MECHANICAL PROPERTIES AND EVOLUTION OF THE Zr1Nb ALLOY NANOSTRUCTURE AFTER VARIOUS RELAXATION IMPACTS

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Abstract: *processes of relaxation of internal stresses of the Zr1Nb alloy nanostructure after various impacts was studied. Shown that heat treatments of Zr1Nb alloy nanostructure, which provide the increase of the plasticity, changed qualitatively the alloy structure, destructing the nanostructured state, that results to decrease of the mechanical characteristics of the material and the degree of resistance to subsequent deformation during the creep at the temperature of 700 K.*
Ultrasonic impact reduces the level of internal stresses of Zr1Nb alloy nanostructure by forming the equilibrium structure of boundaries without noticeable growth of grains. During subsequent creep deformation at 700 K the relaxation of the internal stresses due to dynamic recrystallization and the formation of new stable nanostructure take place that leads to the increase of the material thermomechanical stability.
Keywords: *Zr1Nb alloy, nanostructure, creep, ultrasonic impact, thermomechanical stability.*

МЕХАНИЧЕСКИЕ СВОЙСТВА И ЭВОЛЮЦИЯ НАНОСТРУКТУРЫ СПЛАВА Zr1Nb ПОСЛЕ РАЗЛИЧНЫХ РЕЛАКСАЦИОННЫХ ВОЗДЕЙСТВИЙ

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Аннотация: *исследовали процессы релаксации внутренних напряжений в нанокристаллическом сплаве Zr1Nb после различных воздействий. Показали, что термообработки наноструктурированного сплава Zr1Nb, которые обеспечивают повышение пластичности, качественно изменяют структуру, разрушая наноструктурное состояние, что приводит к снижению механических характеристик и степени устойчивости материала к последующей деформации в процессе ползучести при температуре 700 К.*
Ультразвуковая обработка приводит к снижению уровня внутренних напряжений наноструктурированного сплава Zr1Nb за счет формирования более равновесной структуры границ без заметного роста зерен. В процессе последующей деформации в условиях ползучести при 700 К происходит релаксация внутренних напряжений вследствие динамической рекристаллизации и образование новой стабильной наноструктуры, что приводит к повышению термомеханической устойчивости материала.
Ключевые слова: *сплав Zr1Nb, наноструктура, ползучесть, ультразвуковое воздействие, термомеханическая устойчивость.*

It is known. that the annealings is typically used for the stress relaxation of nonequilibrium structures of nanomaterials, obtained by the IPD methods, the effectiveness of which increases with temperature increasing. However, the probability of the substantial grain increases with increasing the annealing temperature, which may lead to loss of advantage of nanocrystalline state, such as high strength [1]. One of the promising methods for improving the properties of nanostructured materials can be ultrasonic impact. By varying the parameters of ultrasonic impact, the structure, having needed properties, can be obtained in the material [2-4].

The purpose of this paper is to investigate the peculiarities of creep and evolution of Zr1Nb alloy nanostructure, obtained with the use of rolling and subsequent relaxation influences.

Investigation of the Zr1NB alloy prepared by the method of electron-beam melting has been studed. In order to exert influence on the structure and properties of Zr1Nb alloy the following treatment procedures were used: the combined rolling at 77 K-300 K, finite deformation (ε) was 3.9 (MT) and in an effort to reduce the internal stress level and to increase the plasticity of the nanostructured Zr1Nb alloy we have carried out the annealings in the temperature range 500 K – 870 K and the ultrasonic impact with an amplitude of 80 MPa and frequency f = 20 kHz. A selected mode of preliminary ultrasonic impact exerts a softening effect on the deformed material [2-4].

After all treatments the samples of Zr1Nb alloy were studied under creep conditions at T = 700 K. Analysis of the results shows that annealings at temperature of 500 K – 720 K leads to some change in strength characteristics of the material when compared with the initial state, however, do not affect the value of plasticity and the creep rate. The annealing temperature to T > 720 K leads to decrease the strength properties and increase of plasticity and the creep rate of nanostructured samples Zr1Nb alloy at the temperature test of 700 K. As a result of ultrasonic processing the strength characteristics of the material decreased by ~ 15% in comparison with the deformed specimens, at the same time the plasticity increased by ~ 20%.

It is known that as a result of low-intensity ultrasound treatments occurs relaxation of internal stresses in the material volume due to the number of factors. At the high-frequency alternating influences the large number of vacancies is generated, which are stimulate of non-conservative slipping [2-4]. Moreover, the dissipation of vibrational energy occurs mainly at the interface boundaries, which leads to the formation of the equilibrium state of boundary structure, as well as, reducing of the level of local stresses and the revitalization of the dislocation sources. The effect of these factors leads to the active movement, interaction and annihilation of dislocations at grain boundaries, and to the rehabilitation of the structure of boundaries.

Investigations of the structure have shown that after the combined rolling of Zr1Nb alloy on the value of true strain ε ~ 3,9 the nanostructure with the grain size of ~ 60 nm is formed. However, the nanostructure created by IPD rolling, proved to be unstable to subsequent mechanical-thermal impacts in creep conditions at 700 K. Most of the boundaries were destroyed and in their place were formed the dislocations boundaries of polygon type. The transformation of the original structure is due to the activation of the return processes near the grain boundaries [5].

Annealings of Zr1Nb alloy nanostructure in the temperature range 500 K – 800 K does not cause the significant change in the character of the nanostructure. All the properties, which are the characteristic for the nanostructured state, are stored. Initial recrystallization comprise the entire volume of material after annealing at 870 K and the formations of new grains size up to 1 mc are observed. Such structure is unstable in creep conditions at 700 K. The grain boundaries are destroyed and clusters of dislocations with a tendency to the formation of the cellular structure are formed.

Ultrasound impacts of the Zr1Nb alloy nanostructure, obtained by rolling, does not alter the morphology of the initial deformed nanostructure. However, it becomes more homogeneous and equilibrium.

The action of tensile stresses in creep conditions at 700 K of the samples after ultrasounds leads to the structure restruction and to the development of dynamic recrystallization. Average size of recrystallized grains is about 100 nm. The new recrystallization nanostructure is more adapted to the new conditions of deformation and provides the high level of strength properties and resistance to the creep while maintaining the sufficient level of plasticity, i.e. the higher level of thermomechanical stability.

CONCLUSIONS

Heat treatments that provide the growth of alloy plasticity, qualitatively changes the structure, destroying the nanostructured state that leads to the decrease in strength properties and to the increase in creep rate. Moreover, the such structure has the low thermomechanical resistant in relation to the subsequent deformation in the creep condition.

Ultrasonic impacts reduces the level of internal stresses of Zr1Nb alloy nanostructure by forming the equilibrium structure of boundaries without noticeable growth of grains. During subsequent creep deformation at 700 K the relaxation of the internal stresses due to dynamic recrystallization and the formation of new stable nanostructure take place that leads to the marked increase thermomechanical stability of Zr1Nb alloy nanostructure.

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