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NUMERICAL MODELING OF LARGE FREE-SURFACE FLUID FLOW IN FUEL TANKS IN FLIGHT

Abstract

Space explorations at the present stage are completely impossible without wide using of liquid fuel launcher missiles. Nevertheless long time experiences of exploitations of such systems, a lot of relevant specific scientific problems remain in the fields of interests of space scientists and engineers. One of traditional such problem is possible liquid fuel flows in tanks during an active part of the trajectory. It is clear, that the most complicated case of such flows takes place in partially fulfilled tanks due to large deflection free surface flow, especially if the effective mass body force vector is changed sufficiently. It is a pity, but such flows are extremely difficult for experimental investigations. Thus numerical calculations of free-surface flows in fuel tanks of launcher-missiles belong to the most actual theoretical problems of modern missile building. An understanding of a free surface dynamics represents an important theoretical paradigm in diverse areas of science. Therefore interests of many researchers are directed to this class of problems. Nevertheless a lot of works concerning numerical simulation of free surface flow in variable body force field, quite serious unsolved problems remain there. First of all, possible large deflections of free surfaces lead to strongly non-linear problem with very specific kind of non-linearity. Beside of that, mechanical influences on the fuel tank can sufficiently differ with respect to time reference scales. It is assumed on the base of mechanical reasons that all actions are enough short-time and, as a result, ideal fluid flow mathematical model can be used for the fuel flow calculation. The main idea of the present work is decomposition of the problem with respect to time scales of the stimulated actions on short-time and relatively long-time. It is evident from the same mechanical reasons that short-time actions excite small deflection free surface motion, what gives an opportunity to make simple linearization of boundary conditions. Short-time motions can be periodical or non-periodical in dependence on the stimulated actions. In the same time large deflection motions must be considered in the time domain with non-linear boundary conditions, what requires some time-stepping procedure for numerical solution. Thus the general computational scheme is following: large deflection fuel flow is calculated step-by-step in time and at every time step all possible small deflection motions are calculated assumed the fluid domain be frozen. Boundary element method is used for numerical solution of all boundary-value problems in the present work.