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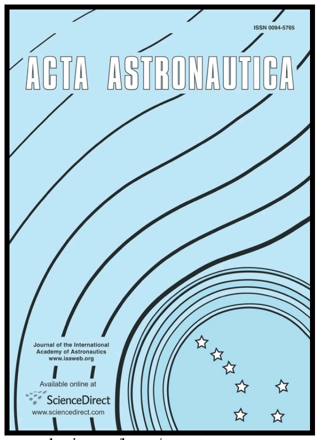

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DYNAMIC MODELLING AND STABILITY PARAMETRIC ANALYSIS OF A FLEXIBLE SPACECRAFT WITH FUEL SLOSH

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Abstract

Modern spacecraft often contain large quantities of liquid fuel to execute station keeping and attitude maneuvers for space missions. In general the combined liquid-structure system is very difficult to model, and the analyses are based on some assumed simplifications. A realistic representation of the liquid dynamics inside closed containers can be approximated by an equivalent mechanical system. This technique can be considered a very useful mathematical tool for solving the complete dynamics problem of a space-system containing liquid. Thus they are particularly useful when designing a control system or to study the stability margins of the coupled dynamics. The commonly used equivalent mechanical models are the mass–spring models and the pendulum models. As far as the spacecraft modelling is concerned they are usually considered rigid; i.e. no flexible appendages such as solar arrays or antennas are considered when dealing with the interaction of the attitude dynamics with the fuel slosh. In the present work the interactions among the fuel slosh, the attitude dynamics and the flexible appendages of a spacecraft are first studied via a classical multi-body approach. In particular the equations of attitude and orbit motion are first derived for the partially liquid-filled flexible spacecraft undergoing fuel slosh; then several parametric analyses will be performed to study the stability conditions of the system during some assigned manoeuvers. The present study is propaedeutic for the synthesis of advanced attitude and/or station keeping control techniques able to minimize and/or reduce an undesired excitation of the satellite flexible appendages and of the fuel sloshing mass.

NOMENCLATURE:

In the following, a list of the main symbols and variables is reported:

m_s , m_f , m_p : main platform, fluid and solar panel mass (respectively)

I_{cms} , I_{jf} , I_{jp} : main platform, fluid and solar panel moment of inertia (respectively)

${}^{s}\vec{d}_{jf}$ and ${}^{f}\vec{d}_{cmf}$: the position of the pivot of the spherical pendulum and the position of the fuel sloshing mass with respect to the fuel reference frame respectively

$\vec{r}_{cms}$: main platform center of mass position

ϑ_S , $\vec{\omega}_s$: main platform attitude and angular velocity

ϑ_f : fluid mass oscillation

$w(\xi)$: solar panel elastic displacement

$\eta_k(t)$: solar panel kth modal amplitude

$\phi_k(\xi)$: solar panel kth modal shape

α_k, β_k :translational and rotational modal participation factors

$k_{p\vartheta}, k_{d\vartheta}$: proportional and derivative gains

I. INTRODUCTION

The analysis and the study of a sloshing fluid in a solid container has received considerable attention for long time [1][2][3]. Sloshing is a wave phenomenon, and is driven by inertial forces, surface tension, and surface kinematics. To take all the detailed dynamics into account in a vehicle dynamic modeling is computational time consuming. On the other hand, a complete dynamic-stability analysis of the vehicle must include the forces produced by the liquid