EFFECT OF STRESS RAISERS ON THE WORKING CHARACTERISTICS OF SHIP-PROPELLER SHAFTS

G. N. Filimonov, R. G. Pogoretskii, M. M. Matseiko, V. G. Kryzhanovskii, and G. V. Karpenko

The effect of stress raisers on the fatigue and corrosion-fatigue strength of steels used in the fabrication of ship-proppeller shafts was studied. It was shown that shafts with sharp stress raisers have higher endurance in a corrosive medium than in air.

Our previous investigation [1] of the effect of working media (air, sea water) on the fatigue strength of structural steels used in the fabrication of propeller shafts for large marine vessels was carried out on notch-free specimens. However, real propeller shafts have effective stress raisers formed by fillet-shaped and tapered changes from the flange to the cylindrical part or from one diameter to another, circular grooves, keyways, etc. During the repair of propeller shafts rejected due to surface cracks or corroded metal such defects are often removed by circumferential or local grinding. Thus, it seemed desirable to study the effect of stress raisers on the working characteristics of steels used in the fabrication of marine propeller shafts carrying cyclic loads and exposed to a corrosive medium.

It has been established that stress concentration in the vicinity of circular grooves, keyways, and fillets produces a substantial reduction in the endurance of steel in air, and the more so the sharper the stress raiser. However, the endurance does not continue to decrease beyond a certain critical degree of notch sharpness. Similarly, the fatigue strength of notched specimens does not increase indefinitely with increasing notch-root radius; this strength ceases to increase when the notch root radius reaches a certain optimum value [2].

Tests [2] carried out on annealed 40Kh steel [2] showed that in the case of specimens with a 40-mm diameter gauge portion the lower and upper critical notch-root radii (ρ_{cr} and ρ_{opt}) are 0.02d and 1.0d, respectively, where d denotes the specimen diameter in the notch region. It can be assumed...
that the critical notch-root radii will be close to the above for 50-mm specimens of structural steels heat-treated to produce Class KM-25 and KT-36 strength characteristics.

Our tests were therefore carried out on cylindrical specimens with sharp \((p = 0.5 \text{ mm})\) and rounded \((p = 50 \text{ mm})\) circular notches (Fig. 1). The nominal specimen diameter was 50 mm and the notch depth 5 mm. It can be assumed that the fatigue limits of specimens with sharp and rounded notches approached, respectively, their minimum and maximum values.

The specimens were cut from large forgings of steel St. 35 carbon steel (Class KP-25 strength characteristics) and 35KhNMA and 38 KhNMA structural alloy steels (Class KT-36 strength characteristics) [1]. The required strength characteristics were obtained by normalizing followed by high-temperature tempering. The way in which specimen blanks were cut from the forgings was described in [1].

To ensure dimensional accuracy (especially for curvature sharp notch root), the notches were produced in two stages: turning with a prismatic thread-cutting tool with a tip of a given radius, followed by coarse and finishing grinding [3]. The rounded notches \((p = 50 \text{ mm})\) were machined on a hydraulically-controlled copying lathe and finished by grinding.

The method of preparing the specimens ensured the minimum depth of work-hardened surface layers and the minimum level of residual stresses.

The fatigue tests in air and in a corrosive medium were carried out in rotating bending on FMI-70 fatigue-testing machines [4]. The method of feeding the corrosive medium ensured a copious and continuous supply of the liquid (3% NaCl solution in tap water) to the specimen surface. The test base was \(10^7\) cycles in air and \(5 \times 10^7\) cycles in the corrosive medium. The stress-reversal frequency was approximately 50 cps.

Fatigue results are shown in Fig. 2, where fatigue curves of unnotched specimens [1] are included for comparison.

It will be seen that the presence of a sharp notch led to a sharp reduction in the fatigue strength of all the steels tested, and that their fatigue limits were approximately the same \((7-9 \text{ kg/mm}^2)\) despite the fact that these steels have different static strength characteristics and different fatigue limits for unnotched specimens. This is another proof of the increased notch-sensitivity of high-strength steels. The effective stress-concentration coefficients \(K_o\) of St. 35, 35KhNMA, and 38KhNMA steels are 2.9, 3.2, and 3.5, respectively, while the theoretical stress-concentration of specimens of the type used is 4.7 [5].

Tests on specimens with a rounded notch \((p = d; t = 0.1d; a_0 = 1.01)\) revealed no significant differences between their fatigue limits and those obtained for unnotched specimens. If anything, the fatigue limits of specimens with a rounded notch was slightly higher than those recorded for unnotched specimens; this effect is associated with the effect of specimen length on its resistance to fatigue [6].

The results of numerous investigations [7, 8] showed that the harmful influence of stress raisers on the endurance of steel is reduced in the presence of corrosive media. The notch-sensitivity of structural steels used in the fabrication of propeller shafts and fatigued in alternating bending in corrosive media depends on the applied stress level (Fig. 2). At