STM JOURNALS

International Journal of
Electro-Mechanics and
Material Behavior

Volume 3, Issue 2, 2025
July–December
DOI Journal: 10.37591/IJEMB

https://journals.stmjournals.com/ijemb

Research IJEMB

Electromagnetic Propulsion Train for Future Transportation

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Abstract

The electromagnetic propulsion train project focuses on the development and analysis of a prototype system that achieves linear motion through the application of controlled electromagnetic forces. Unlike conventional railway systems that rely primarily on mechanical drive mechanisms such as wheels, axles, and traction motors, this project explores an alternative propulsion approach based on electromagnetic interaction. In this system, a sequence of electromagnets is strategically positioned along the track to generate controlled attractive and repulsive magnetic forces, which are responsible for propelling the train forward. The designed prototype retains wheels to provide mechanical support, alignment, and stability during motion; however, the propulsion force is generated entirely through electromagnetic means. This hybrid configuration allows for the practical demonstration of electromagnetic propulsion while maintaining structural reliability and ease of implementation at the prototype level. The sequential energizing and de-energizing of the electromagnets along the track create a moving magnetic field that interacts with the magnetic elements mounted on the train, producing linear thrust. Control of the electromagnets is achieved using an Arduino-based microcontroller system. The microcontroller ensures accurate timing, synchronization, and switching of the electromagnetic coils, which is essential for maintaining smooth and continuous motion of the train along the track. Proper control logic minimizes fluctuations in motion and improves the overall operational efficiency of the system. Experimental testing of the prototype demonstrates that electromagnetic propulsion can successfully drive the train with reduced dependence on mechanical effort. The results confirm that controlled electromagnetic forces can produce effective and stable linear motion in a guided transportation system. These findings validate the feasibility of +electromagnetic propulsion as an alternative or supplementary method for future transportation technologies. The study provides a foundational framework for further research and development in the field of advanced rail transportation. It establishes a basis for future exploration of fully contactless magnetic levitation systems and linear induction motor–based propulsion techniques, which are considered key technologies for next-generation high-speed and energy-efficient rail systems.

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Received: December 02, 2025
Accepted: December 12, 2025
Published: December 18, 2025

Citation: Aniket Kumar Singh, Tej Prakash Verma. Electromagnetic Propulsion Train for Future Transportation. International Journal of Electro-Mechanics and Material Behavior. 2025; 3(2): 25–31p.

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

INTRODUCTION

The continuous demand for quicker, more effective, and sustainable transportation systems has stimulated innovation in conventional mechanical propulsion. Traditional railway systems completely depend on wheel-to-rail interactions for motion, which results in frictional losses, noise, vibration, and regular maintenance. These limitations limit the achievable speed and overall efficiency of the rail transport. To overcome such challenges, researchers have gradually discovered electromagnetic propulsion (EMP), a technology that uses magnetic forces to produce motion with negligible mechanical interactions [1]. Electromagnetic propulsion operates based on the principle of electromagnetic induction, where magnetic fields are energetically generated and controlled to create a push. By sequentially energizing the electromagnets placed along the track, a controlled design of attractive and repulsive forces is produced, causing the vehicle to move linearly. Previous studies and practical systems, such as Japan's SCMaglev and Germany's Transrapid, have established the high-speed ability and dependability of such magnetic propulsion systems [2]. However, these large-scale systems integrate levitation and direction, which makes them highly complex and expensive.

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

This study experimentally confirmed that electromagnetic propulsion is a workable and efficient alternative to traditional mechanical energy. It provides fundamental insights 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 alternative to conventional mechanical propulsion owing to its capability to reduce frictional losses and increase efficiency. A comprehensive survey by Phaenkongngam et al. (2021) [3] examined global maglev systems and found that the sequential activation of electromagnetic coils can generate a stable linear thrust. Their study provides the core theoretical groundwork used in the present study, which is the concept of coil-based magnetic propulsion.

Pavlov (2011) [4] planned an easy laboratory-scale electromagnetic propulsion model based only on sequential coil energization, indicating that controlled magnetic switching can produce smooth linear movement without 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 the wheels deliver mechanical support.

In another important study, Kaye et al. (2002) [5] studied electromagnetic coil gun propulsion and presented how the 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 the coil position and current timing are adjusted—concepts that show 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. Although their work targeted combined Maglev systems, the technical understanding directly influenced the coil arrangement and power breaking in the techniques adopted in this project.

Most previous studies have integrated propulsion with levitation for high-speed Maglev trains; however, such systems are complex and exclusive. The present prototype focuses only on electromagnetic propulsion, using wheels firmly as support and stability components and not as a propulsion mechanism. This creates an easy, scalable stage to experimentally validate the core principles identified in previous studies [7–11].

OBJECTIVES

The main objective of this project is to design a prototype through an experiment that confirms an electromagnetic propulsion system capable of generating linear motion through sequential magnetic attraction and repulsion. The technical objectives of this study are as follows:

1. To control electromagnetic propulsion using controlled magnetic forces, where the motion of the model is reached completely through electromagnetic push, wheels are used only for mechanical provision and reliability and not for propulsion.
2. To alter a sequential control mechanism for track-mounted electromagnets in which an Arduino controls polarity, timing, and start sequence of the electromagnets to generate smooth and nonstop linear motion.
3. To study the effectiveness of propulsion by estimating the effects of coil current, magnetic field strength, switching timing, and coil arrangement on complete motion performance.
4. Plan a low-cost, mountable, and related prototype that effectively exposes the fundamental principles of electromagnetic propulsion, including magnetic interaction, induction, and force generation.
5. To assess the system stability and motion uniformity by examining the response of the sample under different working conditions and confirming that sequential coil opening produces motion without mechanical jerks or unpredictability.
6. To produce a foundation for future advances near a fully contactless electromagnetic transportation arrangement that may include magnetic levitation and advanced linear propulsion skills in the subsequent stages of research.

METHODOLOGY

Problem Identification and Condition Analysis

Education is activated by examining the problems of conservative wheel-based trains, including high friction, energy loss, mechanical wear, and limited speed ability. These topics increase the maintenance costs and limit efficient high-speed actions. To overcome these challenges, this project identified the need for a frictionless, high-efficiency propulsion system. This analysis indicated the acceptance of electromagnetic propulsion as a greater difference for smoother, faster, and low-maintenance transport.

Working Principle

The project focused on choosing the most suitable propulsion principle for realizing frictionless and high-speed motions. Electromagnetic propulsion was selected based on the working concept of linear motors, where magnetic fields interact to produce pushes without physical contact. This principle removes mechanical friction, improves speed, and provides smooth and efficient movement. A notional foundation based on the Lorentz force, magnetic flux interaction, and synchronized coil energization was studied to confirm the feasibility of the prototype.

Electromagnetic propulsion trains use well-ordered magnetic forces, rather than mechanical engines. In this system, electrical power is converted into DC power and supplied to the electromagnets located along the track. A propulsion control unit changes the polarity of these electromagnets in the correct sequence, causing attraction forces in front of the train and repulsion forces behind it. This continuous magnetic push–pull action produces a smooth linear motion. In this prototype, the wheels are used only for mechanical support and permanence. Because movement is produced without physical contact, the friction is very low, making the system faster, easier, and highly effective (Figure 1).

Design of Electromagnetic Propulsion System

The strategy phase focused on creating an effective electromagnetic propulsion unit capable of generating a strong and controlled push. This involves selecting suitable electromagnets, defining the ideal number of coils turns, and choosing a conductive material with low resistance to minimize power loss. The research on the coils and permanent magnets was sensibly related so that the generated magnetic field interacted with the current-carrying conductor, producing the maximum Lorentz force. The track geometry, design between coils, and timing of current pulses were of better quality to ensure smooth acceleration and stable motion. This orderly design process ensures that the prototype can produce consistent, frictionless, and energy-efficient propulsion (Figure 2).

Prototype Construction and Integration

The physical model of the electromagnetic propulsion system was constructed by accumulating track coils, permanent magnets on the train, and external switching circuitry. The switching circuit and power supply were purposely placed externally to the track so that the train remained lightweight and free from the electronics involved. The track was wired such that the outside switching unit could energize the coils sequentially to create a controlled magnetic thrust. All the components were aligned carefully to ensure that the magnetic field produced by the track coils interacted efficiently with the magnets on the train. After the assemblage, the track, circuits, and train were verified together to confirm the smooth propulsion and stable system process (Table 1).

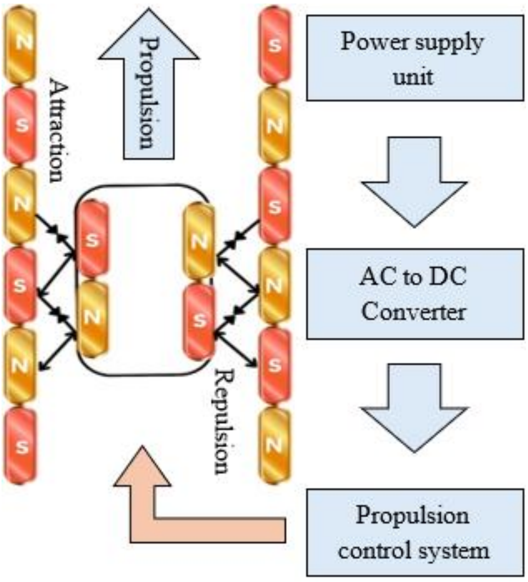

Figure 1. Block diagram of electromagnetic propulsion train.

Figure 2. Electromagnetic propulsion train.

Table 1. Specification of prototype components.

Components	Supply voltage	Current	Power per coil	Length	Quantity
Prototype	12–24 V	1–5 A	12–120 W	--	1
Transformer	220/24 V AC	1–5 A	12–120 W	--	1
H-bridge	12–24 V	1–5 A	12–120 W	--	4
Bridge rectifier	12–24 V DC	1–5 A	12–120 W	--	1
Arduino Uno	6–12 V	20–40 mA	--	--	1
Permanent magnet	--	--	--	4 cm	8
Electromagnets	12–24 V DC	1–5A	12–120 W	4.5 cm	32
Train chassis	--	--	--	23 cm	1
Track	--	--	--	1 meter	1

Electromagnetic Force Testing

The electromagnetic propulsion system was verified by applying a 12 V supply with a fixed current of 2 A to the track coils. With 250 turns in each coil, the magnetic field created inside the solenoid formed a magnetic flux of approximately 7.9×10^{-6} Wb. The interaction between this magnetic field and the permanent magnets mounted on the train creates a propulsion force essential for motion. Through challenging, the movement of the train, smoothness of push, coil heating, and response to different load conditions were detected. These measures helped control whether the generated electromagnetic force was sufficient for stable and nonstop propulsion. This stage confirms the effectiveness of the electrical input in creating an essential forward motion.

Performance Evaluation and Result Recording

The entire system was tested to determine how well the train moved when the coils were energized. The speed, smoothness of motion, and constancy of the train are observed along the entire track. We also checked whether the 12 V, 2 A input produced a reliable magnetic force or whether the performance reformed at different points on the track. The coil heating, response time, and overall behavior of the system were noted to determine the efficiency of the prototype. These observations confirm that the electromagnetic propulsion mechanism worked correctly and yielded reliable results.

Result Analysis

In the final phase, all the recorded marks were studied to verify the performance of the electromagnetic propulsion system. The measured magnetic flux, field strength (approximately 0.00628 Tesla), and train motion are related to the likely theoretical values. The analysis showed that the train moved smoothly when the coils were supplied at 12 V and 2 A, confirming that the generated magnetic force was sufficient for propulsion. Variations in speed, push, and coil heating were studied to determine the system's efficiency and limits. This authentication step proved that the prototype successfully verified the working principle of electromagnetic propulsion and could be further improved to achieve higher efficiency.

Safety Checks and System Reliability Testing

In this step, the entire format is confirmed to ensure that it works safely under dissimilar conditions. The coils, wiring, and switching components were checked for overheating, short circuits, and uncommon vibrations during motion. The correct insulation, stable connections, and controlled magnetic fields were confirmed to avoid any risks during the operation. These checks establish that the electromagnetic propulsion system runs independently without producing electrical or mechanical risks.

RESULT

The prototype electromagnetic propulsion system was verified using a 12 V, 2 A DC supply, and a 250-turn solenoid coil. This research verified the successful linear motion of the model train along the track. The magnetic flux generated in the coil was 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, confirming that electromagnetic push was effectively created. The coil temperature was maintained within a safe range and no overheating or current uncertainty was observed.

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

FUTURE SCOPE

The electromagnetic propulsion system established in this project can be improved by integrating advanced technologies. In the future, 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 increase propulsion speed and overall presentation. The system also has the potential to accept magnetic levitation (Maglev) technology, allowing the train to float slightly above the track, thereby removing friction and allowing smoother, faster, and more energy-efficient movement. In addition, advanced reproduction tools and automated control circuits can be applied for perfect magnetic field delivery and propulsion timing, making the design scalable for future high-speed, contactless transportation applications.

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 an enough magnetic flux of around 0.03–0.04 Tesla, permitting the train to move simply along the track. The results show that proper coil arrangement, stable switching, and accurate timing are important for achieving efficient propulsion.

The experimental results proved the possibility of using electromagnetic principles for small-scale transportation systems. The model performed independently without overheating and provided reliable push and stable motion. This project provides 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.

REFERENCES

1. Phaenkongngam T, Chinnawong K, Patumasuit N, Techawatcharapaikul C. Reviewing propulsion and levitation system for magnetic levitation train. 2021 9th International Electrical Engineering Congress (iEECON), Pattaya, Thailand. 2021. p. 185–188. doi:10.1109/iEECON51072.2021.9440283.
2. Pavlov C. Maglev train propulsion system. Appl Sci Res. 2011;3.
3. de Oliveira RAH, Stephan RM, Ferreira AC, Murta-Pina J. Design and innovative test of a linear induction motor for urban maglev vehicles. IEEE Trans Ind Appl. 2020;56(6):6949–6956. doi:10.1109/TIA.2020.3023066.
4. Kaye RJ, Turman BN, Shope SL. Applications of coilgun electromagnetic propulsion technology. Conference Record of the Twenty-Fifth International Power Modulator Symposium, 2002 and 2002 High-Voltage Workshop., Hollywood, CA, USA. 2002. p. 703–707. doi:10.1109/MODSYM.2002.1189573.
5. Luo J, Su Z, Cui L, Li J, Zhu Z, Ma G. Electromagnetic modelling and ripple suppression of asymmetrical ground coil integrated with propulsion, levitation and guidance for EDS train. IEEE Trans Energy Convers. 2023;38(1):713–723. doi:10.1109/TEC.2022.3210478.
6. Chi Z, Li J. Simulation analysis of the vehicle–guideway coupling vibration of EMS maglev train. 2017 36th Chinese Control Conference (CCC), Dalian, China. 2017. p. 10376–10380. doi:10.23919/ChiCC.2017.8029007.

7. Qadir Z, Munir A, Ashfaq T, Munawar HS, Khan MA, Le K. A prototype of an energy-efficient maglev train: A step towards cleaner train transport. Cleaner Eng Technol. 2021;4:100217. doi:10.1016/j.clet.2021.100217.
8. Dong F, Huang Z, Li X, Hao L, Yao L, Wu W, Jin Z. R&D of no-insulation HTS magnets using 2G wires in a prototype for maglev applications. IEEE Trans Appl Supercond. 2019;29(5):1–5. doi:10.1109/TASC.2019.2904643.
9. Way S. Electromagnetic propulsion for cargo submarines. J Hydronautics. 1968;2:49–57. doi:10.2514/3.62773.
10. Dumm J, Murray K. Electromagnetic propulsion systems: Multipurpose platforms of the future. In: Proceedings of the Ninth Annual Freshman Conference. Pittsburgh (PA), USA; 2009.
11. Pierrejean L, Rametti S, Hodder A, Paolone M. A review of modeling, design, and performance assessment of linear electromagnetic motors for high-speed transportation systems. IEEE Trans Transp Electrification. 2025;11:2146–2159. doi:10.1109/TTE.2024.3416870.

