THEORY

EFFECT OF INHERITANCE IN DEFORMED STEEL 20Kh

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Preliminary plastic deformation has a large effect on the formation of the structure of austenite during heating. The mechanism of this effect is associated with partial retention of strain hardening during phase transformations [1].

In some cases the effect of plastic deformation on the structure and properties of steels is so persistent that it is "inherited" during subsequent heating with phase recrystallization. There have been many studies of the thermal stability of the hardening effect after deformation at elevated temperatures. Many of these concerned the inheritance effect involved in quenching after HTMT. However, the restoration of the high mechanical properties of steels during repeated quenching is more consistent after HTMT with decomposition of deformed austenite in the bainitic range [2].

This work concerns the effect of deformation at temperatures below A1 and intercritical temperatures A1-A3 on the austenite grain size and properties of steel 20Kh subjected to quenching and tempering.

Deformation (ε = 60%) was accomplished by direct extrusion at temperatures of 600, 650, 700, and 800°C. The chemical composition, deformation conditions, and effect on the structure and properties of steel 20Kh were described in [3]. To determine the austenite grain size in the quenched steel the microsections were etched 6-7 min in a saturated aqueous solution of picric acid with 2 g of Novost' powder at 60-70°C.

The grain size was determined by Jeffries' method — for each point the number of grains (~300) was counted in several fields.

It was found that the preliminary warm deformation temperature affects the structure of austenite during subsequent heating with double phase recrystallization α → γ → α (Fig. 1). After deformation at 600°C the grain size is much smaller than in the normalized steel, but the grains differ considerably in size (50-640 μm²). The smallest grains with the minimal difference in grain sizes were observed after deformation at 700°C. At higher deformation temperatures the grain size and difference in grain sizes increase during repeated heating to quenching temperature.

The transformation of pearlite to austenite was studied by means of incomplete quenching of normalized and deformed samples at 700°C. The samples were placed in the furnace at 860°C and held for 3, 5, 10, 15, and 25 min. Holding for 25 min led to complete transformation of pearlite to austenite, while other holding times led only to partial transformation, which was fixed by cooling in water. Austenite transforms to martensite during quenching.

At the beginning of the transformation of fine lamellar pearlite in the normalized steel the austenite absorbs pearlite and steps are formed on the surfaces of separation. With increasing heating time the pearlite colonies are transformed into separate austenite grains and changes in ferrite also begin. The final size of the austenite grains matches the true size.

The pearlite deformed at 700°C has a granular structure. Electron microscopic analysis showed that it is broken up considerably in the process of deformation, with spheroidization of cementite platelets. During heating of this steel the transformation begins with formation of numerous centers of phase recrystallization in pearlite. After holding for 10 min at 860°C the pearlite colonies are transformed into fine austenite grains. Carbide particles are retained, surrounded by austenite. Separate carbides are observed even after 15 min, while in the normalized steel they disappear after heating for 10 min, i.e., the transformation occurs more slowly in the undeformed steel than in the normalized steel. The austenite grains in the deformed steel are much finer than in the normalized steel (grades 8 and 11 respectively).

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To determine the effect of preliminary plastic deformation on the mechanical properties of the steel the samples were subjected to three treatments: normalization at 860–880° (treatment 1); normalization at 860–880°, deformation (ε = 60%) at 600° (treatment 2); normalization at 860–880°, deformation (ε = 60%) at 700° (treatment 3).

The final heat treatment consisted of quenching from 860° + tempering at 100, 200, 300, 400, 500, and 600°. The mechanical properties of the steel subjected to treatments 1 and 2 are practically identical (Fig. 2). Deformation at 700° (treatment 3), leading to fine and even grains with repeated heating, improves the properties of steel 20Kh at all tempering temperatures tested, which is evidently due to inheritance of defects occurring during phase transformations. The results of x-ray analysis indicate that structural imperfections in the steel subjected to warm deformation are retained after quenching — the width of line (110) is substantially larger than for samples subjected to treatment 1 (0.0184 and 0.0087 rad, respectively). The best properties are obtained for quenched samples tempered at 100 and 200° — the ultimate tensile strength increases 5–10%.

The inheritance of the warm deformation structure during heating is retained with fairly rapid heating (100 deg/min) to 1200°. The grain size of the normalized steel after reheating to 1200° is 1240–1960 µm² (grade 6), while after preliminary deformation at 700° it is 113–141 µm² (grade 10).

**CONCLUSIONS**

1. After deformation at 600–800° the austenite grain size resulting from heating with double phase recrystallization is smaller than in the normalized steel. This indicates that the structure of the deformed steel is resistant and affects the formation of austenite grains during heating.

2. The finest grains of austenite are formed after preliminary deformation at 700°, which leads to considerable pulverization and spheroidization of cementite particles.

3. The higher strength and ductility of the deformed steel in comparison with the normalized steel after heat treatment are evidently due to austenite grain refining and inheritance of defects occurring during phase transformations.