NON-STATIONARY HYDRODYNAMIC VORTICES IN OPEN SYSTEMS

E.A. Pashitskii, V.N. Mal'nev[1], *R.A. Naryshkin*[1],
D.V. Anchishkin[2], *V.G. Bar'yakhtar*[3],
Yu.I. Gorobets[3], *O.Yu. Gorobets*[3]

Institute of Physics, Nat. Acad. Sci. of Ukraine
(*46, Nauky Ave., Kyiv 03028, Ukraine*),
[1]Taras Shevchenko Kyiv National University, Physical Faculty
(*6, Academician Glushkov Ave., Kyiv 03022, Ukraine*),
[2]Bogolyubov Institute for Theoretical Physics,
Nat. Acad. Sci. of Ukraine
(*14b, Metrolohichna Str., Kyiv 03143, Ukraine*),
[3]Institute of Magnetism, Nat. Acad. Sci. of Ukraine and Ministry of Science and Education of Ukraine
(*36b, Academician Vernadsky Ave., Kyiv 03142, Ukraine*)

S u m m a r y

A new class of the exact solutions of hydrodynamic equations for the incompressible liquid (gas) in the presence of a bulk sink and uprising vertical flows of the matter is considered. For the existence of such solutions, it is essential that one or several components are excluded from the general collective hydrodynamic motion of the liquid at the expense of chemical or phase transitions, but, due to dynamical and chemical equilibrium of the open system with the surrounding medium, a chemical composition of the matter constant in time and almost homogeneous in space and a constant density $\rho = \text{const}$ are maintained. It is shown that those profiles nullifying the terms in Navier-Stokes equation which describe viscous effects exist and represent vortex structures with "rigid-body" rotation of the core and converging radial flows.

In the case of constant bulk sink and inflow of the matter from the outside, the azimuthal velocity of a "rigid-body" rotation v_φ increases exponentially with time. At a simultaneous infinite increasing of the sink and inflow rates, v_φ increases by the scenario of "explosive" instability, when the infinite rotation velocity is reached during a finite time interval. The acceleration of the rotation velocity of classical non-stationary vortices is conditioned by the joint action of the convective and Coriolis hydrodynamic forces (accelerations) which appear due to the converging radial flows of the matter in the volume of a bulk sink.

The concept of non-stationary vortices in open systems was applied to the consideration of such processes as: the origination of power atmospheric vortices (whirlwinds, tornados, and typhoons); origination of vortices in the process of electro-chemical reactions running in a magnetic field ("magnetic tornado"); vortex instability development in a molten metal during the electron-beam welding; rotational motion of a nuclear matter which is created in collisions of heavy nuclei with large angular momenta; acceleration of a process of decay of a super-saturated ^{3}He—^{4}He solution at the expense of the origination of classical and quantized vortices; origination of non-dissipative hydrodynamic vortices in the liquid planet cores and acceleration of the central cores of stars due to thermonuclear reactions.

In classical hydrodynamics, a favorable condition for the origination and existence of such vortices is the nullification of terms which describe the kinematic viscosity of an incompressible liquid in the cases of cylindrical and spherical symmetries. Such streams have the minimal energy dissipation, i.e. correspond to the peculiar "minimum of entropy production principle", and therefore are relatively easily realized under the corresponding natural conditions.