Comment on "Preliminary Survey of Dynamic Stability of a Cable-Connected Spinning Space Station"

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In a recent article, Pengelley[1] discussed qualitatively some questions pertaining to the dynamic stability of a cable-connected space station. The description of the model tests conducted by the author is both interesting and instructive. However, in his review of the technical literature, Pengelley stated that the axial natural frequency of a cable-connected space station, as found in Ref. 2, was misinterpreted. It is the purpose of this note to point out that the result of Ref. 2 is correct for the explicitly stated assumption of constant angular velocity of rotation. The natural frequency then is given by $\omega_n^2 = \omega_r^2 - \Omega^2$ where ω_r is the frequency of the oscillator at rest and Ω is the assumed constant angular velocity. The control of the spin speed in a space station is likely to be effected by external torquing that in no other way affects the axial motion of the simplified example of Ref. 2. On the other hand, if no restriction on the spin speed is made, then the natural frequency of the system is increased because of the effect of spin yielding $\omega_n^2 = \omega_r^2 + 3\Omega_0^2$ where Ω_0 is some average spin speed, as was found in Ref. 3 and by several other investigators. Similar results were found by Bhuta and Jones[4] as well as Ashley,[5] who considered the axial vibrations of a rotating bar.

The variation of the axial natural frequency with spin speed also can be shown by a simple example of a spring-mass system constrained to move radially on a turntable. The natural frequency of the oscillator increases over ω_r as the inertia of the turntable decreases and, conversely, the natural frequency decreases, approaching the result of Ref. 2, as the inertia of the turntable increases.

The practical significance of the spin speed control on the natural frequency of axial motion should not be underestimated or misinterpreted, as was also done in Ref. 3. Reference 2 showed, for example, that parametric excitation can take place when the natural frequency is some integral value of the spin speed. Furthermore, the turntable example shows that a range of axial natural frequencies can be obtained by varying the turntable inertia, which is similar to controlling the spin speed of a space station by external torques. Consequently, the possibilities of dynamic instability or resonance cannot be ignored but must be evaluated for each specific configuration.

References

[1] Pengelley, C. D., "Preliminary survey of dynamic stability of a cable-connected spinning space station," J. Spacecraft Rockets **3**, 1456–1462 (1966).

[2] Chobotov, V., "Gravity-gradient excitation of a rotating cable counter-weight space station in orbit," J. Appl. Mech. **30**, 547–554 (1963).

[3] Pittman, D. L. and Hall, B. M., "The inherent stability of counterweight cable connected space stations," Douglas Missile and Space Systems Div. Paper 3051 (July 1964).

[4] Bhuta, P. G. and Jones, J. P., "On axial vibration of a whirling bar," J. Acoust. Soc. Am. **35**, 217–221 (1963).

[5] Ashley, H., "Observations on the dynamic behavior of large flexible bodies in orbit," Massachusetts Institute of Technology Fluid Dynamics Research Lab. Rept. 66-2, p. 24 (April 1966).

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Reply by Author to V. Chobotov

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In Chobotov's comment, he states that the result of his original paper[2] is correct for the explicitly stated assumption of constant angular velocity of rotation. However, his statement on natural frequency, which follows Eq. (49) of Ref. 2, actually uses the words, " . . . if ω is essentially constant."

Equation (49) of Ref. 2 is derived for a spinning system moving freely in an inverse square gravitational field and no mention is made of any explicit external torque which could be used to provide independent control of spin rate. If such a controlling torque had been specified so as to maintain the spin rate exactly constant, there would have been no question regarding the expression for natural frequency. Thus, it is the opinion of this writer that the specific words, as well as the over-all context of Ref. 2, convey the impression that the assumption of constant spin rate should be valid when used to derive an expression for the natural frequency of axial oscillations of a freely spinning system when viewed by an observer rotating with it. Such an assumption is not valid—not even approximately—as demonstrated by Pittman & Hall in Ref. 3, who have pointed out that angular momentum should be assumed constant, instead of angular velocity.

In view of Chobotov's current comments on Ref. 1, it must be concluded that if the thoughts behind Ref. 2 were correct, then the words must have been ambiguous.

References

[1] Pengelley, C. D., "Preliminary survey of dynamic stability of a cable-connected spinning space station," J. Spacecraft Rockets **3**, 1456–1462 (1966).

[2] Chobotov, V., "Gravity-gradient excitation of a rotating cable counterweight space station in orbit," J. Appl. Mech. **30**, 547–554 (1963).

[3] Pittman, D. L. and Hall, B. M., "The inherent stability of counterweight cable connected space stations," Douglas Missile and Space Systems Div. Paper 3051 (July 1964).

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Errata: "An Application of Automatic Carpet Plotting to Wind-Tunnel Data Reduction"

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[J. Spacecraft Rockets **4**, 408–410 (1967)]

The authors report that:

1) In the equations for β_c and θ_c the factor $(\alpha - \theta)$ appearing in the last term is corrected to read $(\alpha + \Delta\theta)$.

2) Quoted Ref. 2 should read: Ericsson, L. E. and Reding, J. P., "Analysis of flow separation effects on the dynamics of a large space booster," J. Spacecraft Rockets **2**, 481–490 (1965).

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