INTERACTION OF STEEL ShKh15 WITH CONTROLLED ATMOSPHERE DURING ANNEALING


In domestic industry forged bearings are annealed in air. In this case the metal is oxidized and decarburized, requiring extensive mechanical treatment after annealing. This drawback is eliminated with use of protective atmospheres.

Calculations indicate that the use of protective atmospheres for annealing of forged bearings obtained by precision methods of forming (in Hauertg lines) and rolled shapes produced by precision rolling is economically justified. It is known [1] that foreign firms use bright annealing of forged bearings obtained by precision forging.

In practice, the following protective atmospheres are most widely used for heat treating structural and alloy steels: endothermal gas (20% CO, 40% H₂, small amounts of CO₂ and H₂O, the remainder N₂); exo-endothermal atmosphere, differing from endothermal gas in that it has only half the amount of hydrogen; lean purified explosion-proof exothermal gas or nitrogen (up to 2% CO and H₂, the remainder N₂). Oxidation and decarburization of steel ShKh15* during annealing with use of endothermal gas and exo-endothermal atmospheres are prevented by the equilibrium between the atmosphere and the carbon concentration in the surface of the steel, and with use of purified exothermal gas (nitrogen) are prevented by the inert properties of nitrogen.

Exo-endothermal atmospheres or endothermal gas (which costs 10-15% more than exo-endothermal gas) are most suitable for bright annealing of forged bearings, and therefore the experiments were made with these atmospheres, with tests of nitrogen containing ≦0.002% O₂ (dew point of the nitrogen atmosphere -27°C) with and without additions of methane in only a few experiments.

A diagram of the experimental apparatus is shown in Fig. 1. The protective gas enters through a pipe soldered to the lower section of a quartz retort. For even temperature distribution in the furnace the quartz retort was placed in a metal jacket (pipe of steel Kh23N18

* Steel ShKh15 (≦0.75% C) is single-phase after annealing at 800°C.

Fig. 1. Schematic diagram of experimental apparatus: 1) quartz retort; 2) metal jacket; 3) TEP-1 laboratory furnace; 4) tank with cooling liquid; 5) sample.

Fig. 2. Samples tested: a) specially prepared sample; b) sample cut from forged bearing ring.
with a diameter of 102 mm and wall thickness 5 mm) with a fluidized bed containing sand as the heat carrier. The temperature in the retort and in the fluidized bed was measured with thermocouples. The isothermal zone in the retort was 130 mm high.

The input of the protective atmosphere was controlled by RS-3 and RS-3A flow meters. The composition of the gas at the inlet and outlet of the retort was determined automatically by optical-acoustical gas analyzers.

Tests were made on cylindrical samples 12 mm in diameter and 60 mm long of steel ShKh15 with ground surfaces (Fig. 2a) and also on samples cut from forged bearing rings (Fig. 2b). The cylindrical samples were first decarburized in air at 700–950 °C, sorted in terms of the carbon concentration in the surface layer, and divided into groups corresponding to the degree of decarburization of forgings produced by different methods (Wagner and Hateburg lines, etc.).

The scale formed during preliminary decarburizing of the samples was not removed.

The interaction of the samples with the atmosphere was determined after 2 h at 800 °C and also under conditions simulating annealing (holding at 800 °C for 2 h, lowering the temperature to 700 °C and holding for 2.5 h). Three samples decarburized to different degrees and one control sample (not decarburized) were placed in the furnace together.

After holding in a protective atmosphere the samples were cooled in a stream of protective gas and the carbon content was determined in the surface and also through the section of the surface layer by means of local spectral analysis [2].

With endothermal gas containing 0.1% CO2 the surface is supersaturated with carbon in the process of annealing (Fig. 3). With 0.3% CO2 the carbon concentration in the surface layer increases to 0.9–0.95% even in samples decarburized to a considerable extent. Further reduction of the saturating capacity of the endothermal gas (0.65–0.7% CO2) makes it possible to obtain a carbon concentration of 0.76–0.78% in the surface layer.

Analysis of the data obtained indicates that the use of exo-endothermal atmosphere (20% CO, 20% H2, ~60% N2) makes it possible to obtain practically the same results as after annealing in an atmosphere of endothermal gas, i.e., these atmospheres are interchangeable [3]. This is confirmed in domestic (MAZ, VAZ, 11GPZ) and foreign practice with use of the Hollcroft (USA) generator and the OT-22A generator produced by SKB-3 (Minsk).

Holding in a nitrogen atmosphere with a dew point of –27° (Fig. 3) leads to an increase of the carbon concentration in the surface layer to 0.75%, probably due to the diffusion of carbon from the inner layers of the sample. However, the carbon concentration in the surface of the undecarburized control sample decreases from 1.0 to 0.6% with holding for the same time, which indicates the decarburizing influence of the nitrogen atmosphere on steel ShKh15. Decarburizing is evidently even more substantial under commercial production conditions.

The addition of methane to the nitrogen atmosphere increased the carbon concentration of the surface layer. The addition of 3 vol. % CH4 led to some increase in the carbon concentration in the surface layer, but it remained unchanged in the control sample. With the addition of 5 vol. % CH4 the decarburized surface layer was not only restored but recarburized (1.12% C and higher).

These data confirm the possibility in principle of preventing decarburizing of steel ShKh15 during annealing in a nitrogen atmosphere. However, the use of this atmosphere is economically inexpedient and the carbon potential of this atmosphere does not lend itself to control.