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Multibody System Dynamics in Fluid Flow: Geometric Mechanics Approach

Prof. dr. sc. Zdravko Terze
Chair of Flight Vehicle Dynamics, F. Mech. Eng. & Naval Arch.
University of Zagreb

In order to study dynamics of multibody system (MBS) moving in ambient fluid, we adopt geometric modeling approach of fully coupled MBS-fluid system, incorporating boundary integral method for calculating added masses, and time integrator in Lie group setting. Our aim is to explore numerical advantages of such an approach in comparison to the standard procedures that comprise volume discretization of fluid domain. By assuming inviscid and incompressible fluid, the configuration space of the coupled MBS-fluid system is reduced by eliminating fluid variables via symplectic and Lie-Poisson two stages reduction. The first reduction exploits particle relabeling symmetry, associated with the conservation of circulation: fluid kinetic energy, fluid Lagrangian and associated momentum map are invariant with respect to this symmetry. Consequently, the equations of motion for the whole system are formulated without explicitly incorporating the fluid variables. The effect of fluid flow to the MBS overall dynamics is accounted for by the added masses which are expressed as boundary integral functions. After particle relabeling symmetry - in the case of flapping wing dynamics studied as an example - further reduction is associated with the invariance of dynamics under superimposed rigid body motions. Here, in order to incorporate effects of vorticity in the fluid flow and wing circulation, the vortex shedding mechanism is incorporated in the overall model by numerically enforcing Kutta condition.

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Dip. di Scienze e Tecnologie Aerospaziali
Via La Masa, 34 - 20156 Milano