EVALUATING THE FITNESS OF THE MATERIALS OF STEAM LINES AFTER LONG SERVICE

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The reliability and efficiency of electric power stations depends on the projected service life of certain structural elements. The reliability of the prediction of service life for elements of steam lines, especially pipe bends, is one of the main steps in solving the overall problem of increasing the reliability of heat and electric-power generating equipment.

The present article analyzes some aspects of evaluating the residual service life of heat-resistant materials which have served for long periods under high temperatures. The safe life of structural elements of heating plants is evaluated by several methods which can be tentatively divided into quantitative and qualitative.

The qualitative methods are based on results of studies of the chemical composition, microstructure, and dislocation structure of the material, carbide analysis, and the short-term mechanical characteristics of the structural material, among other factors.

Quantitative methods are based on the use of the calculated working stress in the most heavily loaded volumes of the structural materials and their long-term strength characteristics. There are also methods of evaluating safe life from the change in the density of the material [1, 2] and by monitoring creep of the structural element.

Here we use certain quantitative methods of evaluating residual life.

As the test material we examined pearlitic heat-resistant steel 12Kh1MF. We studied bends in steam lines made with this steel. Table 1 gives data on the geometric dimensions, service conditions, and the plastic strain accumulated in service.

In accordance with specifications, standard specimens are prepared and tested for rupture strength and creep to determine the residual safe life of a structural material (in particular, the material of pipe bends).

The test data and the results of its analysis are used to construct the rupture-strength curve in the coordinates log σ-log τ. Then the residual life is determined from the corrected stress in the material multiplied by the safety factor.
TABLE 1. Main Geometric Dimensions and Service Characteristics of the Investigated Steam Lines of Steel 12Kh1MF

<table>
<thead>
<tr>
<th>Section of steam line</th>
<th>Pipe dimensions, mm</th>
<th>Steam pressure, MPa</th>
<th>Service temp, °C</th>
<th>Service time, 10³ h</th>
<th>Plastic strain, %</th>
<th>Corrected stress in bend, MPa</th>
<th>Theor. stress in bend, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bend № 1</td>
<td>273×10</td>
<td>10</td>
<td>540</td>
<td>68</td>
<td>0.42</td>
<td>68</td>
<td>51.8</td>
</tr>
<tr>
<td>Bend № 2</td>
<td>323×41</td>
<td>14</td>
<td>555</td>
<td>78.2</td>
<td>0.79</td>
<td>68</td>
<td>51.8</td>
</tr>
</tbody>
</table>

Use of the above-described theoretical-empirical method of evaluating the durability of heat-resistant materials requires extrapolation of the rupture-strength characteristics to the value of the theoretical corrected stress.

The results of tests of steel 12Kh1MF at several temperatures including the service temperature, conducted in accordance with OST 108.901.102-78, are shown in Fig. 1.

The stress-rupture test results for steel 12Kh1MF were extrapolated with the use of the following temperature-time relations:

- **Larson-Miller**
  \[ \lg \tau = A_0 + A_1 T^{-1} + A_2 T^{-1} \lg \sigma + A_3 T^{-1} \lg^2 \sigma, \]

- **Dorn**
  \[ \lg \tau = A_0 + A_1 \lg \sigma + A_2 \lg^2 \sigma + A_3 T^{-1}, \]

- **Manson-Sakkop**
  \[ \lg \tau = A_0 + A_1 \lg \sigma + A_2 \lg^2 \sigma + A_3 T, \]

- **Conrad**
  \[ \lg \tau = A_0 + A_1 \sigma + A_2 T \sigma + A_3 T^{-1}, \]

- **Korchinskii-Klauss**
  \[ \lg \tau = A_0 + A_1 \lg \sigma + A_2 T^3 \sigma + A_3 T^{-1}, \]

as well as by the method of generalized curves [3].

The corrected stress in a straight section of a cylindrical pipe was determined from the formula [4]

\[ \sigma_{cr} = \frac{P (D_n - S_w)}{2S_w \varphi_w}, \]

where \( D_n \) is the outside diameter of the pipe, mm; \( S_w \) is the nominal wall thickness, mm; \( P \) is the theoretical excess pressure, MPa; \( \varphi_w \) is the strength factor of the weld.

The following relation was used to calculate the stresses in the knee of the bend [4]

\[ \sigma_{eqv} = \sigma_{cr} \left( K + 4 \chi_e \frac{R}{D_n} \gamma_m \frac{a}{100} \right), \]

where \( K \) is a coefficient, \( K = (4R/D_n + 1)/(4R/D_n + 2); R \) is the radius of the bend; \( \chi_e \) is a coefficient accounting for the reduction in the effect of ovality under creep conditions; \( \gamma_m \) is the hoop-stress intensity factor; \( a \) is the ovality of the cross section,

\[ a = a_{eqv} = \xi \frac{D_{n,\text{max}} - D_{n,\text{min}}}{D_{n,\text{max}} + D_{n,\text{min}}} \cdot 100 \% ; \]

\( \xi \) is a coefficient accounting for distortion of the form of the cross section of the bend.

Table 2 shows extrapolated times to rupture for the thus-calculated working stress in the investigated bends.

One important method of evaluating the residual life of the materials of steam lines in the case of a known working stress is the use of creep characteristics. To this end, we