COMBINED SATURATION OF STEEL WITH CARBON, NITROGEN, AND OXYGEN

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The development of combined saturation of steel with carbon and nitrogen resulted from attempts to speed up the single processes of carburizing and carbonitriding and also to eliminate a series of defects common to these processes. The defects in the case are the formation of troostite, oxides, and a dense layer of cementite at a depth 0.05 mm, which sharply reduces the fatigue and contact strength of machine parts [1]. Nitrides of alloying elements reduce the hardenability of the layer to a depth of 0.4 mm, which limits the applications of steels and excludes the use of carbonitriding for parts of large section and depth of saturation larger than 1 mm [2]. Austenite grain growth occurs in carburized layers, which reduces the service life 30-40% as compared with carbonitriding [3].

To the number of combined processes speeding up saturation of steel with carbon one should add multistage carburizing and also high-temperature carburizing with heating in vacuum.

The essence of multistage carburizing is that a high carbon potential is maintained in the first stage (1.2-1.5% C) and a low potential in the second stage, the value in each specific case depending on the properties desired [4]. With optimal duration of the first and second stages the carburizing time is cut in half for the same total case depth and is reduced to one-quarter when determined by the effective depth.

Vacuum carburizing permits rapid saturation of the steel with carbon due to the increase in the processing temperature (to 1050°C) and the changes in the carbon potential of the atmosphere. This is achieved by alternating the input of city gas and evacuation of the chamber. The absence of oxygen-containing components in the atmosphere excludes the possibility of internal oxidation of the parts.

However, as studies at the Moscow Automobile Factory have shown, cementite forms both during vacuum carburizing and multistage carburizing. Also, due to the coalescence of dispersed particles of second phase after carburizing at 1050°C the austenite grains are coarser than after single-stage or multistage carburizing, even in cases of repeated quenching from lower temperatures [5]. These drawbacks make it impossible to obtain a higher strength by vacuum carburizing than by standard carburizing.

With use of combined saturation a carbon concentration gradient can be achieved by changing the oxygen potential of the atmosphere [6, 7].

In an atmosphere of endothermal gas with additions of methane the basic component — the supplier of active carbon on the surface of the steel — is carbon monoxide. Its dissociation constant at a carburizing temperature of 920-950°C is low and decomposition of CO molecules is possible only in the presence of a catalyst — iron, which is most active in the freshly reduced condition.

It was established that the reduction of iron oxides in the carburizing atmosphere is due to hydrogen. The rate of reduction is high, especially at 500-600°C. Diffusion of carbon into the lattice of the oxide is...
Impossible, and therefore the carbon concentration increases on the surface of the steel only after complete reduction of iron oxides. This is indicated by the change in the concentration of iron in samples of forging scale in an atmosphere of endothermal gas + methane at 920 ° (Fig. 1). After reduction of iron oxides the rate of the increase in the carbon concentration was three times higher in the samples investigated than in samples of Armco iron. The final carbon concentration in reduced samples was 0.2-0.3% higher than in control samples, for which it matched the potential of the furnace atmosphere measured in terms of CO₂.

Oxide films (temper colors) on the steel are reduced almost instantaneously in an atmosphere of endothermal gas. These films also have a positive effect on the rate of increase of the carbon content and its final value.

With these considerations taken into account, the following chemicothermal treatment was developed: oxidation of the parts at 450-500 ° for 0.5 h in the first cycle, followed by carburizing at 920 ° in an atmosphere of endothermal gas + methane.

Figure 2 shows the results of this treatment for piston pins of steel 15Kh. The pins were first oxidized in open resistance furnaces and then placed in a muffle-free apparatus. The carburizing time was 3 h. The accelerating effect averaged 15-20%; the surface hardness after quenching was HRC 60-62. Distortion was negligible. The surface concentration of carbon was the same in both cases, which is due to the fact that the freshly reduced surface, like any catalyst, is poisoned in the process and the activity becomes equal to that of the control sample.

After saturation for 1-1.5 h the carbon concentration in the surface is comparable with the potential of the furnace atmosphere, and consequently this treatment is effective only for short processing times. Saturation at a large depth (1.5-2 mm) requires alternating cycles of carburizing and brief oxidation. In this case the carbon concentration at the surface will vary in a sawtoothed manner. The use of these processes for saturating steel with carbon makes it possible only to speed up the saturation process. The mechanical properties are practically identical after these processes.

A higher strength can be expected from combined saturation of steel with nitrogen and carbon. This requires 100% martensite - austenite in the layer and substantial grain refining of austenite.

The presence of a troostite network during saturation of steel with nitrogen and carbon is due to the formation of nitrides of the basic alloying elements (Cr etc.). A study of the kinetics of their formation in austenite showed that austenite is substantially impoverished in these elements after saturation with nitrogen for 2 h, which greatly reduces the hardness of such steels as KhGT after standard carbonitriding for 5-10 h (Fig. 3, curve 2). Feeding nitrogen for the last two hours of carburizing and lowering the temperature from 930 to 850 °, with equalization of the temperature before quenching, makes it possible to retain nitrogen in the solid solution, exclude the formation of troostite in surface layers, and substantially increase the hardenability of the case (Fig. 3, curve 1) as compared with carburized samples (Fig. 3, curve 3). The addition of nitrogen increases the hardenability in the zone of internal oxidation and additionally accelerates the saturation process.