Chapter 4 — Sliding Contact Coilguns

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Sliding contact coilguns were first investigated by Thom and Norwood in 1961, were revived by Mongeau in the 1980s, and are currently being studied by Engel et al. at the University of Missouri and the U.S. Naval Research Laboratory. Coilguns can be more efficient than a typical railgun, and are only slightly less efficient than contactless coilguns that require expensive power electronics, making them an excellent compromise between simplicity and efficiency.

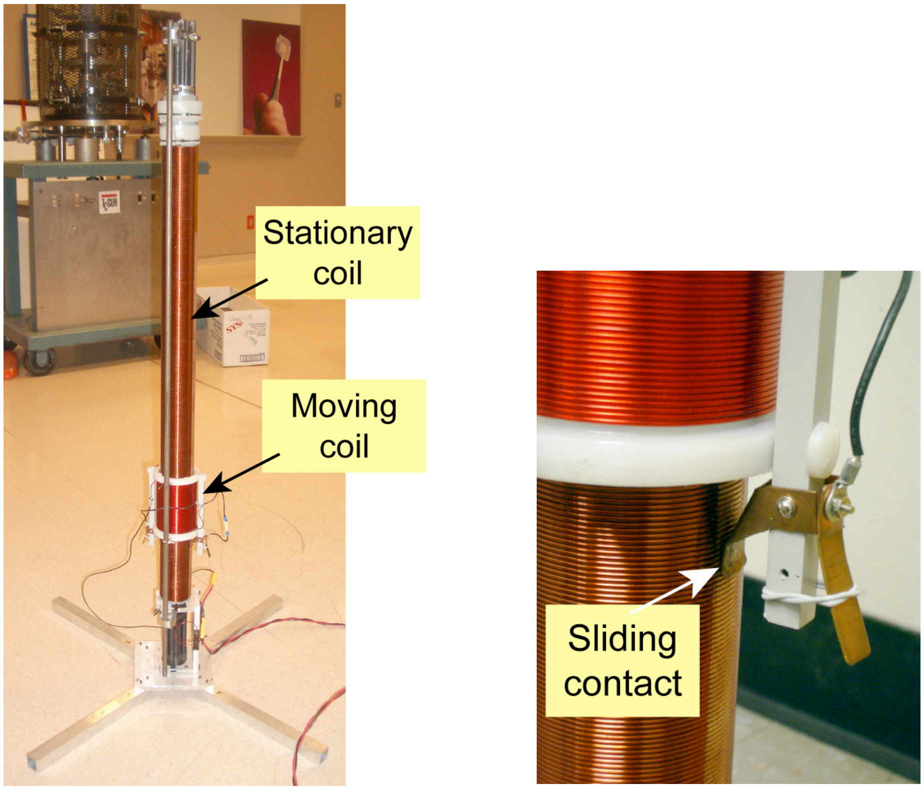

Figure 4-1

In the sliding contact coilgun, a stationary solenoid and a coaxial solenoid that is allowed to move exert a force on each other. The stationary coil has insulation removed from a strip along its length so that sliding contacts can be used to synchronize the current in the stationary coil with the moving coil. Current can be fed to the moving coil using either rails, or, for small launchers, flexible wires.

There are several possible choices of current carrying region for the stationary coil. In the figures below, the red regions indicates current flowing in one sense while the blue regions indicates current flowing in the opposite sense. In the configuration shown in Fig. 4-2, the stationary coil pushes on the moving coil, accelerating it to toward the right in the figure. The power supply is connected to the end of the stationary coil, so that the entire stationary coil behind the sliding contacts carries current. In the figure, two sliding contacts are shown. This is redundant, but provides a convenient method of balancing the lateral forces on the moving coil.

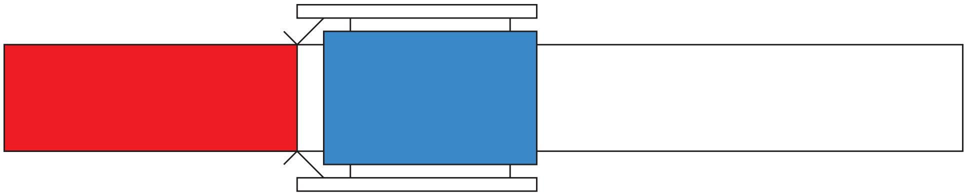

Figure 4-2

In the configuration of Fig. 4-2, a significant amount of energy is left in the stationary coil at the completion of a launch. This can be corrected by adding another set of sliding contacts, shown below in Fig. 4-3. For this to be an improvement, the stationary coil must be inductively commutated (see below); if the energy is dissipated in an arc to the sliding contact, nothing is gained.

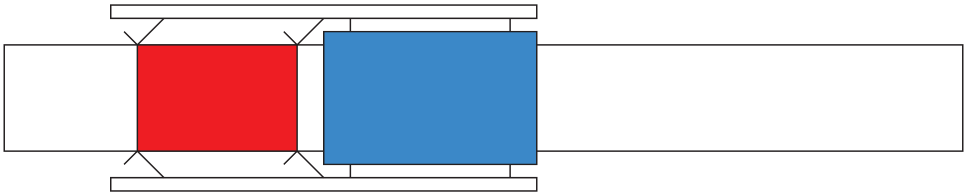

Figure 4-3

Inductive commutation is easier to achieve in a configuration in which the current-carrying region of the stationary coil is ahead of the moving coil, as shown in Fig. 4-4. In this case, the currents in the two coils flow in the same sense, for an attractive force, pulling the moving coil to the right. The drawback of this configuration is that the resistance is largest at the beginning of the launch, decreasing the magnitude of the current.

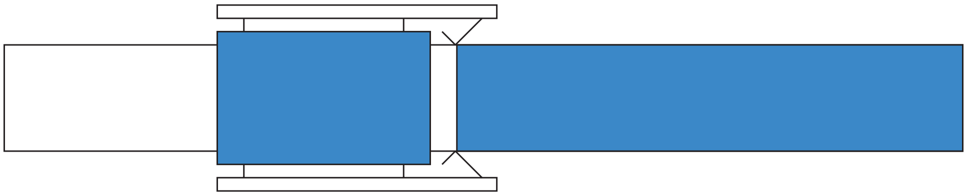

Figure 4-4

Figure 4-5 shows the configuration of Fig 4-4, but with the addition of a second set of sliding contacts. This decreases the initial resistance.

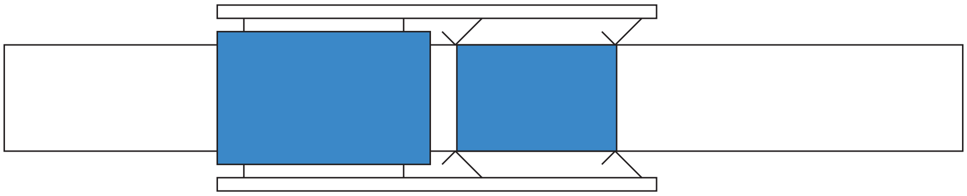

Figure 4-5

Other combinations are possible; In Fig. 4-6, the moving coil has two segments. The segment on the right carries current in a sense that is pushed by the active section of the stationary coil, while the segment on the left is pulled. More moving coils can be used, or more than one active region of the stationary coil. For larger payloads, two stationary coils can be used in parallel, with the payload carried between them by a link between the moving coils. For smaller payloads, the moving coil can sit inside the stationary coil.

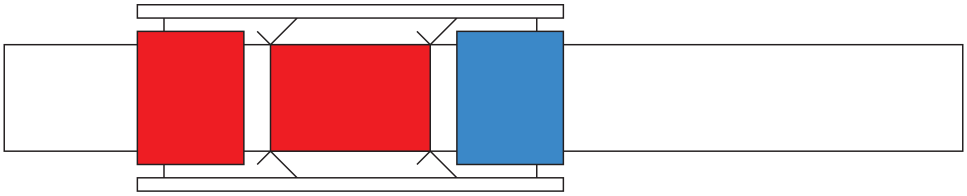

Figure 4-6

The most natural formulation for force calculation in coilguns is usually

$$F = -I_1 I_2 \nabla M_{12},$$

in which I_1 and I_2 are the currents in the two circuit elements, and M_{12} is their mutual inductance. It can be seen that maximizing the mutual inductance gradient is very important. In all of the configurations except those in Figs. 4-2 and 4-4, the mutual inductance gradient remains constant throughout the launch. Notes on calculating inductances can be found in [Thompson]. The value of ∇M_{12} for the coilgun reported in [Engel] is 150 µH/m, 300 times larger than that of a typical simple railgun. The calculated value of ∇M_{12} for the iron-cored launcher shown in Fig. 4-1 is 0.01 H/m.

In all of the configurations except the first, as a sliding contact passes each loop of the stationary coil, the current in that loop is forced to zero. The energy that was stored in the magnetic field of this loop is transferred to kinetic energy of the moving coil and projectile, energy stored in the other loops of the stationary coil, and energy dissipated in the sliding contacts. Only the first of these recipients of the energy is productive, so maximizing this part of the transfer should be carefully considered. The basic analysis is presented in the papers by Mongeau.

References

K. Thom and J. Norwood, "Theory of an Electromagnetic Mass Accelerator for Achieving Hypervelocities," *NASA Tech. Note* D-886, 1961.

P. Mongeau, "Analysis of Helical Brush Commutation," *IEEE Trans. Mag.*, Vol. Mag-20, pp. 231–234, 1984.

P. Mongeau, "Inductively Commutated Coilguns," *IEEE Trans. Mag.*, Vol. 27, no. 1, pp. 568–572, 1991.

T.G. Engel, W.C. Nunnally, and J.M. Neri, "High-Efficiency, Medium-Caliber Helical Coil Electromagnetic Launcher," *IEEE Trans. Mag.*, Vol 41, pp. 4299–4303, 2005.

M.T. Thompson, "Inductance Calculation Techniques — Part I: Classical Methods," *Power Control and Intelligent Motion*, Vol. 25, pp.40–45, 1999.

M.T. Thompson, "Inductance Calculation Techniques — Part II: Approximations and Handbook Methods," *Power Control and Intelligent Motion*, http://www.pcim.com.