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STUDY OF CHANGES IN THE STRUCTURE OF STEELS DURING THERMOMECHANICAL TREATMENT

V. F. GAHRAMANOV
Baku Engineering University, Hasan Aliyev str., 120, Baku, AZ0102, Azerbaijan
vqahremanov@beu.edu.az

N. S. RZAYEV
Baku Engineering University, Hasan Aliyev str., 120, Baku, AZ0102, Azerbaijan
nzayev@beu.edu.az

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ABSTRACT

Thermomechanical processing is a combination of the operations of deformation by heating and cooling (in different sequences), as a result of which the formation of the final structure of a metal alloy, and consequently its properties, occurs under conditions of increased density and the corresponding distribution of structural imperfections created by plastic deformation. Therefore, firstly, research in the field of thermomechanical processing is reduced to studying the effect of plastic deformation on transformations in heat-treated alloys and on the structure in properties after these transformations. Secondly, thermomechanical processing is advisable in all cases where heat treatment of metal alloys is effective. Phase transitions during heat treatment and plastic flow occur as a result of the restructuring of the same atoms, connected not only by general regular structures, but also by certain, also to a certain extent regular, deviations from these structures, the main ones of which are dislocations.

Introduction

Thermomechanical treatment, which has been developed in recent years, allows achieving strength values for technical alloys that are greater than those achieved by alloying and conventional heat treatment. With comparable strength, thermomechanical treatment determines a higher level of plasticity and viscosity than alloying and thermomechanical treatment. Thermomechanical treatment determines a unique combination of increased strength and increased resistance to destruction, which creates better structural strength for real products.

One of the features of the thermomechanical method of hardening is that it bridges the gap between pressure metal treatment and heat treatment. In this case, both of these factors affecting the structure and properties of metal alloys are combined, creating continuity in the technological chain of product manufacturing [1].

Depending on the nature of the alloy, certain schemes of thermomechanical treatment are used, in particular, the variety of options of which is determined in particular by the variety of possible transformations. Identification of the most promising areas of use of thermomechanical treatment is possible with a relatively wide.

Research, when using most modern means of studying the structure and testing properties

As has been said, the use of thermomechanical processing is effective in cases where heat treatment is advisable. This is determined by the fact that the processes of phase and structural transformations occurring during heat treatment are significantly influenced by structural imperfections, the density of which increases as a result of plastic deformation. At the same time, as a result of some processes of phase and structural transformations, a new number of imperfections is formed. Thus, the kinetics and mechanism of phase and structural transformations during thermomechanical and heat treatment depend on the type and density of structural imperfections, and in turn, these transformations affect the number and distribution of imperfections [2].

With regard to the known (traditional) methods of heat treatment that create a complex of high mechanical properties - martensite quenching, isothermal transformation, dispersion hardening - the use of increased density and the corresponding distribution of structural imperfections in the process of structure formation has already brought significant results.

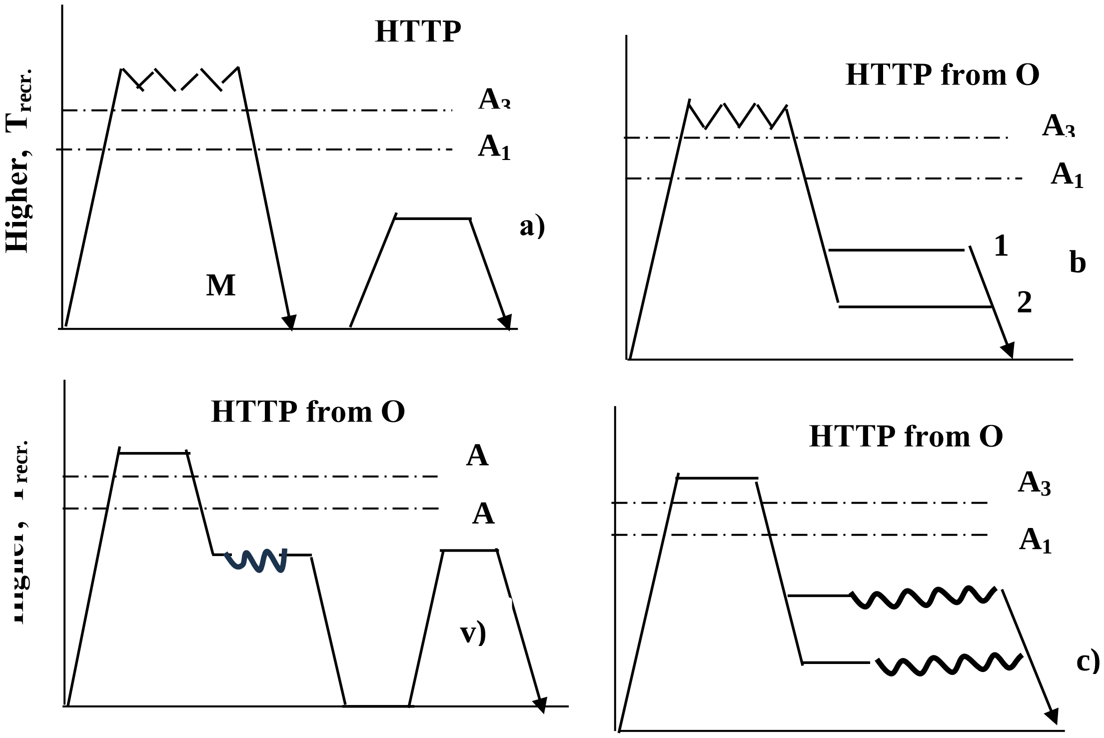

Fig. 1. Scheme of thermomechanical processing processes (meaning the main processing operations that form the final structure of the alloy, which does not change its type in the future).

a – **HTTP** with martensitic hardening and tempering; **b** - **HTTP** surface layers of parts; **v** - high-temperature thermomechanical isothermal treatment with decomposition in the pearlite (1) or bainitic (2) region; **c** - low-temperature thermomechanical treatment (ausforming);

This was manifested, in particular, in the creation of various schemes of thermomechanical treatment, determined by the variety of possible transformations. It seems appropriate to compile a classification of various methods of thermomechanical treatment, choosing in accordance with the stated principles as a classification feature the sequence of the deformation and heat treatment operation (see the diagram in Fig. 1) state if the planes of easy shear are oriented in the direction of maximum shear stress. High temperature thermomechanical treatment (HTTT).

Naturally, each type of thermomechanical In the process of thermomechanical treatment of steels hardened for martensite, all known methods of strengthening are used and enhanced: an increase in the density and, accordingly, the interaction of dislocations as a result of deformation of austenite and phase work hardening during martensitic transformation: a change in the composition of martensite due to the influence of deformation primarily on the redistribution of carbon and on the morphology of martensite crystals: the creation of more dispersed and more dispersed and more uniformly distributed particles of strengthening (carbide) phases at low tempering of martensite, while the martensite crystals themselves are crushed after TMP. Apparently, the complex of high mechanical properties achieved as a result of thermomechanical treatment is determined by a change in many elements of the structure and substructure [3,4].

The mechanical properties of some steels after high-temperature thermomechanical processing are shown in Table 1

Table 1. Mechanical properties of some steels after high-temperature thermomechanical treatment

Thermomechanical processing	**$\sigma_{\text{В}}$, кг/мм^2**	**$\sigma_{\text{Т}}$, кг/мм^2**	**δ, %**	**Ψ, кг/мм^2**	**$a_{\text{Н}}$ kг·m/sm^2**	**HRC**
Compressed air cooling in high temperature thermomechanical processing						
400	128 (113/44,5)	98 (92/103)	11.6 (10,3/13,5)	44,5 (41/47)	6,3 (5,7/6,8)	36
500	112,5 (107/1162)	86,5 (84,5/88)	12,4 (10,8/14)	55 (53,5/57)	9,7 (9,0/10,2)	29,5
600	100 (98,5/103)	82 (80,5/83)	13,6 (12,4/14,5)	58 (56,5/62)	10,4 (9,9/11,2)	28,5
Note: Upper and lower property limits are given in brackets in the numerator and denominator, respectively						

Processing is characterized by the formation of a specific structure and fine structure of steel.

The increasing density of dislocations during the A→M transformation in combination with the low solubility of carbon in the α-lattice leads to an increase in the concentration heterogeneity of martensite.

X-ray structural studies using a mathematical method to analyze the shape of the diffraction line allowed to determine the change in the composition of martensite to carbon after ordinary quenching and HTTP. It is established that as a result of HTTP, the amount of low-carbon martensite increases and the degree of tetragonality of high-carbon martensite increases at the stage of its two-phase decomposition. Compared to conventional quenching, HTTP leads to a greater degree of two-phase decay of martensite and thus to a greater relaxation ability of the martensitic structure. The resulting increased volume of low-carbon martensite in the steel is more evenly and more dispersedly distributed in the structure, which is a consequence of the influence of the most polygonized dislocation substructure of the hot-deformed austenite. These substructural features, in turn, determine a unique combination of properties after HTTP, when the resistance to brittle and viscous destruction increases simultaneously with the increase in resistance to plastic deformation. The high thermal stability of the created substructure with small-angle, fixed segregation sub-boundaries determines the possibility of regulating the mechanical properties during subsequent heat treatment operations [5].

The main mechanisms of the braking of dislocations in steel and alloys:

a) formation of clusters (segregations) of carbon atoms and degenerate elements (or vacancies) around dislocations in solid solutions;

b) increase in the density of dislocations, which leads to an increase in the interaction of moving dislocations, when the tension field around some dislocations prevents the movement of others;

в) the formation of barriers for moving dislocations in the form of interface surfaces (different types of boundaries) in crystals or particles of the second hardening phase, i.e. creation within the raft of volumes with different crystallography of sliding dislocations;

д) the creation of ordered (by composition or by crystallographic orientations) atomic structures, when moving through which dislocations spend part of their energy on performing processes of disordering - disordering, which leads to their braking. One of the structures formed after high-temperature thermomechanical processing is presented in Figure 2.

It would seem that, having such a wide arsenal of mechanisms for restraining dislocations, it is possible to achieve the creation of such a structural state in metallic alloys, in which the mobility of dislocations at the highest loads will decrease sharply, and the resistance to plastic deformation will correspondingly increase significantly.

Fig. 2. Structures formed after high-temperature thermomechanical treatment

The danger of such clusters is determined by the fact that they create a region in the metal with a very high concentration of stresses, reaching theoretical strength. In this case, it is possible to either relax the dangerous nick tensions by "breaking through" the barrier and relay dislocations to adjacent volumes, or the formation of the embryo of a brittle crack (detachment). The latter is also the mechanism of relaxation of dangerous peak tension, but by the exit, dislocation into the cavity of the crack formed [6].

At the same time, the alloy will have high values of pdastichnosti and viscosity of destruction. As convincingly shown by studies of recent years, such a structure in metal alloys, which are in a high-strength state, when semi-permeable barriers are formed, is created during unused thermomechanical processing.

The first scheme differs in relative simplicity for practical implementation.

Its disadvantage is the danger of strong recrystallization development due to high-temperature deformation carried out at the quenching temperature. In products of a significant section, the necessary changes in the structure are saved with effort. However, the use of special methods of deformation (for example, with a low speed) allows to eliminate this drawback to a certain degree. The advantage of processing according to this scheme is that the fragmented substructure created as a result has high mechanical and thermal resistance.

The second scheme essentially provides for polygon processing. Due to the relative complexity of this scheme, special techniques are required when implementing it on concrete details: in addition, the increase in service properties is observed only at relatively low temperatures [7].

The fragmented structure does not disappear, then high mechanical properties are preserved, so a short softening vacation, during which recrystallization is excluded, will lead to the disintegration of martensite (and will make possible mechanical processing, for example, by cutting) , but will not cause a significant decrease in the density of imperfections and destruction of the dislocation structure (due to the absence of migration of high-angle boundaries), characteristic of the development recrystallization. The subsequent high-speed heating under quenching with short-term exposures will lead to the transition of the α-phase with an increased density of dislocations to the γ-phase, which will also have a high density of them (the mechanism of inheritance of dislocations will be implemented here, as well as during the transition of metal from g.t.c. to[8-11]. After the final quenching, martensite is formed, which preserves (to one degree or another) the additional density of dislocations, and most importantly, to one degree or another, preserves the fragmentation that was immediately after TMO, which determines the "restoration" of the high mechanical properties that were obtained as a result "Private" TMO (effect "following").

Thus, the high-temperature deformation of austenite, accompanied by polygonization processes, leads to the formation of a stable fragmented substructure, and the martensite formed during quenching inherits the specified structural changes. In it, a thin submicroscopic delamination is created on carbon, which determines its increased resistance to deformation and plasticity (increased plasticity allows to realize high strength of low-tempered martensite, therefore the maximum hardening effect of HTTP during relatively tough tests, (for example, on tension) is observed at low tempering temperatures. However, when moving to an even tougher test method (at low temperatures, impact with a crack, etc.), an effect is found HTTP and after high tempering) in comparison with the martensite obtained by conventional quenching.

There are many experimental proofs of the preservation of the stable substructure created by HTTP during high-temperature tempering and subsequent heating under quenching and phase recrystallization. Changes in mechanical properties are determined not only by the dislocation structure, but also by changes in the degree of its interaction with carbon at various stages of processing. When the annealing temperature increases after HTTP, carbon atoms leave the martensite lattice, forming carbides, and the connection with dislocations weakens. When, upon subsequent heating to the austenitic state and rapid cooling, a sufficient amount of carbon is fixed in the solid solution, its interaction with the dislocation structure appears again, causing a corresponding change in mechanical properties

The effect of inheritance also manifests itself after cold hardening with subsequent heat treatment that does not cause recrystallization, which is achieved with rapid and short-term heating. This was the main technological scheme of preliminary thermomechanical treatment (PTMT), the feasibility of which has been confirmed by many studies.

The above methods for creating a high-strength state are carried out on steel of optimal chemical composition with a regulated method of its production, ensuring high metallurgical quality. Rational alloying of high-strength steel is of independent importance. Data on the effect of thermomechanical hardening on the structure and properties of various types of metallurgical products and specific steels are presented in the sections of this volume. The theoretical foundations of thermomechanical treatment are presented in the section.

3. Conclusions and Discussions

1. Positive changes are noticeably felt in parts subjected to thermomechanical treatment
2. During deformation, new separation boundaries are formed in austenite grains, which depends on the degree of deformation and temperature after thermomechanical treatment
3. The decrease in the carbon content (compared to the thermal treatment processing mode) increases the degree of deformation during high-temperature thermomechanical treatment
4. The mechanical properties of the plates after low and high-temperature thermomechanical treatment have increased in a complex way.
5. As a result of the high-temperature thermomechanical treatment process, not only the mechanical properties of the steel increase, but also a significant change in the shape and size of the grain is observed

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