# Ferrofluid surface simulations go more than skin deep

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The magnetic responses of ferrofluids can be modeled to expand their use in a broader range of fields such as advanced electronics and nanomedicine. Credit: KAUST

Computer models efficiently and accurately simulate the magnetic responses of ferrofluids by considering only the fluid's surface.

The spiky structure that erupts from the smooth surface of a ferrofluid when a magnet is brought close can be predicted more accurately than previously thought. KAUST researchers have shown that computational

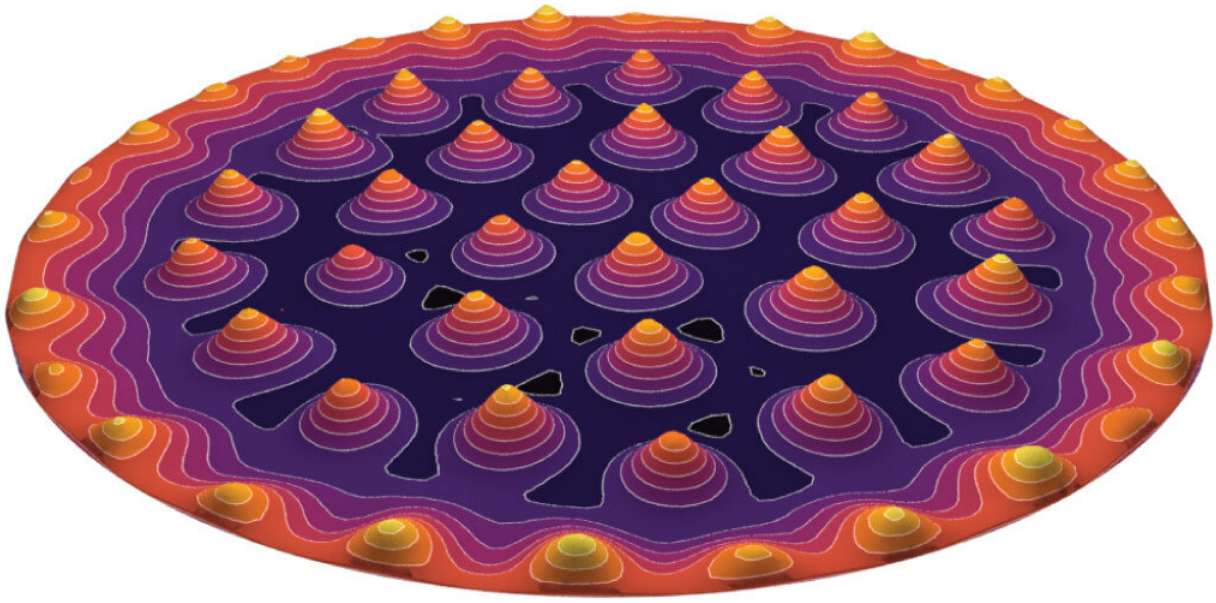
algorithms can calculate the ferrofluid's bristling response to a magnet by simulating only the liquid's surface layer.

Ferrofluids are liquid suspensions of iron-based particles that behave like a regular fluid, but once a magnet is present, the ferrofluid rapidly shape-shifts to form spikes that align with the magnetic field. Originally developed by NASA, ferrofluids have numerous uses ranging from advanced electronics to nanomedicine and have the potential for even broader use, if their magnetic responses could be predicted more accurately.

Dominik Michels and his team are applying computer simulations to model ferrofluid behavior. "Our aim is to develop an efficient and accurate algorithm to simulate the macroscopic shapes and dynamic movement of ferrofluids," says Libo Huang, a Ph.D. student in Michels' team.

Recently, looking at the wider field of fluid simulation, the team has shown that the concept of simulating fluid motion by considering only the liquid's surface can be adapted to ferrofluids.

"While the surface-only liquid simulation provides a platform for fluid simulation, its extension to ferrofluids is significant," Huang says. To model a fluid's behavior based only on its surface, the liquid must respond to inputs in a simple linear fashion. Most ferrofluids have a complex non-linear response to a magnetic field.



When a magnet is brought close to a ferrofluid, the ferrofluid shape-shifts to form spikes that align with the magnetic field. Credit: Huang et al.

However, the team showed that as long as the magnetic field is not too strong, the response is close to linear, enabling them to perform a surface-only calculation of the magnetic field response.

In the simulation, the researchers represented the liquid surface as a series of triangles, Huang explains. "The representation of ferrofluids as surface triangles allowed us to accurately estimate the curvature of the liquid interface as well as the interface position," he says. The spike structure can be simulated by calculating the interplay between the magnetic force and the liquid's surface tension.

Considering only the fluid's surface, rather than its entire volume, made the simulation far more computationally efficient, enabling more accurate simulation of the complex ferrofluid behavior. "We were able

to reproduce the distance between spikes of the real fluid's spike pattern in an accurate quantitative fashion," Michels says. "We could simulate much more complex dynamic motion."

**More information:** Huang, L., Michels, D.L. Surface-only ferrofluids. *ACM Transactions on Graphics* 39, 174 (2020).

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