EFFECT OF THE STRUCTURE AND TEMPERING ON THE TEMPERATURE DEPENDENCE OF THE PROPERTIES OF STEEL 09Kh15N8Yu

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Maraging steel 09Kh15N8Yu of the transition class is widely used for manufacturing elastic elements of compressors operating in aggressive media. Elastic elements, especially membranes, are subjected to considerable deformation in operation and also to compressed gases at temperatures of 150-200°C. Operating tests of membrane compressors have shown that the service life of membranes operating under identical conditions varies from 100-3000 h. This may be due to the use of materials differing in structure which, under the influence of deformation and temperature, differ in resistance to failure.

Depending on the condition of cold plastic deformation (CPD), steel 09Kh15N8Yu differs in structure and thus in physicomechanical properties [1, 2].

We investigated four sets of cold rolled bands 0.3-0.4 mm thick, the chemical composition and properties of which are given in Tables 1 and 2, respectively. The mechanical properties of the steel were determined in the IMASh-5S apparatus with recording of strain diagrams in tension in the temperature range of 20-400°C, which simulates to some extent the process of deformation under operating conditions. The fatigue strength was determined in an Amsler machine with an asymmetric loading cycle. The structure was examined by means of optical metallography and x-ray analysis.

Figure 1 shows the variation of the properties with testing temperature. It can be seen that with deformation at elevated temperatures the ductility of all sets decreases sharply, while $\sigma_{0.2}$ rises to values close to $\sigma_{B}$. The similar change in the properties of the steel in the process of deformation at elevated temperatures from the effect of strengthening and embrittlement and also the sawtoothed elongation curve after reaching the value of $\sigma_{0.2}$ lead to the conclusion that the material is subject to strain aging [3, 4], which differs with regard to the original condition. The difference in the character of the temperature dependence of the properties may be due to differences in the amount of martensite in the structure, in which the diffusion rate of impurity atoms is higher than in austenite. Also, the increase in the dislocation density with increasing rolling reduction ratios promotes a reduction in the time required for directional diffusion of impurity atoms [4]. An analysis of the results showed that the larger the deformation [the effect of deformation is determined from the change in the broadening of $(211)_{\alpha}$] and the larger the amount of martensite, the lower the testing temperature at which the strain aging effect is evident. For example, the ductility of steel from set 1 decreases sharply in the process of deformation at a temperature above 200°C, while embrittlement occurs in steel from set 4 at 75-100°C.

It can also be seen from Fig. 1 that the variation of the relative elongation with deformation temperature is extremal in character (with a peak). The larger the amount of retained austenite after CPD, the higher the peak. Examination of the structure of the deformed material showed that this change in the properties is due to the additional $\gamma\rightarrow\alpha$ transformation that occurs in the process of deformation. Thus, the properties of membrane material formed under the influence of temperature and deformation (i.e., under operating conditions) depend on the processes of dynamic strain aging and the $\gamma\rightarrow\alpha$ transformation.

In the existing procedure the bands are subjected to tempering (aging) at 450-480°C after CPD in order to improve the strength characteristics, especially the fatigue limit [5]. We investigated the effect of tempering temperature (200-600°C) on strain aging of bands of steel 09Kh15N8Yu. Figure 2 shows the variation of the relative elongation with testing temperature for steel from set 3, which is produced in the largest quantities, after tempering at different temperatures. It can be seen that preliminary tempering at 470°C does not eliminate embrittlement up to a temperature of 200°C. Raising the tempering temperature of the cold worked bands shifts the minimal ductility, which does not exceed 2%, to a higher temperature range. The maximal ductility in the process of deformation at temperatures up to 200°C is observed after tempering at 550°C.

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TABLE 1

<table>
<thead>
<tr>
<th>Set No.</th>
<th>C</th>
<th>Ni</th>
<th>Cr</th>
<th>Mn</th>
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<th>Cu</th>
<th>S</th>
<th>P</th>
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<td>8.1</td>
<td>15</td>
<td>0.51</td>
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<td>0.08</td>
<td>0.008</td>
<td>0.017</td>
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<td>0.08</td>
<td>0.09</td>
<td>0.005</td>
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</tr>
<tr>
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<td>8.6</td>
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<td>0.016</td>
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<tr>
<td>4</td>
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<td>8.1</td>
<td>15</td>
<td>0.42</td>
<td>0.08</td>
<td>0.13</td>
<td>0.009</td>
<td>0.018</td>
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</tr>
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</table>

TABLE 2

| Set No. | σ₀ | σ₀.2 | σ₀.1-MPa | % δ | % δ₅₀ | % δ₅₀ | % δ₀.01 | % δ₀.1 | % δ₀.2 | % δ₀.3 | % δ₀.5 | % δ₀.8 | % δ₀.9 | % δ₁ | % δ₂ |
|---------|----|------|----------|-----|-------|-------|--------|-------|--------|-------|-------|-------|--------|-------|------|------|
| 1       | 1200| 500  | 13       | 380 | 292   | 25.5  | 35     | 55    | 35     | 55    | 35    | 55    | 35     | 55    | 35   |
| 2       | 1050| 700  | 11       | 620 | 384   | 29.6  | 55     | 35    | 55     | 35    | 55    | 35    | 55     | 35    | 55   |
| 3       | 1350| 1300 | 11       | 640 | 476   | 34.1  | 60     | 60    | 60     | 60    | 60    | 60    | 60     | 60    | 60   |

Fig. 1. Mechanical properties of cold rolled steel 09Kh15N8Yu in relation to testing temperature: a, b, c, d) sets 1, 2, 3, and 4, respectively.

Fig. 2. Effect of testing temperature on the ductility of cold rolled steel 09Kh15N8Yu. The tempering temperatures are given on the curves.

Fig. 3. Variation of the fatigue limit and relative elongation at 150°C with tempering temperature for cold rolled steel 09Kh15N8Yu.

On the basis of the variation of the properties with deformation one can select the optimal temperature for preliminary tempering. However, it should be kept in mind that material for elastic elements must have a certain level of fatigue strength. The variation of the fatigue strength and relative elongation under deformation conditions at 150°C with tempering temperature is shown in Fig. 3. It can be seen that with rising tempering temperatures from 470°C (present procedure) to 550°C the fatigue strength decreases. However, taking