Modeling and numerical simulation for an asymmetric dimer on a vibrating plate

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The dimer, as depicted in Fig. 1, composed of two spheres rigidly connected by a light rod, is used to explore the influence of the particle shape in the physics community recently. The experiment of a symmetric dimer bouncing on an oscillating plate showed that the bouncing dimer displays spontaneous symmetry breaking and ratchet-like transport in the system without externally imposed asymmetry [1]. Liu *et al.* [2, 3] numerically and theoretically studied the dynamics of a bouncing dimer by the LZB method and the trial-and-error method. Good agreements were achieved between their numerical results and experimental results in Ref. [1]. Furthermore, Gehlen *et al.* [4] studied the symmetric dimer with different friction coefficients between dimer components, which break the dynamical symmetry of the system. However, few studies have been devoted to the asymmetric dimer, where the two spheres have different sizes.

The main purpose of this paper is to present a method to model and simulate a 2D asymmetric dimer on a vibrating plate based on non-smooth dynamics [5]. The Hertzian-based contact model and Coulomb's law for dry friction are employed to describe the normal forces and frictional forces, respectively. Equations of motion of the dimer are established by Lagrange's equations of the second kind,

$$\boldsymbol{M}\ddot{\boldsymbol{q}} + \boldsymbol{Q}_g = \boldsymbol{W}_n \boldsymbol{F}_n + \boldsymbol{W}_\tau \boldsymbol{F}_\tau \tag{1}$$

where $\boldsymbol{q}$, $\boldsymbol{M}$, and $\boldsymbol{Q}_g$ are generation coordinate, intertie and gravity matrices, respectively. $\boldsymbol{F}_n$, $\boldsymbol{F}_\tau$ are the normal and tangential contact forces matrices. The matrices $\boldsymbol{W}_n$, $\boldsymbol{W}_\tau$ are the functions of $\boldsymbol{q}$. Based on non-smooth dynamics [5], the complementarities between friction saturations and relative tangential accelerations are formulated when the relative tangential velocities are equal to zero. Then the stick-slip transitions for contact points and the static frictional forces of the contact points can be determined. However, system-singular modes are likely to occur due to the absence of the tangential compliance in Coulomb's friction. Resolutions for these system singularities are given similar to Ref. [3]. Finally, the numerical results of a symmetric dimer are validated by comparing with the results from Ref. [1] and the influence of asymmetry is discussed according to the results from numerical simulation.

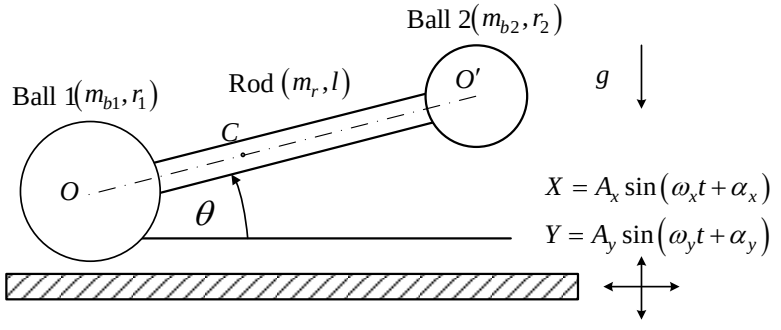

Fig. 1: the asymmetric dimer on a virbrating plate

References

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