a much wider temperature range of 23.5° C to 90° C (Fig. 1, b). This is due not only to high value of the difference between the minimum and maximum martensitic shear stress among all examined diameters of thin fibers, and the lowest value of the dissipative losses (<230 MPa) under martensitic transformations (Fig. 1). Expansion of temperature range of existence superelastic properties indicates a change in the ratio of titanium and nickel in the basic TiNi phase.

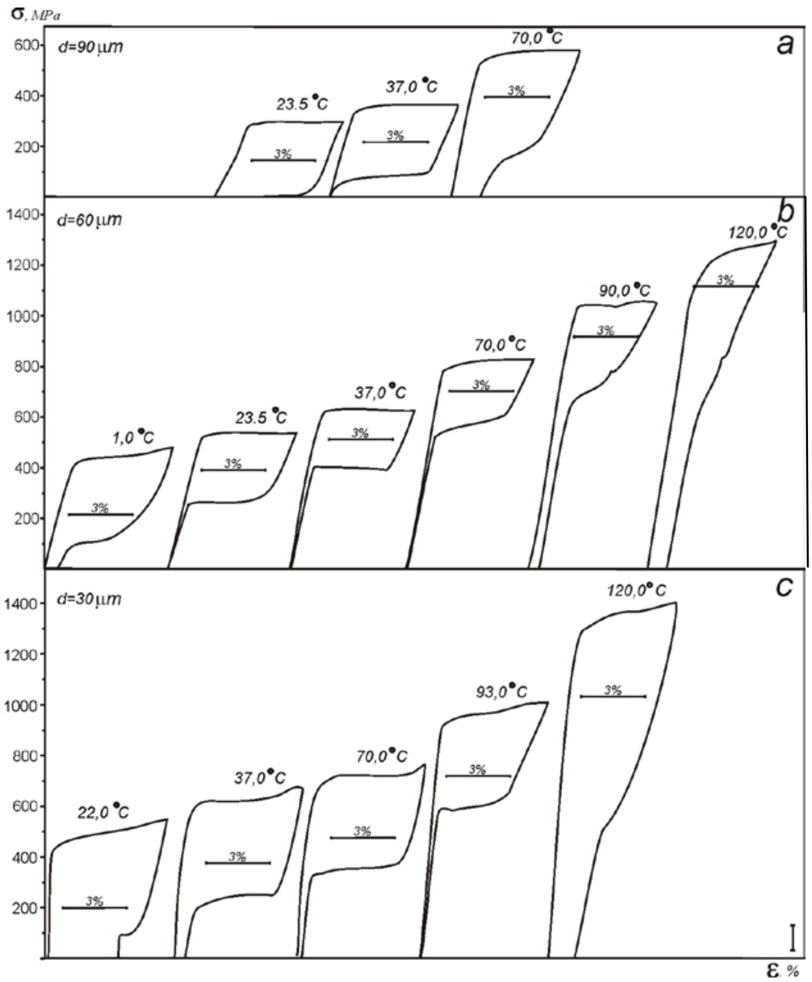

Fig. 1. Superelastic properties of thin NiTi fibers at different temperatures

Displacement occurs in the direction of enrichment nickel. Titanium, in turn, tends to segregate on the surface of NiTi fibers where oxidized, thereby increasing the relative amount of oxide layer with their thinning [2]. It sets the maximum temperature at which superelasticity fibers diameter of 60 μm has not a residual deformation, which amounted to 70° C. It should be noted that despite the fact that the residual deformation at T = 90° C does not exceed 0.5%, with a further increase in temperature of experiment superelastic properties of fibers are reduced due to increasing influence of plastic deformation mechanism. This dissipative losses when moving boundary between martensite and B2-phase rise sharply.

The effect of oxide layer increases with thinning of fibers as a factor which blocks development of the martensitic transformation in some parts of NiTi, directly adjacent to the oxide layer [3]. Superelastic behavior is characterized by a wide hysteresis in the stress-strain curve. The fibers which have diameter of 30 μm exhibits superelastic properties without residual deformation over a wider temperature range, up to 90° C (Fig. 1, c). For fine fiber from TN-10 type alloy 30 μm diameter the oxide layer is about 20% all volume fiber and this directly affects on martensitic transformation. It requires an additional load, in order to initiate a phase transition in the areas lying near the oxide layer. Thus, thinning NiTi fibers superelastic properties can occur at higher temperatures. It would seem that there is a contradiction, because the stress at which there is a complete recovery of shape after load is removed, approaching more and more to the values of yield strength and plastic deformation must increase. The authors attribute this to a size factor and increase the yield strength of thin NiTi fibers. During the manufacture of thin NiTi fibers are deformed repeatedly. As is known, any deformation value is additive and includes the bending deformation, torsion and dilatation. Thinner NiTi fibers hold reversible, without plastic deformation of the bend to a smaller radius, the same applies to torsional deformation, consequently, contribute to plastic deformation for thinner samples will be less than [4]. Repeated traction of thin NiTi fibers through a die, grains ensemble more than once deformed in one direction and grains are, firstly, more uniform in terms of grain size, and secondly, they are stretched along the axis of deformation and intertwined that positively affects the yield point and other strength characteristics [4]. In fact, considering the thin NiTi fibers, it is possible to draw an analogy with metal ropes, where individual wire elements - it is elongated and one-dimensional grains. Multiple annealing thin fibers during traction through great number dies lead to depletion of primary TiNi phase on titanium, which leads to an increase in yield strength. Increased yield point thinning fibers leads to a shift of the maximum temperature manifestation superelastic properties at higher temperatures, as confirmed experimentally (Fig. 2).

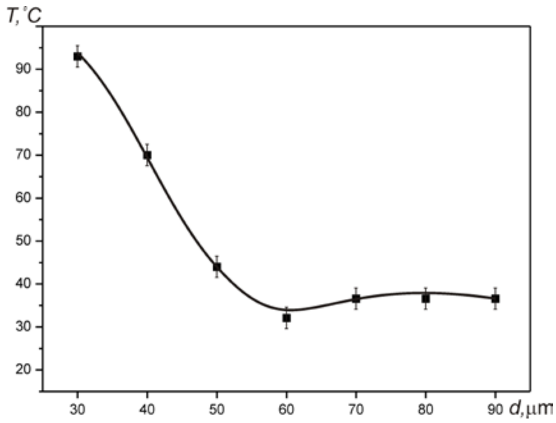

Fig. 2. Dependence of the maximum temperature at which the most pronounced effect of superelasticity from diameter of thin NiTi fibers

Thus, it is established that a decrease in the diameter of NiTi fibers most vivid manifestation of superelastic properties shifted toward higher temperatures. This shift is due to size factor and increase in yield strength with thinning NiTi fibers.

4 Summary

1. It is found that the optimum superelastic properties of thin NiTi fibers with a diameter 90-30 µm correspond to temperatures of 36 - 37 ° C.
2. With decreasing NiTi fibers diameter from 60 to 30 µm maximum temperature manifestations superelastic properties without residual deformation is shifted to higher temperatures, reaching values of 93 - 95 ° C for 30 µm diameter fibers.
3. Change the superelastic properties of the thin nickel titanium fibers associated with changes in structure and titanium ratio of nickel in matrix material, size of the oxide layer, and the size factor, which influences the reduction of accumulation of plastic deformation in bending, torsion, tension and compression superfine fibers.

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