STRATIFICATION AND ROTATION EFFECTS ON TRANSPORT OF SUBSTANCES

Yuli D. Chashechkin
A.Yu. Ishlinskiy Institute for Problems in Mechanics, RAS, 101/1 prospect Vernadskogo, Moscow, 119526, Russia, e-mail: chakin@ipmnet.ru

Dynamic and structure of stratified flows are studied thoroughly in environmental and laboratory conditions. Now it is recognized that both large scale (such as internal waves and vortices) and small scale components (high gradient interfaces) affect flow structure, stability and admixture transport. Remote sensing instruments have shown that contaminants in the environmental flows form extended narrow bands having irregular of even arch forms. The goal of paper is theoretical searching of mechanisms of such flow patterns formation and their laboratory modeling. The fundamental set of governing equations including empirical equation of state named by Mendeleev and differential equations by Navier-Stokes, Fourier's and/or Fick's describing flows of stratified or generally rotating fluids is selected for analysis.

The set is treated as a high order singular perturbed system as the terms with the highest spatial derivatives contain small factors (that are kinetic coefficients). Solutions of such systems include regular and singular perturbed functions which are split for specific boundary conditions. Regular perturbed functions (*redics*) describe large scale flow components that are jets, wakes, vortices and waves. More rich family of singular perturbed functions (*sidics*) describes extended and thin flow components. In contrast with conventional boundary layers the singular disturbed components can be disposed inside a fluid body and be stationary type (soaring interfaces inside attached waves past uniformly moving obstacles) or blinking type. Their thickness is defined by kinetic coefficients, characteristic velocity and buoyancy or rotation frequency.

All flow components are dynamically active and interact between themselves directly. The minimal number of singular disturbed components is associated with viscosity effects and is equal two. In flows energy and momentum are transported by regular disturbed components. The energy dissipation and vorticity generation and transportation are associated with singular disturbed components. Complete classification of linearized periodic flow components for compressible, rotating and stratified fluids with standard no-slip and no-flux boundary conditions for given particular geometry of the problem is given [1]. Calculations of periodic internal wave beams produced by a compact source and flows produced by uniformly moving strip reveal strong influence of the finest component on geometry and energetics of the flows [2, 3].

To visualize flow components of all length scales, which are observed in the environment high resolution and sensitive instruments have to be used. Field of observation has to be large enough to observation of jets, wakes, vortices and internal waves. In given study different optic methods namely interferometer, schlieren and shadow methods based on the Russian IAB-458 instruments were adopted to measure stratified medium properties and to visualize flows. Investigation of flows in different transparent tanks with high quality optic windows filled with stratified brine was performed. Effects of light dispersion and refraction of the light rays even in the undisturbed medium were taking into account for adaptation conventional instruments for stratified flow studies as a tank with the vertical wall filled with stratified brine is similar to an optical prism. The optic length of the light ray is determined by the refractive index profile for a constant geometrical width of the tank. Moreover in a stratified liquid all the changes in reflected index are many times greater than those encountered in compressible gas flows. That is why the conventional visualization instruments (interferometer, schlieren, shadow) cannot be applied directly for stratified flows. Special platform was developed for fast re-tuning of the instrument when the basic stratification was changed.

In practice different modifications of schlieren methods proposed by D.D. Maksoutov are used here in view of their sensitivity, flexibility and universality. To produce the schlieren effect part of the light forming the image of the light source is cut off in the receiving part. Besides a sharp blade edge (the Foucault knife), several kinds of light cutting diaphragms, specifically, a

thin filament, a narrow slit between two blade edges or a graded schlieren filter for closing part of light rays was used. Due to a mean deflection and dispersion of the light ray in a stratified liquid the action of cutting diaphragm depends on angular positions of the illuminating slit and of the cutting diaphragm in the focal planes. To produce 'natural rainbow' image the slit is placed horizontally and regular grating serves as 'diaphragm in focus' [4].

To study the matter transport electrolytic precipitation and dyeing by different solvable dyes was used. To measure buoyancy the horizontal velocity components profiles internal oscillations and displacements of vertical markers produced by wakes past sinking salt crystals or arising small gas bubbles were registered.

All varieties of visualization techniques was applied to visualize regular and singular disturbed components of flows produced be periodic oscillating and uniformly moving obstacles of a simple form that are plain strip, circular horizontal cylinder and sphere. Formation of high gradient envelopes in the field of periodic wave beams and their transformation into autocumulative jets with amplitude of the wave source oscillation increasing was investigated [2]. Different regimes of vortex formation on uniformly moving strip aliened or placed under angle of attack were registered [3]. The strip slope creating lift manifests itself in deformation of internal wave pattern and asymmetry pf steaks above and below the strip. With towing velocity increasing strips are retransformed in conventional vortex street gradually deformed by buoyancy forces.

Experiments show that passive admixtures are accumulated on singular disturbed components and transported along their surfaces or lines of their intersections. In domains of their convergence compact vortices are self-organized. In experiments with stratified flows accumulation of a dye was observed on interfaces formed inside the fluid past moving 2D (horizontal cylinder) and 3D flows (a uniformly moving sphere).

More that twenty different flow regimes past uniformly moving horizontal cylinder including diffusion induced flows on a motionless cylinder are described. Family of high gradient interfaces inside the wake as well as soaring interfaces and soaring vortices are studied. Isolated interfaces act as collectors of any admixture due to specificity of flow structure organization in their vicinity and provide its fast super diffusion transport.

Analogy between stratified and rotating flows was used for extrapolation description on vortex flows. To investigate the rotation effects on transport of the matter the dynamics of fluid and shapes of water surface in cylindrical container deformed by a compound vortex. Compound vortex flow was created by a horizontal disk uniformly rotating in a cylindrical container. Transport of contaminants from a compact spot placed on the free surface is studied. Shapes and depth of surface depressions for different values of experimental conditions that are depth of the fluid layer, diameter and angular velocity of rotating disc and compared with calculated flow parameters were fixed. Comparison of calculated and observed caverns shapes shows that including the capillary effects in to calculation of surface cavern improves the data fitting when the angular velocity of disc rotation is high and the cavern touches the disc surface.

Strong anisotropy of substance transport from compact spot of miscible or immiscible fluid placed on the surface of fluid involved in composite vortex motion in a cylindrical container is observed. In a fluid at rest spot of miscible dye dropped on the plane free surface forms submerging circular vortex which decays on the few of smaller vortices which are also transformed into circular rings on the next level. So the drop falling on the liquid surface produces multilevel expanding cascade of secondary vortex rings.

Drop of dye placed on a free surface of the cavern produced by the compound vortex is transformed firstly into spiral arms. From drop placed in the centre of cavern only one spiral arm is extended. From drop placed on same distance from the cavern centre to spiral arm expanding in cyclonic and anticyclonic directions are formed [5]. Dye from spiral is extracted into rotating fluid inside container and transported along a filaments covering same vertical cylindrical surface. Running large-scale inertial waves and short spiral waves are observed on the cavern surface.

Spot of oil ore a light immiscible fluid placed on the surface of the compound vortex is also extended into spiral arms, which are split on separated floating drops. Drops arms are separated by striae of pure water. The oil is partly accumulated at the centre of surface cavern [6]. With increasing of the oil volume the depth of surface cavern is decreased.

Extrapolation of theoretical and laboratory data on the environment is discussed.

References.

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