INCREASE OF THE STRENGTH OF TRACTOR GEARS
BY CASE HARDENING AND NITROCEMENTATION

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MAMI, Central Scientific Research Institute of Automobile Industry, ZIL
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Gear teeth are subjected in use to static, cyclic, and impact stresses. Transmission gears and rear transmission gears are subjected to particularly severe stresses. For example, in the gear teeth in ZIL-130 trucks the bending cyclic stresses are as high as 70 kg/mm² and contact stresses reach 200 kg/mm². To ensure such a high resistance to stresses the gears are subjected to chemicothermal treatment (case hardening or nitrocementation) and polishing of the teeth after heat treatment.

The investigation consisted in determining the conditions of treatment which would ensure optimum strength after case hardening and nitrocementation.

Case Hardening

Critical analysis of the results obtained in previous investigations showed that to increase the strength of case hardened steel the following conditions must be satisfied. The surface hardness must be HRC 60-63 and the hardness in the center HRC 30-43; no large martensite needles; no great amount of residual austenite and no accumulation of carbides in the structure of the layer; no ferrite in the structure of the center of the article. The thickness of the layer containing up to 0.4% C must be no smaller than 15% of the thickness of the gear tooth at the outer circumference.

For mass production of gears the optimum heat treatment condition is direct quenching with additional cooling in the case of low alloyed and small grained steels [1]. The carbon concentration on the surface should be within 0.8-1% [2], which can be ensured under industrial conditions only by operating in an endothermic atmosphere with automatic control of the carbon potential [3]. To reduce the time of chemicothermal treatment one should use combined cycles of saturation during which the carbon potential of the furnace atmosphere is kept at the level of 0.8-1% during the second (final) stage. The method of calculating the combined cycles which we checked experimentally showed that when such saturation cycles are used the duration of the process is decreased by a factor of 1.5-2 [4].

However, laboratory and industrial experiments showed that high and stable strength characteristics of the steel cannot be guaranteed even when these conditions are satisfied.

It was found that when case hardened steel containing 0.5-1% Cr and 1% Mn (steels 25KhGT, 25KhGM, 15KhGNTA, 20KhNM) are used there are two types of defects in the case hardened layer.

1. Combined saturation cycles lead to considerable heterogeneity in the distribution of elements (see figure) and of carbon in the solid solution at a distance of 0.25 mm from the surface. As the result, the hardenability in the surface zone and the strength of the case hardened steel decrease by 25-30% [5]. This defect can be completely eliminated or at least its unfavorable influence can be reduced by using a single saturation cycle with a constant carbon potential of 0.8-1%. However, this increases the saturation time by a factor of 1.5-2, and most important, one still cannot guarantee high stable strength because of the formation of the second defect.

2. The second defect is due to internal oxidation of alloyed elements—Cr, Mn, and Ti—during saturation in an atmosphere preventing scale formation (endothermic and other controlled atmospheres). Chromium and manganese are transformed into oxides at a distance of 0.02-0.03 mm from the surface. Therefore, the solid solution impoverished in alloyed elements at the periphery of the layer cannot be quenched to martensite when quenched in oil. As the result, a troostite network extending to a depth of 0.01-0.03 mm is formed on the surface of the steel. The strength of the case hardened steel decreases sharply as the result.
Further investigation confirmed the fact that internal oxidation can be prevented by adding 10% ammonia to the furnace chamber 10 min before the end of saturation [6]. However, in view of the necessity of eliminating the first defect one must necessarily use saturation conditions for one cycle with a carbon potential of 0.8-1% C, and this method is economically disadvantageous.

The most promising method of increasing the strength of case hardened steel is alloying with elements which do not undergo internal oxidation and are not susceptible to irregular distribution in the solid solution over the thickness of the case hardened layer. Molybdenum is an element which satisfies these requirements.

When the case hardenable steel is alloyed with molybdenum in the absence of chromium or when the chromium concentration is no higher than 0.5% and the concentration of manganese is no higher than 0.8% then no internal oxidation occurs in the steel, the troostite network is absent, and all the molybdenum is preserved in the solid solution, even when combined cycles of saturation are used. The quenchability of the case hardened layer in the steel with molybdenum is considerably higher than in steels containing 1% Cr and 1% Mn.

Preliminary tests of transmission gears of the ZIL-130 truck showed that the strength gears made of molybdenum steel is 25-30% higher than the strength of the steels widely used for automobile gears today. Industrial tests of this steel are in progress at the present time.

\[ \text{Nitro cementation} \]

The nitro cementation process began to be used for automobile gears quite recently, and therefore it was necessary to study the influence of a number of additional factors on the strength of the gears.

In order to ensure optimum strength, the carbon and nitrogen concentrations in the layers must be kept within definite limits. The concentration of carbon and the total concentration of carbon and nitrogen in the layer must be controlled separately [7]. In 40Kh and 25KhGT steels the total carbon + nitrogen concentration must be 1-1.25% when the carbon concentration is 0.65-0.9%. In 25KhGM steel containing molybdenum the limit concentration of carbon and nitrogen together is much higher (1.3-1.60%) when the carbon concentration is 0.75-1.20% [8].

When the concentration of nitrogen is too low (less than 0.1%) in steels used today for nitro cementation then internal oxidation of elements develops in the same way as in the case of case hardening. When the nitriding activity of the gaseous medium is high then the layer is formed in two stages: first, the steel is saturated with nitrogen to a high concentration; during the second stage the nitrided phases are decomposed with the evolution of molecular nitrogen. This leads to the formation of internal pores in the metal, probably filled with graphite (the dark component) formed as the result of the decomposition of carbide phases.

When the dark component is formed the bending and contact fatigue resistances decrease and the bending strength of the steel decreases also. Since the dark component is unacceptable in the structure of the nitro cementated steel, particular attention should be given to controlling the amount of ammonia during nitro cementation. Thus, when the layer is 0.2-0.4 mm thick the amount of ammonia added must be 3-7% of the volume of the principal gas; then the layer is 0.5-0.7 mm thick no more than 5% ammonia should be added; when the layer is 0.8-1.1 mm thick no more than 2% ammonia should be added.

A special investigation showed that the carbon in the layer resulting from nitro cementation is more active than in the layer resulting from case hardening. When the machine parts are transferred from shaft furnaces for the purpose