STM JOURNALS

Trends in
Mechanical Engineering & Technology

ISSN: 2231-1793 (Online)
ISSN: 2347-9965 (Print)
Volume 15, Issue 3, 2025
September–December
DOI (Journal): 10.37591/TMET

https://journals.stmjournals.com/tmet

Research TMET

High Efficiency Linear Motion Using Sequential Coil Electromagnetic Propulsion Train

Aniket Kumar Singh[1,*], Golu Gupta[2], Nitesh Kumar Chauhan[3],
Ranjeet Gupta[4], Tej Prakash Verma[5]

Abstract

The Electromagnetic Propulsion Train project efforts on developing a model that determines linear motion using controlled electromagnetic forces. Different conventional trains that depend only on mechanical drive, this system employs a sequence of electromagnets located along the track to create attractive and repulsive forces, providing propulsion to the train. The current prototype works with wheels for mechanical support and motion, while propulsion is entirely touched through electromagnetic interaction. The converting of electromagnets is managed by an Arduino-based microcontroller, ensuring correct timing and smooth motion along the track. Experimental results show that the electromagnetic propulsion successfully drives the train with reduced mechanical effort, confirming the possibility of using magnetic propulsion principles for transportation. The study lays the basis this work creates a foundational context for future research on fully contactless levitation and linear induction motor–based systems for next-generation high-speed rail technology. Experimental tests led on the prototype show that electromagnetic propulsion can effectively drive the train with markedly reduced mechanical effort. The system verified stable linear motion, confirmative that the controlled magnetic forces are enough to generate propulsion without relying on conventional mechanical power transmission. The outcomes confirm the opportunity of electromagnetic propulsion as a practical way for future transportation systems, offering the advantages of low friction, reduced wear, softer operation, and improved efficiency. This research offers a initial understanding that can support future developments in totally contactless transportation technologies. It places the groundwork for advanced studies involving magnetic levitation, linear induction motors, and high-speed propulsion techniques. The insights increased from this prototype model contribute to the larger vision of next-generation railway technology, where electromagnetic systems may exchange traditional mechanical methods to reach faster, cleaner, and more efficient transportation

Keywords: Electromagnetic propulsion, magnetic force, arduino, linear motion, sustainable transport

INTRODUCTION

The continuous demand for quicker, more effective, and sustainable transport systems has stimulated innovation outside conventional mechanical propulsion. Old-style railway systems depend completely on wheel-to-rail interaction for motion, which results in frictional losses, noise, vibration, and regular maintenance. These limitations confine the achievable speed and overall efficiency of rail transport. To overcome such challenges, researchers gradually discovered electromagnetic propulsion (EMP) a technology that uses magnetic forces to produce motion with negligible mechanical interaction [1].

Electromagnetic propulsion operates on the principle of electromagnetic induction, where

***Author For Correspondence**
Aniket Kumar Singh
E-mail: aniketsingh3128785@gmail.com

[1-4]Student, Department of Electrical Engineering, BIET, Lucknow, Uttar Pradesh, India
[5]Assistant Professor, Department of Electrical Engineering, BIET, Lucknow, Uttar Pradesh, India

Received Date: December 03, 2025
Accepted Date: December 06, 2025
Published Date: December 15, 2025

Citation: Aniket Kumar Singh, Golu Gupta, Nitesh Kumar Chauhan, Ranjeet Gupta, Tej Prakash Verma. High Efficiency Linear Motion Using Sequential Coil Electromagnetic Propulsion Train. Trends In Mechanical Engineering & Technology. 2025; 15(3): 32–39p.

© STM Journals 2025. All Rights Reserved

magnetic fields are energetically generated and controlled to create push. By sequentially energizing electromagnets placed along the track, a controlled design of attractive and repulsive forces is produced, causing the vehicle to move linearly. Preceding studies and practical systems, such as Japan's SC Maglev and Germany's Trans rapid, have established the high-speed ability and dependability of such magnetic propulsion systems [2]. However, those large-scale systems integrate levitation and direction, making them highly complex and expensive.

The present research efforts focus solely on the propulsion part of electromagnetic transportation technology. The proposed Electromagnetic Propulsion Train (EMPT) is a small-scale prototype designed to establish linear motion through controlled magnetic contact. A series of track-mounted electromagnets are serially energized using an Arduino-based control circuit to create forward push. In this prototype, wheels are used only for mechanical support and stability, while the propulsion is completely driven by electromagnetic forces between the energized coils and the permanent magnets installed on the train chassis..

This study experimentally confirms electromagnetic propulsion as a workable and efficient alternative to traditional mechanical systems. It provides fundamental insight into the working behavior of electromagnetic motion systems and creates a technical foundation for future work in the direction of a fully contactless, levitation based transportation model.

LITERATURE REVIEW

Electromagnetic propulsion (EMP) has been commonly studied as an alternate to conventional mechanical propulsion due to its capability to reduce frictional losses and expand efficiency. A complete survey by Phaenkongngam *et al.* (2021) [3] studied global Maglev systems and recognized that sequential beginning of electromagnetic coils can createstable linear push. Their paper providing the core theoretical groundwork used in the present study, definitely the concept of coil-based magnetic propulsion. Pavlov [2011] [4] planned a easy laboratory-scale electromagnetic propulsion model based only on sequential coil energization, indicating that controlled magnetic switching can produce smooth, linear movement lacking the need for levitation. This study is directly applicable to our prototype, as the same principle of timed coil beginning is used for propulsion while wheels deliver mechanical support.

In another important study, Kaye *et al.* (2002) [5] studied electromagnetic coil gun propulsion and presented how accurate control of magnetic pulses can generate determinate push. Their work supports the impression that strong propulsion can be achieved even on small arrangements when coil position and current timing are adjusted concepts that showed the switching logic of our Arduino-based system. Advanced modelling by Luo *et al.* (2022) [6] investigated unequal ground coils for EMP and determined that push regularity depends heavily on coil geometry, current stability, and switching frequency. While their work targeted combined Maglev systems, the technical understanding directly influenced the coil arrangement and power breaking in techniques adopted in this project.

Most previous studies integrate propulsion with levitation for high-speed Maglev trains; however, such systems are complex and exclusive. The present prototype purposely focuses only on electromagnetic propulsion, using wheels firmly as support and stability components, not as a propulsion mechanism. This creates a easy, scalable stage to by experimentation validate the core principles identified in the works.

Objective

The primary objective of this project is to design and experimentally validate an electromagnetic propulsion system capable of generating linear motion through controlled magnetic attraction and repulsion. The study aims to ensure that the propulsion is achieved entirely through electromagnetic force, while wheels are used only for structural support and stability. A sequential control mechanism is developed for track-mounted electromagnets, where an Arduino regulates polarity, timing, and activation order to achieve smooth and continuous motion. The project further focuses on analyzing propulsion efficiency by examining the influence of coil current, magnetic field strength, switching timing, and coil arrangement on system performance. Additionally, it aims to design a low-cost and modular prototype that clearly demonstrates the core principles of electromagnetic propulsion, including magnetic interaction, induction, and force generation. System stability and motion uniformity are evaluated under varying operating conditions to confirm that sequential coil activation results in jerk-free and predictable motion. Finally, the project establishes a foundation for future advancements toward a fully contactless electromagnetic transportation system that may incorporate magnetic levitation and advanced linear propulsion technologies.

METHODOLOGY

Electromagnetic Propulsion Configuration

The propulsion system is constructed using a linear array of 16 electromagnets mounted along one side of the track, as shown in the project prototype. These coils are positioned at equal distances to ensure uniform magnetic field overlap and smooth propagation of force as the train advances. Each electromagnet functions as an independent propulsion segment, generating magnetic fields sequentially when energized through the switching circuit [7–12].

On the train chassis, 8 high strength permanent magnets are fixed in a parallel alignment facing the coil side of the track. Their alternating north–south orientation ensures maximum interaction with the switching magnetic fields produced by the track coils. When a coil is activated, attractive, or repulsive forces are produced depending on its polarity, enabling controlled linear thrust without any mechanical contact.

This asymmetric configuration electromagnets on one side of the track and permanent magnets on the train reduces structural complexity while delivering consistent propulsion. The precise alignment between the coil array and the magnet assembly minimizes lateral vibration, improves force transfer efficiency, and stabilizes the motion of the train throughout the track (Figures 1–5).

Construction of Electromagnetic Coils

The propulsion coils were prepared using enameled copper wire with a total of 250 turns per coil to produce an adequate magnetic field strength. The coils were wound uniformly to maintain consistent inductance and avoid air gaps. After winding, each coil was insulated and mounted along the track at equal distances. This controlled spacing allowed the magnetic fields to overlap seamlessly as the train moved forward (Figure 3).

Magnetic Force Generation Mechanism

The propulsion force was produced using the electromagnetic field generated inside each coil when current was supplied. Once the coil was energized with 12 V and a current of 2 A, it created a magnetic flux of approximately 0.03–0.04 Tesla. This magnetic flux interacted with the permanent magnet on the train, resulting in a forward thrust based on the Lorentz force principle. The direction of motion was controlled by ensuring that each coil produced an attractive or repulsive force at the right moment.

Coil is air core (relative permeability $\mu r = 1$)
Coil length =10 cm.
Coil radius = 2 cm.
Number of turns N = 250.
Current I = 2 Amp.
Voltage V = 12v.
Cross section area $A = \pi r^2 = 3.14 \times 0.0004$
$= 0.001256$ m^2.
Magnetic field inside an solenoid B =

B = μ0(NI/L)

= 1.2566 × 10^-6 × (250×2/0.10)

Ø = 7.90×10^-6 weber.

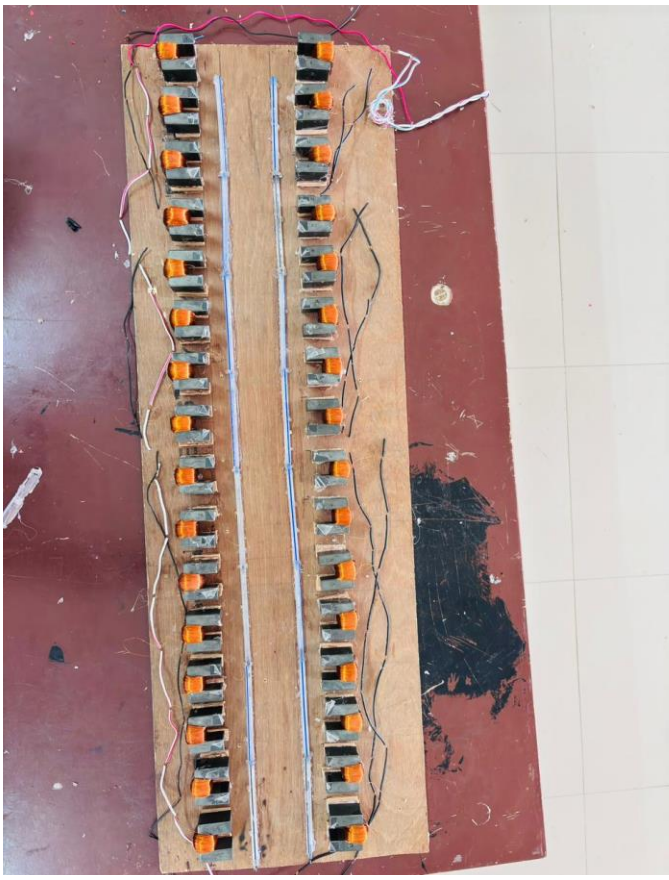

Figure 1. Trace.

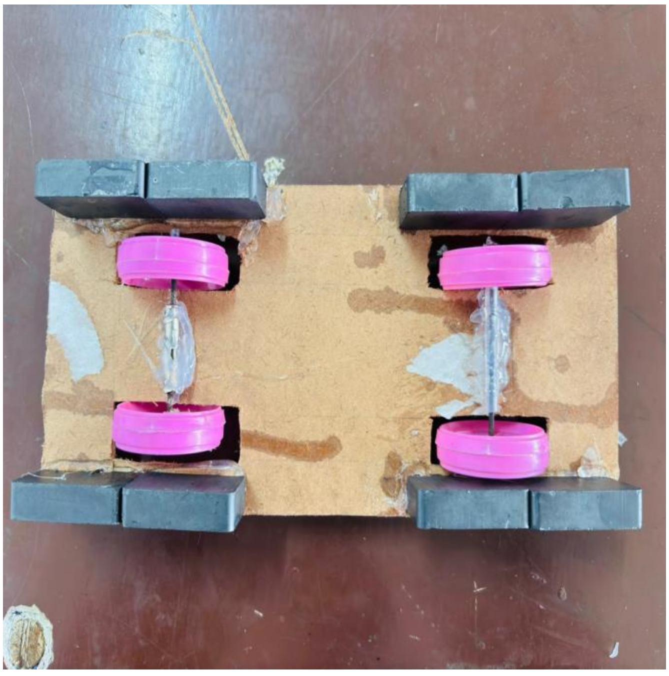

Figure 2. Train chassis.

Figure 3. Electromagnet.

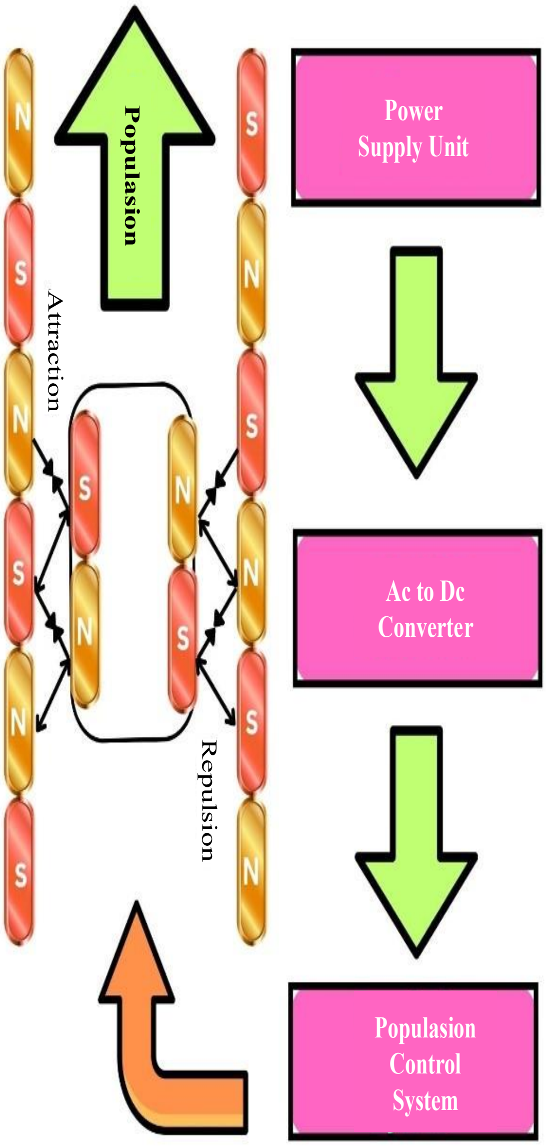

Figure 4. Block diagram of electromagnet propulsion train.

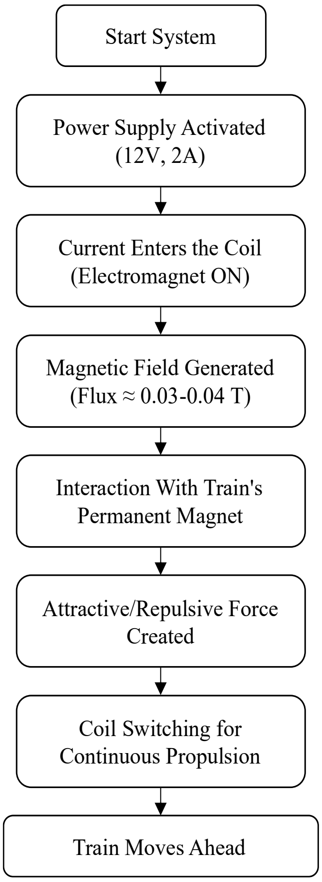

Figure 5. Step wise process of electromagnetic propulsion train.

External Switching and Control Operation

A manually operated switching circuit was connected externally to activate the coils in sequence. Instead of placing the circuitry on the vehicle, the control system remained outside, making it easier to manage coil timing. By turning each coil ON one after another, a “pull–push” effect was created, causing the train to move forward. Proper switching timing was essential to maintain smooth motion and stable propulsion.

Power Input and Performance Observation

The system was powered using a 12 V, 2 A DC supply, giving a total input power of 24 W. During testing, the magnetic flux, coil heating, and motion stability were continuously experiential. The coil produced consistent thrust without overheating, and the train achieved a steady movement along the track. These explanations complete that the chosen coil dimensions and power input were suitable for prototype-level electromagnetic propulsion.

Testing and Safety Validation

After collecting the prototype, several tests were performed to assess working safety and system dependability. All electrical connections, insulation layers, and coil terminals were check for temperature increase and short-circuit risks. The model was tested under multiple runs to confirm smooth performance without mechanical obstruction or electrical faults. The system verified safe and stable process throughout the testing stage.

RESULT

The prototype electromagnetic propulsion system was verified using a 12 V, 2 A DC supply and a 250-turn solenoid coil. The research verified successful linear motion of the model train along the track.

The magnetic flux generated in the coil was considered to be around 0.03–0.04 Tesla, which was enough to produce a clear pulling force on the train.

During testing, the train attained an average speed of 0.28–0.32 m/s, depending on the coil activation timing. The motion was smooth when the switching was properly synchronized, confirmative that electromagnetic push was effectively created. The coil temperature continued within a safe range, and no overheating or current uncertainty was observed.

Complete, the results confirmed that the designed coil, switching mechanism, and arrangement of the magnetic field worked reliably, proving the viability of electromagnetic propulsion on a small-scale model.

CONCLUSION

The established electromagnetic propulsion prototype successfully verified that linear motion can be attained using controlled magnetic fields. With a 12 V, 2 A supply and a 250-turn coil, the system produced a enough magnetic flux of around 0.03–0.04 Tesla, permitting the train to move simply along the track. The results whole that proper coil arrangement, stable switching, and accurate timing are important for reaching efficient propulsion.

The experimental outcomes proved the possibility of using electromagnetic principles for small-scale transportation systems. The model performed dependably without overheating, and providing reliable push and stable motion. This project founds a basis for future improvements such as higher-power coils, enhanced switching control, and greater track design, allowing a more advanced and efficient electromagnetic propulsion arrangement.

FUTURE SCOPE

The electromagnetic propulsion system established in this project can be additional better quality by integrating advanced technologies. In future growths, the prototype can be promoted into a Linear Induction Motor (LIM)-based system to achieve continuous thrust without mechanical contact or manual switching. Enhancing coil efficiency, optimizing switching timing, and using quality conductive materials can knowingly rise the propulsion speed and overall presentation. The system also has strong possible for accepting magnetic levitation (Maglev) technology, qualifying the train to float slightly above the track, thereby removing friction and allowing smoother, faster, and more energy-efficient movement. Also, advanced reproduction tools and automated control circuits can be applied to perfect magnetic field delivery and propulsion timing, making the design scalable for future high-speed, contactless transportation applications.

REFERENCES

1. Research on Electromagnetic Characteristics of Linear Synchronous Motor for High-Speed Maglev Train.
2. Algorithm of Linear Induction Motor Control Considering End-effect of Maglev Propulsion System.
3. T. Phaenkongngam, K. Chinnawong, N. Patumasuit, and C. Techawatcharapaikul, “Reviewing Propulsion & Levitation System for Magnetic Levitation Train,” IEEE iEECON, 2021.
4. R. J. Kaye, B. N. Turman, and S. L. Shope, “Applications of Coilgun Electromagnetic Propulsion Technology,” IEEE Power Modulator Symposium, 2002.
5. J. Luo et al., “Electromagnetic Modeling and Ripple Suppression of Asymmetrical Ground Coil Integrated with Propulsion,” IEEE Transactions on Energy Conversion, 2022.
6. Kaye, Ronald J., Bob N. Turman, and Steven L. Shope. "Applications of coilgun electromagnetic propulsion technology." Conference Record of the Twenty-Fifth International Power Modulator Symposium, 2002 and 2002 High-Voltage Workshop. IEEE, 2002.
7. Qadir, Zakria, et al. "A prototype of an energy-efficient MAGLEV train: A step towards cleaner train transport." Cleaner Engineering and Technology 4 (2021): 100217.

8. Roland, Kircher, et al. "Electromagnetic fields related to high speed transportation systems."Инновационные транспортные системы и технологии 4.2 (2018): 152-166.
9. Pavlov, Catherine. "Maglev Train Propulsion System." Applied Science Research (2011).
10. Way, Stewart. "Electromagnetic propulsion for cargo submarines." Journal of Hydronautics 2.2 (1968): 49-57.
11. McNab, Ian R. "Electromagnetic Propulsion." Encyclopedia of Space Science and Technology (2003).
12. Jabari, Hamid, et al. "Case Studies and Recent Developments in Propulsion Drive Trains of Electric Ships." Journal of Energy Management and Technology 9.3 (2025): 190-202.