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ON THE STABILITY OF SPINNING SATELLITES

Abstract

Since the dawn of the space age, spin-stabilization has been an attractive and straightforward method to stabilise a satellite's attitude. The often told problems with the Explorer-I satellite indicate that initially there was inadequate understanding of this stabilization method in the Western space community.

In this paper, we study the directional stability of free-spinning satellites, rigid or deformable. The directional stability is defined by two angles. Investigations of this type of stability problems do not amount to a straight-forward application of Lyapunov stability theory, not even in the case of a rigid body. The Euler equations of attitude motion are linearized with respect to a reference solution representing a uniform spin rate. The resulting linearized system is written in the generic MGK format. Such (conservative) systems are at best oscillatory stable (when all roots lie on the imaginary axis). Theoretically one cannot extrapolate any stability results from the linear system to conclusions about the stability of the non-linear system.

A practical method to obtain sufficient stability conditions is to reduce the system of linear equations by the Frobenius-Schur reduction formula to the attitude variables. This method is an alternate route to the stability matrix developed by McIntyre Myiagi. The method of McIntyre Myiagi does not require the linear equations of motion and is the most useful tool when the deformable parts are liquids.

Examples that are used in practice as simple models for spinning satellites will be provided. Both methods produce the same stability conditions. We also study a spinning satellite under a constant axial thrust. In that case, we cannot linearize about the (unknown) reference solution of the full non-linear system but only about an assumed initial state. In such a situation Lyapunov's direct method is not applicable. The generic form of the linearized equations is an MGKN system because a constant thrust in the body system is a follower force. When this linearized system is stable (i.e., when it has bounded solutions), the non-linear system may still be unstable. This is illustrated by an example that occurred in practice on the ESA GEOS-I satellite in the 1970's. Such an instability can only be detected by a second-order analysis. When such a linear system is unstable, the full system is definitely unstable. This is illustrated by a model studied by Mingori Yam were a particle can move on a circle inside a spinning satellite.