Surface Layer Metal Diagnosis of Carburized Parts

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Abstract: The connection is made between the thickness troostite strip, hardened surface microhardness and durability of carburized parts. The technique of controlling metal properties of steel products carburized layer by the new criteria is given. The possibility of carburized parts service life predicting upon the structure and surface microhardness of hardened products is shown.

Key words: Steel · Carburized parts · Durability · Troostite strip · Microhardness · Hardened layer · Quality control

INTRODUCTION

Service life of the automobile is directly connected to the carrying surface capacity of mating parts, as they are in all cases the most loaded areas of operation. Improving the quality of the base layer, which is achieved by the accuracy of geometrical parameters, surface hardening, special coatings, etc. significantly increases the reliability and durability of engineering products [1-4]. Among all parameters involved in the formation of functionally oriented features of carburized products, an important role is paid to metal stress state and microhardness of the near-surface and subsurface layer. These factors are responsible for the ability of metal surface to resist the action of static and dynamic alternating loads, since the vast majority of parts destruction begins just from this zone [6-10].

It's not uncommon that heterogeneous structure of the hardened layer with the fine troostite strip (Fig. 1) or grid is formed on the surface of carburized parts, which leads to the creation of tensile stresses in this zone [1-3]. This will have a negative effect on the fatigue strength of parts. Therefore, the identification of structural features in the hardened surface of steel products and their neutralization is an important scientific and technical challenge to the creation of reliable and competitive metal production of machine-building industry.

The purpose of work is surface layer metal diagnostics and improvement of carburized steel parts quality control techniques.

Work procedure. Carburized tooth parts were subjected to analyses after bench and road tests with exactly defined resource resistance. Steel grades 20HGNMTA, 15HGN2TA were used for manufacture of parts.

Metallographic examination of specimens was performed at 100 and 400* magnification microscope «Neophot-21» and «IM-7200» with image system «Video Test-M» and software «Trixomet-PRO». Troostite strip (grid) identification was carried out after weak etching of
samples in 0.4% nitric acid solution in ethyl alcohol for about 15-20 seconds. Microhardness of the surface and by the cross section of reinforced carburized layer was defined on microdurometer «Durimet» at loading on indenter 0,1N and 0,05N. For effective depth of carburized layer a distance was taken from the surface to the zone with microhardness HV550. Bench and road tests of gear parts were conducted, comprising axles and gearbox of a truck.

**Results of Work:** Long production experience in the study of reinforced carburized layer metal quality showed that it is impossible to identify structural features in the near-surface zones during the assessment of surface hardness by Rockwell. Typically, these areas have a thickness not more than 0.05 mm and troostite structure, which undoubtedly has an impact on the functional properties of parts operating at alternating loads [5].

Reliable information about the quality of the near-surface carburized hardened layer by the structural state can be obtained by determining microhardness. Depending on the thickness of the troostite strip not only the microhardness of the surface changes (Fig. 2), but also the life of the parts (Table 1).

Statistical analysis of the parts resistance and subsequent metallographic researches allowed making a contribution of troostite strip to gears durability. These data showed that troostite strip thickness must be considered in determination of the effective thickness of the hardened layer as follows:

$$ \tau_{ef} = \tau_{total} - 7,3 \cdot \tau_{tr} $$

$\tau_{total}$ - the total effective thickness of the layer (including the troostite strip) mm;

$\tau_{tr}$ - troostite strip thickness, mkm.

No doubt about the legitimacy of such an approach, as the durability of parts depends on effective thickness of the hardened layer (Fig. 3).

Results of researches indicate that the quality of the hardened layer depends on a criterion which takes into account the thickness of troostite strip (grid) and microhardness, primarily of the surface, as follows:

- **Criterion ($K_r$) of troostite strip accounting:**

$$ K_r = \frac{\tau_{total} - 7,3 \cdot \tau_{tr}}{\tau_{total}} $$

- **Criterion ($K_{HV}$) of the near-surface zone hardness accounting:**

$$ K_{HV} = \frac{HV_{fact}}{HV_{theor}}, $$

where

$HV_{fact}$ - actual surface microhardness of the part;

$HV_{theor}$ - theoretical surface microhardness of the carburized part (without troostite strip) equal to 850HV.

![Fig. 2: Change of the surface of carburized parts microhardness (HV0,05) upon the thickness of troostite strip.](image)

![Fig. 3: Dependence of durability during flexural tests on the effective thickness of the hardened layer (HV0,550) in a tooth slot.](image)

<table>
<thead>
<tr>
<th>Microhardness, HV</th>
<th>Indicator, $HV_{theor}$</th>
<th>Mileage, km</th>
</tr>
</thead>
<tbody>
<tr>
<td>657</td>
<td>0,773</td>
<td>14734</td>
</tr>
<tr>
<td>878</td>
<td>1,033</td>
<td>62038</td>
</tr>
<tr>
<td>874</td>
<td>1,028</td>
<td>(2h 45 min)</td>
</tr>
<tr>
<td>965</td>
<td>1,114</td>
<td>(4h 05 min)</td>
</tr>
</tbody>
</table>

Maximum durability of parts comes on the value of the index which is equal to 1.0, i.e. if there is no troostite strip (grid) on the surface of the product.
It should be noted that this index takes into account the presence of the troostite strip and testifies the effect of a surface hardening, followed by increasing of microhardness (Table 1).

**CONCLUSIONS**

- Structural features in the hardened surface layer were identified with metal technical diagnostics of carburized parts that significantly affect the performance of operational properties of the products.
- New criteria for evaluating of the carburized layer metal properties on the steel products were proposed, which allow with a high degree of certainty judging on reliability and workability of parts in operation.
- Metal quality control technique of carburized products was worked out, based on determination of hardened layer effective depth considering the thickness of troostite strip (grid) and determining the microhardness of the surface layer of the part.

**REFERENCES**