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On viscosity peculiarities of the Al-(Ni/Y) (up to 5 at.% Ni/Y) and the glassforming melts of the system Al-Tm-REM

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Recently most attention has been concentrated on the Al-based (80 at. % - 90 at. %) alloys with transition and rare-earth metals used as admixtures [1]. Increasing stability of physicalmechanical characteristics may be reached by optimizing technological regimes, i. e., temperature and exposure time of the melt. Structural-sensitive properties (in particular, viscosity) of the Al-Ni-REM system of the melts have been investigated to only a small extent.

The subject of the present work is investigation of temperature, time and concentration dependences of kinematic viscosity (ν) of the Al-Ni and Al-Y binary system, with second element content being less than 5 at. %, as well as studying the polytherms and time dependences ν of the $Al_{87}Ni_8Y_5$, $Al_{86}Ni_8La_6$, $Al_{86}Ni_8Ce_6$, $Al_{87}Ni_8Y_5$, $Al_{86}Ni_6Co_2Gd_4Tb_2$ и $Al_{86}Ni_6Co_2Gd_4Y_2$ liquid alloys over the range of liquidus up to 1300 ℃.

The samples under study were melt in an arc furnace in the atmosphere of purified argon after preliminary vacuum pumping of the working chamber up to 10 - 5 mm of the mercury column. The initial components for melting the alloys were the elements with the content of the basic metal: aluminium 99. 99; lanthanum 99.99; yttrium 99.8; cerium 99.9; gadolinium 99.9; terbium 99. 9; electrolitical nickel 99. 96 and cobalt 99.96 wt. %.

Measuring the kinematic viscosity (ν) of the liquid alloys was carried out by the method of damped torsional vibrations of the cylindrical crucible with the melt [2]. The determination of the logarithmic decrement (δ) and period of vibrations of the suspended system of viscosimeter (τ) was carried out by the optical method using helium-neon laser and a precision photosensor.

Calculating the viscosity with the help of numerical methods, equation [3] was solved:

$$f(\nu) = \mathrm{Re}(L) + \frac{\delta}{2\pi}\mathrm{Im}(L) - 2I\left(\frac{\delta}{\tau} - \frac{\delta_0}{\tau_0}\right) = 0 \qquad (1)$$

where I-the inertia moment of the suspended system, δ_0 и τ_0-the decremeter of damping and period of vibratious of the suspended system without a sample, Re(L) и Im(L)-real and imaginary parts of the friction function L [2].

From equation (1) viscosity cannot be expressed explicitly, which complicates the error estimation in its calculation. To calculate the error, a relative change of viscosity caused by the error of each experimentally determined value, while other parameters were unchanged, was determined. In particular, a mean square error in the calculation of the temperature dependence of viscosity due to the change of δ и τ, is calculated by:

$$\left(\frac{\Delta\nu}{\nu}\right)_T = \left[\left(\frac{\Delta\nu}{\nu}\right)^2_{\Delta\delta} + \left(\frac{\Delta\nu}{\nu}\right)^2_{\Delta\tau}\right]^{1/2} \qquad (2)$$

where $\left(\frac{\Delta\nu}{\nu}\right)_{\Delta\delta}$ и $\left(\frac{\Delta\nu}{\nu}\right)_{\Delta\tau}$-are relative deviations of viscosity on changing δ и τ within their errors. A total mean square error in the viscosity calculation was estimated according to the formula:

$$\left(\frac{\Delta\nu}{\nu}\right)_\Sigma = \left[\left(\frac{\Delta\nu}{\nu}\right)^2_T + \sum_n\left(\frac{\Delta\nu}{\nu}\right)^2_{\Delta n}\right]^{1/2} \qquad (3)$$

where n are all the values in calculation equation (1) and friction function: the moment of inertia of the suspended system, mass, radius and height of the sample. The total mean square error in the measurement of ν does not exceed 4% with the error in a single measurement being not higher than 2. 5%.

Prior to measuring the alloys were re-melted directly in the viscosimeter for not less than 1 h at the temperatures by 300 - 400 ℃ increasing their temperatures of melting. All the measurements were carried out in the atmosphere of high purity helium. Cylindrical Al_2O_3

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crusibles with an inner diameter of 16 mm and height of 40 mm were used. To eliminate the effect of the oxide film formed on the alloy surface, an Al_2O_3 cover was placed above the sample, which was used as a second face surface. The construction of the cover allowed it to move freely along the vertical crucible axis and rotate during torsional vibrations together with it. The temperature in the viscosimeter furnace was determined with the W-Rh(5%) - W-Rh(20%) thermocouple with the precision of ±10 ℃ and it was maintained on the same level with the help of a high-precision temperature control (HTR) with the precision of ±0.5 ℃.

The polyterms of viscosity of liquid aluminium do not differ features. As the temperature changes the viscosity of aluminium is changed, too, according to the Arrhenius equation [2]:

$$\nu = A \cdot \exp\left(\frac{E_\nu}{RT}\right) \tag{4}$$

where A is a constant value, E_ν is the energy of the viscous flow activation, R is the molar gas constant, T is the absolute temperature.

Time dependences of ν of the melts of the Al-Ni system are generally devoid of peculiarities and the equilibrium in the melts established rather quickly (5 - 10 min). The viscosity minimum has been observed in the concentration curve and the curves of equal overheating close to of the eutectic composition (~2.7 at.%). Also the viscosity maximum has been observed in the concentration curve close to 1.5 at.%. For alloys with the contents from 2.5 up to 5 at.% Ni the break has been observed on temperature dependences of viscosity. The break is accompanied by change of value of energy of activation of viscous flow.

When the melts of the Al-Y system are heated nonmonotone irreversible changing of viscosity is observed. If they are further cooled hysteresis is found in the polytherms of viscosity. In case if the melts are held for a long time at high temperatures being liquid the nonmonotone changing of viscosity is also revealed. As the melt temperature increases the time of the viscosity stability (the relaxation time) decreases. Viscosity temperature and time dependences, obtained for $Al_{87}Ni_8Y_5$, $Al_{86}Ni_8(La/Ce)_6$, $Al_{86}Ni_6Co_2Gd_4(Y/Tb)_2$ are of the same character. In the concentration curve of the Al-Y the viscosity minimum has been observed close to of the eutectic composition (~3 at.%Y).

Apparently, nonmonotonic concentration dependence of viscosity of the Al-Y and Al-Ni melts is caused by competing influence of various types of composite near ordering at change of composition.

Taking into account a model of microinhomogeneous liquid structure the viscosity changing of the Al-Y and $Al_{87}Ni_8Y_5$, $Al_{86}Ni_8(La/Ce)_6$, $Al_{86}Ni_6Co_2Gd_4(Y/Tb)_2$ melts with time is caused by the microheterogeneous state decay which, in its turn, is determined by the presence of atomic groups based aluminides containing REM (Y). Non-monotonicity of time dependences of the melts viscosity is due evidently, to non-uniform dissolution and dispersion of that non-equilibrium microgroups.

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