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DISCUSSION

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The authors have made a significant contribution to the literature concerning magnetic bearings.

The reader should note that the analysis presented here is more general and broadly applicable than the example implies. For example, the bearing discussed will levitate with no spin speed ($\Omega = 0$), and the analysis is also valid for a bearing with DC driven magnets ($\omega = 0$). The discussor believes this is the first paper to present a thermal analysis in a magnetic bearing, and the implications for the temperature rise would be interesting to pursue.

The reference to equations (8), (10) in [13] should be equations (B.7, B.8).

For readers considering an actual implementation, the bearing generates lift by differential repulsion between the top and bottom pads. The top pad is not contributing in a positive fashion to the load carrying capability and is only heating the shaft. Similarly, the lateral pads are heating the shaft while providing lateral stability. In the design of an actual bearing, it would probably be desirable to have unequal magnet sizing. However, the assumption of equally sized magnets is almost universally made in analyses (the discussor's included).

The authors are asked to respond to the following:

1) The square wave applied fields are approximated by a first order fourier expansion (a single sine wave). Hebbale [13] used the first 20 terms of such a series to reduce error below 10 percent.
2) The tractions on the horizontal surface in Fig. 3 are actually wrapped around the circular surface in Fig. 2. Therefore, for the top magnet, a positive τy contributes to either lift (Fy) or lateral face (Fx) depending upon Θ (and therfore x). It would seem that the direction of the tractions should be taken into account in the averaging process for each face ($\langle t_x \rangle$, $\langle t_y \rangle$) in the same way the magnet angle is included in equations (31, 32). The tractions should be "wrapped" around the shaft before integration of each pad's result at radial and tangential force.

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Electromagnetic bearings involve inter-discipline of electrical and mechanical engineering. There appears to be a communication gap between the conventional bearing user and the researchers of these types of unconventional bearings. In this regard, the authors are congratulated for their excellent work in that they have not only identified the pertinent parameters of the Eddy current bearing, but also formulated these parameters in a concise fashion consistent with the conventional fluid-film bearing methodology.

One of the good features of an Eddy current bearing is that it is inherently a positive "spring" without using any servo system. However, damping is required for a dynamically stable bearing. This has not been addressed in the paper. Therefore, the authors are encouraged to evaluate the damping of the Eddy current bearing in a similar approach. The damping analysis may also shed light on the significance of the attitude angle ϕ.

The ability to brake and propel is a favorable Eddy current bearing feature with potential applications. To this end, a parameter defining the ratio of the propulsion power to the power dissipated as heat on the rotor may be useful. The significant drawback of the Eddy curent bearing appears to be the large I^2R loss on the rotor. Future effort to achieve Eddy current bearing designs with minimized power loss seems justifiable.

Authors' Closure

The authors thank Dr. Chen and Professor Taylor for their insightful comments. The points they raise are valid and will be addressed more fully in a paper we are now preparing. The following paper analyzes a more "true" journal bearing in which a continuous magnetic field is wrapped around a shaft rather than the present series of linear pads. Our responses to the issues raised above are as follows:

1) Unfortunately, we failed to even think of damping. One of us, a fluid dynamicist by education, should surely have appreciated this important consideration.
2) Professor Taylor's second comment is probably correct. We time averaged first (in the Cartesian configuration) and then wrapped the pads around the shaft, rather than the reverse. Since the force arises from a nonlinear effect (proportional to the square of the magnetic intensity), the two cases are not necessarily equal.