The process of creation and subsequent hardening of a gradient carburized layer in low-carbon martensitic steel 17Kh2G2NMFTB is studied. It is shown that the structure and properties of the carburized layer can be optimized due to formation of reverted austenite hardened by quenching from the intercritical temperature range.

**Key words:** gradient layer, reverted austenite, lath martensite, low-carbon martensitic steels (LCMS).

### INTRODUCTION

Low-carbon martensitic steels (LCMS) possess a number of unique features distinguishing them from other structural steels traditionally used in machine building [1 – 5]. Rational alloying and low content of carbon in LCMS promote elevation of the stability of supercooled austenite and yield a martensite structure in large cross sections after comparatively slow cooling in air.

In order to widen the range of application of LCMS to operation under conditions of contact friction it is necessary to develop processes of their surface hardening. LCMS of grades 07Kh3GNYuA, 10Kh3GNM, and 08Kh2G2F operating under contact friction (gears, turbodrill parts) are subjected to surface hardening by carburizing and nitriding. However, grades 12Kh2G2NMFT, 15Kh2G2NMFB, and 17Kh2G2NMFTB having the highest strength are not used in a surface-hardened state [7 – 10].

In the present work we had an aim to study the formation of a surface layer in the process of carburizing of low-carbon martensitic steel 17Kh2G2NMFTB, to determine the structure and properties of the layer, and to estimate the possibility of its hardening by optimizing the modes of subsequent heat treatment at preserved structure and properties of the matrix of the metal.

### METHODS OF STUDY

We studied low-carbon martensitic steel 17Kh2G2NMFTB and (for comparison) 12Kh2G2NMFT. The chemical compositions, the hardness, and the structures of the steels in the initial state are presented in Tables 1 and 2.

Gas carburizing of the steels was performed in a Ts-75 shaft furnace at 900 – 910°C for 4 h at benzene feeding rate of 80 – 100 drops/min. Subsequent heat treatment was performed in a SNOL-type laboratory furnace. The carburized specimens were placed into a container with waste carburizer in order to avoid decarburization.
The microstructure of the steels was studied using an “OLYMPUS GX-51” microscope at magnification of ×100 – ×1000 and a “Video Test-Master. Structure 4-0” software for image analysis. The hardness was measured by the Rockwell method in accordance with GOST 9013–59; the microhardness was measured in accordance with GOST 9450–76 using a PMT-3 microhardness meter at a load of 0.5 and 0.2 N.

X-ray diffraction analysis was performed with the help of a DRON-3 x-ray diffractometer in iron Kα radiation; the results were recorded using a “DRON System for Automation of x-ray Diffractometers.”

The content of retained austenite (in %) was determined using the ratio of the integral intensities of line (311) of austenite and line (211) of martensite, i.e.,

\[ A_{\text{ret}} = \frac{100}{[1.273(I_{(311)\alpha}/I_{(311)\beta}) + 1]}, \]

where \( I_{(311)\alpha} \) and \( I_{(311)\beta} \) are the intensities of the lines of retained austenite and martensite, respectively.

The microstresses and the sizes of subgrains in austenite and martensite were computed by the method of approximation from x-ray lines (110) – (211) of martensite and (111) – (311) of austenite. The approximating functions were [6]

\[ y = \frac{1}{(1 + \alpha x^2)} \quad \text{and} \quad y = \frac{1}{(1 + \alpha x^2)^2}. \]

The standards were powders of technically pure iron and copper.

The process of decomposition of retained austenite was studied and the critical points of the carburized layers were determined using a Chevenard dilatometer on specimens 3.5 mm in diameter subjected to through carburizing. The standard was a “piros” alloy. Layer-by-layer chemical analysis was performed using an ARL-31.100 emission quantum meter.

### RESULTS AND DISCUSSION

The microstructure of the carburized layer of steels 17Kh2G2NMFTB and 12Kh2G2NMFT is presented in Fig. 1. The microhardness and the content of retained austenite are presented in Fig. 2a and b.

The structure of the carburized layer on steel 17Kh2G2NMFTB may be divided conventionally into three zones. In the first (surface) layer martensite and retained austenite are accompanied at a distance of up to \( h = 0.10 \) mm by a high amount of carbides. In the second (austenite) zone the content of austenite at a distance \( h \approx 0.20 – 0.30 \) mm from the surface attains 77% and the microhardness decreases abruptly to 460 HV (Fig. 2a and b). At \( h \approx 0.40 – 0.45 \) mm the content of retained austenite decreases to 40% due to the decrease in the carbon concentration in the layer. This causes formation of a third (martensite) zone, where coarse acicular martensite gradually transforms into lath martensite of the matrix. The microhardness in this zone increases to 620 HV in steel 17Kh2G2NMFTB and to 800 HV in steel 12Kh2G2NMFT. As the distance from the surface increases and the carbon concentration decreases, the microhardness decreases uniformly and attains 400 HV, which corresponds to the microhardness of the matrix of the steel. The hardness of the carburized layer is 58 HRC.

A distinctive feature of the microstructure of the carburized layer of steel 12Kh2G2NMFT is a high content of retained austenite (up to 85%). The distribution of the microhardness and of the amount of retained austenite after carburizing of steels 17Kh2G2NMFTB and 12Kh2G2NMFT has the same nature (Fig. 2a and b). The hardness of the carburized layer of steel 12Kh2G2NMFT is only 40 HRC due to the higher content of retained austenite in it as compared to steel 17Kh2G2NMFTB.

In order to decrease the content of retained austenite and to optimize the structure and properties of the carburized