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Influence of the Production Method on the Viscosity of Liquid 100Г13Х2Л Steel

V. V. Konashkov[a], V. S. Tsepelev[a], O. A. Chikova[a], and A. V. Belonosov[b]

[a] *Ural Federal University*

[b] *Ural State Pedagogic University*

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Abstract—Viscosimetric data are derived for liquid 100Г13Х2Л steel during the heating and subsequent cooling of samples. The samples are taken from ingots produced by different methods: by oxidation and by remelting. On the basis of the experimental temperature and time dependences of the liquid steel's kinematic viscosity, the optimal melt treatment prior to solidification is identified.

Keywords: viscosity, liquid steel, treatment temperature, treatment time

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Researchers are very interested in the influence of production methods on the casting of steel melts, which determines the ingot structure. We know that the fluidity of the melt affects the solidification process and the mechanical characteristics of the steel components produced [1–4].

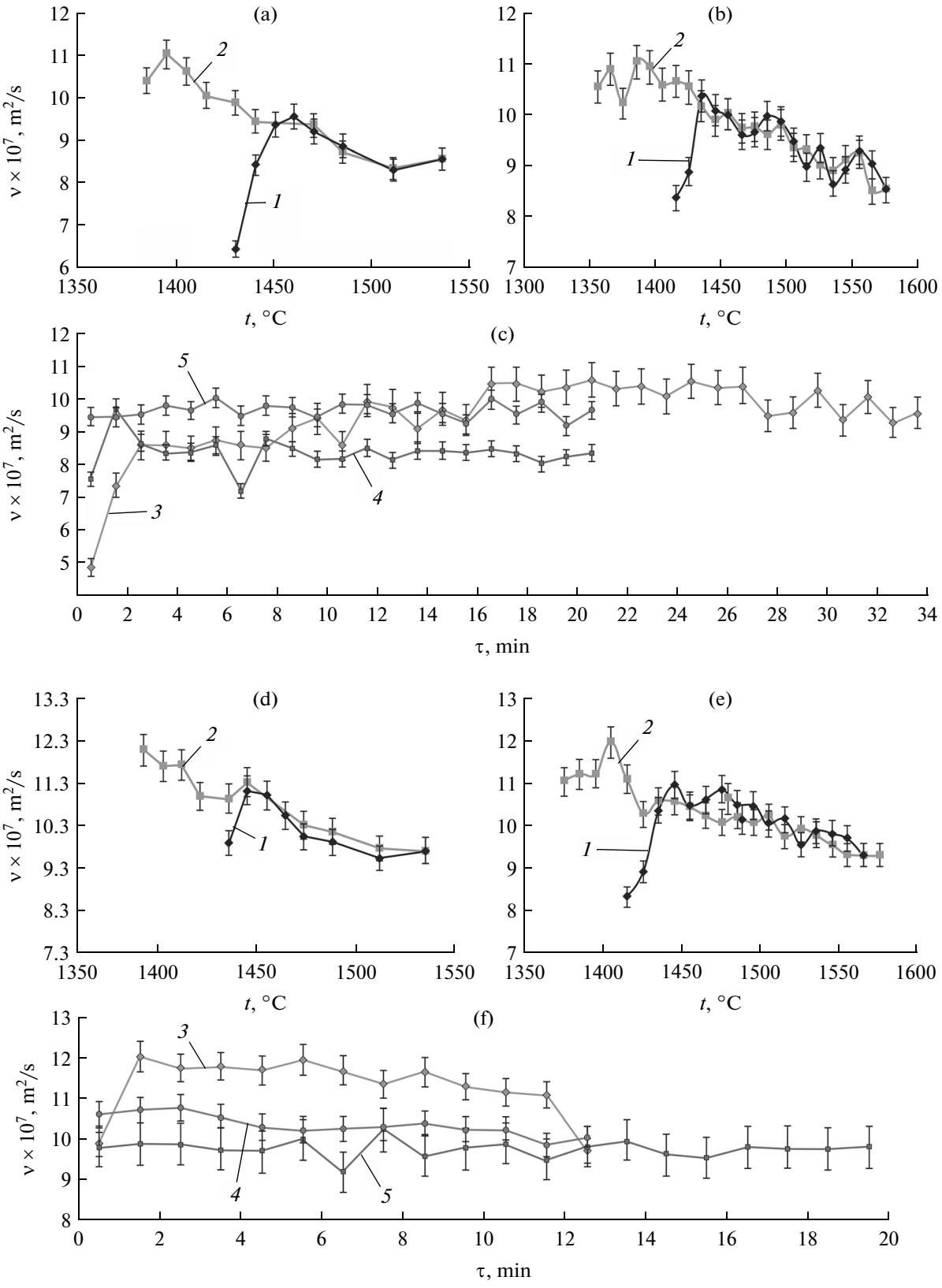
In the present work, we propose a promising method of boosting the quality of 100Г13Х2Л steel: homogenizing heat treatment of the metallic melt [3]. This improves the mechanical properties of the metal casting and does not require high cooling rates [3, 4]. The basis of this method is that microinhomogeneities that differ in chemical composition from the surrounding metal melt may exist for a long time above the liquidus temperature. Their destruction requires heating the melt to some homogenizing temperature T_{hom}, which is specific to each metal. After such heating, the melt is irreversibly converted to a true solution, with significant change in its solidification conditions. Experiments show that destruction of the microheterogeneous structure of metal melts is usually associated with anomalous temperature dependences of the melt's properties—in particular, its viscosity. The temperature dependence of the melt viscosity is different in heating and subsequent cooling. In that case, the temperature T_{hom} corresponding to irreversible conversion to the homogeneous state is determined from the beginning of the high-temperature section where the heating and cooling polytherms are the same. In viscosimetric experiments with microheterogeneous melts, anomalously large spread in the kinematic viscosity is observed. On heating T_{hom}, this spread is irreversibly reduced to values corresponding to the random error of the measurements.

In the present work, we investigate the influence of the method of producing 100Г13Х2Л steel ingots on the structural state of the liquid steel. We propose heat-treatment times and temperatures that enhance the quality of the cast product. We investigate the temperature and time dependences of the viscosity $\nu(t)$ of liquid 100Г13Х2Л steel. The samples are taken from ingots produced by different methods: by oxidation and by remelting.

The composition of 100Г13Х2Л steel includes silicon (no more than 1%), copper (no more than 0.3%), manganese (11.5–14.5%), chromium (1.2–1.7%), nickel (no more than 1%), phosphorus (no more than 0.1%), and sulfur (no more than 0.05%).

We measure the viscosity ν by means of the damping torsional oscillation of a crucible with steel melt in heating and subsequent cooling (temperature range 1410–1575°C). The temperature dependence of ν is measured with at least 30-min isothermal holding; the temperature steps are relatively small (10–15°C). The systematic error in measuring $\nu(T)$ is 3%; the random error, determining the spread of the points in a single experiment, is no more than 1.5% (confidence level $p = 0.95$). The time dependences of the viscosity ν are measured in individual experiments. At each temperature, 15–40 successive measurements are made. The temperature is maintained at the specified level (to within 1°C) by means of a high-precision regulator. In the measurements, the oscillation parameters are recorded by means of an optical system. The experimental apparatus and measurements methods, as well as the analysis of the results, were described in detail in [5–7]. BeO crucibles are used in all the experiments, which are conducted in an atmosphere of high-purity helium at 10^5 Pa.

The viscosimetric data for liquid 100Г13Х2Л steel are shown in the figure. Two viscosimeters of analo-



Experimental temperature (a, b, d, e) and time (c, f) dependences of the kinematic viscosity ν of liquid 100Г13Х2Л steel: (a, b, d, e) curves for heating (*1*) and cooling (*2*) for samples from ingots obtained by oxidation according to viscosimeters 1 (a) and 2 (b) and for ingots obtained by remelting according to viscosimeters 1 (d) and 2 (e); (c) curves with heating to 1460°C (*3*) and 1485°C (*4*) and cooling to 1440°C (*5*) for samples from ingots obtained by oxidation; (f) curves with heating to 1445°C (*3*) and 1475°C (*4*) and cooling to 1440°C (*5*) for samples from ingots obtained by remelting.

gous design are employed, so as to obtain more objective results. For all the melts, 40°C supercooling is observed. In the region above the liquidus, discrepancy in the heating and cooling polytherms (hysteresis) is observed. We note that $T_{hom} = 1435$°C. On heating in the range 1410–1435°C, the viscosity of the melt increases. This may be attributed to postmelting phenomena. For all the samples, elevated (within 10%) spread of the kinematic viscosity is observed on heating at 1445 and 1460°C, as we see in the figure. On cooling, the spread of the kinematic viscosity is within the experimental error at 1440°C. Note the qualitative and quantitative agreement of the viscosity measurements obtained for 100Г13Х2Л steel by different viscosimeters. These results indicate that the temperature of the melt affects its structural state.

The findings may be qualitatively interpreted in terms of the microheterogeneous structure of metallic melts [2, 3]. In those terms, the melting of a multiphase steel ingot does not lead immediately to the formation a solution of the alloying elements in iron that is uniform at the atomic level. Rather, a microheterogeneous state persists over some temperature range. Within the range where the extent of the microheterogeneous state is significant, the recorded viscosity values are unstable. If we inspect the branching of the $\nu(T)$ curves, we conclude that the melt only becomes a true solution close to the branching points. The temperature T_{hom} corresponding to irreversible conversion to the homogeneous state is determined from the beginning of the high-temperature section where the heating and cooling polytherms are the same. For liquid 100Г13Х2Л steel, $T_{hom} = 1435$°C, as we see in the figure. Above T_{hom}, liquid 100Г13Х2Л steel is irreversibly converted to a true solution, with significant change in its solidification conditions even at industrial cooling rates [2, 3]. As a result, significant improvement in the ingot properties may be expected. For 100Г13Х2Л steel, it is expedient to raise the temperature of the melt to 1450–1560°C prior to casting. That ensures homogenization of the melt.

CONCLUSIONS

Viscosimetric data are obtained for liquid 100Г13Х2Л steel. The samples are taken from ingots produced by different methods: by oxidation and by remelting. On the basis of the results, the influence of production method on the temperature and time dependences of the liquid steel's kinematic viscosity is confirmed.

For all the 100Г13Х2Л steel samples, a discrepancy in the heating and cooling polytherms (hysteresis) is observed. We note that $T_{hom} = 1435$°C. Elevated (within 10%) spread of the kinematic viscosity is observed on heating.

For 100Г13Х2Л steel, we recommend raising the temperature of the melt to 1450–1560°C prior to casting. That ensures homogenization of the melt.

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