INFLUENCE OF STRUCTURAL INSTABILITY AT THE CREEP CHARACTERISTICS OF CONSTRUCTING MATERIALS

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The structural instability, which observed during the creep of constructing materials in different structural states, is the result from changes in the geometry of the applied stresses and strain rate and significantly influences on the creep characteristics. It is shown that the result of appearance of structural instability and the subsequent restructuring of Zr, ZrlNb, and Nb, subjected to severe plastic deformation, was the change in the law creep. Transformation of the structure of the steel 15Cr2NMFA during creep leads to changes in the character of plastic flow, the appearance of jumplike creep deformation especially at stresses close to the ultimate strength.

PACS: 62.20.HG, 61.72.FF, 61.10.-I

INTRODUCTION

It is known that non-equilibrium physical processes and systems characterized by internal instability because they contain elements of both the ordering and imbalance (ie, order and chaos). However, according to Prigogine, chaos is not only destructive force, but also the source of a new order. It contains a certain positive potential, and controlling it, can achieve improve the whole system [1–3].

However, in order to control, it is necessary understanding of causality, ie. which of actions will lead to any result. Active plastic deformation is a non-equilibrium and irreversible process. The condition of the material continuity is reduced to the need to maintain the rate of dissipation of energy, which delivered to the sample, on the certain level, predefined by external devices. In the course if this rate is less than the rate of increase of energy, the critical structural state appearing and cracks is forming. This or that structure can be maintained during plastic deformation, and can be completely destroyed.

Internal stresses field is very heterogeneous and in the local places near the top of dislocation clusters it may be sufficient for the nucleation of microcracks on the relatively early stages of deformation. To avoid such a turn of events the crystal changes the response to an external load, acting in accordance with the principle of self-preservation. of plastic deformation. According to it, such changes of the geometry or the mechanism of plastic deformation should occur, which will reduce the work hardening coefficient, i.e. should occur significant structural transformation, the essence of which – accommodative adaptation. Accommodative processes there are under the influence of the field of internal stress and executes it plastic relaxation. The nature of the external action uniquely determines the type of the stable structural state with respect to it. With respect to active plastic deformation at moderate temperatures, i.e. if to the crystal is constantly introduced dislocation the motion of which is given by the stress field, the fragmented structure will be kinetically stable The reason of stability is that the fragmented structure is not the simply barriers to strain, it takes in a plastic deformation of the sample directly involved. Fragmentation is the dominant mode of evolution of the defect structure at the stage of plastic deformation.

Another cause of kinetic instability may be the change in geometry of plastic deformation and deformation speed mode that will be accompanied by structural adjustment so as to cause the maximum intensity of the relaxation of internal stresses in accordance with the desire of the crystal to maintain its continuity. The newly formed structure as a result of the restructuring can also be fragmented but stable with respect to the new scheme of the elastic-stress state and temperature-speed mode of deformation [1–7]. Restructuring processes lead to changes in macro characteristics of the crystal.

In purpose of study the effects of structural instability on the creep characteristics of various fragmented structures carried out a number of studies in which investigated the creep of different materials and alloys with a structure formed by severe plastic deformation.

MATERIAL AND EXPERIMENTAL PROCEDURE

The material investigated was polycrystalline Zr, and ZrlNb, deformed by rolling at 300 K on different degrees of deformation. The object of investigation was also the 99.9% niobium, deformed by drawing 80% at 77 K and the ferrite pearlitic steel 15Cr2NMFA after standard processing factory.

Creep tests were carried out in the step loading regime at 300, 600, and 700 K, the measurement accuracy was $5 \cdot 10^{-5}$cm. The activation parameters and level of internal stresses were determined using the differential methods described in [8]. Tempering was carried out using a cylindrical heater, inside of which is located the sample. Limiting heat increase achieved by using special screens and isolations. The sample temperature to within 10^{-2} was measured by differential thermocouple chromel-alumel, EMF is measured with a digital voltmeter.

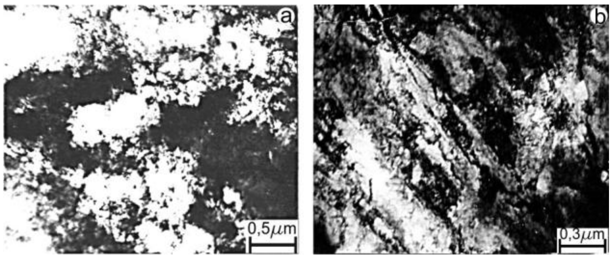
Measurements of the electrical resistance were made by the compensation scheme. The error of resistivity determination was 3 %. Investigations of the electron-microscopic structure were made on the microscope EMV-100BR.

RESULTS AND DISCUSSION

Studies Zr, Zr1Nb, and Nb, which were subjected to severe plastic deformation, have shown [9–13], that under conditions of constant rise of energy (rolling, drawing) is formed the fine fragmented structure with a high level of internal stresses.

If the elastic-stress state and the mode of speed deformation to change, i.e., under creep conditions, such structures becomes kinetically unstable and rearranges even at stresses below the yield strength, what is accompanied by a decrease in the level of internal stresses [9–13].

Fig. 1 show the structure which formed after creep Zr, strained by rolling at 300 K. As can be seen, as a result of the return process, a less strenuous structure is formed. For example in samples deformed by rolling on 0.35 cellular structure between powerful high-angular boundaries is formed (see Fig.1,a) and as a result of the restructuring of the samples, deformed by rolling on 2.5, fragmented structure is formed, but less intense and more resistant to subsequent deformation under creep conditions.



a *b*

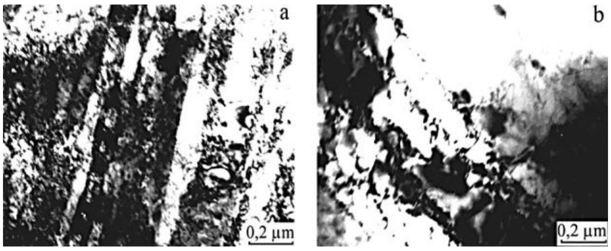
Fig. 1. TEM images of zirconium after rolling at 300 K and subsequent creep at 300 K

and $\sigma \approx 0{,}9\sigma_B$, $\varepsilon \approx 0{,}35$ *(a),* $\varepsilon \approx 2.5$ *(b)*

It seems that the plastic flow during creep first carried out by sliding the free intra-bloc dislocations and output them to the boundaries.

Next, with the strain raise, the contribution of the relaxation mechanisms (dislocation creep at grain boundaries, annihilation of opposite dislocations and absorption the dislocation of boundaries) increases. Thus in boundaries also there can be a redistribution of dislocations, accompanied by some ordering. All these processes lead to micro localization of deformation and stress relaxation [9–13].

Structural investigation of specimens of niobium after creep deformation to ~ 1% (Fig. 2) has shown that the defect structure of niobium predeformed by drawing becomes instable, when the deformation conditions are changing. Thus, the density of randomly distributed dislocations sharply decreases, the dense elongated like-sign dislocation formations are nucleated, creating a rather large gradient of local internal stresses. The old boundaries are broken and new boundaries with smaller disorientation angles are formed. In the remained boundaries the processes of dislocation redistribution occur, being accompanied by some ordering, i.e. the effects of deformation microlocalization are observed.



a *b*

Fig. 2. TEM images of niobium after drawing to 80% at 77 K (a); after creep deformation at 77 K (b)

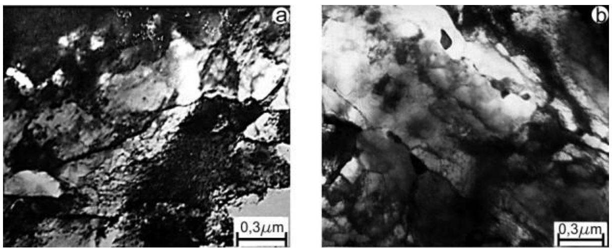
It is necessary to note that the development of creep processes in the highly distorted fragmented structures (Zr, Zr1Nb, Nb) cannot be described by the classical representations. The transition from the logarithmic creep to the power law creep, characteristic for much higher temperatures is observed, at same time the total level of internal stresses being decreased [9–13].

During the creep of steel samples at T = 600 K and strain slightly higher than the yield stress observed local area of inhomogeneous plastic flow. This is expressed in a sharp increase the magnitude instantaneous deformation. The average value of the creep rate does not change.

As a result of the processes that led to a jump in instantaneous deformation, the further character of plastic flow of the material ceases to be monotonic. The jumplike creep is observed, especially at stresses close to the ultimate strength [14].

The observed effect is the result of the kinetic instability of the structure that has arisen as a result of changes in the conditions of deformation. The structure of steel after processing factory – is a structure that was formed during hot forging of the material and subsequent annealing. In creep process, i.e during deformation under the action of the slowly increasing stresses, the elements of the recovery structure can be formed (Fig. 3). Their stability will determine the further evolution of the structure of the material and its creep resistance [15].

At stresses above the yield point, this structure is destroyed, which results in a sharp splash the value of the instantaneous deformation. This means that the energy imparted to the metal was more of binding energy between dislocations and point defects, which have ceased to be effective brakes.



a *b*

Fig. 3. TEM images of steel 15Cr2NMFA:

a – after creep at T=600 K и $\sigma \approx \sigma_{0.2}$*;*

b – after creep at T=600 K и $\sigma \approx \sigma_B$

However, the processes of the slip do not obtained development because of the high density of defects and boundaries. With further increase of stress the new dislocations boundaries are generated. They are more resistant to new conditions of deformation, however, the process creep achieves the jumplike character, and instability of plastic flow is enhanced at stresses close to the ultimate strength.

CONCLUSIONS

It is shown, that the observed during creep conditions instability of the structural state of the investigated materials is a result of the change in the geometry of the applied stress and low strain rate and significantly influences on the creep characteristics.

Consequence of the formation of structural instability and the subsequent restructuring of Zr, ZrlNb, and Nb, subjected to severe plastic deformation, transition from the logarithmic creep to the power law creep is observed, at same time the total level of internal stresses being decreased, which is the result of simultaneous work the processes of hardening and return.

Restructuring of the steel 15Kh2NMFA during creep leads to appearance a local region of inhomogeneous plastic flow at stresses slightly above the yield stress and, as a consequence, to change in the characters of further plastic flow, namely the emergence of jumplike creep.

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Article received 18.02.2015

ВЛИЯНИЕ СТРУКТУРНОЙ НЕУСТОЙЧИВОСТИ НА ХАРАКТЕРИСТИКИ ПОЛЗУЧЕСТИ КОНСТРУКЦИОННЫХ МАТЕРИАЛОВ

Е.В. Карасева

Неустойчивость структурного состояния, наблюдаемая в условиях ползучести конструкционных материалов в различных структурных состояниях, является следствием изменения геометрии приложенных напряжений и скорости деформирования и существенно влияет на характеристики ползучести. Показано, что следствием возникновения структурной неустойчивости и последующей перестройки структуры для Zr, ZrlNb и Nb, подвергнутых большим пластическим деформациям, является изменение закона ползучести. Перестройка структуры в процессе ползучести стали 15Х2НМФА приводит к изменению характера пластического течения и появлению скачкообразной деформации ползучести.

ВПЛИВ СТРУКТУРНОЇ НЕСТАБІЛЬНОСТІ НА ХАРАКТЕРИСТИКИ ПОВЗУЧОСТІ КОНСТРУКЦІЙНИХ МАТЕРІАЛІВ

Є.В. Карасьова

Нестабільність структурного стану, що спостерігається в умовах повзучості конструкційних матеріалів у різних структурних станах, є наслідком зміни геометрії прикладених напруг і швидкості деформування та істотно впливає на характеристики повзучості. Показано, що наслідком виникнення структурної нестабільності і подальшої перебудови структури для Zr, ZrlNb і Nb, що піддавалися інтенсивним пластичним деформаціям, є зміна закону повзучості. Перебудова структури в процесі повзучості сталі 15Х2НМФА призводить до зміни характеру пластичної течії і появі стрибкоподібної деформації повзучості.