Investigation of Energy Conversion Efficiency in Railguns

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Abstract

While railguns are used in a variety of applications, ranging from military to public transportation, there is currently no model that can accurately predict their output energy efficiency. This study explores the creation of an energy conversion efficiency model for railguns. A railgun is a device that can shoot a conductive projectile and is comprised of three main components: two rails, the conductive projectile, and capacitors as a power source. The projectile is placed in between the rails, and when the capacitors discharge their energy via an electrical current, it accelerates due to a Lorentz force; the current flowing through the rails induces a magnetic field, which then accelerates the current-carrying projectile forward. However, throughout this process, significant amounts of energy are lost. A railgun can be considered a variation of a Resistor-Inductor-Capacitor (RLC) circuit but ultimately differs due to its large size, miniscule inductance, and incorporation of a projectile. Still, the existing mathematical models for real RLC circuits can help provide a general idea of the energy behavior of railguns before experimentation. Using the RLC circuit models as a starting point for the creation of a new efficiency model specific to railguns, the student created predictive, theoretical equations for the output energy of the projectile. After he constructed a fully functional railgun and tested how the energy conversion behaved from the capacitors to the projectile, he found that the existing model for RLC circuits accurately describes the energy efficiency of railguns to a certain point. However, it does not consider additional losses that only occur in railguns during conversion from the current's electrical energy to projectile's mechanical energy. Experimental results and analysis showed that mechanical friction was a significant factor in the energy transfer, and, after adjusting the existing equations to account for variable frictional losses, the student developed a more accurate model that correctly predicts the output energy conversion efficiency of railguns.