Coupled Dynamics of Solid System with Slider-Crank Mechanisms as Internal Movers on Rough Surface with Friction

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ABSTRACT

An interest in solid systems driven by inner movements of masses without outer movers, such as wheels, chain tracks, or legs, arises in the last decade [1-4]. A new class of mechanisms (robots), able to move in a resisting medium without external movers due to movement of internal bodies, attracts attention and is studied. At constant outer shell by changing internal geometry of mass the movement of solid system can be carried out in an arbitrary point.

This work is devoted to the same class mechanism. Studied solid system consists of main frame that has three points of contact with rough surface and moves coplanar; and two nesting slider-crank mechanisms that move respectively two internal masses relatively to the frame. The crank is rotated by direct-current motor, so in mathematical modelling it moves under assumption of a decreasing linear relationship between torque of motor and its angular velocity. In dry friction between frame and surface the local Amontons–Coulomb law is used. The movement of the system is studied with the help of mathematical modeling and numerical integration.

The equations of motion of the system with movable masses are obtained. Two types of the frame movement are considered: translational (sliding) and rotational (spinning). As we can see, the movement takes place at a constant average speed. Approximately periodic movement occurs sliding forward (or spinning for rotational movement of frame) with some setback (or temporary stop).

Such movement can be explained qualitatively as follows. Slider-crank mechanism moves masses with different accelerations in different directions. Unequal pulses of the masses are converted into a non-uniform translational/rotational movement of the base frame, and hence there are unequal frame pulses differently compensated by friction forces between points of contact and surface.

Such class mechanism being isolated from surrounding space in shell can be used in conditions where traditional movers (wheels, tracks, legs) for some reasons are not applicable: corrosive environments or limited in size, on the outside plating of a spaceship or pipeline, in conditions of different planets, etc.

REFERENCES

[1] F.L. Chernous'ko, N.N. Bolotnik, T.Yu. Figurina, "Optimal control of vibrationally excited locomotion systems", *Regul. Chaotic Dyn.*, Vol. **18** (1–2), pp. 85–99, (2013).

[2] A. P. Ivanov, A. V. Sakharov, "Dynamics of rigid body, carrying moving masses and rotor, on a rough plane", *Nelin. Dinam.*, Vol. **8** (4), pp. 763–772, (2012), (Russian).

[3] L.Yu. Volkova, S.F. Jatsun, "Control of the three-mass robot moving in the liquid environment", *Nelin. Dinam.*, Vol. **7** (4), pp. 845–857, (2011), (Russian).

[4] A.V. Sakharov, "Rotation of the body with movable internal masses around the center of mass on a rough plane", *Regular and Chaotic Dynamics*, Vol. **20** (4), pp. 428-440, (2015).