ABSTRACT. A turbulent flow in an aluminium electrolysis cell driven by the electromagnetic force due to the electric current passing through the liquid layers of aluminium and electrolyte, and the magnetic field of this current and the currents in supplying leads, is analysed by means of numerical and experimental simulation. The experimental cell models the electric current and magnetic field distributions in dependence of the nonuniform current loads in the anode and cathode elements, and the associated flow driven in the single fluid layer (mercury). The mathematical model uses effectively the small relative depth of the fluid layers and enables to simulate economically the three-dimensional distributions of electric current and magnetic field, the horizontal flow and the interface deformation.

Total electric current passing through a modern electrolysis cell for aluminium production reaches in magnitude 200 kA and higher. The associated electromagnetic forces mainly determine hydrodynamics of the adjacent liquid aluminium and electrolyte layers, and, thereby, thermal balance and physico-chemical processes in the cell [1]. In fact, the design of modern electrolysis cells has become impossible without accounting for the MHD-processes within the bath. The vortical electromagnetic forces, first, drive large scale flows in the liquid layers. Typical Reynolds numbers $Re \approx 10^5 - 10^6$, and the flow is turbulent (this is promoted by wall roughness, intense gas escape in the electrolyte, a nonuniform shear layer at the interface). Secondly, the electromagnetic forces are responsible for a deformation of the interface between the liquid layers of metal (of density $\rho_m = 2.3 \times 10^3$ kg/m$^3$) and electrolyte ($\rho_e = 2.1 \times 10^3$ kg/m$^3$); a wave motion is easily developing there due to the small difference of densities. The exact knowledge of the electromagnetic force distribution is a key factor in a development of mathematical model. One can explain by the adequate simulation of the electromagnetic forces the success of stationary flow mathematical models [1,2] based on the two-dimensional Navier-Stokes equations for motion in the horizontal plane, where a turbulent viscosity is calculated according to $k$-$\varepsilon$ turbulence model [2], what may be considered also a formal deficien-
cy, since this does not account for the vertical momentum transport, i.e., the friction of liquid layers at the bottom of bath, anodes, and between themselves [3,4]. Moreover, the two-dimensional horizontal flow model cannot account for the effect of channels between the anodes and walls.

The variety of physical effects within the electrolysis cell does not permit to restrict attention only to the mathematical modeling, therefore experimental investigations have been initiated with liquid metal at suitable temperatures [3]-Woods metal, [6]-mercury.

THE EXPERIMENTAL FACILITY permits a separate investigation of MHD-processes in the liquid electrolyte and metal in a single layer model (liquid mercury). The facility consists of two working baths containing liquid mercury, placed between imitators of the neighbouring cells electromagnetic field. All the main elements of the current-carrying external circuit are variable in space and current loads. The model is made from non-ferromagnetic materials what permits additionally to investigate an effect of different ferromagnetic parts in the industrial cell by introducing these in the model. The present model repeats in scale 1:10 the industrial cell of 175 kA of end to end orientation in the line of cells. The working baths contain liquid mercury layer of dimensions 1.0x0.42x0.02 m (the depth can be varied).

At the beginning stage the facility included merely one - the graphite - working bath shown in Fig.1. In the process of work electrical contacts between the graphite anodes and copper rods, and also between the copper cathode bars and graphite bath bottom, aged (eroded) leading to a nonuniform distribution of currents along the anodes and cathodes, what significantly altered the hydrodynamics in the bath. Nevertheless, this situation with a nonuniform current distribution is quite typical for industrial cells with disturbances in the technology [6], and we shall analyse this situation coupled with the corresponding theoretical model.

Figure 1. Experimental graphite cell (empty of mercury).