

Study of martensite in hydraulically pressed 60C2A steel by internal friction method

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Thin structure changes in martensitic state of 60C2A steel have been studied using acoustic spectroscopy, optical microscopy and X-ray one. The hydraulic pressing followed by aging and quenching of the specimens has been found to influence considerably the level and temperature localization of the internal friction as well as the relaxation stability parameters, coercive force, and microhardness. This fact is associated with carbon deposition from the solid solution and distortion of tetragonal character thereof.

Методами акустической спектроскопии, оптической и рентгеновской микроскопии исследованы тонкие структурные изменения мартенситного состояния термообработанной стали 60C2A. Установлено, что гидропрессование с последующим старением и закалкой образцов существенно влияет на уровень и температурную локализацию внутреннего трения, а также на параметры релаксационной стойкости, коэрцитивную силу и микротвердость, что связывается с выделением углерода из твердого раствора и снижением тетрагональности его решетки.

The aim of this work is to study the martensite and its decomposition kinetics in 60C2A steel subjected previously to hydraulic pressing. The specimens pressed out through a matrix with the cone angle 38° and 14 mm in diameter at the deformation degree of 30 %. The deformed specimens were tempered at 350°C for 2 h (deformational aging). The heat treatment was carried out in salt baths to protect the specimen surface against oxidation and decarbonization. The heating rate for martensite quenching was 250°C/min. The experimental procedures are described in more details elsewhere [1].

The specimen structure changes were examined by optical microscopy and transmission electronic one (TEM) and X-ray phase analysis (XPA) using a DRON-2 unit in iron emission at the scanning step 0.05°C and 0.01°C for (211) and (220) lines, respectively. Moreover, the coercive force was measured using a KF-1 instrument as well as the Vickers hardness and the impact strength that were determined by standard physical procedures. The martensite decomposition kinetics was studied on quenched specimens using the internal friction (IF) method in vacuum under heating from 200 to 600°C at the 10 Hz frequency. The relaxation assays of the specimens in the low-tempered martensite state were carried out by determining the torque decrease at a constant strain under 1500 MPa stress. The relaxation duration was 30 min, the stress was measured every 5 min.

The complex examination has shown that the previous hydraulic pressing, deformational aging, and martensite quenching cause an increase of the specimen microhardness by 22 HV units and that of the impact strength, by 0.1 MJ/m^2 as compared to the initial non-deformed state. The grain size determination in the specimens quenched and low-temperature tempered using various regimes has shown only slight distinctions, the average grain size was about 29 μm. The foil examination provided data on the martensite thin structure. In the hydraulically pressed steel martensite, a number of specific features has been found, such as the martensite plate diminution, the structure fragmentation, and increased broadening of the diffraction lines.

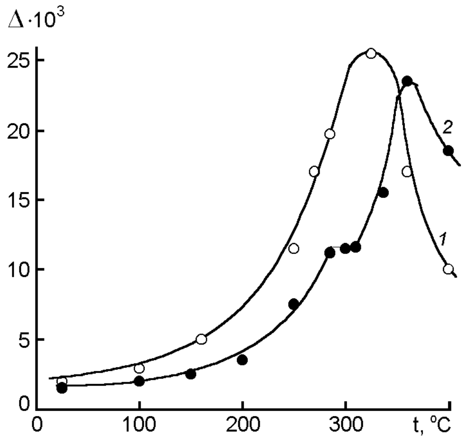

Fig. 1. Temperature dependences of IF for quenched 60C2A steel at heating in the range of 0 to 400°C. The initial state: non-deformed specimen (*1*), deformed at $\varepsilon = 30$ %, deformational aging at 350°C (*2*).

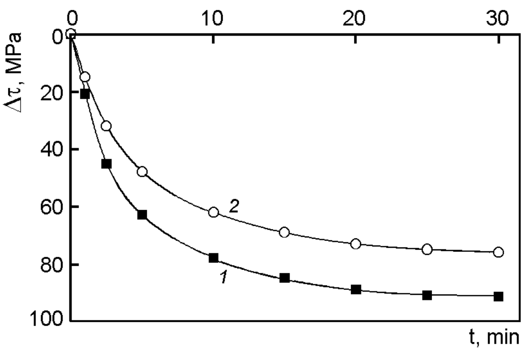

Fig. 2. Effect of hydraulic pressing and deformational aging on relaxation resistance of the steel in martensitic state. The initial state: non-deformed specimen (*1*), deformed and deformational-aged (*2*).

The experiments have shown that different technological treatments result in considerable changes in the specimen acoustic properties. The temperature dependences of IF for 60C2A steel specimens treated to martensite (see Fig. 1) demonstrate the different maxima positions. The first treatment regime (without previous hydraulic pressing) gives the maximum at 320°C (Fig. 1, curve 1). The hydraulic pressing and deformational aging prior to quenching result in a considerable decrease of the peak low-temperature branch and shift the peak as a whole towards high temperatures (curve 2). Basing on [2, 3], this fact could be related to carbon segregation out of the solid solution and distortion of its lattice tetragonality. The IF level position is associated with the residual stress relaxation [4]. After the quenching, the coercive force H_c of pressed and aged specimens is higher than that of the non-deformed ones (Table).

The XPA data and the martensite decomposition kinetic study by IF method evidence a lower carbon content in the deformed metal martensite. Perhaps the H_c increase must be related to increased density of crystal structure defects after the treatment that agrees with the increased microhardness and X-ray line broadening observed in experiments. Moreover, the low-temperature branch of the resonance curve shows a small inflection about 270°C that, according to [5], can be related to ε-carbide formation. Taking into account the lesser tetragonality extent of the martensite obtained in specimens deformed under high pressure, this carbide can be supposed to be formed already during the quenching due to spontaneous tempering. This testifies the acceleration (as compared to the "ordinary" martensite) of two-phase decomposition occurring at moderate temperatures and causing the ε-carbide release. In contrast, the single-phase decomposition occurring at higher temperatures becomes decelerated, that is, the martensite depleted of carbon becomes more resistant against tempering.

Table

Treatment mode	HV	H_c, 10^2 A/m	β (211), rad
Quenching	625	18	8.5
Hydraulic pressing, aging, and quenching	647	28	29

Fig. 2 presents the study results of relaxation resistance of the specimens. Consideration of these curves shows that the 60C2A steel in martensitic state has an insufficient relaxation resistance: at the stresses of 1500 MPa the stress drop $\Delta\tau$ is 90 to 95 MPa during 30 min (Fig. 2, curve 1). The preliminary hydraulic pressing results in increased relaxation resistance (by 16 to 17 MPa for this regime). Basing on the results presented, the specimen treatment using deformation under high pressure followed by aging and quenching can be concluded to provide an improved defect inheritance during the α-γ-α transformation. This process results in a fragmented martensite with a developed substructure and lowered carbon content as compared to the non-pressed state. This fact can be explained by accelerated two-phase decomposition. In contrast, the second stage, the single-phase decomposition, is decelerated, thus resulting in the martensite conservation up to higher temperatures. This, in turn, favors the decomposition resistance under alternating loads, thus improving considerably the working capacity of elastic elements.

References

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Дослідження мартенситу гідропресованої сталі 60С2А методом внутрішнього тертя

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Методами акустичної спектроскопії, оптичної і рентгенівської мікроскопії досліджено тонкі структурні зміни мартенситного стану термооброблeної сталі 60С2А. Встановлено, що гідропресування з наступним старінням та загартовуванням зразків суттєво впливає на рівень і температурну локалізацію внутрішнього тертя, а також на параметри релаксаційної стійкості, коерцітивну силу та мікротвердість, що пов'язується з виділенням вуглецю із твердого розчину та зниженням тетрагональності його гратки.