A first model to approach the stress-strain curves of entangled materials

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The aim of the model would be to reproduce the stress-strain curves of entangled materials when compressing or pulling on one fiber, or a bundle of fibers.

- experimental results for this phenomenon? (did anyone made such experiments?) Very fine force measurements would be interesting, because I think Barkhausen-noise type jumps could exist in this system.

The main elements of the model would be fibers. The fibers interact with each other by friction and pinning. Pinning can model geometrical frustrations as well. The fibers can also very their length, which models the complex entanglement or de-entanglement process. We model the fibers as straight line drawn in blue on Fig.1.
The equilibrium length of the fibers is distributed according to a given distribution. The variation of the length can be considered by randomly positioned springs (drawn wit red), with spring constants and equilibrium length distributed according to a given distribution. The friction and pinning forces are modeled by the black arrows, which have their bases fixed on the fiber. The top can touch the neighboring fibers, exerting a fixed friction force on them. When arrows from neighboring fibers superimpose on each other we have an additional pinning force.

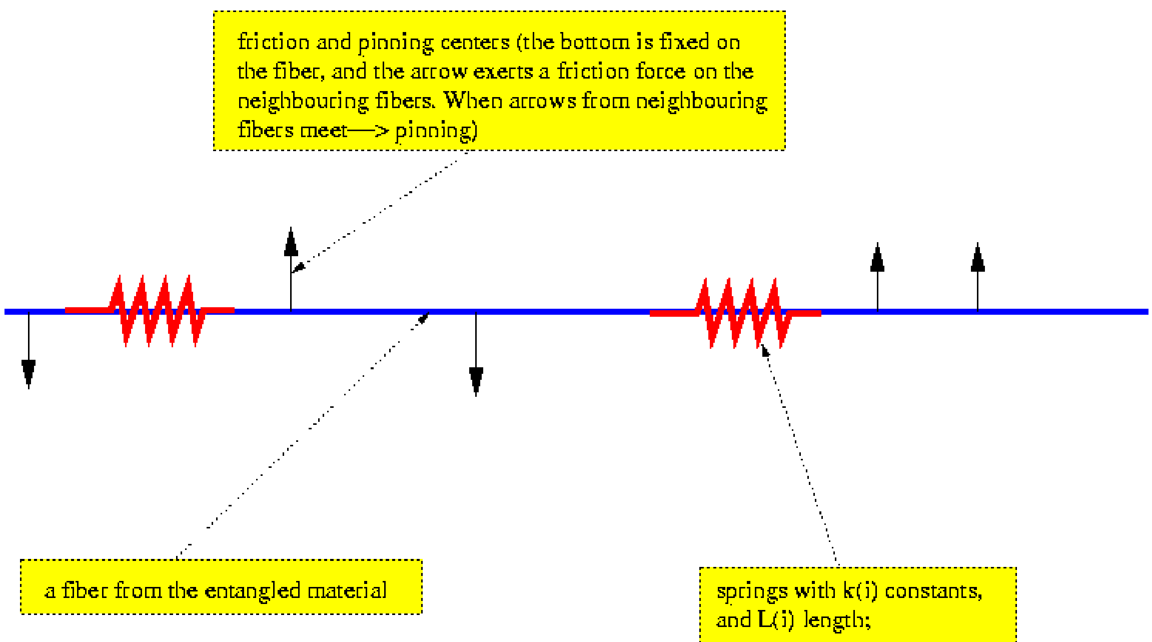

Fig. 1

The fibers are arranged in a 1+1 dimensional model as illustrated on Fig2 and Fig. 3. The distance between neighboring fibers is kept fixed, and the fibers can slide in the horizontal direction only. By pulling a bundle of fibers (Fig. 2) or one fiber (Fig.3) a series of stick-slip phenomenon occurs, leading to a specific stress-strain curve. The objective of the simulation would be to compute these stress-strain curves.

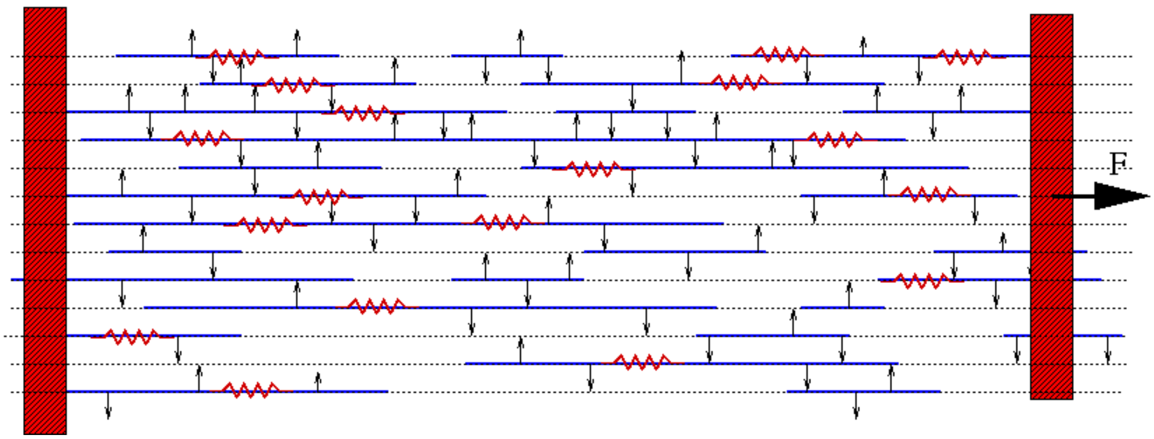

Fig. 2

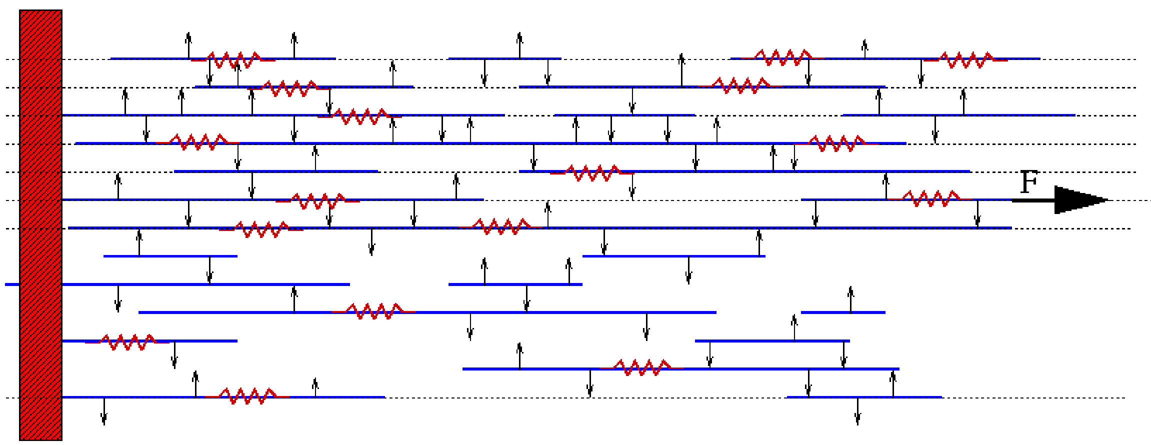

Fig. 3

The computational difficulty can be overcome by using object-oriented programming, defining the fibers and the elements on the fibers as C++ objects. Then the whole problem reduces on the application of the basic laws of dynamics. We do not want to do molecular dynamics, rather a cellular automata approach. This means that whenever a fiber begins to slide, it will slide until is stopped by pinning. Taking into account the complex system of action-reaction forces and especially the friction and pinning forces (which can equilibrate a given intensity force) we could face a computationally heavy problem…. Writing up the code would also need a lot of attention!

Question? Can we still simplify this model, without loosing the main ingredients it incorporates?