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Structure-phase Transformations in Dispersive-hardening 47CrNiMo Alloy at High Temperature Deterioration

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ABSTRACT--- ***Revealed peculiarities of changing of the structure of CrNiMo alloy depending on temperature and aging time.It is disclosed that discontinuous decay forming lamellas ofα-phase occurs during the deterioration of 47CrNiMo alloy in 800-900°C temperature interval. At the same time there is a change of dispersion patterns, increasing betweenlamellae distance increases the thickness of the slats. At the front there are initial stages of the reaction slat coagulation discontinuous precipitation, which leads to a drop in the strength properties of the alloy.It is ascertained that change of decay mechanism in γ–phase from discontinuous to continuous occurs after rising the deterioration temperature to 1000°C.Phase particles can be observed already after 5 minutes of aging. Further aging at this temperature increase the volume fraction of precipitates. Similar processes occur in the alloy at 1100°C. Raising the temperature as well as increasing aging time leads to coagulation of the particles isolated α-phase. Changing the decay mechanism with a continuous intermittent causes slumping that the strength properties and increased ductility.***

Keywords--- high-temperature heating, hardening, morphology, alloy, decay

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1. INTRODUCTION

The materials used in modern technology, consist of several elements fused together, mostly metals. The number of components in industrial alloys is sometimes very large. Even with the two components of the alloy components, the result of the fusion is very complex and depends on many factors. It is very important to know what phase of the alloy are stable, what their structure is and in what proportions the elements and the temperature at which the alloy can be used most effectively in production. All these issues are usually solved experimentally, with different methods-thermal, metallographic, electron microscopic and roentgen diffraction and others.

Alloy 47CrNiMo along with high resistance to small plastic deformation and relaxation resistance in the conditions of statistical and cyclic loading has a very specific properties: high corrosion resistance, non-magnetic, low hysteresis and elastic springback, high fatigue strength, and others. 47CrNiMo alloy has satisfactory plasticity sufficient to obtaining predetermined configuration the elastic members and good weldability.

Nickel-chromium alloy 47CrNiMo used in the manufacture of elastic sensitive elements of different devices and machines, and different from other precipitation hardening alloys significantly higher corrosion resistance in aggressive environments [1]. Besides 47CrNiMo alloy is used as a material for structural elements of nuclear and thermonuclear reactors with water coolant [2].

Earlier shows the effect of quenching temperature, holding time for quenching and cooling rate on phase-structural state of the alloy 47CrNiMo. Thus, after quenching in the temperature range of the alloy structure 900-1300^{0}C 47CrNiMo is biphasic, consisting of the γ-matrix grains and α-phase particles. With increasing exposure time is set for quenching hardening dissolving α-phase, the grain growth of the matrix alloy and increase inequigranular changing nature of grain boundaries [3]. Grain growth in the alloy 47CrNiMo very strongly suppressed due to the presence of excess α-phase, which inhibits the migration of boundaries during recrystallization. Changing the structure and phase state of the alloy 47CrNiMo at various modes of quenching produces the mechanical properties [4].

2. OBJECTIVE

The aim of this work is to study the effects of aging on the structure and properties of the alloy 47CrNiMo.

3. MATERIALS AND METHODS

As shown above, the alloy 47CrNiMo relates to precipitation hardening austenitic alloys which are used in the industry. Spring-hardenable alloys - one of the most important classes of structural metallic materials, which, depending on the purpose and conditions of service of the elastic elements of the equipment must have the most diverse properties. In operation, products from spring alloys should have sufficient strength and elasticity in static, cyclic and dynamic loading, as well as high resistance to small plastic deformation. In addition, they must also meet the specific requirements of the technology, without which it is impossible to produce high quality elastic elements given configuration of devices and get a set of high physical and mechanical properties.

Subjects - alloy 47CrNiMo industrial manufacturing and standard chemical composition (47% -Cr, 5% -Mo, rest. - Ni).

As you know, metallographic analysis is widely used in industry to control the structure of the metal, semi-finished and finished products to ensure their quality. Metallographic analysis method introduced in a number of existing standards. In the microstructure control the amount of grain size, the volume fraction of the material has undergone decay and volume fraction α -phase in the alloy 47CrNiMo.

Filming of the microstructure of thin microscope was carried out with a digital camera OLYMPUS. The total increase of a microstructure in the photograph was determined by shooting in the same mode micrometer range (price 0.01 mm).

Transmission electron microscopy of thin foils, together with the methods of electron diffraction analysis gave us the opportunity to carry out the identification of precipitates at a very low volume fraction of precipitates, explore the local distribution of the phases and morphology discharge at very high resolution. Thus, in the study of the structural and phase transformations using an electron microscope, not only solved the problem of analysis of the microstructure morphology, i.e. shape, size and arrangement of phases and structural components, but electron diffraction structural and phase analysis. Observations of the collapse of the structure of the supersaturated solid solution was performed on electron microscopes EMW-100B, EM-125K, with a resolution of about 50Å. (Studies performed with the goniometer) that completely satisfied the task. Thin sections for metallographic investigations polished and etched by electrolytic method in 10% acetic chlorine electrolyte. The samples for electron microscopy as discs prepared by electro-jet, as well as the method of thinning foils.In this paper, as the main research methods were used: micro hardness testing, the study of the structure using light and electron microscopy, roentgen diffractometer analysis phase.

The heat treatment of the alloy samples was carried out in laboratory 47HNM tubular electric resistance-type SUOL-0,4.4/12-M2-U4.2 in vacuum with a residual pressure not higher than 1 Pa. The temperature is measured and regulated by a precision temperature controller VRT-2 with two thermocouples type TPP 1378. Precision control and maintain the temperature of the appliance of ART-2 was ± 0,5°Cand thermocouple temperature measurement error of the CCI in 1378 at the upper limit of the measurement 1300°C no more ±3°C, that is, the total error of the temperature measurement in the furnace does not exceed ±4°C.

4. RESULTS AND DISCUSSION

Typical microstructures corresponding to different stages of aging in the temperature range 800-1100^{0}C shown in fig.1-4. After aging at 800^{0}C over the entire volume of the material flows of discontinuous decomposition with the release of α- phase chromium-based bcc. At the same time there is a change of dispersion structure, increase corrected distance increases the thickness of the lamellae. At the front, the initial stages of the reaction occur coagulation of lamella discontinuous precipitation (fig.1b), which leads to a drop in the strength properties of the alloy. Migration of the reaction front is carried out at a considerable segment of the boundary, so while there are many plates α-phase, growing perpendicular to the moving boundary. Increasing the surface of the reaction front leads to the appearance of new particles between the growing lamellae. That during the growth take the form of plates or rods. The origin of the particles can occur both independently and branching of existing as it does not require strict crystallographic matching between the initial release and the matrix.

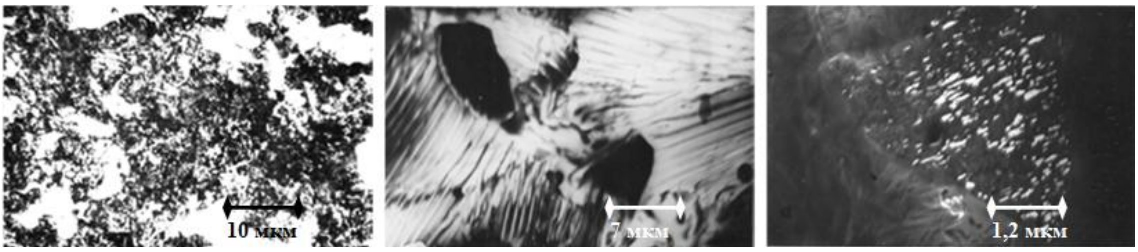

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Fig.1. Microstructure of tempered 1250^{0}C, 1 min. 47CrNiMo alloy after aging at 800^{0}C, 2:00 hours a - x1000; b - x1300; c - x8500

Decay within the globular particles α-phase leads to the formation of the layered structure of the form, with the particle size increases in comparison with the decomposition of the 700^{0}C. Particularly clearly noticeable on dark-field shot in the reflexes of α-phase, shown in Fig.1c.

Further coarsening of the structure occurs when the aging temperature and time of annealing. Thus, when 900^{0}C alloy structure becomes coarse (fig.2), dramatically increases the thickness of the lamellae and corrected distance in the areas of discontinuous precipitation. In globular particles of α-phase, a layered structure is larger than in the preceding heat treatment.

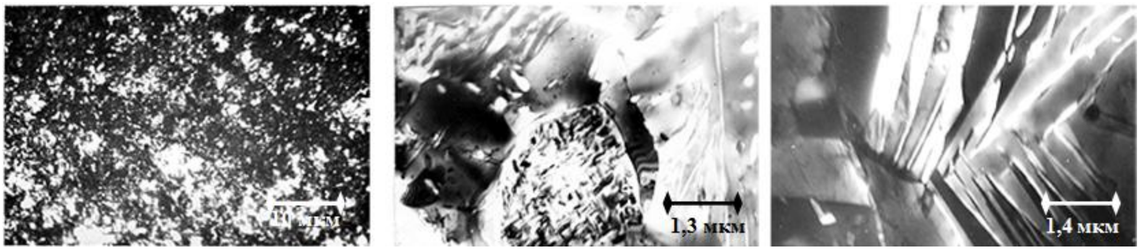

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Fig.2. The microstructure of the alloy aged at 900^0C 1250^0C from pre-hardened, 1 min: a - x1000; b - x7500; c - x7000

Increasing the temperature to 1000^0C aging leads to a change in the mechanism of decomposition of γ-phase. In contrast to the case of excess continuous phase released (fig.3, 4). Phase particles can be observed already after 5 minutes of aging. Further aging at this temperature increase the volume fraction of the precipitates. Similar processes occur in the alloy at 1100^0C (fig.4b, c). Raising the temperature as well as an increase in aging time leads to coagulation of the particles isolated α-phase. Changing the decay mechanism with a continuous intermittent causes slumping that strength properties and increases ductility of the alloy.

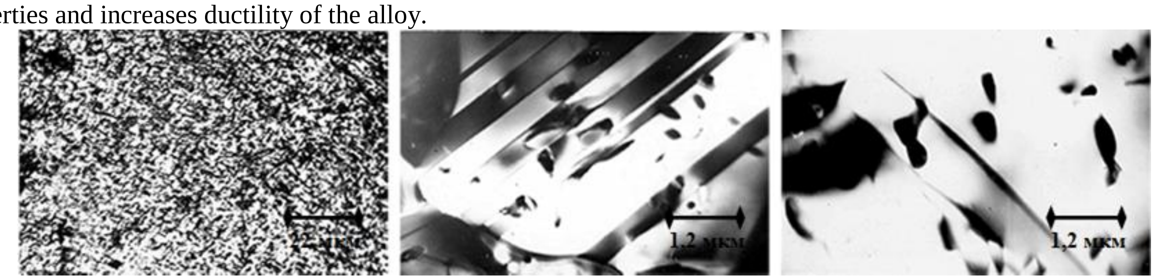

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Fig.3. The microstructure of the alloy after quenching from 47CrNiMo 1250^0C, 1 min. and aging at 1000^0C: a - 5 hours, x450; b - 1 hour,x8500; c - 1 hour,x8500

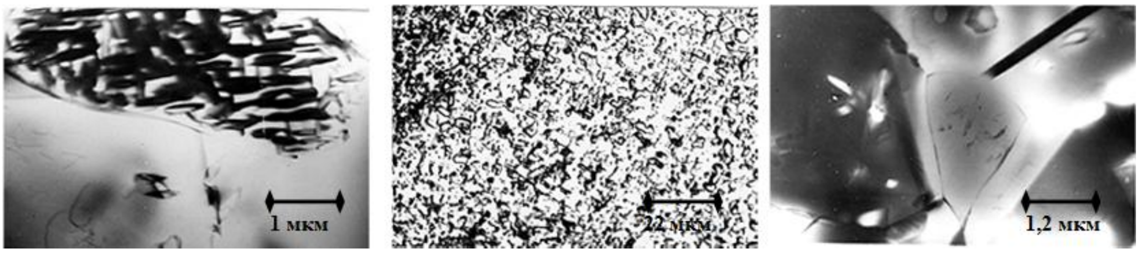

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Fig.4. Microstructure of pre-hardened by 1250^0C, 1 min. alloy after aging: a - 1000^0C 0.1hours, x10000; b - 1100^0C 0.5 hours, x450; c - 1100^0C, 1 hours, h8000

It is interesting to follow the kinetics of decay inside the globular particles of α-phase. Fig.5 shows a typical microstructure in the alloy 47CrNiMo, aged at 600^0C containing particles of α-phase. This low temperature aging was chosen for the following reasons. Firstly, at this temperature, there is no completely intermittent disintegration and therefore it is possible to clearly define α-phase particles, their morphology and the volume fraction. Secondly, at a temperature 600^0C can be disregarded practically diffusion processes, leading to dissolution of the particles. From the analysis of the structure shows that the particle volume fraction α-phase is rather high and is 10-15%α-phase particles are mainly located at the grain boundaries, mostly in the area of the three grains. Statistical research shows the structure of the structural heterogeneity of the alloy 47CrNiMo because there are areas with a volume fraction of particles α-phase more than 50%. Perhaps this is a consequence of metallurgical defects of character.

At the electron microscopic study of particle α-phase after a short aging at 600^0C established the presence of decay inside such particles (fig.5, 6). The structure of the collapse was so dispersed that gave the so-called speckled contrast and clearly manifested only in dark-field images taken in strands α-phase (fig.5a and b). Increase the aging time to 10 hours at 600^0C clearly allowed to examine the structure of the decay (fig.6a). And finally, an increase in aging temperature led to the formation of 700^0C type vidmanshtet structure (fig.6b). Thus darkfield study revealed that each plate has the form of a laminate (fig.6c). With further increase in the annealing temperature α-phase particles, as well as in the matrix structure coarsening process is observed.

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Fig.5. The structure of globular particles α-phase after quenching from 1250^0C, 1 min. and aging at 600^0C, and 2 hours: dark-field image strands α-phase x18500; b –optical photomicrography the structure shown in Fig. 5a; c - an optical micrograph, x1000

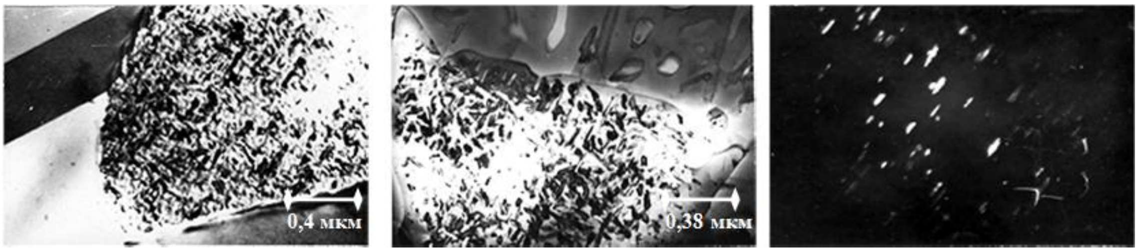

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Fig.6. The microstructure of the particles within the decay α-phase after quenching from 1250^0C, 1 min. and aging: a - 600^0C, 10 hours, x24000; b - 700^0C 5 hours, x26000; c - darkfield image structure in Fig. 6b.

5. FINDINGS

Based on these results we can conclude that:

It is found that the decay with aging of the alloy begins with 600^0C beans α-phase and has the character of a homogeneous sustained release particles, first discovered in the alloy phase based on nickel. When 700^0C in γ-alloy matrix decay occurs intermittently to form lamellae secondary α-phase, resulting in a significant hardening of the alloy. Simultaneously, there is a continuous primary decay beans α-phase.

After aging at 800^0C throughout the volume of the alloy occurs intermittently 47CrNiMo decay with allocation of α-phase based on chromium. Aging at 900^0C leads to coarsening of the structure, while dramatically increasing the thickness of the lamellae and corrected distance in the areas of discontinuous precipitation. Increasing the temperature to 1000^0C aging leads to a change in the mechanism of decomposition of γ-phase, excess α-phase is released continuously. The presence of globular particles decay inside the α-phase.

By increasing the temperature from 1200 to 1300^0C holding time for hardening of 5 seconds to 30 minutes, there are processes of dissolution of particles of the second phase, the grain growth of the matrix alloy and increase inequigranular. With increasing quenching temperature ductility of the alloy is increased, and the deforming stress decreases, which is caused not only by dissolving, but the coalescence of particles and spheroidization α-phase.

Presented in the article data on the effect of various modes of quenching and aging on the structure and properties of technological properties 47CrNiMo alloy can be used in practice in the technology of the sensitive elements elastically devices.

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