The significant influence exerted on cyclic longevity by not only the static coaxial components of the cycle, but also the latter's static components perpendicular to the applied load is established on the basis of experimental data on the fatigue of specimens with a riser and residual stresses. These data are analyzed, however, using familiar limiting relationships of the principal static and variable components of the stress-strain state. The applicability of the criterion of octahedral stresses for predicting the effect of residual stresses on the cyclic longevity of specimens with a riser is established.

The majority of currently known approaches to determination of the cyclic longevity of specimens and structural components containing a stress riser are based on consideration of the first principal stress and the strain corresponding to it [1-3]. The presence of residual stresses at the riser results in the fact that the direction of the first principal stress due to the cyclic load and the first principal stress due to residual stresses may not coincide. In this connection, we should proceed from solution of the three-dimensional problem with respect to both the stress state, and the criteria employed for the limiting state of the material. These approaches are also described [4-6]; moreover, they require experimental confirmation for different relationships between the stresses at the riser and the materials.

In a previous report [7], we analyzed the stress-strain state at a riser with allowance for residual stresses and demonstrated that the stage of instability of residual stresses, which is governed by their relaxation in the presence of cyclic stresses, consumes no more than 10% of the overall longevity (as determined by the initiation of a crack with a length of 100 μm), after which the variation in residual stresses with increasing number of load cycles is extremely small, and they can be considered constant. An analytical expression is proposed for determination of the steady-state value of the residual stresses. Thereafter, no attention is given to the damage sustained by the material as a result of residual-stress relaxation, and the effect of residual stresses on the material under a cyclic load may similarly be defined more precisely by the static component [8, 9]; this will be discussed below.

This report presents a method developed for predicting the longevity of specimens with allowance for the influence exerted by stress concentration and residual stresses. These problems involving consideration of the nonuniformity of the stress distribution across the specimen's section and nonuniaxiality of the stress-strain state of the material at the riser are solved for this purpose.

Fatigue tests were conducted on smooth and notched steel 10GN2MFA specimens to confirm the applicability of the method that we developed for longevity calculation. In that case, we used the specimens and diagrams for residual-stress initiation at the riser, which are given in [7]. In view of the fact that steady-state residual stresses are hereinafter treated as a static component during cyclic loading, one of the loading schemes calls for biaxial static compression (BSC) of the specimen. A schematic diagram of this compression of specimen 1, where the static component of the load along the y-axis, which
Fig. 1. Apparatus for creating transverse load on specimen with riser: 1) specimen; 2) spherical tip of adjusting screw; 3) adjusting screw; 4) ring; 5) resistance-type strain gages for ring calibration; 6) measuring instrument.

Since $\sigma_{rx}$ is more than an order smaller than $\sigma_{ry}$, we can assume that under BSC and PT, those static stresses along mutually perpendicular axes, whose values are close, are created at the specimen’s riser prior to the fatigue tests; in the case of a pretensioned specimen, however, the greater of the stresses ($\sigma_{ry}$) coincides with the axis of the cyclic load, and a similar stress ($\sigma_{cx}$) is perpendicular to this axis in the case of a specimen subjected to BSC.

The fatigue tests were conducted on an apparatus with an electromechanical drive under symmetric tension-compression with a frequency of 36 Hz. The initiation of a crack 0.1-mm long was adopted as a failure criterion.

Fatigue curves of smooth specimens (1), specimens with a riser and no residual stresses (2) (designation for these specimens is NRS), specimens with residual stresses at the riser (3-7), and specimens with a riser under BSC (8) are presented in Fig. 2. Fatigue curve 3 was obtained for specimens, the residual stresses at the riser of which were induced by pinning with a 2% negative allowance and subsequent unpinning (2UP), curve 4 for specimens after pinning with a 4% negative allowance and subsequent unpinning (4UP), curves 5 and 6, respectively, for specimens after preliminary compression and pretensioning.