INFLUENCE OF THE CONDITION OF THE METAL AND THE LEVEL OF STRESSES
ON THE LIFE OF STEAM LINE BENDS OF 12Kh1MF AND 15Kh1M1F STEELS

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On the basis of known data on the properties of 12Kh1MF and 15Kh1M1F steels in various structural conditions the interrelationship of the structural condition, work hardening, and strength safety factor of typical steam line bends was established. The approximate values of the creep properties of the steels at the service level of stresses were determined. There was noted a significant difference (primarily in the direction of a reduction) in the strength safety factors corresponding to them from those calculated from the properties obtained in tests at high stress levels.

Bends are the steam line elements most subject to damage and more accurate determination of their calculated life remains a pressing problem. The stresses and strains necessary for determination of the life of a bend are determined with use of the power rule of creep

$$\dot{\varepsilon} = 10^{-\gamma} (\sigma/\sigma_c)^m,$$

where $\dot{\varepsilon}$ is the rate of steady creep, $\sigma$ is stress, and the parameters $m$ and $\sigma_c$ are, respectively, the exponent of creep and the creep strength (1% in $10^5$ h) and are obtained from uniaxial tensile tests of specimens.

Normally the calculation is made using reference values of the parameters for a certain type of steel and a given temperature. It is known, however, that the creep characteristics change depending upon the structural condition of the steel, the degree of work hardening caused by plastic deformation of the pipe in production of the bend, and the level of stresses. In connection with this the question arises of how significant the influence of these factors is on the life of a bend and whether they must be taken into consideration in the calculations. This question is considered below on the basis of data on 12Kh1MF and 15Kh1M1F steels, which are widely used for steam lines.

Method. The influence of individual factors on the life of bends was determined from the results of comparison of calculations made by the same method with values of the creep and stress-rupture properties corresponding to different conditions of the steel or different levels of stresses. Basically a simplified variation [1] of the earlier described method [2] making it possible to take into consideration loading of the bend not only by internal pressure but also the bending moment from relaxing compensation loads was used. To calculate the influence of nonuniform distribution of the properties of the material in the cross section of the bend the calculations were made using the method of [3].

The calculations were made for typical dimensions and loading conditions of bends with three values of compensation loads: in the absence of a bending moment; with greatest positive bending moment allowed by standards; with the same negative moment. The investigation results were compared based on the stresses, on the change in out-of-round of the bend, and on the strength safety factor

$$n = \sigma_{s.r}/\sigma_c,$$

where $\sigma_{s.r}$ is the stress-rupture strength of the steel during the time of creep and $\sigma_c$ is the calculation stress equal to the maximum circumferential stress in the cross section of the bend averaged for the time of creep.

The dimensions of the bends for which the calculations were made and their loading conditions are given in Table 1.

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TABLE 1. Dimensions of the Bends and Their Loading Conditions

<table>
<thead>
<tr>
<th>Bend No.</th>
<th>Steel</th>
<th>Pipe outer diam., mm</th>
<th>Wall thickness, mm</th>
<th>Bend radius, mm</th>
<th>Initial out-of-round of bend, mm</th>
<th>Temperature, °C</th>
<th>Internal pressure, MPa</th>
<th>Initial bending moment, N·mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12Kh1MF</td>
<td>273</td>
<td>20</td>
<td>1370</td>
<td>6</td>
<td>540</td>
<td>10</td>
<td>±69·10^6</td>
</tr>
<tr>
<td>2</td>
<td>12Kh1MF</td>
<td>426</td>
<td>17</td>
<td>1700</td>
<td>4</td>
<td>570</td>
<td>4</td>
<td>±12·10^6</td>
</tr>
<tr>
<td>3</td>
<td>15Kh1MF</td>
<td>465</td>
<td>75</td>
<td>2100</td>
<td>4</td>
<td>545</td>
<td>25</td>
<td>±52·10^6</td>
</tr>
<tr>
<td>4</td>
<td>15Kh1MF</td>
<td>630</td>
<td>30</td>
<td>1000</td>
<td>8</td>
<td>540</td>
<td>4</td>
<td>±76·10^6</td>
</tr>
<tr>
<td>5</td>
<td>15Kh1MF</td>
<td>630</td>
<td>30</td>
<td>1000</td>
<td>4</td>
<td>540</td>
<td>4</td>
<td>±76·10^6</td>
</tr>
<tr>
<td>6</td>
<td>12Kh1MF</td>
<td>159</td>
<td>22</td>
<td>650</td>
<td>5</td>
<td>520</td>
<td>25</td>
<td>±32·10^6</td>
</tr>
</tbody>
</table>

![Graph](image-url)

**Fig. 1.** Stress-rupture strength for 10^5 h in relation to the structural condition of the steels [5-11] and temperature: 1) structure 1; 2) structure 2-3); 3) structure 4-5; 4) structure 6; 5) structure 7-8.

**Influence of Structural Condition.** Data on the creep and stress-rupture strength of 12Kh1MF and 15Kh1MF steels in different structural conditions known from literature sources differs significantly [4-11]. Differences are observed in the values determined but the character of the change in them in relation to structure rating is preserved (Fig. 1).

In the calculations made by us the fullest and most systematized information presented in [6, 7] was used.

From the calculations it follows that with an increase in the structure rating there is an increase in the rate of change of out-of-round of the bend. In the bend with a structure with a rating of 6 the rate of change is several times greater than in the bend with a structure rating of 1. Subsequently to abbreviate the description of the structure with a rating of 1 we will call it a 1 structure, the structure with a rating of 6 a 6 structure, etc.

With a bending moment of M ≤ 0 the calculated stresses in a bend of 12Kh1MF steel with a 6 structure are 20-25% lower than with a 1 structure. In the case of a positive moment they may be both 7% lower and 20% higher. In the 15Kh1MF steel thick-walled bend No. 3 with a 6 structure and M ≥ 6 the stresses differ from those in a bend with a 1 structure only within limits of +2 to -8%. With M < 0 they are 4-13% lower. For the No. 4 and 5 thick-walled bends with a small ratio of bend radius to pipe diameter the differences are more significant.

On the basis of the strength safety factors obtained (Table 2) the following was noted. In the case of a moment of M > 2, which is most frequently encountered in practice, the strength of a 12Kh1MF steel bend with a 4-5 structure is 80-90% and with a 6 structure less than 70-80% of the strength of a bend with a 1 structure. Taking into consideration the spread in properties the life of bends with a 6 structure may be significantly less than 50,000-100,000 h.