

**Abstract of Ph.D. Thesis**  
**“Design and Performance Enhancement of Electromagnetic Railgun for High Velocity Launching”**  
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**Abstract**

Conventional launchers use chemical propellants to launch projectiles, where the gases expand at the bottom of the barrel and the projectile is pushed forward due to the pressure exerted by expanding gases. In the place of detonation, instead, a force generated solely by means of current can provide a lot of velocity to the projectile with improved efficiency. From this comes the question of why not electric weapons are a possible reality? Directed energy weapons are kind of weapons that use electricity to power themselves. However, directed energy can mean from particle beams to electromagnetic beams. In this category of electric weapon systems electromagnetic railguns have created their own niche because they use electric energy to power a projectile's launch. In this way railgun combines both conventional type and futuristic type weapon systems. Appropriate metrics are derived to evaluate conventional and novel designs in rails and armatures of the railgun. In this work a railgun with a combination of narrowed rails and concave armature, that is more efficient as compared to a standard electromagnetic launcher with rectangular rails and a monolithic 'C' armature. However, it is observed that role of armature in improving the inductance gradient is minimal and the research work focused on rail design. Since tapering is improving inductance gradient, highest tapering would provide the highest improvement in inductance gradient. The result of the logic did show improvements in inductance gradient but depleted the barrel efficiency of the railgun. Hence there is a need to balance the muzzle velocity of armature, system efficiency and barrel efficiency through design changes. From the above constraints, a new rail design of filleting is applied to improve the inductance gradient without suffering the efficiency. The question raises from this mechanical design is whether to apply this on one side of the rail or both sides. It is observed that applying it on one side provided the flexibility to vary the fillet radius to extended limits than applying fillet on both sides. The design changes of fillet and taper, when applied together to a rail went hand in hand. The design changes helped each other by not allowing a steep taper angle and allowing highest fillet radii on outer edges. This combination provided the highest system and barrel efficiencies compared with conventional railgun design for the same amount of current input. Apart from improving efficiency through design changes for a normal railgun, augmented railguns can also be improved by using the taper and fillet designs for the augmenting rails. To elaborate, if a railgun already exists and an extra pair of rails with taper or fillet can be added upon to the existing railgun to improve the inductance gradient by nearly 40%. Efficiency calculation requires new relations for breech voltage which should consider the effects of augmenting rails. Considering the design change limits for fillet and taper, heavier loads can be easily pushed with augmented railguns with improved efficiency. Since the current in any of the designed railguns rises abruptly, there is a chance for the armature to melt or break. It has been identified that sudden application of force can create a fracture inside the armature which can be detrimental for the railgun. It hampers the multi-shot capability of railgun. Hence railguns are studied from jerk point of view and the jerk seen on armature is quantified using mathematical equations derived from inductance gradient. Tapered and filleted models are also included in the study of armature jerk along with changes in current rise time and fall time. Most of the work performed is characterised using finite element simulations, which take a long time to provide results. Hence there is a need to find a solution that can provide results of high-fidelity simulation with the least possible error. Railgun is modelled as a controlled voltage source and pulse forming network is used as a energy source to the modelled railgun and Simulink models are created. An interoperability of finite element simulations and real time simulation is established to provide quicker results. From above discussion, it is observed that different design changes of rails of an electromagnetic railgun not only for conventional railguns but also augmented railguns are presented in this research work. Apart from it, jerk analysis with and without considering inductance gradient variation is incorporated and characterised. Moreover, interoperability of real time and finite element simulation is envisaged. Due to which, the results of high-fidelity simulations of railgun can be obtained using spice models or simulink models.