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Non-Uniform Flow Hydrodynamics of Deformable Shapes

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We consider the practical case of a rigid or deformable body of arbitrary shape moving unsteadily with six degrees of freedom in an inviscid, incompressible and nonhomogeneous flow field possessing a uniform shear (vorticity) and fluid density gradient. By integrating the Euler equations, we derive analytic expressions for the pressure induced force and moment exerted by the fluid on the moving body which determine its spatial trajectories. A distinction is made between 2d and 3d flow geometries in the sense that in 3d the analysis is valid only during a short time interval after the body is introduced into the fluid as a result of vortex stretching effects. Nevertheless, it is demonstrated that the small-time 3d analysis can be also applied to viscous flows governed by the Navier–Stokes equations. Special attention is given here to the puzzling problem of self-propulsion of a general deforming shape (bubble, drop, elastic structure etc.) in the Eulerian realm resulting from non-linear coupling between body's shape modes and non-uniform flow parameters. Also considered is the feasibility for a Lorentz-type MHD self-propulsion mechanism of a non-rigid shape embedded in a conducting fluid due to controled resonant interactions between the applied magnetic field and body deformation in the limit of a small magnetic Reynolds number. Demonstrations are given for some time-dependent simple shapes embedded in a linear shear flow with a constant applied magnetic field and fluid density gradient in both unbounded or bounded flow domains.

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