On the Rectilinear Motion of a Two-body Limbless Crawler along an Inclined Plane

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Abstract

We study the motion of a simple two-body limbless crawler along the line of maximum slope on an inclined plane. Dry friction (anisotropic in the general case) is assumed to act between the system's bodies and the plane. The motion is excited by a periodic change in the distance between the bodies, which leads to the change in their velocities relative to the plane and, consequently, to a change in the friction forces. Such a way of motion is inherent in some terrestrial limbless animals, e.g., snakes and worms. Of most interest are periodic motions in which the velocity of the center of mass of the system changes periodically with a period equal to that of the excitation.

The conditions subject to which the crawler can move upward along an inclined plane are analyzed for the case of low friction. The rate of change in the distance between the bodies is specified as a function of time. The investigation is based on the approximate equation of motion obtained by averaging the right-hand sides of the primary equation with respect to the explicit time. A criterion for a given excitation law to be able to sustain the periodic motion upward along an inclined plane is established, and the maximum inclination angle for this motion is defined. The value of this angle depends on the total times during which the distance between the bodies increases and decreases and is independent of other characteristics of the excitation law. An expression for the maximum inclination angle for which there exists an excitation that can provide an upward motion for the system is obtained.

It is shown that the system can move upward not only in the direction of lower friction but also in the direction of higher friction, provided that the masses of the system's bodies and the respective coefficients of friction are related by appropriate inequalities. A computer simulation of the behavior of the locomotor on the basis of the primary, rather than averaged, equation of motion is performed to evaluate the coefficients of friction for which the results obtained on the basis of the averaged equation provide an acceptable accuracy. A prototype of the locomotor is designed and built, and the experiments with this prototype are performed. The experiments demonstrate a qualitative agreement with the analytical and computational results.