Self Alignment using Electromagnetic Induction for Mass Fabrication of Micro-Coils

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Our work is motivated by the proposition that electromagnetic forces may be utilized to achieve self aligning of large plates (e.g. wafers) and self assembly of micro-scale components. We analyze the electromagnetic levitation and alignment forces between two parallel conducting rings. We present a new simplified functional form of the electromagnetic levitation and aligning forces, and provide new insight and better understanding of this problem. To this end we developed a 2D model which captures the physics of the more complex 3D problem of two interacting rings. Our 2D model explains why size mismatch between the rings can reverse the action of aligning forces.

The two parallel conducting rings are illustrated in Figure 1a. Two parallel rings with initial horizontal eccentricity $X$ and vertical separation $Z$ carry currents in the same direction (e.g. clockwise). This 3D problem of interacting rings is rather difficult to analyze, and it is not easy to understand various features of the computed interaction forces. Our simplified 2D model considers the electromagnetic interactions between two infinitely long rectangles, and provides new insight. The two infinite parallel rectangle wires are illustrated (in cross-section) in Figure 1b.

Figure 1 – The 3D problem of two conducting rings (a) A simplified 2D model of two infinite conducting rectangles (b).

Two conductors will attract or repel each other if the current they carry is in the same or opposite direction, respectively. The currents in each of the two problems presented in Figure 1 will produce alignment\misalignment and levitation\attraction forces. The properties of these forces are a
function of the horizontal eccentricity $X$, vertical separation $Z$ and the ratio between the sizes of the rings/rectangles. Figure 2 presents a map of the alignment and levitation forces for two infinite rectangles which are identical (Fig. 2a) or of different width (Fig. 2b).

![Figure 2 - The alignment/misalignment and levitation/attraction regions between the equilibrium curves for two identical rectangles (a) and two different width rectangles (b). The solid and dashed lines describe stable and unstable equilibriums, respectively. The blue and red colors describe the horizontal and vertical interaction forces, respectively.](image)

Our simplified model explains and provides insight on the physics behind these alignment maps. For example, it explains the horizontal instability region around the origin obtained for rectangles of different width. The aligning force between two eccentric circular rings was investigated in a paper by Ki-Bong Kim [1]. Kim suggested that a neutral plane exists where the horizontal force vanishes for any given value of horizontal eccentricity. The alignment maps show that this suggestion is only a local phenomenon (Green line in Figure 2b), and this puts Kim’s findings in context.

We re-derive Kim’s analytic expressions which we present in a new functional form. In this new form it is easier to identify the effect of size mismatch and the effect of eccentricity on the interaction force. In fact, the force maps illustrated in Figure 2 are a new and clearer means of presenting the electromagnetic interaction.

In our presentation, we will also show how conducting rings may be used for aligning and levitating substrates.

References: