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Dynamics of a Chain of Permanent Magnets

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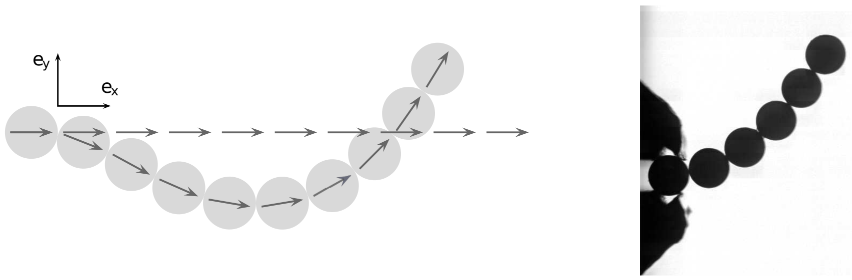
ABSTRACT

An arrangement of several spherical or cylindrical magnets presents different stable configurations [1]. One of them is the straight chain (figures 1a, 1b), whose dynamics is studied in the present work. This structure behaves similarly to a beam, but here the rigidity is exclusively due to magnetic forces.



(a) (b)

Figure 1: Sketch (a) and binary image (b) of a chain of cylindrical magnets at equilibrium and deformed configurations

Theoretically, the dynamical equations of the structure are obtained by first providing an expression of the energies involved in the system. At this stage, the magnetic interactions are either modelized by considering dipoles approximations for the magnets or by computing numerically the magnetic field around the magnets. Conditions of contact are introduced in the model thanks to Lagrange multipliers and a dynamical system governing the displacement of each magnet is finally obtained. An analogy with the eigenfrequencies of elastic beams allows to provide a model of an equivalent flexural rigidity induced by magnetic forces. Good agreement is found with the equivalent rigidity obtained for circular rings of magnets [2].

An experimental study of rigid assembly composed with neodymium permanent magnets is also performed. Free oscillations and forced oscillations experiments are realized. A good agreement is found between experimental and theoretical eigenfrequencies and eigenmodes (figure 2).

Next, the effect of an external magnetic field on the dynamics of a clamped-free chain of cylindrical magnets is studied. Here, the magnetic field is even able to modify the stability properties of the system. The clamped-free chain can now buckle in the same way as a beam would buckle when submitted to gravity. The comparison between theoretical and experimental results emphasizes the limitations of the dipolar description for cylindrical magnets.

Using full computations of the magnetic field, we now develop dynamical models of other systems involving differents shapes for the magnets (spheres, cylinders, plates...), as well as corresponding experiments.

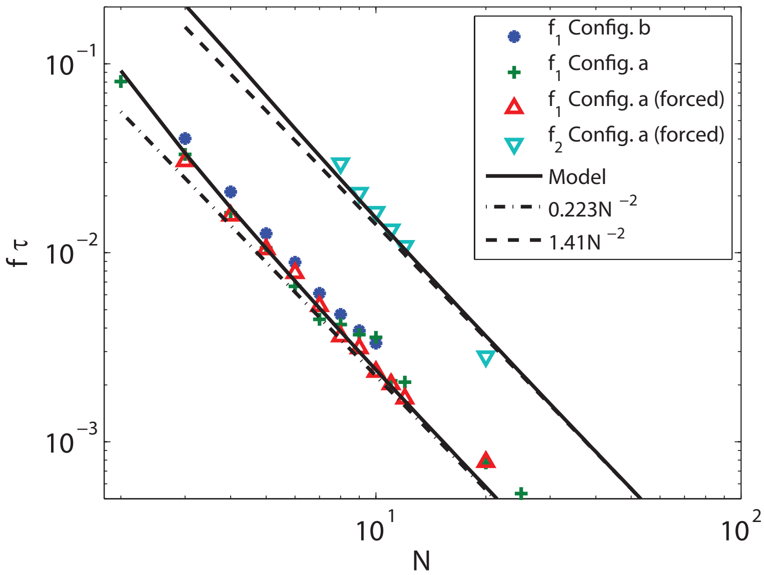


Figure 2: Comparison of experimental and theoretical eigenfrequencies. Symbols present experimental results for different cases, plain lines show the two first theoretical eigenfrequencies, dashed and dash-dotted lines are the asymptotic behavior of theoretical eigenfrequencies for large n.

References

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[2] D. Vella, E. Du Ponctavice, C.L. Hall and A. Goriely, *Proc. Roy. Soc. A*, 470, 20130609 (2014)