ENDURANCE OF SURFACE-ROLLED NOTCHED SHAFTS

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This work is concerned with the effect of surface cold working on the fatigue strength of shafts with circular grooves machined after surface rolling. The depth of the grooves was either equal to or exceeded the depth of the cold-worked layer. For comparison, identical shafts but not surface rolled were tested. The aim of the experiments was to obtain a confirmation of an assumed redistribution of the residual stresses in the notch zone of the surface work hardened shafts, Figure 1. If the residual stresses are redistributed as shown in Figure 1, the fatigue strength of surface worked specimens should increase even when the depth of the groove exceeds the depth of the hardened layer.

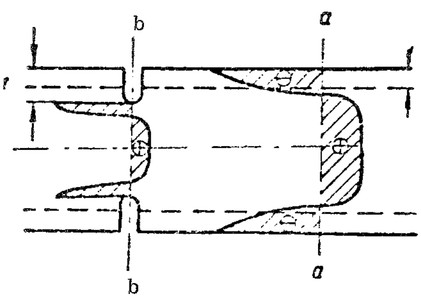

Fig. 1. Distribution of axial residual stresses in zones a-a and b-b of a surface work-hardened shaft.

t — groove depth; c — depth of the cold-worked layer.

We studied 32 mm dia bars of hot-rolled steel 45 of the following composition (%): 0.54 C, 0.70 Mn, 0.23 Si, 0.027 P, 0.021 S.

After annealing, the specimen blanks had the following mechanical properties: σ_b 63.1 kg/sq.mm, σ_s 28.6 kg/sq. mm, δ_5 22.5%, ψ 43.6%, Bhn 187.

Cylindrical specimens with a single circular groove of variable depth at mid-length were machined from this material. The grooves were made with a turning tool at a minimum depth of cut. To eliminate the work-hardening effect of the turning tool, the groove was finished with a grinding wheel by taking off a 0.2 mm layer. For the surface-rolled specimens the grooves were prepared prior to rolling.

Rolling was performed with a three-roll, spring-loaded device mounted on a lathe. The rolling parameters were as follows: roller dia - 20 mm, profile radius - 6 mm, roll pressure - 250 kg, rotational speed - 185 rpm, feed - 0.12 mm/rev, single pass. The surface hardness of the specimens measured on an oblique surface after rolling increased from

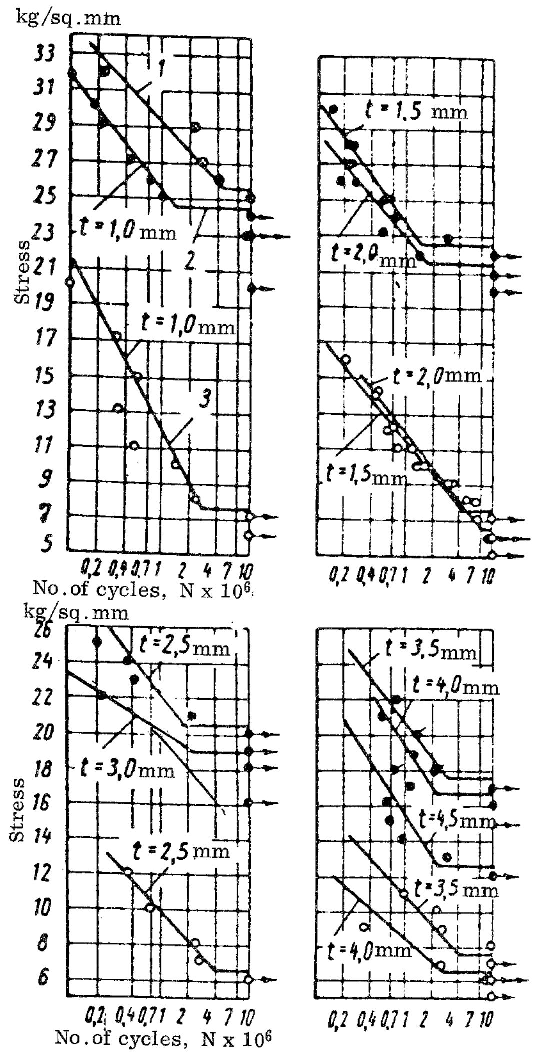

Fig. 2. S-N curves for steel 45 with grooves of various depths:

1 — unnotched; 2 — surface-rolled; 3 — unworked.

187 to 275 Vickers points. The radial depth of the worked layer was 1.8 – 1.9 mm.

Fatigue tests were conducted on UIPM machines using the principle of alternating pure bending of the rotation specimen. The tests were on a 10 million cycle basis. Figure 2 gives the fatigue curves for smooth (unworked) and notched specimens.

The unnotched specimens were characterized by a high stress concentration factor (3.5). This high value was evidently due not only to the geometrical parameters of the notches but also to the method of finishing the notch bottom (grinding). The fatigue limits were determined according to the Lokata method [not mentioned in the more common Russian text books. T.N.]. The initial stress was purposely set below the probable fatigue limit of the specimen.

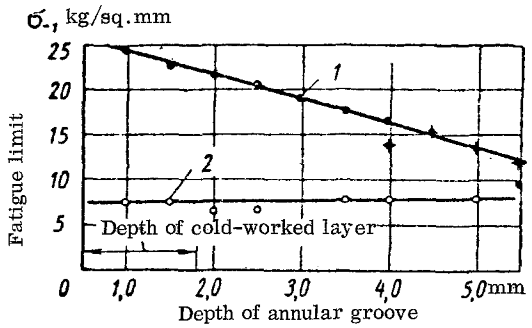

Fig. 3. The effect of depth of the annular groove on the fatigue limit. Cylindrical steel 45 specimens, 30 mm dia:

1 – specimens surface rolled prior to grooving, tested by the Lokata method; 2 – unworked specimens.

As is seen in Figure 3, the fatigue limit of surface-rolled specimens decreases with increasing depth of the material removed by the notch. However, the fatigue limit of surface-rolled specimens after providing them with a 5.5 mm deep notch was higher than in the unworked specimens of the same material.

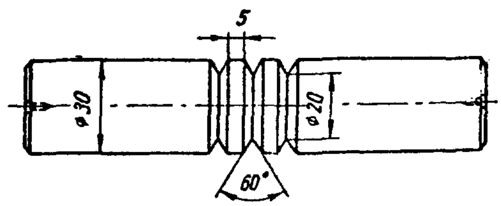

Fig. 4. Steel 45 specimen with a triple anuular notch.

To confirm the beneficial role of residual stresses due to surface hardening in increasing the fatigue strength of specimens with deep single notches, we tested also specimens with triple nothces, Figure 4. We found that there were no residual stresses at the roots of the triple notches, whether survace-rolled or not; hence, the fatigue limit of these specimens was the same.

CONCLUSIONS

1. Surface cold-working improves substantially the fatigue limit of cylindrical parts with single annular notches. This is true even when the depth of the single notch exceeds considerably the depth of the work-hardened layer.

2. The advantageous effect of surface strengthening for specimens with deep single notches is explained by a redistribution of the residual compressive stresses in the notch area.

EXCHANGE OF EXPERIENCE

CARBURIZING WITH AN OXY-ACETYLENE FLAME

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The writer conducted high-temperature carburizing experiments using an oxy-acetylene flame. The part being carburized, Figure 1, was mounted between centers vertically or horizontally. It was surrounded with burners equipped with slotted end pieces. The number of the burners and the width of the end pieces was selected so that the entire surface to be carburized is covered with a gas flame which prevented oxidation of the surface by atmospheric oxygen. An oxy-acetylene mixture was fed into the burner with an oxygen deficiency for complete combustion, i.e., to create around the treated surface a carburizing atmosphere. The flame heats the surface of the part to 1100-1200°C. Not only acetylene but also methane, natural gas or other C – containing gases can be used.

The part must be rotated all the time to secure a uniform carburized case thickness. By altering the gas to oxygen ratio, the necessary carbon content in the case can be achieved. A fine-grained structure after high-temperature carburizing can be restored by normalizing, using the same station and oxy-gas heating.

A study of high-temperature carburizing with an oxy-gas flame was conducted on steel 20 containing (%) 0.20 C,