NUMERICAL SIMULATIONS OF LIQUID METAL CONVECTION IN A CYLINDRICAL VESSEL OF THE APPARATUS FOR TITANIUM REDUCTION

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A numerical study of the structure of convective flows of molten magnesium in the apparatus for metallothermic reduction of titanium is performed for different configurations of vessel cooling and heating zones. The large mass and dimensions of the vessel and very high temperatures complicate the direct experimental measurements inside the reactor, which is one of the motivations for the numerical study of the process.

The computational domain is a cylinder with radius R = 0.75 m and height H = 2.5 m. The convective parameters of the medium correspond to liquid magnesium at 850°C. During the process the combination of heating by furnace heaters in the lower part of the vessel, heating by exothermic chemical reaction on the top surface of the magnesium layer and cooling on the side walls in the reaction zone by airflow lead to substantial temperature gradients which generate convective flow inside the reactor. The structure of this convective flow may have significant influence on the reaction process.

The mathematical model is based on the Boussinesq equations for thermogravitational convection of a single-phase fluid. The numerical simulations were performed on the «Triton» supercomputer of ICMM UB RAS. It is shown that axisymmetric stationary flows exist under moderate Grashof numbers (Gr ~ 10[illegible]), but nonstationary turbulent flows are established under Grashof numbers, which correspond to the actual titanium reduction process ($Gr \sim 10^{12}$). An estimate is made for the maximal velocity of flows in the reactor. It is shown that more intensive velocity and temperature pulsations occur near the interface between the cooled and heated parts of the lateral surface of the vessel. Fig.1 shows the results for $Gr = 2.2 \cdot 10^{12}$ during the process with furnace heaters operating at full capacity and the height of the cooled part of the side surface being h = 0.7 m.

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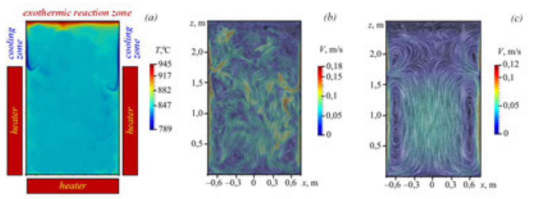

Instant temperature field (a), instant velocity field (b), time averaged velocity field (c).