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Analysis of the influence of thermal and thermocyclic technology on the properties of maraging steel

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Abstract. The article presents experimental data obtained by studying the influence of changes in the geometry of parts made of maraging steels, depending on the modes of thermal and thermal cycling treatment with heating in the temperature range of α-γ transformation. The experiments were carried out on samples cut from hot-rolled sheets, pre-hardened at a temperature of 1000°C for 1 hour. Using the accelerated testing method, the relative change in resistance to stress corrosion damage was determined depending on the phase composition and aging temperature (strength) of maraging steel.

1 Introduction

The paper presents that there are some peculiarities in the production of maraging steels (MS) [1]. For example, after hot deformation of ingots (in domestic production conditions), it is not possible to obtain a homogeneous fine-grained structure in semi-finished products with large sections. To eliminate the noted shortcomings in order to increase the mechanical properties, including ductility and toughness, special heat treatment modes are proposed, including quenching from high temperatures with cooling in water and subsequent quenching (thermocyclic process) to obtain a uniform fine-grained structure. The authors note that the use of such heat treatment modes for parts provides high plasticity in the transverse direction. However, it should be taken into account that the heat treatment modes of steel are quite complex and energy-intensive [2,3].

The assessment of the mechanical properties of maraging steels, heat-treated according to an energy-efficient regime, is carried out, as a rule, on semi-finished products of various sections [4-6]. Based on a comprehensive study [7] of the structure and properties of various corrosion-resistant steels, the use of maraging steel for the manufacture of fasteners operating in marine conditions at low climatic temperatures is justified.

Thus, as noted in [8], extensive information has recently been accumulated based on the results of the analysis of the properties and structures of maraging steels. Therefore, it is relevant to analyze experimental data on the influence of changes in the geometry of parts

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made of maraging steels, depending on the modes of thermal and thermal cycling treatment. The analysis is performed with heating in the temperature range of α-γ transformation.

2 Materials and methods

A review of the work shows that the following methods are used to analyze the influence of thermal (TT) and thermal cycling treatment (TCT) on the properties of maraging steel:

- X-ray structural phase analysis;
- method of analysis of anode deposits;
- methods of chemical analysis;
- metallographic analysis;
- tests to determine mechanical, fatigue, cyclic, and corrosion properties.

In this study, the study of the influence of changes in the geometry of parts depending on the TT and TCT modes was carried out on samples 70x10x10 mm, cut from hot-rolled sheets 10 mm thick, pre-hardened at 1000°C, 1 hour. Experimental results were obtained for measuring the length of the samples depending on the preliminary HT and TCO from different temperatures in the temperature range 550...800oC. The results of changes in dimensions during subsequent hardening from 1000°C for 1 hour were also obtained.

Of practical interest is the change in dimensions during hardening relative to the dimensions of previously thermally and thermally cyclically treated samples.

An analysis of the change in dimensions after hardening from 1000°C, 1 hour and aging at 538°C, 3.5 hours, was also carried out on 26 samples from sheets 10 mm thick of steel 03X11H10M2T-VD, pre-hardened at 950°C, 1 hour and TT from a temperature of 650°C, 1 h.

3 Results and discussion

The results of the analysis of changes in dimensions after quenching are shown in Table 1, which shows the range of quenching temperatures and changes in dimensions of samples during thermal and thermocyclic (values are given after the fifth cycle) treatment.

With a normal distribution of measurement results, the change in the size of samples after quenching and aging, pre-TT at 650°C, 1 hour, is almost an order of magnitude less than those quenched at 950°C, 1 hour.

Analysis of the change in length and cross-section (thickness), obtained by calculating the change in volume determined by the method of hydrostatic weighing, showed that after TT and TCT from the low-temperature region of the α-γ transformation, the same change occurs. With an increase in temperature to 800°C, 1 hour, a decrease in the length and an increase in the cross-section (thickness) of the samples are observed.

The change in dimensions along the length and cross-section (thickness) of the samples after hardening at 1000°C, 1 hour, pre-TT and TCT from the temperature range 600...800°C, 1 hour are given in Table 1.

Table 1. Change in the dimensions of samples 70x10x10 mm of steel 03X11H10M2T-VD during hardening from 1000oC (1 hour depending on the preliminary temperature TT and TCT).

Preliminary temperature TT and TCT, °C	**Change in sample sizes after TT, %**		**Change in sample sizes after the fifth TCT cycle, %**	
	Length	**Section (thickness)**	**Length**	**Section (thickness)**
600	-0.080	0.224	0.250	0.429
650	0.040	0.259	0.320	0.463

750	-0.150	0.145	-0.080	0.334
800	-0.200	0.100	-0.180	0.140

The changes obtained in the dimensions of 03X11H10M2T-VD steel samples make it possible to predict their change during the hardening process by changing the preliminary TT and TCT modes in the temperature range of the α-γ transformation within a wide range from -0.200 to 0.320% in length and from 0.100 to 0.463% in thickness.

Table 2 presents the characteristics of resistance to stress corrosion failure (SCF) of maraging steel 03X11H10M2T-VD. The table shows the range of aging temperatures and destruction time, as well as the number of failed samples.

Table 2. Change in resistance to SCF of MCC 03X11H10M2T-VD steel depending on aging temperature.

Aging temperature, °C, during 3…5 h	**Time to destruction, hours**				
	from 0.5 to 1.5	**from 1.5 to 2.5**	**from 2.5 to 10**	**from 10 to 24**	**24 and more**
	Number of failed samples				
320	0.0	0.0	0.0	0.0	100
350	0.0	0.0	0.0	0.0	100
360	0.0	0.0	0.0	0.0	100
370	0.0	0.0	0.0	50	50
380…385	0.0	16	16	40	28
390…395	43	35	15	7	0.0
400…435	50	27	21	2	0.0
450…480	72	23	5	0.0	0.0
500	54	40	6	0.0	0.0
520	26	26	35	13	0.0
535	0.0	14	38	28	20
540	0.0	0.0	20	20	60
550	0.0	0.0	0.0	12	88
560	0.0	0.0	0.0	0.0	100
580	0.0	0.0	0.0	0.0	100

Analysis of the change in mechanical properties and phase composition as a result of TCT showed that the resulting change in phase composition with the formation of up to 50% austenite leads to a decrease in strength characteristics while simultaneously increasing the ductility of steel 03X11H10M2T-VD.

Samples subjected to TT and TCT at 650 and 750°C, 1 hour, are highly resistant to SCF. The mechanical properties of samples containing up to 50% austenite have high strength and plastic characteristics and are at a high level in comparison with modern austenitic, ferritic and austenitic-ferritic corrosion-resistant steels [9-12].

4 Conclusion

The results obtained on the change in mechanical properties and resistance to SCF depending on the aging temperatures of steel 03X11H10M2T-VD showed that with an increase in strength above 1300...1350 MPa, a relative decrease in resistance to SCF is observed. Samples aged in the temperature range of 400...500°C for 1 hour have a minimum relative resistance to SCF, and after aging at temperatures above 540°C and with a strength of 1300...1350 MPa, resistance to SCF increases significantly.

When aged from 560...650°C, steel 03X11H10M2T-VD has high resistance to SCF. The presence of retained austenite in the structure has a significant influence on the SCC resistance. Specimens containing more than 5% retained austenite when subjected to the appropriate TT during accelerated testing did not fail when held for more than 24 hours, which indicates high resistance to SCF.

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