Mean-field modeling of the interaction of soft iron with helical flows

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We have performed kinematic simulations of dynamo action of a helical flow of a conducting fluid with a flow geometry in the style of the G.O. Roberts flow. As an extension to the original model, we have taken into account internal rods and/or walls that lie in the center of individual eddies and/or provide a separation of the eddies from each other. These flow guiding fixtures can be made of soft iron with a relative permeability much larger than one and the associated inhomogeneity significantly alters the behavior of the leading dynamo eigenmodes. The investigations are motivated from the roughly unknown induction effects of the forced helical flow that is used in fast reactors to remove the heat from the reactor core and from the supporting impact for dynamo action caused by the presence of soft iron impellers in the von-Karman-Sodium (VKS) dynamo.

Applying the testfield method we have computed the elements of the alpha tensor from direct simulations of a restricted number of helical eddies. The results may be extrapolated to model the combined induction effect of an extremely large number of individual helical eddies that cannot be resolved in direct simulations.

We will show which properties of the small scale induction in principle can be reproduced in a simplified mean-field model and where discrepancies/inconsistencies might arise. Furthermore, we investigate the possibility to include spatial "fluctuations" of the permeability into the framework of simple mean-field simulations.