References

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Reply by Author to D. L. Mingori and W. J. Russell

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THE method of Ref. 1 is essentially based on the assertion†: "For an isolated spacecraft any disturbance will vanish through internal dissipation and the spacecraft will go to its minimum energy state consistent with the angular momentum and any other explicit constraints." The author agrees with Mingori's clarification that the validity of the stability criterion given in Ref. 1 is subject to the condition of constant absolute rotor spin ($\omega_3{}^S = \text{const}$). The example constructed by Mingori[3] is correct, although by an obvious oversight, the spin axis is taken to be the major axis. However, the commentators' symmetry arguments are not sufficiently persuasive, for a similar stability criterion can be obtained for a spacecraft with a constant relative rotor spin ($\omega_3{}^S - \omega_3{}^A = \text{const}$).[2] The symmetry argument is more relevant for this case, but the criterion can indeed be arranged to exhibit such symmetry. The real challenge is the spacecraft model considered by Mingori in Ref. 4. This model has dampers in both bodies of the spacecraft and, if the author is correct, admits only one constant energy (equilibrium) state, namely a constant spin about the rotor axis. Therefore, for this model, instability can occur only in the following ways:

1) The spacecraft will go into some "limit-cycle like" stationary periodic motion. This motion is possible if during each cycle the energy input is equal to the energy dissipated. Although the existence of such motions is not proved, one feels this has to occur in view of the angular momentum constraint and the existence of dissipation.

2) The spacecraft will not be able to maintain its dual-spin eventually and degenerates into a single-spin vehicle. This can occur if no energy source exists.

Received November 18, 1968; revision received January 2, 1968.

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† A thorough discussion of explicit assumptions can be found in Ref. 2.

Either of the preceding possibilities contradicts the derivations used in Ref. 1. Therefore, the author is inclined to agree with the commentators' statement that the stability criterion given in Ref. 1 excludes possible damping in the rotor.

Russell[5] is correct in saying the minimum energy state given in Eq. (17) of Ref. 1 does not satisfy the equations of motion exactly for the model considered by Likins.[6] As stated in Ref. 1, the exact result can be obtained if the potential energy of deformation of the spring is also taken into consideration. However, it can be shown that, for intentionally introduced damping mechanisms, the potential energy is always small in comparison with the spin energy.[2] The improved accuracy obtained that way is not warranted by the additional algebraic complexity involved and, furthermore, the result will be restricted to a particular damping mechanism. The author cannot agree with Russell's overemphasis on the necessity of postulating specific internal structure in order to discuss the stability of a physical system.

Also in Ref. 5, Russell uses the stability criterion given by Likins[6] to gauge the adequacy of the result of Ref. 1. First of all, Likins himself states his criterion is approximate.[6] Furthermore, if one examines the definitions $P_A = -I_3{}^A\dot{\omega}_3{}^A\lambda_A$ and $P_S = -I_3{}^S\dot{\omega}_3{}^S\lambda_S$ Likins' criterion becomes

$$d/dt(I_3{}^A\omega_3{}^A + I_3{}^S\omega_3{}^S) > 0$$

This is equivalent to saying that, if the spacecraft angular momentum component about the rotor axis always increases, eventually the angular momentum components about other axes would have to vanish and the spacecraft is stable. The statement is logical, but is hardly useful as a stability criterion. To be of use, Likins identifies P_A and P_S as average dissipation rates in body A and body S, respectively. This identification is plausible under the condition stated (bearing friction and torque arbitrarily small). However, the validity of this condition for the cases at hand (constant rotor absolute and relative spin) is doubtful. In all the work referenced, the equations of motion of the rotor are tacitly assumed to be satisfied by a constant rotor spin (absolute or relative). This most likely will require certain motor torques which violate Likins' condition that motor and friction torques be arbitrarily small.

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