THERMALLY IMPROVED STEEL 17G2SF FOR
LARGE-DIAMETER GAS PIPE

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Gas pipelines with a diameter of 1020-1220 mm, which were formerly made of steels 17G1S and 14Kh-GS with an ultimate strength of 50-52 kg/mm², are now made of steel 17G2SF, with an ultimate strength of 55 and 60 kg/mm². In order to increase the carrying capacity of trunk lines and save metal it has been proposed that pipes up to 2000-2500 mm in diameter be used, in which case a steel of higher strength is needed - up to 70-80 kg/mm². The maximum strength of low-alloy steel attainable by alloying alone (without heat treatment) is around 60 kg/mm². Further increases in strength can be obtained by thermal improvement - quenching + tempering. Improved steel has a high strength and resistance to brittle fracture, and therefore this treatment has been proposed for pipe 2000-2500 mm in diameter.

This work concerns the properties of low-alloy manganese-vanadium steel 17G2SF from commercial heats after heat treatment under various conditions.

The plates investigated were manufactured from heats with different concentrations of manganese and vanadium (see Table 1).

Samples 10 × 150 × 300 mm were quenched from 930°C (with holding 30 min) in running water at 20-25°C and tempered at 500, 550, 600, 650, 680, and 730°C for 1.5 h, with cooling in air.

The results of static tensile strength tests (Fig. 1) indicate that tempering at 500°C for heat 1 results in ultimate and yield strengths of not less than 80 and 70 kg/mm² respectively. The elongation was at least 19% and the reduction in section at least 69%. Increasing the tempering temperature to 550-600°C lowers the ultimate strength by 5-6 kg/mm² but has almost no effect on ductility. Further increase of the tempering temperature notably reduces the strength and increases the elongation. Changes in the tempering temperature have little effect on the reduction in section.

Fig. 1. Effect of tempering temperature on the mechanical properties of steel 17G2SF. The heat numbers are given on the curves.

TABLE 1

<table>
<thead>
<tr>
<th>Heat No.</th>
<th>Composition, %</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>1</td>
<td>0,17</td>
</tr>
<tr>
<td>2</td>
<td>0,18</td>
</tr>
<tr>
<td>Nominal composition</td>
<td>0,15–0,2</td>
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</table>

Samples from heat 2 were tempered at 600–730°C. After tempering at 600°C the lowest value of the ultimate strength was 77 kg/mm², and the yield strength 65 kg/mm², with elongation 23% and reduction in section 69%. After tempering at 730°C the respective minimum values were 65 and 51 kg/mm², 29 and 72%. Judging from the high values of the ductility, it seems possible to reduce the tempering temperature (to 500–550°C) to retain an ultimate strength of 80 kg/mm² with satisfactory ductility.

The impact toughness was determined at +20, —40, and —80°C, and also the percentage of ductile components in the fractures (Fig. 2). The impact toughness of both heats in the improved condition (under the tempering conditions given) proved to be high at all testing temperatures. With increasing tempering temperatures the impact toughness increases only slightly. However, the lowest percentage of ductile components in the fractures at —80°C was observed in samples from heat 1 tempered at the highest temperature.

The absolute values of the impact toughness at —40°C were at least 10.8 kgm/cm² for heat 1 and 9.8 kgm/cm² for heat 2, and at —80°C were 9.3 and 8.5 kgm/cm². The percentage of ductile components in the fractures of heat 1 tempered at 500–680°C was 100% at —40°C, 65–95% at —80°C. For heat 2 it was 40–50% at —40°C and 20–35% at —80°C.

Thus, the data obtained lead us to conclude that steel 17G2SF in the thermally improved condition can be used as a high-strength steel with an ultimate strength up to 80 kg/mm², with high ductility and low cold-brittleness threshold, for large-diameter pipe operating in the northern regions of the country.

The microstructure of 17G2SF after quenching from 930°C and tempering at 500–730°C consists of temper sorbite (Fig. 3). With an increase of the tempering temperature (within the limits given) the structure becomes more stable, which lowers the strength and increases the plastic and ductile characteristics.

We investigated the effect of strain aging (GOST 7268-54) on the properties of the heat treated steel.

The results of determining the impact toughness at 20°C and the coefficient of susceptibility to aging are given in Table 2.

The absolute values of the impact toughness and coefficient of susceptibility to aging indicate that steel 17G2SF is insusceptible to strain aging after thermal improvement.

To determine the working capacity of the steel under complex stress conditions after improvement (quenching from 930°C in water, tempering at 650°C for 1.5 h) we compared the strength at different temperatures, using flat samples 10 × 40 × 300 mm with symmetrical lateral notches 3 mm deep (root radius 0,25 mm), with the basic characteristics of the material (σB, σT) measured on smooth samples of the same size [1].

The fractures of notched samples from heat 1 were mixed at temperatures from +20 to —60°C. Brittle fracture began to develop from ductile cracks, the size of which decreased with the temperature. It can be seen from Fig. 4 that the strength of notched samples is intermediate between the yield strength and ultimate