CHANGE IN THE DIMENSIONS OF GEAR WHEELS 
DURING GAS CARBURIZING AND QUENCHING

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The hardening of gear wheels by gas carburizing and subsequent heat treatment is always accompanied by changes in dimensions and distortion of the wheels, leading to inaccurate meshing of gears.

This is especially true of gear wheels in which the teeth are not ground after chemicothernal treatment and the distortion of the size and shape of the rim is retained in the finished part after heat treatment.

Relatively little research has been done on the technological factors involved in deformation of parts during gas carburizing and quenching. One of the most detailed studies of the distortion of gear wheels of steel 20KhNM during carburizing and quenching was made at the Gor'kii Automobile Factory in 1968. The investigation was conducted on samples of simple shape without teeth, and therefore the deformation was determined only in terms of the change in the diameter of a center hole. The analysis of the experimental data consisted of comparing the average values of the deformation obtained with different values of the factor under investigation. The results were not treated by mathematical statistics in this work or in others, and therefore much time and equipment are needed to obtain the data required. Insufficiently complete mathematical treatment of the experimental results does not make it possible to formulate objective practical recommendations.

We investigated the relationship between the structural characteristics of the material and the dimensions of carbide gear wheels, which change during chemicothernal treatment.

The dimensions of parts change during heat treatment for two principal reasons - the change in the specific volume of the steel in the carburized case during quenching and the thermal and structural stresses that occur.

Uneven deformation during quenching is one of the reasons for distortion of the geometric shape (warping) of parts. On the basis of a qualitative analysis of the factors involved in deformation we selected the criteria and planned the program of measurements to solve the problem.

The increase in the volume of the diffusion coating is proportional to its depth, the amount of martensite formed in quenching, and the carbon content of the steel. Positive quenching deformation can be reduced and its sign changed by reducing bulk deformation due to an increase in the amount of retained austenite and the larger plastic contraction in the hardened layer. It was shown in [1] that austenite may contain different amounts of carbon after carburizing, depending on the cooling rate. For this reason, the lattice constant of austenite and bulk deformation in the hardened layer change during quenching. Recrystallization also occurs in the core of Cr-Ni steels during quenching of carburized gear wheels. Due to the negligible quantity of carbon in such steels the increase in the volume is small, with mainly plastic contraction due to thermal stresses. It follows that deformation during quenching of carburized parts varies with random changes in the depth, structure, and phase composition of the hardened layer. This work was undertaken for experimental verification of this assumption.

The study was made on 50 conical gear wheels (m = 5 mm, z = 15) of steel 12KhN3A.

The experimental parts were subjected to gas carburizing in the Ts-105 furnace at 930 ± 10°C for 14 h. The parts were cooled in pits after carburizing. The parts were heated to quenching temperature

(810°C) in the electric furnace and cooled in oil to 70-80°C, followed by air cooling. Before gas carburizing and after quenching, the inside and outside diameters were measured in two planes, the tooth spacing, the deviation of the circumferential circular pitch from the nominal value, the ovality of the outer surface, and the flatness of the face.

It was assumed that the changes in the size and shape of the parts result from changes in the physical condition of the material in the process of chemicothermal treatment, and therefore the parameters characterizing the geometric accuracy will be called resultant parameters (y). The characteristics of the material responsible for the geometric accuracy of the parts will be called factorial parameters (x).

The following resultant parameters were determined from the measurements: \( y_1 \), warping of the face; \( y_2 \), the change in the diameter of the hole; \( y_3 \), the change in the diameter of the gear wheel rim; \( y_4 \), warping of the rim; \( y_5 \), the change in tooth spacing; \( y_6 \), the change in the cumulative error in the circumferential circular pitch.

The following factorial parameters were considered: \( x_1 \), the amount of retained austenite, \( \% \); \( x_2 \), the relative microdeformation of the martensite lattice, \( \% \); \( x_3 \), the size of coherent scattering blocks, \( \text{Å} \); \( x_4 \), the total line broadening from plane (110) of martensite, mm; \( x_5 \), the lattice constant of retained austenite, \( \text{Å} \); \( x_6 \), the hardness HRC on the surface of the face. Samples cut from the quenched parts were used to determine these parameters.

The phase composition and fine structure of the hardened layer were determined by x-ray analysis. X-ray patterns were made with \( K_\alpha \) Fe radiation in the URS-50IM diffractometer. A flat surface (section) at a depth of 0.8 mm in the zone of constant phase composition was analyzed on each of the 50 samples. The intensities of reflections from planes (110) and (211) of martensite and line (111) of austenite were plotted on the diffraction patterns for the samples and the annealed standard. Measuring the area under the curves of intensity distribution and the height, and dividing the area by the corresponding height, we obtained the total line broadening. The lattice constant of austenite was calculated from the diffraction peak of the intensity distribution for lines (111) of austenite [2]. X-ray analysis of the diffusion layer showed only two phases — martensite and retained austenite. The amount of retained austenite in the quenched steel was determined by comparison of the integral intensities of \( \alpha \) and \( \gamma \) phases. The approximation method [3] was used to determine the effect of block structure and microdeformation on broadening of lines (110) and (211), and the sizes of mosaic blocks and the microdeformation of the martensite lattice were calculated.

The statistical characteristics of the parameters are given in Table 1.

The experimental data were treated by the multifactoral correlation method and by regression analysis with use of the M-20 computer [4].

The main computer results and formulas were as follows:

1. Tables of original data (to verify the accuracy of the original data fed to the computer).

2. The average value of parameters \( x \) and \( y \)

\[
\bar{x}_j = \frac{1}{n} \sum_{i=1}^{n} x_i. \quad (1)
\]

3. The standard deviation of the parameters

\[
S_x = \sqrt{\frac{\sum (x_i - \bar{x}_j)^2}{n}}. \quad (2)
\]

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<th>Parameter</th>
<th>( y_1 )</th>
<th>( y_2 )</th>
<th>( y_3 )</th>
<th>( y_4 )</th>
<th>( y_5 )</th>
<th>( y_6 )</th>
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