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Numerical Analysis toward the Rosensweig Instability by the Boundary Element Method Considering Multiplicity and Singularity

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For investigating the phenomena on magnetic fluid interfaces precisely, such as the Rosensweig instability, a numerical analysis in real space and time has been developed in this research by the Direct Boundary Element Method (DBEM). When the magnetic fluid is assumed incompressible-irrotational and electrically-insulative, the fluid velocity potential φ and normal fluid velocity v_{n} for the fluid analysis are obtained confined to the boundaries, as well as the magnetic potential ϕ and normal magnetic induction b_{n} for the magnetic analysis.
During the discretizing process of the basic equations for the DBEM,
one of the problems is the multi-valued physical quantities at the points where boundaries cross sharply, which was solved by grouping the discretization elements at the same position. Another problem is the diagonal discretization terms where singular area integral of the Green's function is required (singularity). This problem was avoided by using the sum rules for discretization coefficients derived from the "uniform vector field conditions".
The "equation for interface motion" (EIM) integrated in time provides φ, where the sum of interface stresses S includes the magnetic stress difference T_{N} considering the nonlinear magnetization. In the fluid analysis, φ gives the Dirichlet condition on the interface, and v_{n} is obtained, Then, φ and v_{n} compose the interface fluid velocity {\boldmath$v$} which is integrated in time to determine the interface elevation ζ. In the magnetic analysis, both of the continuity condition for ϕ and b_{n} are imposed.
In the two-layered system under homogeneous vertical magnetic field, the interface was initially deformed into the profile of axisymmetric solitary-wave, and its behavior afterward was observed. For larger intensity of applied magnetic induction b_{app}, the interface oscillates faster but smaller, and destabilizes finally. Quantities before this destabilization is shown. When b_{n} is intensified locally near the center of the concave interface, S as well as T_{N} is amplified in the negative direction, and causes the driving force toward the center. Instead of instantaneously, however, the flow toward the center arises later as its accumulated effect, which brings about the sudden rise in the interface after some period.

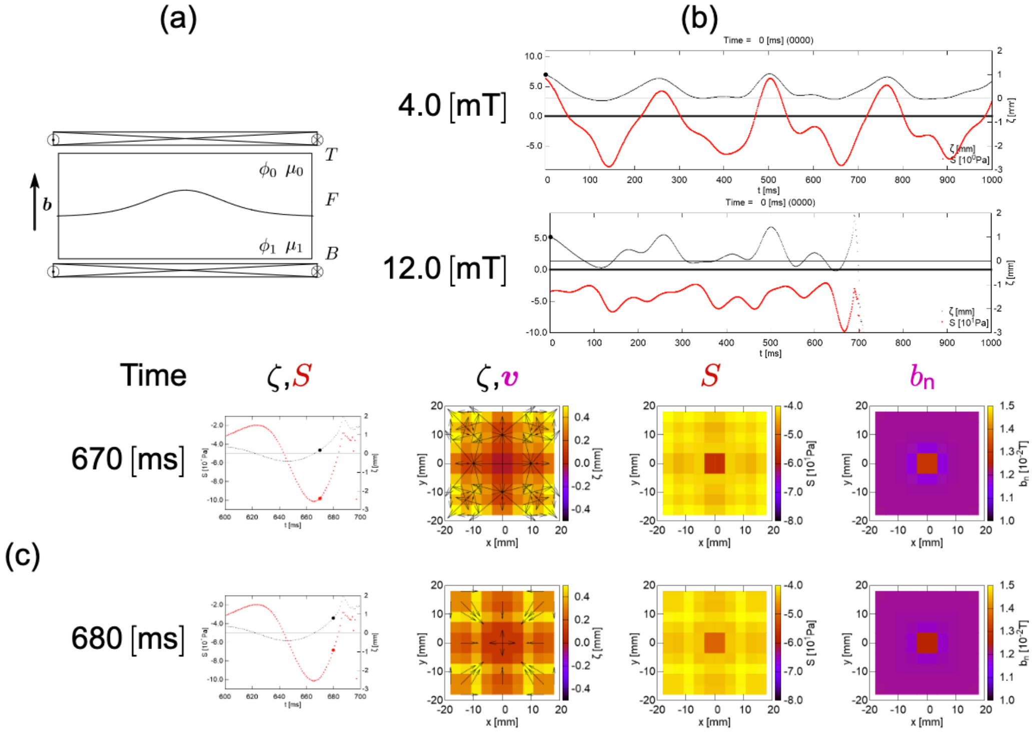

Figure 7: (a) Longitudinal section of two-layered system under homogeneous vertical magnetic field in a square container. (b) Temporal change of ζ (black) and S (red) at the center of the interfase for different bapp's. (c) Spatial distribution on the interface of ζ, S, bn and v (vector) at some time steps before the destabilization for bapp=12.0 [mT].

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