Chapter 3 — Railguns

Phil Putman
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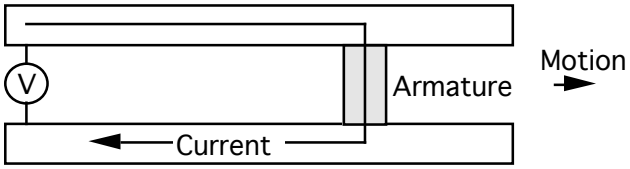

Figure 3-1

Current flowing in a loop of wire exerts an outwardly directed force on the wire. A railgun can be thought of as a big loop of wire, with one section, called the armature, free to accelerate. Armature speeds up to 6 km/s have been attained by several groups. However, because the railgun in its simplest form is a single-turn machine, the operating currents are very high, resulting in poor efficiencies. The high currents carried by the sliding contact of the armature also cause severe wear problems.

The force on the armature can be expressed as

$$F = \frac{1}{2} L' I^2,$$

where L' is the derivative of the self inductance of the rail pair along the direction of motion of the armature, or, equivalently, the inductance per unit length. The value of L' for a typical railgun is 0.5 μH/m.

If there is also a magnetic field B applied perpendicular to both the direction of current in the armature and the direction of motion, the expression for the force on the armature becomes

$$F = \frac{1}{2}L'I^2 + IBd,$$

where d is the effective length of the armature, that is, the distance between the rails. An applied field results in a higher force for a given current, increasing the efficiency.

Many other methods have been proposed for increasing efficiency and addressing other problems. The list below is compiled from the book *Physics of Electric Launch*, by Ying, Marshall, and Shukang. Even a superficial description of each method is beyond the scope of this guide; obtaining a copy of the book is highly recommended.

1. Distributed energy storage
2. Distributed energy feed from a single source
3. Segmented rails
    - Equal length segments
    - Equal time segments
4. Magnetic field augmentation in series with the power supply
    - Stacked sub-rails
    - Planar sub-rails
5. Guard plate augmentation
6. Magnetic field augmentation by independent magnets
    - Conventional electromagnets
    - Permanent magnets
    - Superconducting magnets
    - Multiple stage coils
7. Four rails
    - Round-bore
    - Square bore
    - X-shaped bore

8. Discrete electrodes
    - With fuses
    - Without fuses
9. Coaxial rails
10. Continuous outer rails
11. Segmented outer rails
12. Polyphase power supplies
    - Two phases
    - Three phases
    - Six phases
13. Power fed from the rail front
    - Augmented
    - Double front fed

Combinations of some of these concepts are also possible.

References

W. Ying, R. Marshall, and C. Shukang, *Physics of Electric Launch*, Science Press, Beijing, China, 2004.