THE EFFECT OF DEEP ANNULAR GROOVES AND FILLETS ON THE STATIC AND FATIGUE STRENGTH OF CARBURIZED STEEL 12KhN3A

E. N. Myadzelets, Yu. P. Kukhar', and T. A. Pumpyanskaya

The question of the static and fatigue strength of steel specimens having deep annular grooves and fillets has been discussed in a number of articles [1-4, et al.]. In these articles the authors, wishing to obtain specific data, have, as a rule, only investigated either repeated alternating bending, tension, or torsion of cylindrical specimens containing grooves or fillets, or their static tension. In the case of static torsion, experimental data are given mainly for specimens with fine grooves [3]. For carburized-steel specimens with annular grooves and fillets, the experimental data are meager, particularly in the case of static tension and are even less for static torsion.

In the present research we have investigated the effect of deep annular grooves and fillets of various curvatures on the static strength of carburized specimens of steel 12KhN3A in torsion, and also on the fatigue limit in pure bending with rotation.

For the investigation, we chose stock in the form of rods of steel 12KhN3A, 24 mm in diameter, from a single melt; from these rods specimens for static and fatigue testing (Figs. 1-3) were prepared, with tolerances on the final machining of 0.2 mm (on the section within the gage length) and up to 0.5 mm (over the rest of the specimen).

The grooves on the specimens (see Figs. 1b, 2b, and 3) were machined with tools of hyperbolic profile, and the fillets (Figs 1c, 2c) with tools of semicircular profile, the thickness of the final turnings being ±0.02 mm. In the static tests, 3-5 specimens were used for each radius of curvature of the groove or fillet in the case of torsion and tension separately, while in fatigue testing 10-12 specimens were used so as to enable the results to be treated statistically by the shortened method [1, 4].

The specimens were carburized by the following procedure.

1. Case-hardened to a depth of 1.2-1.3 mm in a furnace containing a gaseous carburizing agent at 930°C, held for 10 h, and air cooled.
2. Annealed at 650°C for 9 h and air cooled.

<table>
<thead>
<tr>
<th>ρ, mm</th>
<th>a₀</th>
<th>σₘₐₓ, kgf/mm²</th>
<th>q</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>1.015</td>
<td>112.0</td>
<td>—</td>
</tr>
<tr>
<td>8.0</td>
<td>1.153</td>
<td>97.0</td>
<td>0.91</td>
</tr>
<tr>
<td>1.0</td>
<td>1.80</td>
<td>63.0</td>
<td>0.97</td>
</tr>
<tr>
<td>0.5</td>
<td>2.34</td>
<td>52.0</td>
<td>0.86</td>
</tr>
<tr>
<td>0.25</td>
<td>3.09</td>
<td>38.1</td>
<td>0.92</td>
</tr>
<tr>
<td>0.18</td>
<td>3.59</td>
<td>35.0</td>
<td>0.85</td>
</tr>
</tbody>
</table>

3. Oil quenched from 800°C after being held for 1.5 h.

4. Annealed at 170°C for 3 h and furnace cooled.

Then all the specimens were grouped and polished with diamond abrasives in order to give them the required shape, which had been distorted as a result of warping that arose during heat treatment of the specimens, and to remove the oxidized surface layer of metal from the gage length. Finally the specimens were electropolished. As a result of this treatment a layer of metal 0.1-0.12 mm was removed over the gage length.

The diameter in the region of the gage length and the coordinates of the groove profiles (required for checking their curvature) were measured with a traveling microscope having scale divisions of 0.005 mm.

Below are given the results of tests on smooth specimens in tension and torsion, and also data on the hardness of the carburized layer and the impact strength of steel 12KhN3A:

\[
\begin{array}{cccccc}
\sigma_0 & \sigma_{0.2} & \% & \psi & \sigma_s & \sigma_{0.2} \\

gf/mm^2 & gf/mm^2 & gf/mm^2 & gf/mm^2 & kgf/m^2 & kgf/m^2 \\
189 & 110 & 6 & 174 & 565 & 10
\end{array}
\]

Figure 4 shows the effective coefficients of stress concentration for tension \(K_\sigma\) and torsion \(K_\tau\) as functions of the corresponding theoretical coefficients of stress concentration \(\alpha_\sigma\) and \(\alpha_\tau\) for specimens with annular grooves.

The effective coefficients of stress concentration were calculated as the quotient obtained by dividing the conventional ultimate-strength values in tension and torsion of grooved specimens (see Figs. 1b and 2b) by the corresponding conventional ultimate-strength values for smooth specimens (Figs. 1a and 2a); the theoretical coefficients of stress concentration \(\alpha_\sigma\) and \(\alpha_\tau\) were derived from Neuber's data [5], taking into account the observations of Podzolov [6] and using a Poisson's ratio of 0.3.

It can be seen from Fig. 4 that carburized steel 12KhN3A is very sensitive to stress raisers in the form of annular grooves, particularly in torsion. The fall in the conventional ultimate-strength values of grooved specimens as compared with those of smooth specimens in the range of stress-concentration levels