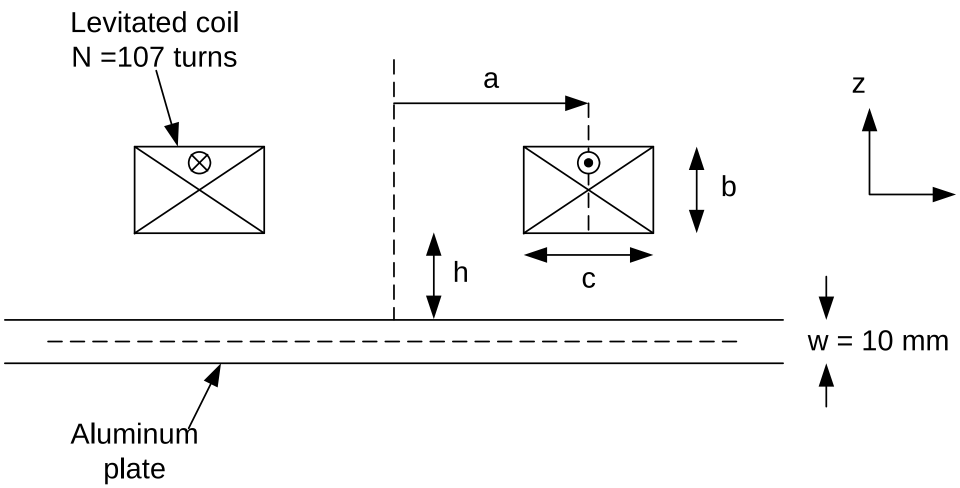
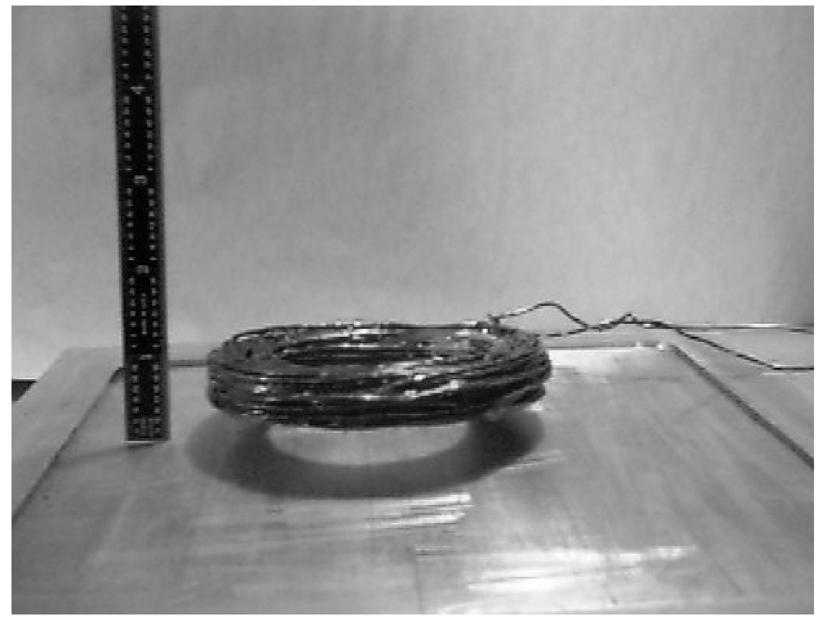
Power Electronics Notes 30F
Electrodynamic Levitation Demo

Marc T. Thompson, Ph.D.
Thompson Consulting, Inc.
9 Jacob Gates Road
Harvard, MA 01451
Phone: (978) 456-7722
Fax: (240) 414-2655
Email: marctt@thompsonrd.com
Web: http://www.thompsonrd.com

AC Eddy Current Suspension Experiment

- For an electronic copy of the paper, email the author



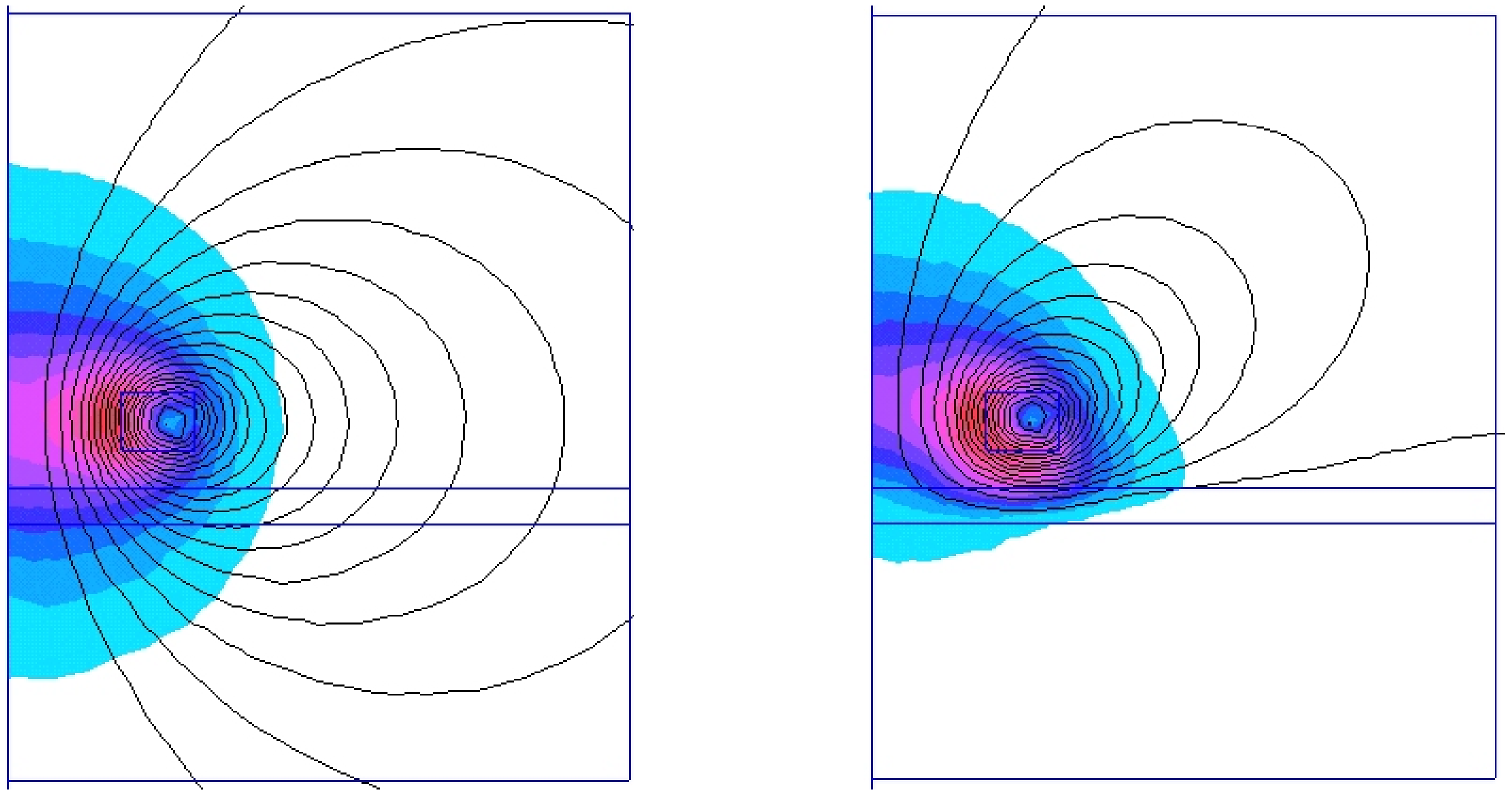


References:

1. Marc T. Thompson, "Eddy Current Magnetic Levitation--- Models and Experiments," *IEEE Potentials*, vol. 19, no. 1, Feb./March 2000, pp. 40-44
2. Marc T. Thompson, "Electrodynamic Magnetic Suspension --- Models, Scaling Laws and Experimental Results," *IEEE Transactions on Education*, vol. 43, no. 3, August 2000, pp. 336-342

Flux Plot at DC and 60 Hz

- At sufficiently high frequency and coil current, induced magnetic pole in conductor creates enough force to lift coil



One Method to Calculate Lift Force

- We can deduce force acting on the coil by making measurement of inductance of coil at different heights

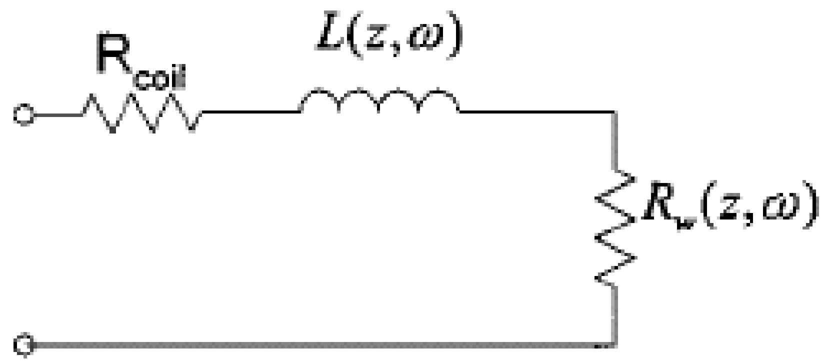


Fig. 2. Electrical model of system

One Method to Calculate Lift Force

Fig. 5. The 60 Hz coil inductance for various coil heights above aluminum plate. Dotted line is curve fit to data.

One Method to Calculate Lift Force

A possible functional dependence for the terminal inductance (confirmed by measurements given later in this paper) is

$$L(z) \approx L_o - L_r(\omega)e^{((-z)/\gamma)}. \qquad (6)$$

In this thought experiment, assume that the coil is driven by a fixed frequency ac current source. The magnetic energy stored in the inductor is

$$E_m = \tfrac{1}{2}L(z)I^2. \qquad (7)$$

$$f_z = -\frac{d}{dz}E_m = \frac{I^2}{2}\,\frac{dL(z)}{dz} = \frac{I^2}{2\gamma}\,L_r e^{(-z)/\gamma}. \qquad (8)$$

Stability of Suspension

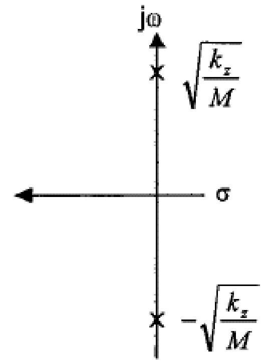


Fig. 4. Approximate pole locations for vertical mode of motion of electrodynamic magnetic suspension

$$\tilde{f}_z = -Mg\frac{\tilde{z}}{\gamma} \equiv -k_z\tilde{z}. \qquad (10)$$

C. Resonant Frequency of Suspension

The curve fit shows that the characteristic decay length for inductance is approximately 20 millimeters. Therefore, our estimate for resonant frequency is

$$f_{osc} \approx \frac{1}{2\pi}\sqrt{\frac{g}{\gamma}} \approx \frac{1}{2\pi}\sqrt{\frac{9.81}{0.02}} \approx 3.5 \text{ Hz}. \qquad (16)$$

How Hot Does it Get ?

TABLE III
PREDICTED AND ACTUAL COIL CURRENT VS. LEVIATION HEIGHT, AND CALCULATED POWER DISSIPATION IN COIL

h (mm)	$I_{measured\ (A\text{-}RMS)}$	$I_{calc\ (A\text{-}RMS)}$	*Q (Watts)*
0	21	22.1	168
10	26	28.4	257
20	39	36.5	578

$$Q = (h_c + h_r)A(T_{coil} - T_A). \qquad (17)$$

The free convection heat transfer coefficient (h_c) is approximately 0.001 W/cm^2-K [26] and the surface area of the test coil $A = 196$ cm^2. The radiation heat transfer coefficient is more difficult to calculate, as radiation loss depends on the forth power of the absolute coil temperature. The radiation heat transfer coefficient may be expressed as [26]

$$h_r = \frac{\sigma_t \varepsilon (T_{coil}^4 - T_A^4)}{(T_{coil} - T_A)} \qquad (18)$$

How Hot Does it Get ?

$$\Delta T \approx \frac{Qt}{C_{TH}} = \frac{(168 \text{ J/s})(30 \text{ s})}{135 \text{ J/K}} \approx 37\text{K}. \qquad (19)$$

Reference

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Electrodynamic Magnetic Suspension—Models, Scaling Laws, and Experimental Results

Marc T. Thompson, *Member, IEEE*