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Formation and mechanics of fire ant rafts as an active and self-healing membrane

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The unique ability of fire ants to form a raft to survive flooding rain has enchanted biologists as well as researchers in other disciplines. It was established during the last decade that a three-dimensional aggregation of fire ants exhibits viscoelasticity with respect to external compression and shearing among numerous unusual mechanical properties. Continuing these works, we will study the ant raft in its natural form, i.e., composing no more than two layers. This allowed us to focus on the cracks that are unique to membranes and see how their patterns are influenced by the fact that these ants are mobile and can self-repair the damage to keep their raft from disintegration. In the beginning, we show that vertical and horizontal shaking can also prompt fire ants to aggregate. The canonical view that the stability of ant raft relies on the Cheerios effect and a combination of other parameters is tested. The force-displacement experiment is performed to show that two distinct mechanical responses and fracture patterns, characteristic of ductile and brittle materials, can be elicited, depending on the magnitude of the pull speed. During the process, we counted the number of ants that actively participated in the stress-strain relation and used this information to roughly sketch out the force chain. The latter information reveals that the pull force expedites the alignment of fire ants, in analogy to the effect of an electric field on liquid crystal polymers. To highlight the self-healing nature, we employ the creep experiment to study how the length and Young's modulus of the raft change or relax with time. One major finding is that the raft can exhibit zero Poisson's ratio without resorting to specific geometry structures. This is enabled by the active recruitment of ants from the top layer to the bottom layer to keep the raft from disintegrating.

Primary author: CHEN, Chung Hao

Presenter: CHEN, Chung Hao

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