"Knotting and Re-knotting in Vibrating Ball-Chains"

Outline

Goals

1. Find unknotting and re-knotting times for vertically vibrating ball-chains as a function of the chain physical and geometrical properties, as well as the characteristics of the driving force.
2. Create software to process experimental data.

Specific Safety Issues

1. Working with vibrating metal chains is associated with annoying noise. The hearing protection is highly recommended.
2. The shaker must be treated with care to not permit destroying it under resonance condition while tuning frequency and amplitude of the driving force

Ball-chain as a model of a polymer molecule

The metal chain of beads, connected by small metal bars, is used worldwide for modeling the behavior of a polymer molecule. Vibrating the chain with different frequencies and amplitudes of the driving force, an experimenter is studying the behavior of a molecule under different temperatures. Placing the vibrating chain into restricted space, one can study the influence of boundary conditions, i.e. the environment, on the topology of the molecule. Knots can spontaneously appear on a real DNA/RNA molecule which is then unknotted with an assistance of topoisomerases. The time of unknotting and re-knotting processes depends on a variety of parameters. In our experiment these parameters can be:

- the beads' diameter;
- the length of the bond between the beads;
- the number of beads in a chain;
- the linear mass density of the chain;
- the size of the envelope enclosing the vibrating chain;
- frequency and amplitude of vertical vibrations of the shaker

The project can be divided into the following main stages:

1. Study of published results for experiments with vibrating ball-chains for both unknotting and knotting. Study existing software for measuring and calculating the radius of gyration. Creating a code for calculating the survival probability and cumulative number of knotting events. Choosing a set of ball-chains perfect for measuring unknotting and knotting, or re-knotting.
2. Within a reasonable range of driven frequencies, driving force amplitudes and properties of the ball-chains measure the unknotting and re-knotting time as a function of a number of beads with simultaneous recording the vibrating chain with a digital camera. Calculate survival probability and cumulative number of knotting events as a function of time. Find the radius of gyration of the vibrating chain as a function of time.
3. Study topological transformation of the ball-chain enclosed in an envelope with varying width.
4. Create a database of photos and videos of the observed chain behavior.