ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIAL ENGINEERING

CONSTRUCTION OF SIMPLE PROTOTYPE MAGLEV TRAIN BASED ON REVIEW OF THE EXISTING EXPERIENCE

A Project Submitted in Partial Fulfillment of the requirements for the award of degree of Master of Science in Automotive Technology Teachers Education

BY:-

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Department of Mechanical and Vehicle Engineering

June, 2015

Ethiopia, Adama

CANDIDATES DECLARATION

We hear by declare that the work which is being presented in the project entitled **"Construction of simple prototype maglev train based on review of the existing experience"** in partial fulfillment of the requirements for the award of the degree of master of Science in Automotive Technology Teachers Education is an authenticate record of our own work, carried out from March 2015to July 2015 under the supervision of **Mr.Mekonen Liben (Asst.Professor) and N. Ramesh Babu (Asso.Professor)**, Department of Mechanical and Vehicle Engineering, Adama Science and Technology University(ASTU).

The matter embodied in this project has not been submitted by us for the award of any other degree or diploma. All relevant resources of information used in this project have been duly acknowledged.

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This is to certify that the above statement made by the candidates is correct to the best of our Knowledge and belief. This project has been submitted for examination with our approval.

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Advisor: Mr.Mekonen Liben (Asst. Prof) Date

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Co Advisor: N.Ramesh Babu (Asso. Prof) Date

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Approved by Board of Examiners

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Chairman, Dept. Graduate committee **Signature** **Date**

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External Examiner **Signature** **Date**

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Advisor **Signature** **Date**

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ABSTRACT

Magnetically-levitating ("maglev") train technology is a high-speed urban transportation solution capable of contributing to pollution reduction and energy efficiency.

The objective of the project is to Construct a simple prototype maglev train based on review of the existing experience. It is proposed to construct a simple prototype maglev train that will travel on the test track. To construct the simple maglev train prototype we use simple motor and fan for propulsion, arranged permanent magnets for stabilization and levitation, cement fluid for attachment, glass for guide and compass for identifying pole of the magnets, wood stock for the constructing of train and track and the prototype maglev train is done based on EDS technology.

The significance of the project is to give some hint on the working principle of the maglev train and how it constructs for the coming generation. Meanwhile, the technology has transferred to our country so that the transportation sector will improve a service in the near future.

The group of the project on Maglev's working prototype will show consumers, investors, and regulators that maglev technology is a smart option for new infrastructure development.

This project will be considered complete when the prototype train has come to levitate, propel, and stable on the test track. Conventional locomotives and the highway system create traffic congestion and contribute heavily to smog and pollution in metropolitan areas. Maglev infrastructure can be implemented to move trains much faster, produce no pollution from the train itself, and require easy and minimal upkeep as there are no moving parts and no friction in standard operation. Maglev trains are a sustainable and efficient form of mass transportation for people, commercial, and military applications.

Keywords: *maglev, maglev train, levitating, propulsion, stability.*

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ACRONYMS, ABBREVIATION AND SYMBOLS

Maglev	Magnetically-Levitating
EMS	Electromagnetic Suspension
EDS	Electrodynamic Suspension System
EDL	Electrodynamic Levitation
AC	Alternating Current
TEA	Transportation Equaty Act
Ft	Feet
H	Halbach
LSM	Linear Synchronous Motor
LEM	Linear Electric Motor
LIM	Linear Induction Motor
F	Force
V	Velocity
B	Change in Flux
Emf	Electromotive Force
DC	Direct Current
Q	Charge
FAA’s	Federal Aviation Administration’s
MTAC	Maglev Technical Advisory Committee
TR	Trans Rapid
Mph	Mile per Hour
JNR	Japans National Rail Way
UT	University Of Texas
NASA	National Aeronautics and Space Administration

CHAPTER ONE

1. INTRODUCTION

Magnetic levitation is the process of levitating an object by exploiting magnetic fields. In other words, it is overcoming the gravitational force on an object by applying a counteracting magnetic field. Either the magnetic force of repulsion or attraction can be used. In the case of magnetic attraction, the experiment is known as magnetic suspension. Using magnetic repulsion, it becomes magnetic levitation.

In the past, magnetic levitation was attempted by using permanent magnets. Attempts were made to find the correct arrangement of permanent magnets to levitate another smaller magnet, or to suspend a magnet or some other object made of a ferrous material. It was however, mathematically proven by British mathematician Samuel Earnshaw in 1842 that a static arrangement of permanent magnets or charges could not stably magnetically levitate an object apart from permanent magnets, other ways to produce magnetic fields can also be used to perform levitation. One of these is an electro dynamic system, which exploits Lenz's law. When a magnet is moving relative to a conductor in close proximity, a current is induced within the conductor. This induced current will cause an opposing magnetic field. This opposing magnetic field can be used to levitate a magnet. This means of overcoming the restrictions identified by Earnshaw is referred to as oscillation [1].

Maglev trains reduce pollution and increase both speed and efficiency when compared to other modes of transportation. It is a proven technology that is becoming more feasible technically and financially. Recent innovations in maglev technology, such as the Inductrack system, promise "fail-proof" operation. Since maglev trains do not produce any pollutants themselves, they can reduce pollution in transportation corridors and cities compared to their currently-operating alternatives [2]. Our group seeks to construct a small-scale proof-of-concept maglev system in order to demonstrate to the respected members and regulators that maglev is a feasible and efficient option for new transportation infrastructure development.

1.1 HISTORY AND DEVELOPMENT

Maglev has been a long standing dream of railway engineers for the past century. These engineers envisioned a train that could float above its tracks. They saw the enormous potential for a train like this. The vision of Maglev began in the beginning of the 20th century with two scientists.

Early Dreams

In 1904, Robert Goddard, who was a college freshman at the time, wrote a paper proposing a form of frictionless travel by raising train cars off the rails by using electromagnetic repulsion roadbeds [2]. He said the train would travel at super fast speeds. In 1910, Emile Bachelet applied for a patent on a rail car which for levitation would use alternating-current electromagnets and for propulsion would use solenoids at intervals along a road-bed [2]. Bachelet's dreams couldn't be realized because his concept used too much power for conventional magnets [3].

In the early 1920s, a German scientist named Hermann Kemper pioneered in work in attractive-mode Maglev [4]. He received a patent for magnetically levitating trains. Kemper continued to research and pursue his concept through the 1930s and 1940s and established the basic design for practical, attractive-mode Maglev in a 1953 paper [4].

In 1969, two Americans, Gordon Danby and James Powell, were granted a patent on their design of a magnetically levitated train. This was the first patent for a design of this kind of train [5]. This was around the same time that Germany and Japan were both getting very interested in Maglev technology. In 1970, both countries start investing money into researching maglev. That same year, the United States Federal Railroad Administration studied high-speed ground transportation. Little Maglev research was actually done and in 1986, all Maglev research funding was stopped and the United States officially stepped out of the Maglev race for the time being.

Maglev train developed by German

In 1969, the German government sponsored a research project which built their first full scale model of a Maglev design [6]. They called their version of the Maglev the TransrRapid 01. A few years later, the first passenger Maglev debuted and carried people for a few thousand feet at speeds of only 50 mph. The German company, Munich's KraussMaffei, which built the first TransRapid, continue to build improved versions of the TransRapid in a joint private-public funded research effort. In 1971, they completed the TransRapid 02. They completed the TR 03, TR 04 in 1972 and 1973, respectively. The TR 04 set a new speed record for passenger MagLevs by going 157 mph in December of 1973 [6].

Germany's first large scale demonstration of the TR was in 1979 was at the International Transportation Fair in Hamburg, where the TR 05 carried about fifty thousand visitors between a parking lot and the exhibition hall for six months [6].

At this time, a test track was erected to test the system in real world conditions. The test track was a nineteen mile figure "8" track that was built between 1979 and 1987 in Northern Germany [6]. The TR 06 was the first to be tested on this track and it reached speeds of 221 mph after the completion of the first 13 miles of the track. The TR 06 eventually reached a speed of 256 mph and was finally retired after traveling 40,000 miles in 1990 [6]. The TransRapid 07 was built by Thyssen Co. in Kassel. The TR 07 reached a record speed of 280 mph [6].

A TransRapid route was planned from Hamburg to Berlin in 1992. In 1998, a joint company was formed under the system houses Adtranz, Siemens, and Thyssen [6]. This new joint company was called TransRapid International. In 2000, the government said that the Berlin-Hamburg route will not be realized and TransRapid International proposed 5 alternative routes where the TransRapid can be built. None of the routes were accepted and TransRapid International started looking for outside interest in their project to save a billion dollars and 30 years of investment [6].

China expressed their interest in the German Maglev technology. After statistical gathering and analyzing, a contract was reached on January 23, 2001 between Shanghai and TransRapid International to build a line between Shanghai and its airport.

On December 31, 2002, the first commercially operated Maglev line took it maiden voyage carrying on board Chinese Prime Minister Zhu Rongji, German Chancellor Gerhard Schroder and other high ranking politicians and business people from both countries. One year later, the world's first commercial TransRapid route starts scheduled operation in Shanghai.

Maglev train developed by Japanese

The Tokaido Shinkansen [7] was the early Japanese high speed train line. It opened in 1964 and since then has expanded considerably. Its success also prompted the development of high speed trains in the west. But the Japanese public demanded an even faster form of high speed rail travel. The Shinkansen used a conventional train design, with motors and other equipment mounted on the rolling stock, electric power gathered from overhead wires, and wheels running on rails. It was impossible to increase the speeds much more. Some of the limitations included: Greater size and weight of on board equipment, difficulty in collecting electric power, and reduced adhesion between wheels and rails at higher speeds that may cause wheel slipping [7]. There had to be some new sort of technology that could create faster trains that were just as safe as or even safer than the trains running on the Shinkansen lines. The answer to this problem lied in electro magnetism [7].

The former Japanese National Railways (JNR) began conducting Maglev research and development in 1970. The Miyazaki Test Track was built in southern Japan was experiments and test runs were being conducted on the tracks [7]. In 1979, the prototype ML-500 test train reached an unmanned speed of 517 km/h on the 7 km track, which proved that Maglev had a great potential for reaching higher speeds than any other train built before that. The Miyazaki track was later modified into a U shaped to simulate more real world track curves.

At this stage of development, the government started funding the project. The MLU001 was the first Maglev developed with government financial aid [7]. Other models were built and continued to be tested and experimented on the Miyazaki test track. But there was a problem with the track. It was too short and only had a single guideway with no tunnels and no inclines or declines. The experimental data gathered on the Miyazaki test track would be too limited to verify trains commercial potential and use.

After the JNR was split and privatized in 1987, the Tokaido Shinkansen experienced an increase in passengers which led to more calls to build a commercial Maglev line as soon as possible [7]. As a result, the Yamanashi Test Line was constructed in Tamanashi Prefecture, approximately 100 km west of Tokyo [7].

The Yamanashi test line was 18.4 km long and supported a wide range of tests to determine the commercial feasibility of the Maglev train. The track was made up 16 km of tunnels and an open section that was 1.5 km long in the middle of the track. A substation for power conversion and other facilities were located in the 1.5 km stretch of open section. Part of the line was double tracked to simulate trains going in opposite directions at super high speeds.

Trial runs began on the Yamanashi Test line in April 1997. The cars weren't levitated but instead were driven at low speeds on rubber tires. Once tests confirmed that there were no defects in the vehicles or the guideway itself, levitation runs began at the end of May 1997. The speeds were increased incrementally to monitor car movement and verify braking performance [7]. On December 12 1997, a new world record of 531 km/h was set for manned train travel. A maximum speed of 550 km/h was set for unmanned travel 12 days later.

There was a problem that remained: air vibration that rattles the windows of buildings near tunnel portals when a Maglev trains enters or leaves a tunnel at high speeds [7]. Everything else seemed to be in good shape. There were no environmental problems, ground vibration measurements were well within acceptable limits. Magnetic fields measured at ground level directly under than the elevated guide ways were also within acceptable limits.

Tests were conducted so that two cars passed each other at high speeds. The vibration of the trains passing each other was so small that it could only be felt by someone actually expecting it [7]. Overall, there were no major problems that occurred during the test runs. More testing will be required before commercial use of Maglev trains in Japan will start. During the next few years, these test runs will be focusing on 3 things:

- Verifying long-term durability
- Finding ways to reduce costs
- Achieving more aerodynamic car designs [7]

1.2 Background of the project

A- Maglev in General

Maglev technology is somewhat well-known due to its Pudong-Shanghai installation in China, where a maglev line runs from the airport to the subway line. However, the track is infamous for its cost problems. Most of the concern is due to the line's high cost [2]. Existing commercial technology utilizes electromagnetic suspension (EMS), which has an extremely fine operating requirement of maintaining a ten to fifteen millimeters gap between track and train. The EMS system is also inherently unstable system due to its reliance on magnetic attraction rather than repulsion.

Basic principle

A method of supporting and transporting objects or vehicles which is based on the physical property that the force between two magnetized bodies is inversely proportional to their distance. By using this magnetic force to counterbalance the gravitational pull, a stable and contactless suspension between a magnet (magnetic body) and a fixed guide way (magnetized body) may be obtained. In magnetic levitation (Maglev), also known as magnetic suspension, this basic principle is used to suspend (or levitate) vehicles weighing 40 tons or more by generating a controlled magnetic force. By removing friction, these vehicles can travel at speeds higher than wheeled trains, with considerably improved propulsion efficiency (thrust energy/input energy) and reduced noise. In Maglev vehicles, chassis-mounted magnets are either suspended underneath a ferromagnetic guide way (track) or levitated above an aluminum track [17].

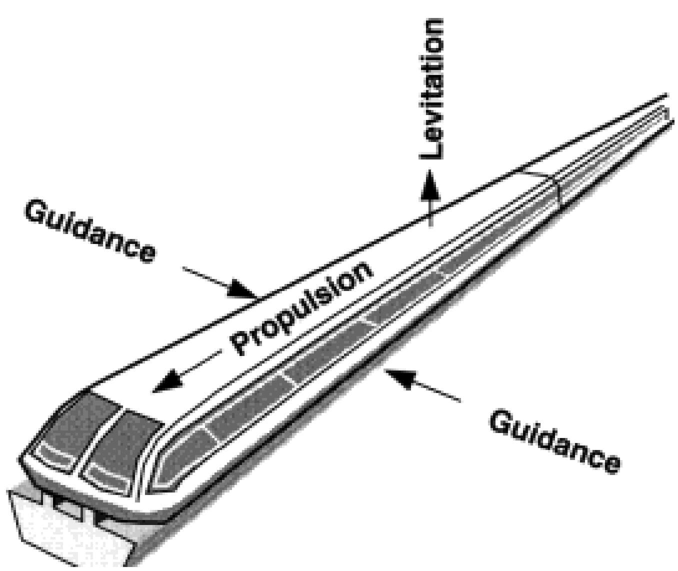


Figure 1. Primary functions of Maglev

Figure 1. Depicts the three primary functions basic to Maglev technology:

(1) Levitation or suspension;

(2) Propulsion and

(3) Guidance or stability

In most current designs, magnetic forces are used to perform all three functions, although a nonmagnetic source of propulsion could be used. No consensus exists on an optimum design to perform each of the primary functions.

In the attraction-type system, a magnet-guide way geometry is used to attract a direct-current electromagnet toward the track. This system, also known as the electromagnetic suspension (EMS) system, is suitable for low- and high speed passenger-carrying vehicles and a wide range of magnetic bearings.

The electromagnetic suspension system is inherently nonlinear and unstable, requiring an active feedback to maintain an upward lift force equal to the weight of the suspended magnet and its payload (vehicle).

In the repulsion-type system, also known as the electrodynamic levitation system (EDS or EDL), a superconducting coil operating in persistent-current mode is moved longitudinally along a conducting surface (an aluminum plate fixed on the ground and acting as the guide way) to induce circulating eddy currents in the aluminum plate. These eddy currents create a magnetic field which, by Lenz's law, opposes the magnetic field generated by the travelling coil. This interaction produces a repulsion force on the moving coil. At lower speeds, this vertical force is not sufficient to lift the coil (and its payload), so supporting auxiliary wheels are needed until the net repulsion force is positive. The speed at which the net upward lift force is positive (critical speed) is dependent on the magnetic field in the air gap and payload, and is typically around 80 km/h (50 mi/h). To produce high flux from the traveling coils, hard superconductors (type II) with relatively high values of the critical field (the magnetic field strength of the coil at 0 K) are used to yield air gap flux densities of over 4 tesla. With this choice, the strong eddy-current induced magnetic field is rejected by the superconducting field, giving a self-stabilizing levitation force at high speeds (though additional control circuitry is required for adequate damping and ride quality [17],[18],[19].

B- Inductrack

The inductrack system, developed at Lawrence Livermore National Laboratory by Richard Post, is an electrodynamics suspension system (EDS) which has an advantage over other EDS technologies; It relies on completely passive (non-superconducting and non-powered) magnets for stability and levitation. This system delivers a reduction in cost and maintenance per track-mile [3].

Proposed Design

Permanent magnets are capable of levitating huge trains due to two inventions from the 1980's: Halbach arrays, which direct flux in one direction, and neodymium-iron-boron magnets, which have higher intrinsic magnetic fields than other magnets. The small-scale system to be developed will be driven along the track by simple motor and fan. The moving train will generate the magnetic lift force by interaction between the permanent magnet on the train and on the track.

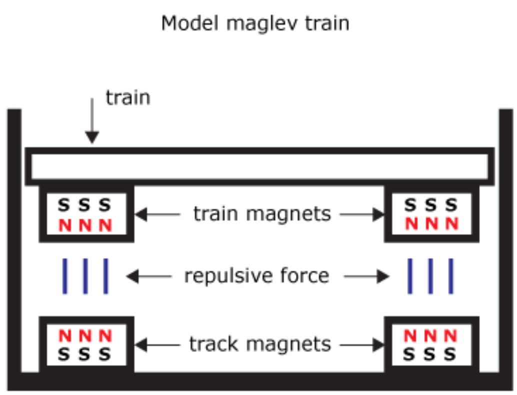


Figure: 2- Track I and Train Design to be constructed as a prototype mode

Figure 2 depicts track and train design to be constructed as a prototype model

- Wood stock for train
- Train permanent magnet
- Track permanent magnet
- Wood stock for track
- Repulsion force between like poles of permanent magnets which is installed in the track and train.

1.3 Statement of the problem

Transportation infrastructure around the country is less efficient, more costly to maintain, and relatively unsafe compared to maglev technology. Conventional locomotives and the highway system create traffic flow issues and contribute heavily to smog, noise and pollution in metropolitan areas. Maglev infrastructure provides lower operating costs due to no moving parts and no friction during standard operation and reduces the area needed for the infrastructure when it compares to Conventional transportation system [1]. Given the advantages of maglev technology, investors and developers should consider maglev as a way to increase efficiency and value for communities and commuters. Maglev trains can also reach higher speeds than conventional rail and provide a direct benefit to the shipping and coast-to-coast public transportation industries.

1.4 Project Objectives

1.4.1 General objective

The main objective of the project is to Construct asimple prototype maglev train based on review of the existing experience.

1.4.2 Specific objectives

- Construct small model Maglev Train,
- Demonstrate how Maglev Train will levitate,
- Check for the stability of Maglev Train,
- Demonstrate how the Maglev Train propels.

1.5 Scope of the study

The scope of the project is to construct a simple magnetic levitation train prototype that is capable of levitation, stability and propulsion on the test track. The model has 77cm track length and 15cm of train length.

1.6 Significant of the study

The main importance of the project is to transfer the technology that is constructing a simple maglev train model which has a benefit for

- ✓ the transportation sector by sustainable and efficient mass transportation of people, commercial freight, and military applications,
- ✓ the community which gives service by low and minimizes the maintenance cost,
- ✓ the researchers it gives some hint to study the existing maglev train and to transfer the technology to our country,
- ✓ the students it initiates and motivates to understand and grow up the technology with them from the scratch in preparatory, colleges and universities

1.7 limitation of the project work

The problem faced is lack of relevant literatures like periodicals, Journals, in the library and unavailability of the expected materials like permanent flat bar magnet, magnetic field strength tester for permanent bar magnet.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Maglev train

Thomas Bachelet and Robert Goddard [18] both came up with ideas for maglev in the early twentieth century, but had no way to actually create them.

The goal of using magnets to achieve high speed travel with non-contact magnetically levitated vehicles is almost a century old. In the early 1900's, Bachelet in France and Goddard [18] in the United States discuss the possibility of using magnetically levitated vehicles for high speed transport. However, they did not propose a practical way to achieve this goal.

On August 14, 1934, Hermann Kemper [19] of Germany receives a patent for the magnetic levitation of trains. Research continues after World War II. In the 1970s and 1980s, development, commissioning, testing and implementation of various Maglev Train systems continue in Germany by Thyssen Henschel. The Germans name their Maglev system "Transrapid".

In 1966, in the USA, James Powell and Gordon Danby [20] propose the first practical system for magnetically levitated transport, using superconducting magnets located on moving vehicles to induce currents in normal aluminum loops on a guide way. The moving vehicles are automatically levitated and stabilized, both vertically and laterally, as they move along the guide way. The vehicles are magnetically propelled along the guide way by a small AC current in the guide way.

In 1992, the Federal Government in Germany decides to include the 300 km long super speed Maglev system route Berlin-Hamburg in the 1992 Federal Transportation Master Plan.

In June of 1998, the US congress passes the Transportation Equity Act for the 21st Century (TEA 21). The law includes a Maglev deployment program allocating public funds for preliminary activities with regard to several projects and, later on, further funds for the design, engineering and construction of a selected project. For the fiscal years 1999 - 2001, $55 million are provided for the Maglev deployment program. An additional $950 million are budgeted for the actual construction of the first project. In November of 1999, the Chinese Ministry of Science and Technology and Transrapid International sign a letter of intent to select a suitable Transrapid route in the People's Republic of China and evaluate its technical and economic feasibility.

In January of 2001, in the US, Transportation Secretary Rodney Slater selects the Pittsburgh and the Washington - Baltimore routes for detailed environmental and project planning. Later that month in China, a contract is concluded between the city of Shanghai and the industrial consortium consisting of Siemens, ThyssenKrupp, and Transrapid International to realize the Shanghai airport link. In March, the construction of the Shanghai project begins [17].

Currently, the original Powell-Danby Maglev inventions form the basis for the Maglev system in Japan, which is being demonstrated in Yamanashi Prefecture, Japan. Powell and Danby have subsequently developed new Maglev inventions that form the basis for their second generation M-2000 System. Other Maglev Train systems are in the planning and development stages in various cities in the US, including projects in Georgia, California and Pennsylvania.

In the future, Maglev promises to be the major new mode of transport for the 21st Century and beyond because of its energy efficiency, environmental benefits and time-saving high velocity transport. Because there is no mechanical contact between the vehicles and the guide way, speeds can be extremely high. Traveling in the atmosphere, air drag limits vehicles to speeds of about 300 - 350 mph. traveling in low pressure tunnels, Maglev vehicles can operate at speeds of thousands of miles per hour.

The energy efficiency of Maglev transport, either in kilowatt-hours per passenger mile for personal transport, or kilowatt hours per ton-mile for freight, is much lower for Maglev than for autos, trucks, and airplanes. It is pollution free can use renewable energy sources such as solar and wind power, and in contrast to oil and gas fueled transport, does not contribute to global warming. It is weather independent, and can carry enormous traffic loads - both people and goods on environmentally friendly, narrow guide ways. The cost of moving people and goods by Maglev will be considerably less than by the present modes of auto, truck, rail, and air [11].

2.2 Types of Maglev train

2.2.1 EDS (Electrodynamic suspension)

Electrodynamics suspension (EDS) is a form of magnetic levitation in which there are conductors which are exposed to time-varying magnetic fields. This induces eddy currents in the conductors that create a repulsive magnetic field which holds the two objects apart.

Electrodynamics suspension (EDS) uses superconducting electromagnets or strong permanent magnets that create a magnetic field which induces currents in nearby metallic conductors when there is relative movement which pushes and pulls the train towards the designed levitation position on the guide way.

These time varying magnetic fields can be caused by relative motion between two objects. In many cases, one magnetic field is a permanent field, such as a permanent magnet or a superconducting magnet, and the other magnetic field is induced from the changes of the field that occur as the magnet moves relative to a conductor in the other object.

Electrodynamics suspension can also occur when an electromagnet driven by an AC electrical source produces the changing magnetic field, in some cases; a linear induction motor generates the field [22].

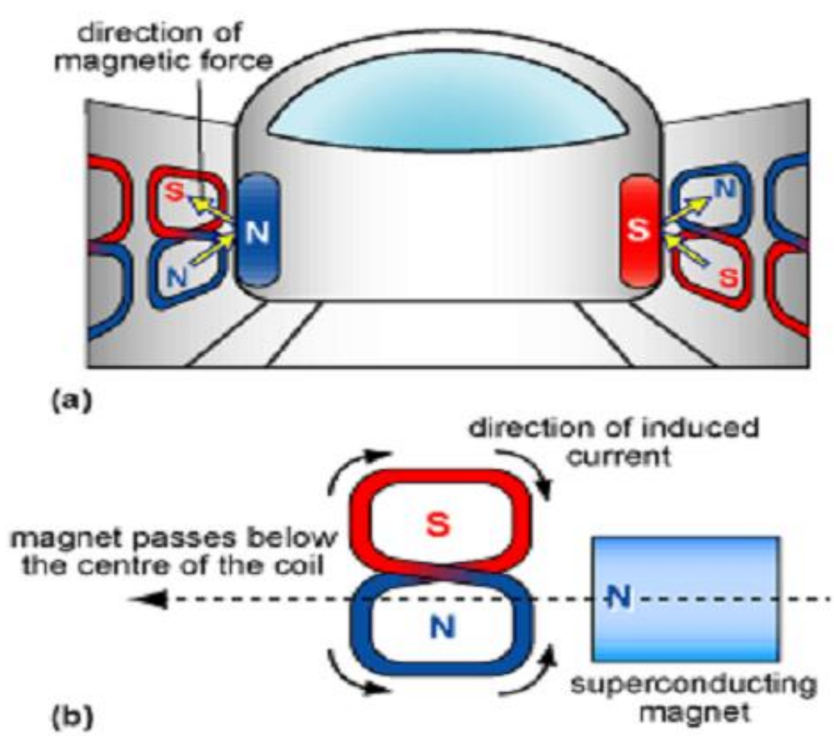


Figure:3- EDS Maglev propulsion

From the above figure 3 the repulsion-type system, also known as the electrodynamic levitation system (EDS), a superconducting coil operating in persistent-current mode is moved longitudinally along a conducting surface (an aluminum plate fixed on the ground and acting as the guide way) to induce circulating eddy currents in the aluminum plate. These eddy currents create a magnetic field which, by Lenz's law, opposes the magnetic field generated by the travelling coil. This interaction produces a repulsion force on the moving coil. At lower speeds, this vertical force is not sufficient to lift the coil (and its payload), so supporting auxiliary wheels are needed until the net repulsion force is positive. The speed at which the net upward lift force is positive (critical speed) is dependent on the magnetic field in the air gap and payload, and is typically around 80 km/h (50 mi/h). To produce high flux from the traveling coils, hard superconductors (type II) with relatively high values of the critical field (the magnetic field strength of the coil at 0 K) are used to yield air gap flux densities of over 4 tesla. With this choice, the strong eddy-current induced magnetic field is rejected by the superconducting field, giving a self-stabilizing levitation force at high speeds (though additional control circuitry is required for adequate damping and ride quality [18],[19],[20],[21].

2.2.2 EMS (Electromagnetic suspension)

Electromagnetic suspension (EMS) is the magnetic levitation of an object achieved by constantly altering the strength of a magnetic field produced by electromagnets using a feedback loop. In most cases the levitation effect is mostly due to permanent magnets as they don't have any power dissipation, with electromagnets only used to stabilize the effect [22].

Electromagnetic suspension (EMS), electronically controlled electromagnets in the train attract to a magnetically conductive (usually steel) track.

According to Earnshaw's theorem a paramagnetically magnetized body cannot rest in stable equilibrium when placed in any combination of gravitational and magnetostatic fields. In these kinds of fields an unstable equilibrium condition exists. Although static fields cannot give stability, EMS works by continually altering the current sent to electromagnets to change the strength of the magnetic field and allows a stable levitation to occur. In EMS a feedback loop which continuously adjusts one or more electromagnets to correct the object's motion is used to cancel the instability.

Magnetic levitation technology is important because it reduces energy consumption, largely obviating friction. It also avoids wear and has very low maintenance requirements. The application of magnetic levitation is most commonly known for its role in Maglev trains .

Electromagnetic suspension works like an active magnetic bearing. This principle is sometimes called a servo-stabilization. Sensors measure the air-gap between an electromagnet and guide way. Control system tries to keep it constant. This principle is very often used in commercial applications like Transrapid [22].

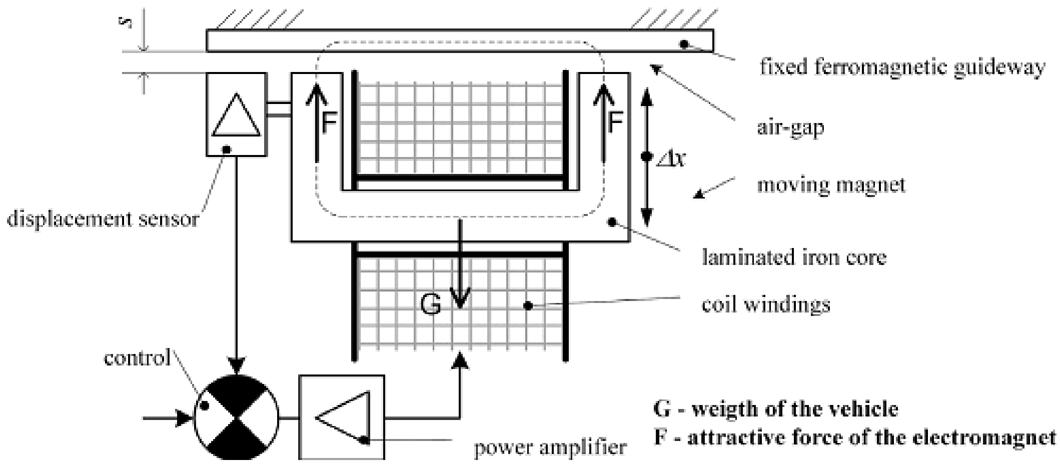


Figure: 4- EMS levitation principle

From the above figure 4 the Servo-stabilization is able to hold the body in the required position, even if the train is standstill. Therefore no wheels are required for assuring of the main levitation function. However some retainer wheels for safety purposes are usually employed.

Typical for this levitation principle is lower air-gap between the magnets and the guide way (in comparison to EDS) and existence of a feedback control system [22].

- **Advantage of EMS (Electromagnetic suspension)**

Magnetic fields inside and outside the vehicle are less than EDS; proven, commercially available technology that can attain very high speeds (500 km/h); no wheels or secondary propulsion system needed [23].

- **Disadvantage EMS (Electromagnetic suspension)**

The separation between the vehicle and the guideway must be constantly monitored and corrected by computer systems to avoid collision due to the unstable nature of electromagnetic attraction; due to the system's inherent instability and the required constant corrections by outside systems, vibration issues may occur [23].

2.2.3 Inductrack

The **Inductrack** is a newer type of EDS that uses permanent room-temperature magnets to produce the magnetic fields instead of powered electromagnets or cooled superconducting magnets. Inductrack uses a power source to accelerate the train only until begins to levitate. If the power fails, the train can slow down gradually and stop on its auxiliary wheels.

Inductrack is a passive, fail-safe magnetic levitation system, using only unpowered loops of wire in the track and permanent magnets (arranged into Halbach arrays) on the vehicle to achieve magnetic levitation. The track can be in one of two configurations, a "ladder track" and a "laminated track". The ladder track is made of unpowered Litz wire cables, and the laminated track is made out of stacked copper or aluminum sheets.

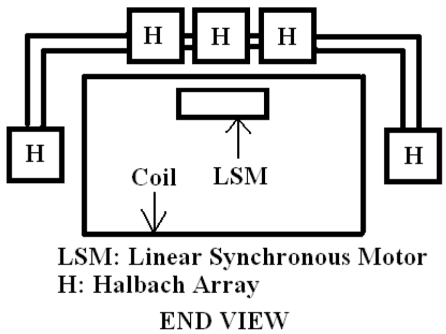
There are two designs: the Inductrack I, which is optimized for high speed operation, and the Inductrack II, which is more efficient at lower speeds.

The track is actually an array of electrically-shorted circuits containing insulated wire. In one design, these circuits are aligned like rungs in a ladder. As the train moves, a magnetic field repels the magnets, causing the train to levitate.

There are two Inductrack designs: Inductrack I and Inductrack II. Inductrack I is designed for high speeds, while Inductrack II is suited for slow speeds. Inductrack trains could levitate higher with greater stability. As long as it's moving a few miles per hour, an Inductrack train will levitate nearly an inch (2.54 centimeters) above the track. A greater gap above the track means that the train would not require complex sensing systems to maintain stability.

Permanent magnets had not been used before because scientists thought that they would not create enough levitating force. The Inductrack design bypasses this problem by arranging the magnets in a **Halbach array**. The magnets are configured so that the intensity of the magnetic field concentrates above the array instead of below it. They are made from a newer material comprising a neodymium-iron-boron alloy, which generates a higher magnetic field. The Inductrack II design incorporates two Halbach arrays to generate a stronger magnetic field at lower speeds [22].

Track Deign I



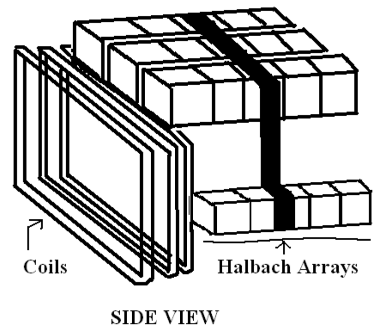


Figure: 5 - Track I and Train Design principle

The design incorporates two models. The track I and train design shown above in Figure 5, will be constructed first, due to the lower number of components required.

This topology, labeled as Track , uses the rectangular coils as the main track bed. The bottom portion of the train will consist of Halbach arrays that are in parallel with the track. A Halbach array will also extend down from the sides of the train. The track and train will then be encapsulated with 1/8" plexiglass to inhibit the track from damaging the coils in the event of a crash. To test Track I, the rectangular coils will be hand wound onto either a wooden or plastic beam. The levitation and lateral stabilization magnets will be attached together to form a train car. Spacing between the arrays and the track will be between two and three mm. Initially, the coils will remain open circuits so that a dc current source can be connected to the coils to make them electromagnets. Although the real system implementation will use passive induction to generate the coil currents, the electromagnet coil test track will give insight into how drag and lift occur for static magnetic fields.

Next, the coils will be soldered to form shorted loops necessary for the Track I design. An external device such as a bungee cord or gravity drive will then be used to propel the train from its rest state. Visual observation will be used to test for train levitation, and a stopwatch will be used to compute train speed. A video camera may also be utilized to provide more exact speed and levitation measurements required for calculating the transition speed. One coil will also be left open and connected to an ammeter to measure the induced current. This will allow for theoretical calculations and modeling.

Track Design II

If the Track I design fails, the Track II design will be constructed and tested. Shown below in Figure 6, it will implement two parallel rails of magnetic coils.

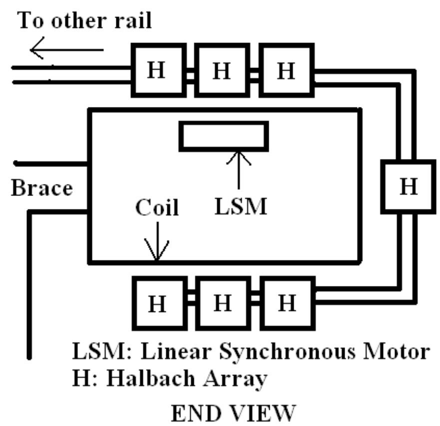


Figure 6. Track II Design principle

A dual rail design is required in order to allow the Halbach arrays to be in a paired configuration that will position them above and below the track. Although the Track II topology involves far more construction, a lower transition speed is achieved since the lower Halbach arrays can be adjusted to cancel a given amount of the vertical flux component from the upper array [25]. By creating a lower vertical flux component, less current is induced in the track coils. The lower coil current directly reduces the magnetic drag force and allows for magnetic lift to occur at speeds as low as one mph [25].

The Track II construction will reuse the Track I prototype developed since Track II is essentially two parallel Track I designs, with the addition of Halbach arrays underneath the rectangular coils. To test the concept of the dual Halbach arrays, Track I will be turned vertically and a dual Halbach configuration with stability arrays will be constructed and dropped down the track from a rest state. This test will allow for adjustment of the levitation Halbach arrays to induce the least amount of coil current. Manual adjustment then provides the lowest transition speed for the Track II prototype.

Table 1. Specifications for Train Operation [25]

Criteria	Design Specification
Initial Launch	External Force (Elastic Cord, Gravity Drive)
Operating Speed	4-8 mph
Top Speed	8-10 mph
Acceleration	0 mph to 8-10 mph in under two seconds

Table 2. Specifications for Magnetic Field Producing Track Elements [25]

Criteria	Design Specification
Topology	Shorted Rectangular Coils
Turns/Coil	40 – 60
Wire Material	Aluminum or Copper
Wire Diameter	18-24 (gauge) / .5105 -1.0236 diameter (mm)
Loop Dimensions	3”-6” x 1.5”-3”
Internal Loop Bracing	Wood, Hollow Plastic Tubing

2.3 Pros and cons of EMS, EDS and Indutuck systems

Each implementation of the magnetic levitation principle for train-type travel involves advantages and disadvantages.

Table: 3 Pros and cons of EMS, EDS and Indutuck systems [23]

Technology	Pros	Cons
Electromagnetic suspension	Magnetic fields inside and outside the vehicle are less than EDS; proven, commercially available technology that can attain very high speeds (500 km/h); no wheels or secondary propulsion system needed.	The separation between the vehicle and the guideway must be constantly monitored and corrected by computer systems to avoid collision due to the unstable nature of electromagnetic attraction; due to the system's inherent instability and the required constant corrections by outside systems, vibration issues may occur.
Electrodynamic suspension	Onboard magnets and large margin between rail and train enable highest recorded train speeds (581 km/h) and heavy load capacity; has demonstrated (December 2005) successful operations using high temperature superconductors in its onboard magnets, cooled with inexpensive liquid nitrogen.	Strong magnetic fields onboard the train would make the train inaccessible to passengers with pacemakers or magnetic data storage media such as hard drives and credit cards, necessitating the use of magnetic shielding; limitations on guide way inductivity limit the maximum speed of the vehicle; vehicle must be wheeled for travel at low speeds.
Inductrack System	FailsafeSuspension—no power required to activate magnets; Magnetic field is localized below the car; can generate enough force at low speeds (around 5 km/h) to levitate maglev train; in case of power failure cars slow down on their own safely; Halbach arrays of permanent magnets may prove more cost-effective than electromagnets[23].	Requires either wheels or track segments that move for when the vehicle is stopped. New technology that is still under development (as of 2008) and as yet has no commercial version or full scale system prototype.

2.4 Advantages of maglev train over conventional trains

Maglev transport is non-contact and electric powered. It relies less or not at all on the wheels, bearings and axles common to wheeled rail systems. Some advantages are as follow:-

- **Speed:** Maglev allows higher top speeds than conventional rail, but experimental wheel-based high-speed trains have demonstrated similar speeds.
- **Maintenance**: Maglev trains currently in operation have demonstrated the need for minimal guideway maintenance. Vehicle maintenance is also minimal (based on hours of operation, rather than on speed or distance traveled). Traditional rail is subject to mechanical wear and tear that increases exponentially with speed, also increasing maintenance.
- **Weather**: Maglev trains are little affected by snow, ice, severe cold, rain or high winds. However, they have not operated in the wide range of conditions that traditional friction-based rail systems have operated. Maglev vehicles accelerate and decelerate faster than mechanical systems regardless of the slickness of the guide way or the slope of the grade because they are non-contact systems.
- **Track**: Maglev trains are not compatible with conventional track, and therefore require custom infrastructure for their entire route. By contrast conventional high-speed trains such as the TGV are able to run, albeit at reduced speeds, on existing rail infrastructure, thus reducing expenditure where new infrastructure would be particularly expensive (such as the final approaches to city terminals), or on extensions where traffic does not justify new infrastructure. John Harding, former chief maglev scientist at the Federal Railroad Administration claimed that separate maglev infrastructure more than pays for itself with higher levels of all-weather operational availability and nominal maintenance costs. These claims have yet to be proven in an intense operational setting and do not consider the increased maglev construction costs.
- **Efficiency**: Conventional rail is probably more efficient at lower speeds. But due to the lack of physical contact between the track and the vehicle, maglev trains experience no rolling resistance, leaving only air resistance and electromagnetic drag, potentially improving power efficiency. Some systems however such as the Central Japan Railway Company SCMaglev use rubber tires at low speeds, reducing efficiency gains.
- **Weight**: The electromagnets in many EMS and EDS designs require between 1 and 2 kilowatts per ton. The use of superconductor magnets can reduce the electromagnets' energy

consumption. A 50-ton Transrapid maglev vehicle can lift an additional 20 tons, for a total of 70 tons, which consumes 70-140 kW. Most energy use for the TRI is for propulsion and overcoming air resistance at speeds over 100 mph.

- **Weight loading**: High speed rail requires more support and construction for its concentrated wheel loading. Maglev cars are lighter and distribute weight more evenly.
- **Noise**: Because the major source of noise of a maglev train comes from displaced air rather than from wheels touching rails, maglev trains produce less noise than a conventional train at equivalent speeds [23].

2.5 Magnet Basics

A **magnet** is a material or object that produces a magnetic field. This magnetic field is invisible but is responsible for the most notable property of a magnet: a force that pulls on other ferromagnetic materials, such as iron, and attracts or repels other magnets [26].

A **permanent magnet** is an object made from a material that is magnetized and creates its own persistent magnetic field. An everyday example is a refrigerator magnet used to hold notes on a refrigerator door. Materials that can be magnetized, which are also the ones that are strongly attracted to a magnet, are called ferromagnetic (or ferromagnetic). These include iron, nickel, cobalt, some alloys of rare earth metals, and some naturally occurring minerals such as lodestone. Although ferromagnetic (and ferromagnetic) materials are the only ones attracted to a magnet strongly enough to be commonly considered magnetic, all other substances respond weakly to a magnetic field, by one of several other types of magnetism[26].

Ferromagnetic materials can be divided into magnetically "soft" materials like annealed iron, which can be magnetized but do not tend to stay magnetized and magnetically "hard" materials, which do. Permanent magnets are made from "hard" ferromagnetic materials such as alnico and ferrite that are subjected to special processing in a powerful magnetic field during manufacture, to align their internal microcrystalline structure, making them very hard to demagnetize. To demagnetize a saturated magnet, a certain magnetic field must be applied, and this threshold depends on coercively of the respective material. "Hard" materials have high coercively, whereas "soft" materials have low coercively [26].

An electromagnet is made from a coil of wire that acts as a magnet when an electric current passes through it but stops being a magnet when the current stops. Often, the coil is wrapped around a core of "soft" ferromagnetic material such as steel, which greatly enhances the magnetic field produced by the coil. The overall strength of a magnet is measured by its magnetic moment or, alternatively, the total magnetic flux it produces. The local strength of magnetism in a material is measured by its magnetization [26].

2.6 Types of magnet

2.6.1 Permanent Magnets

Permanent magnets are those we are most familiar with, such as the magnets hanging onto our refrigerator doors. They are permanent in the sense that once they are magnetized, they retain a level of magnetism. As we will see, different types of permanent magnets have different characteristics or properties concerning how easily they can be demagnetized, how strong they can be, how their strength varies with temperature, and so on [26].

Magnetic field of permanent magnets

The magnetic field of permanent magnets can be quite complicated, especially near the magnet. The magnetic field of a small straight magnet is proportional to the magnet's *strength* (called its magnetic dipole moment **m**). The equations are non-trivial and also depend on the distance from the magnet and the orientation of the magnet. For simple magnets, **m** points in the direction of a line drawn from the south to the north pole of the magnet. Flipping a bar magnet is equivalent to rotating its **m** by 180 degrees.

The magnetic field of larger magnets can be obtained by modelling them as a collection of a large number of small magnets called dipoles each having their own **m**. The magnetic field produced by the magnet then is the net magnetic field of these dipoles. And, any net force on the magnet is a result of adding up the forces on the individual dipoles.

There are two competing models for the nature of these dipoles. These two models produce two different magnetic fields, **H** and **B**. Outside a material, though, the two are identical (to a multiplicative constant) so that in many cases the distinction can be ignored. This is particularly true for magnetic fields, such as those due to electric currents, that are not generated by magnetic materials.

Materials used for permanent magnets

There are four classes of permanent magnets:

1. Neodymium Iron Boron (NdFeB or NIB)
2. Samarium Cobalt (SmCo)

2.6.2 **Temporary Magnets**

Temporary magnets shown below figure 7 are those which act like a permanent magnet when they are within a strong magnetic field, but lose their magnetism when the magnetic field disappears. Examples would be paperclips and nails and other soft iron items [27].

Figure: 7 -Temporary magnet

2.6.3 **Electromagnets**

An electromagnet which shows in figure 8 is a tightly wound helical coil of wire, usually with an iron core, which acts like a permanent magnet when current is flowing in the wire. The strength and polarity of the magnetic field created by the electromagnet are adjustable by changing the magnitude of the current flowing through the wire and by changing the direction of the current flow [26].

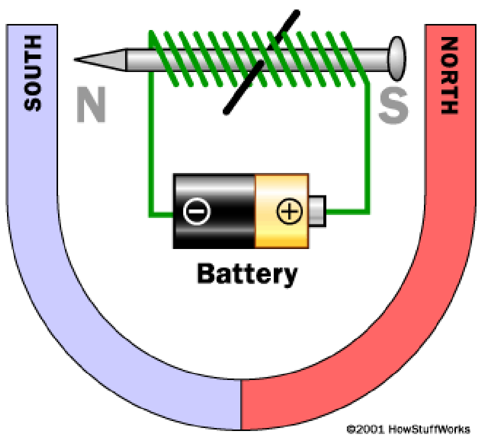


Figure: 8 – Electromagnet

Measurement for strength or power of a magnet

A **magnet** is any object that produces its own **magnetic field**. Magnets are made using pressing and sintering, extruding, injection molding, calendaring, casting, and compression bonding. The **magnetic strength** of these subjects can vary from weak fields to incredibly strong fields, depending on a number of characteristics such as temperature, electric current and grade of the material the magnet is made of. A **magnetic field** is an area of space where there is a detectable magnetic force which has a measurable strength and direction.

There are actually three common ways to measure the strength of a magnet.

- **Gauss meter** - Magnetic strength is measured generally in terms of **gauss rating** in the commercial magnets
- **Magnetometer** - These devices measure magnetic strength in **gauss or arbitrary units**
- **Pull-tester -** They measure the amount of weight a magnet can hold in pounds, kilograms or other force units.

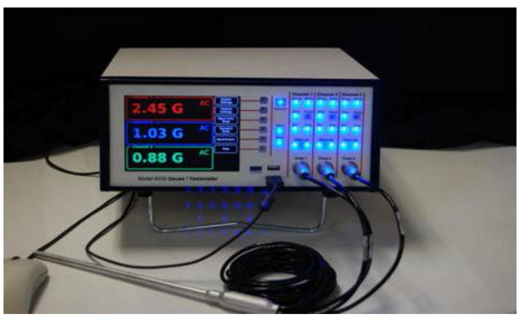


Figure: 9- Gauss Meter

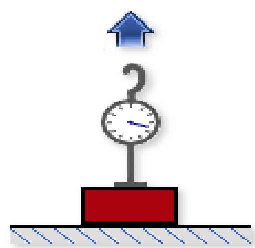


Figure: 10- Pull Tester

2.7 Working principle of Maglev train

2.7.1 Levitation

Basics of Magnetic levitation

Magnetic levitation or magnetic suspension is a method by which an object is suspended with no support other than magnetic fields. Magnetic pressure is used to counteract the effects of the gravitational and any other accelerations.

Magnetic Fields

The creation of magnetic forces is the basis of all magnetic levitation. The creation of a magnetic field can be caused by a number of things. The first thing that it can be caused by is a permanent magnet. These magnets are a solid material in which there is an induced North and South pole. These will be described further a little later. The second way that an magnetic field can be created is through an electric field changing linearly with time. The third and final way to create a magnetic field is through the use of direct current[26].

There are two basic principles in dealing with the concept of magnetic levitation. The first law that is applied was created by Michael Faraday. This is commonly known as Faraday's Law.

This law states that if there is a change in the magnetic field on a coil of wire, there is seen a change in voltage. Taking that a bit further, it could be said that if there was a change in voltage, then there would be a change in magnetic field. This occurs in the coil when there is a current induced as a result of that change in voltage. From Figure 11 below it is illustrated that the change in the magnetic field produces a current.

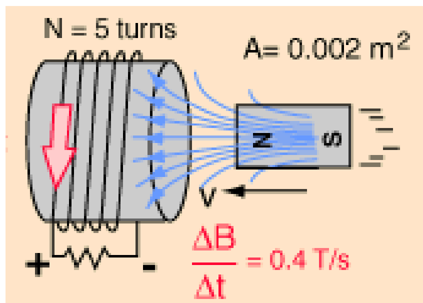


Figure: 11 - Induced Current from Change in Magnetic Field

For the purposes of magnetic levitation the ability to change the strength of a magnetic field by just changing the current is powerful. If there is a need for more of a force, then sending more current through a coil of wires will produce more of a greater magnetic force.

The direction of the forces created by Faraday's Law was discovered by a man named Heinrich Lenz. His theory states that "the emf induced in an electric circuit always acts in such a direction that the current it drives around the circuit opposes the change in the magnetic flux which produces the emf "[24]. In other words, this is stating that if there was a current that was created in a coil of wires, then the magnetic field that is being produced will be perpendicular the current direction.

The application that this has on magnetic levitation is that this will allow the direction of the magnetic field to be predictable and thus a set up can be created for a specific purpose to maximize the force that is created.

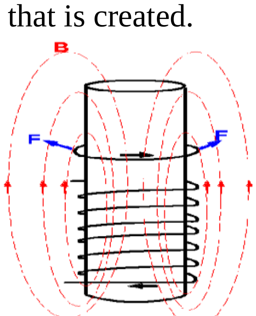


Figure: 12 - Perpendicular Force from Induce Current

From Figure 12 above, it is illustrated that there is a coiled wire around the cylinder. Inside that coiled wire is a current that is traveling from left to right. The resulting magnetic force from that current is shown to be perpendicular to the current and is traveling from bottom to top.

2.7.1.1 Types of Magnetic Levitation

Although the concepts of magnetic levitation are all the same, the way that those concepts are brought about can vary. These options are controlled and changed depending on the type of application that is necessary.

I. Permanent Magnets levitation

The first type of levitation is the implementation through permanent magnets. These magnets are made of a material that creates a north and a south pole on them. This can be seen in Figure13below.

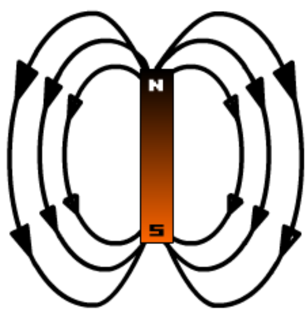


Figure: 13- Permanent Magnet Fields

The formal definition of a permanent magnet is "a material that retains its magnetic properties after and external magnetic field is removed" [28]. The whole idea behind permanent magnets is that like ends will repel and opposite ends will attract.

Permanent magnets require very little if any maintenance. These magnets do not require cryogens or a large power supply for operation. The magnetic field is measured vertically within the bore of the magnet. The main disadvantages of a permanent magnet are the cost of the magnet itself when put into large scale systems. Another disadvantage is the varying changes in the magnetic field. The ability to control a constant magnetic force from a permanent magnet is an on-going problem in the application of these types of magnets. Different applications that use these types of magnets can be found in a number of different areas. Examples of these applications are compasses, DC motor drives, clocks, hearing aids, microphones, speedometers, and many more.

II. Electromagnetic Magnets levitation

The basic idea behind an electromagnet is extremely simple. By running electric current through a wire, you can create a magnetic field. When this wire is coiled around a magnetic material (i.e. metal), a current is passed through this wire. In doing this, the electric current will magnetize the metallic core. This can be seen in Figure 14.

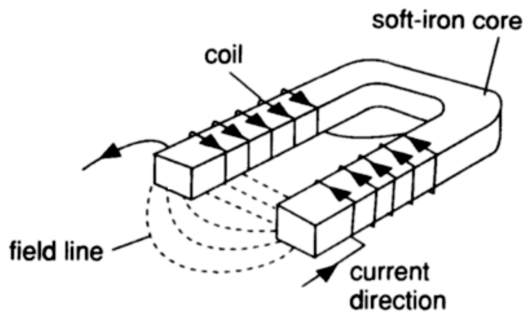


Figure: 14- Electromagnet principle

By using this simple principle, you can create all sorts of things including motors, solenoids, heads for hard disks, speakers, and so on. An electromagnet is one that uses the same type of principles as the permanent magnet but only on a temporary scale. This means that only when the current is flowing is there going to be an induced magnet. This type of magnet is an improvement to the permanent magnet because it allows somebody to select when and for how long the magnetic field lasts. It also gives a person control over how strong the magnet will be depending on the amount of current that is passed through the wire.

III. Superconductive Magnet levitation

Superconductive magnets are the most common of all the magnets, and are sometimes called cryo magnets. The idea behind the superconducting magnets is that there is a material which presents no electrical resistivity to electrical current. Once a current has been fed into the coils of this material, it will indefinitely flow without requiring the input of any additional current. The way that a material is able to have such a low resistivity to current is that it is brought to very low temperatures. The temperatures that are commonly found in superconducting magnets are around -258^{o}C. This is done by immersing the coils that are holding the current into liquid Helium; this also helps in maintaining a homogenous magnetic field over time. The advantage to the superconducting magnet is that they do not require constant power from a source to keep up the value of the current in the coils. Although a disadvantage is that they require an expensive cryogen such as helium to operate correctly. The magnetic field is in the direction of the long axis of the cylinder or bore of the magnet.

2.7.1.2 Principle of Magnetic Levitation

In the EMS-attractive system in the figure 15 below, the electromagnets which do the work of levitation are attached on the top side of a casing that extends below and then curves back up to the rail.

Table 4. Specifications for Magnetic Levitation [25]

Criteria	Design Specification
Ride Height	0 mm : Train Speed < Transition Speed
Ride Height	5 mm - 15 mm : Train Speed > Transition Speed

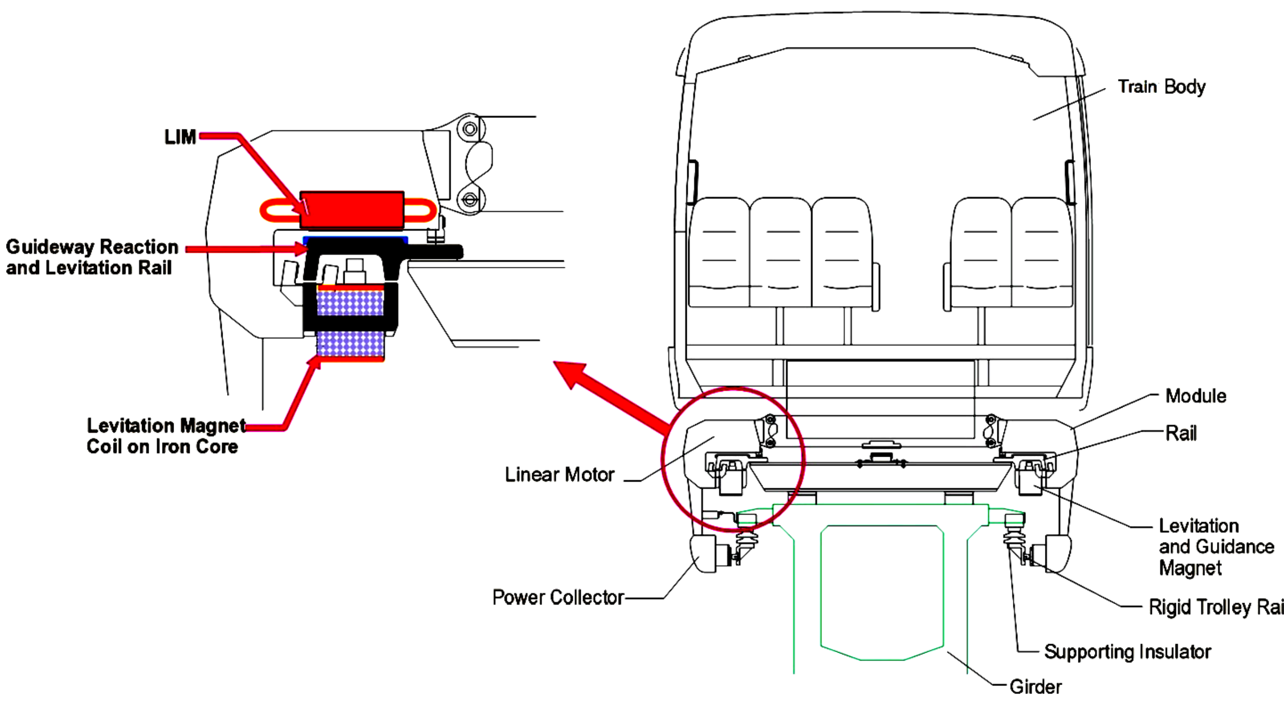


Figure: 15 -principle of EMS-attractive system Magnetic Leviation

From the above figure 15 the principle of levitation is work by constantly altering the strength of a magnetic field produced by electromagnets using a feedback loop.

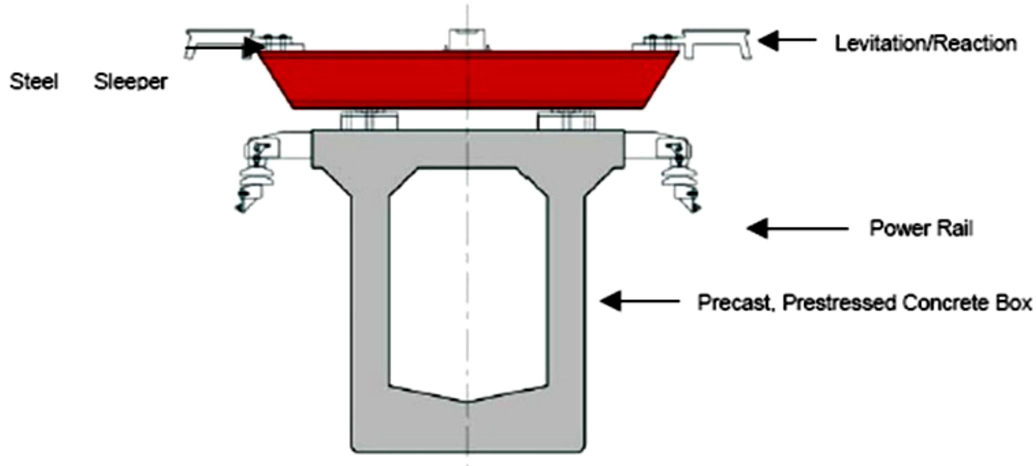


Figure: 16 – Ferromagnetic rail

From figure 16 above

- The rail, which is in the shape of an inverted T, is a ferromagnetic rail.
- When a current is passed through it, and the electromagnet switched on, there is attraction, and the levitation electromagnets, which are below the rail, raise up to meet the rail. The car levitates.

2.7.1.3 Applications for magnetic levitation

- ✓ **Novelty Toys**

The most popular application for magnetic levitation by far has been through the novelty toys. This application has been made possible because of how relatively inexpensive it is to manufacture a small magnet for use with in a toy. Along with that is the actual display of the toy that amazes people. These are toys that not many people can explain. It showcases a product that is defying gravity without the use of strings, or other hidden tricks[26].

- ✓ **Globes**

Novelty toys can be found everywhere when it comes to magnetic levitation. One of the most popular gadgets is the magnetic globe. This is one that a lot of professionals keep on their desks as a way of impressing people that come into their office. These electromagnetically suspended globes are actually high-tech instruments. A magnetic field sensor permanently measures the height at which the globes are suspended. This sensor feeds that data into a micro computer in the base of the unit. This computer than calibrates the electronic magnets at the top of the frame based on the distance between the globes and the top magnet to keep the globes correctly positioned. So not only do these look great on the desktop levitating in thin air, they are also technological marvels. Once it's levitating, it can even be spun slightly and watch as the globes rotate for extend periods of time [28]. Figure 17 below shows an example of one of this magnetic levitation.

Figure: 17 -. Magnetically Levitating Globes

- **Fast Food Toys**

Fast food chains is one area where the magnetic levitation scheme has taken off. The way that this is done is by creating a toy that has to do with a popular theme, and construct it to levitate in some way. One example of this is the Tasmanian devil in the cartoon Looney Toons. The Tasmanian devil is a character that always leaves the scene in a small tornado of dust. The fast food chain Wendys picked up on this idea when they created a toy that had a tornado spinning in air. This is a relatively inexpensive thing to make and it seems amazing because it is floating in the air [26].

- **Transportation**

Trains

A super high-speed transport system with a non-adhesive drive system that is separate of wheel-and-rail frictional forces has long been a vision of railway engineers. Maglev, a combination of superconducting magnets and linear motor technology, realizes super high-speed running, safety, reliability, low environmental impact and minimum maintenance. For the past two decades, prototype magnetically levitated (maglev) trains cruising at up to 400 kilometers per hour have pointed the way to the future in rail transport. Their compelling advantages include high speeds, little friction except aerodynamic drag, low energy consumption, and negligible air and noise pollution.However, maglev trains also pose significant drawbacks in maintenance costs, mechanical and electronic complexity, and operational stability. Some maglev train cars, for example, employ superconducting coils to generate their magnetic field. These coils require expensive, cryogenic cooling systems. These maglev systems also require complicated feedback circuits to prevent disastrous instabilities in their high-speed operation. These social implications will be described in its entirety later on in the paper [29].

Maglev is a system in which the vehicle runs levitated from the guide way (corresponding to the rail tracks of conventional railways) by using electromagnetic forces between superconducting magnets on board the vehicle and coils on the ground. The following is a general explanation of the principle of Maglev. There are many different moderations of the technology used in levitating train cars for transportation, but the following in the first example. This example can be seen in Figure 18, 19, and 20 below. In the first figure is where the principle of magnetic levitation is employed. In the picture you can see the figure '18' of levitation coils that are installed on the side walls of the guide way. Also from the figure 18 you can see that there are superconducting magnets attached to the vehicle itself. As the vehicle is moving at a high rate of speed, there is an electric current that passes through the coils only at the instant that the vehicle is passing the coils. Once this happens, this turns the coils into electromagnets temporarily.

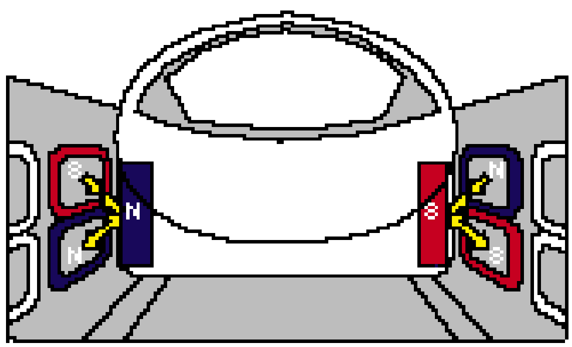


Figure: 18 - Principle of Magnetic Levitation [29].

Once the electromagnets are turned on, the interaction between the coils on the guide way and the magnets on the vehicle allow the vehicle to stay levitated above the track for a few centimeters. As can be see from the figure 18, on the side of the vehicle there is a magnetic force acting to push the vehicle up from the bottom, and at the same time there is a force pulling it up from the top part of the coil. This process is responsible for the levitating aspect for the track.

The main task to complete for the system is to levitate the vehicle; otherwise the technology is not breakthrough at all. But on the other hand there are a couple more important things to remember. With magnetic forces there is an unstable force that needs to be contained to act efficiently. So with this known, care must be take to make sure that the vehicle does not slide from side to side [29]. This is done by the principle of Lateral guidance. This is illustrated in Figure 19 below.

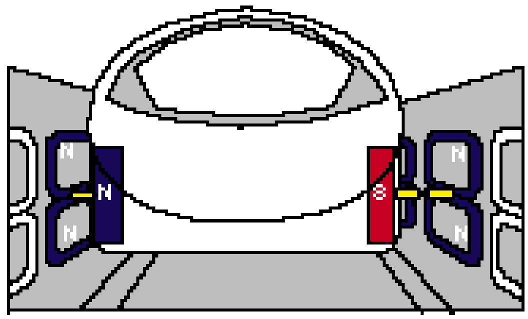


Figure: 19 - Principle of Lateral Guidance [29].

The levitating coils that are facing each other are connected under the guide way. These coils are of the same pole on the same side. Although they alternate as you go down the track. When the train is moving and the vehicle is overtop the coils, a current is sent through the coils to create an electromagnetic force. This force is then reacting with the forces that are coming from the vehicle. Once the current is running through the loops, a repulsive force acts on the coils on the side nearest the car and an attractive force acts on the coils furthest away from the car. At first this may seem as though the car is going to be attracted to the side wall of the guide way. The coils of the like pole are being alternated down the track so when one side is being attracted at one point, once it gets a little further then it is being repelled at another point. This whole process that is happening very fast and only one set of coils is being turned on at one point. Thus while this car is being ran, it is always located at the center of the guide way.

Once you have the vehicle centered and floating, then there is the issue of how you will keep the vehicle moving without the use of a propellant. After all that is the whole idea for this technology, is that it will not use any propellants. This idea is called the principle of propulsion. All through the side of the guide way are coils that are alternating north and south poles as in the last case above. This can be seen in the illustration in Figure 20 below. Just as before the magnets are only activated once the vehicle is passing by. This whole process will save money in the end because of the lack of power that is needed in running the magnets all the time. This also is necessary in the theory that is involved in running the cars. If the magnets were run all of the time, this would create unnecessary and unpredictable results on the outcome of the vehicle. Superconducting magnets of unlike kinds are also placed on the side of the car. The opposite arrangement is also seen on the other side of the car. The propulsion coils located on the sidewalls are energized by a three-phase alternating current from a substation, creating a shifting magnetic field on the guide way[30].

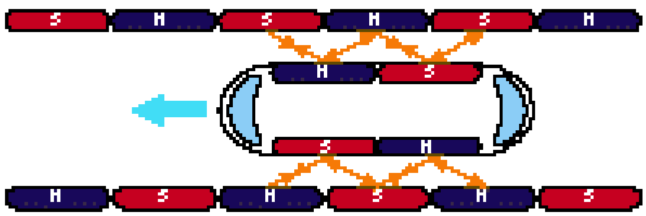


Figure 20. Principle of Propulsion

Once this happens, the on-board superconducting magnets are attracted and repelled by the shifting field. This shift in the field will provide the push necessary needed to get the car moving. Once the car is moving the forces are present already and acts as just to intensify the force that it started with. This exponential increase in the forces creates the acceleration for the high speed running. Although it doesn't get out of control because of the ability to turn on and off the current in the coils as well as the amount of current that is being sent through.

This type of technology in the application of the Maglev system is the one that has been developed in Japan already. This system is already running and has been very successful. Below in Figure 21 it is illustrated the track that this type of system is running on.

Figure: 21- Japanese Guide ways [7]

It can be seen from the picture that there is a lot of development that went into the building of this type of system. The walls alone carry the vital magnetic coils required to levitate and stabilized the car. The problem that is seen with this type of implementation is that there is a lot of development that is needed to go into the walls because of the vital coils within the walls.

The type of application that the U.S. is considering is a type that has all of the vital components at the bottom of the vehicle and there are no walls on the tracks that will be developed. The U.S. finds that this way there will be no need for the walls and will save a lot of money in development. The type of design the U.S. is considering is shown below in Figure 22. This design can be implemented using two different types of magnets. The one on the left is the type that uses superconducting magnets, and the one on the right uses electromagnets[31].

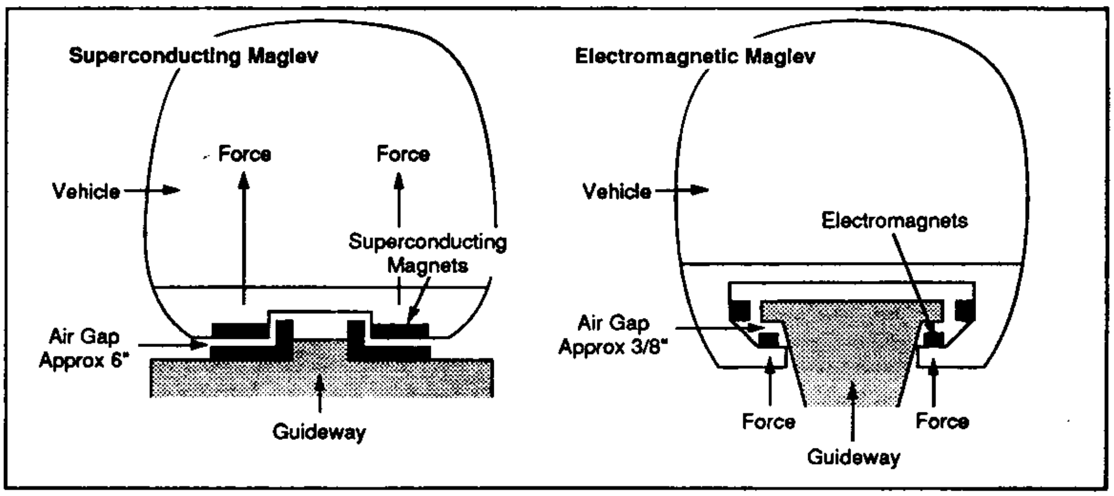


Figure: 22- Different Implementation of MagLev [31]

Even though the two designs are different they both use the same principles. The most popular of the designs that is going to be implemented is the superconducting. The way that this works is that it uses powerful superconducting magnets mounted on the vehicles. The magnets interact with a guide way that is usually made of aluminum. Currents are induced in the aluminum only when the vehicles magnets are directly overhead. This is just like the last system that was described. This limits the amount of power that is used, and it also limits the amount of electromagnetic forces that could result in unpredictable behavior. Once the currents are running, then the electromagnetic forces keep the vehicle elevated as well as stabilized against left and right direction. By looking at the figure above, the magnets can be seen to be situated in such a way that they serve a dual role. The magnets are laid flat on the guide way for the levitating. They are also brought up at a right angle so that they are raised vertical as well. This then allows the reaction of the magnetic forces to keep it centered on the track. With this system built into both sides of the vehicles, the natural repulsion of the magnets on both sides naturally centers the vehicle[31].

The guide ways are configurable to maintain a stable position or “magnetic well.” This is done by automatically inducing strong restoring forces that will push the vehicle back to its equilibrium position. The reason for this is that there will be a need to combat forces that may try to tip or throw the vehicle over the track. Some of those forces could be wind that is perpendicular to the motion of the vehicle. This would try to make the vehicle fall with a left to right motion. Another force that could affect the tilting is the natural momentum that is created from taking a turn. This can be combated with banking of the turns, but there is only so much banking that can be done without creating discomfort to the passengers of the rail car. An example of the restoring forces that could be used on the vehicles is that there could be more current passed through the coils on the right side of the vehicles on a turn that goes to the left. In doing this, it would create a more magnetic force that would try to push against the momentum of the vehicle in the opposite direction. But once the vehicle came out of the turn the current would need to be turned down, otherwise the car will be unbalanced and feel the need to tip over on its side. The currents are carefully monitored by computers along the way for the seamless transfer of current between the different magnets and at different times [31].

- ✓ **Floaters (Steel Industry Application)**

Magnetic Levitation doesn’t have to be used for only transportation purposes. The principles behind magnetic levitation can be applied to manufacturing processes as well. One example of this would be for the steel industry. The way that this industry uses this is through components called floaters. An example of these floaters can be seen in Figure 23 below.

Figure : 23 - Floaters in the Steel Industry[32]

The way that these are used are through the use of magnets to continually count and separate sheets of steel that have already been processed. The reason that this method was devised was because of the error that was being seen on the products that were coming through the line. Using this technique you have no human contact with the steel and also no mechanical contact with the steel because of the sheets of steel are levitating above each other. These magnetic sheet floaters operate by the use of mutual magnetic repulsion to separate sheets in a stack. One of the advantages to this type of system is that it is able to handle clean, oily, or painted sheets of steel when normally there would have needed time to wait for the sheets to dry, clean the sheets off from the oil that is on them, and also keep the sanitation of the sheets that have already been clean. Also it eliminates prying, scratching, marring, and bending of costly stock. This will also protect expensive dies, punches, shears, and forming equipment [32],[33].

When the sheet floaters are situated at opposite edges of the workplace, the work pieces become magnetized by induction with similar polarity and the top two or three work pieces repel each other and float in the air. This also creates a neat an easy way to stack the units of steel once they are in need to packaging.

The floater units contain an arrangement of powerful magnets housed in an iron casing. These units can be housed in both the vertical and horizontal stacks. It is most commonly used in the horizontal direction for the smaller sheets, and the vertical direction for the larger sheets.

- ✓ **Rail Guns (electromagnetic propulsion)**

RailGuns are by far the most spectacular type of electromagnetic accelerators ever developed. They hold the record for fastest object accelerated of a significant mass, for the 16000m/s firing of a .1 gram object by Sandia National Research Laboratories' 6mm Hypervelocity Launcher. They can also propel objects of very sizeable masses to equally impressive velocities., Maxwell Laboratories has been able to fire a 1.6 kilogram projectile at 3300 m/s. The kinetic energy produced from that type of acceleration is of 9 Mega joules of energy. Their ability to propel objects at speeds which are simply impossible for conventional (chemical or mechanical) means makes them extremely useful for a range of functions. The most obvious one being defense, where most of the research money in this area comes from nowadays, but NASA has also been heavily funding RailGun research for hypervelocity impact simulations which will allow shields to be developed which will protect orbiting aircraft from high velocity debris surrounding the earth. NASA is also researching the possibility of a launcher which would deliver payloads into orbit at a fraction of the cost of a rocket launch. Similarly, other studies are under progress for the utilization of RailGuns in Fusion Fuel pellet Injectors for experimental nuclear fusion reactors, and also for metallurgical bonding; the University of Texas (UT) in Austin, identified that the Electromagnetic Powder Deposition (by a railgun) process is capable of achieving a coating of deposit material with bond strength equal to the base material while achieving less than 3% porosity. This is the process of propelling a mixture of finely produced powder at an object. This powder would then coat the object that it is being shot at. Since the powder is being fired at such high speeds, it is compacted against the object very tightly. This provides a coating on the object that if very fine. This should soon become a repair method for jet engine components, as similar processes are also being employed to produce extremely high shock pressures on collisions between unlike materials in an attempt to produce new materials[34].

The whole idea of a rail gun begins with two rails. This pair of conducting rails is separated by a distance of L. One of these rails is connected to the positive side of a voltage source and the other is connected to the negative side of the power source. Once connected, there is now both a voltage V and the potential for current I. To launch an object, this conducting object must be placed in the middle of the two rails. This completion of the gap allows the completion of the circuit. Current I begins to flow through the rails, and a magnetic field B is generated in the direction of the opening of the rail gun. A drawing of this can be seen in Figure 24 below.

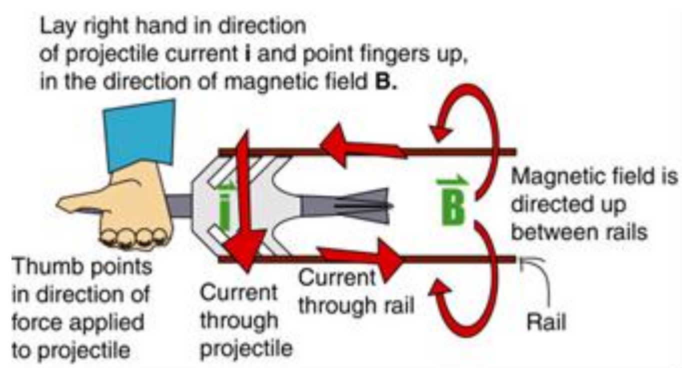


Figure : 24- Impact of Magnetic Field on the Projectile[34]

The magnitude of the magnetic force is best represented from Equation (1) below.

Magnetic Field Intensity

$B = N\,(1.25X\ 10^{-6})\ I$…………………….… ………….(1)

Where:-

B = Magnetic Field Strength (Teslas)

N = Number of Turns in Solenoid

I = Current Through the Rails and Conducting Object (Amps)

When the current moves through the conducting object over Length L in the presence of a magnetic field B, a force is created. That force can be calculated from Equation (2) below.

Force On An Object From Magnetics

$$F = I \times L \times B \quad \ldots\ldots (2)$$

Where:-

F = Force on Conducting Object (Newtons)

I = Current Through the Rails and Conducting Object (Amps)

L = Length of the Rail Separation (Meters)

B = Magnetic Field Strength (Teslas)

The direction of the force depends on the direction of the current through the projectile and the magnetic field since the force is truly a vector with direction dictated by the cross product of the vector quantities I and B. Figure 24 shows that the direction of the force is orientated down the rails, away from the power source.

As seen from the above figure 24, the magnetic field from both of the rails is created from the current. This magnetic field then creates a field that is directed up and through the rails. Using the right-hand rule it can be seen that the direction of the object is directed out of the rail gun.

At this time there is not a lot of implementation for these types of magnetic guns. There is still a lot of research that needs to be put into these types of systems. Although a lot of the applications for the rail guns have been tested and prototypes have been built, there is still a lot before these types of systems are put into common use. The technology is still new to the market, so this means there will be a lot of work and money to produce these at such in a mass production setting. The major applications that are being developed from this technology use different variations of the same ideas. For example a lot of electromagnetic propulsion systems are being put onto aircraft carriers, and other systems to launch large objects in such a small frame of time. There is also the advantage of achieving such a large burst of acceleration with so little chemical resources[33].

✓ **Magnetic Rail Systems**

America pioneered the technology of levitating superconducting transportation in the 60s and the 70s, but only on the prototype scale model stage. This was abandoned due to the lack of federal funding and had been picked up by the Japanese. As seen above, the U.S. transportation system has severe problems. Both ground and air transport experience congestion and delays. Emissions cause unacceptable pollution at many locations. Autos and planes use a lot of petroleum which is quickly becoming a scarce product.

In a study done by the Maglev Technical Advisory Committee (MTAC), the impacts of a magnetic rail system were considered and also the feasibility of such a system in the U.S. In introduction, the committee described these types of vehicles as "exploiting the levitation properties of superconductors for high speed vehicles." The committee also made the claim that the "maglev is to diesel locomotives what StarTrek is to Wagon Train"[35]. From this study done by the committee, there were a number of things that were established in developing a system. A lot of the information is based on theoretical calculations and estimation because of the inability to do such a large study on this type of system that hasn't been implemented yet.

The committee suggested that a system of magnetically levitated vehicles could be implemented alongside of existing highways. From Figure 25, it can be seen that the Maglev systems would be an elevated roadway that would even reach over bridges. Also seen on the figure is that the systems would ride along side of the lanes of the highway with the same direction of traffic that is associated with that side[35].

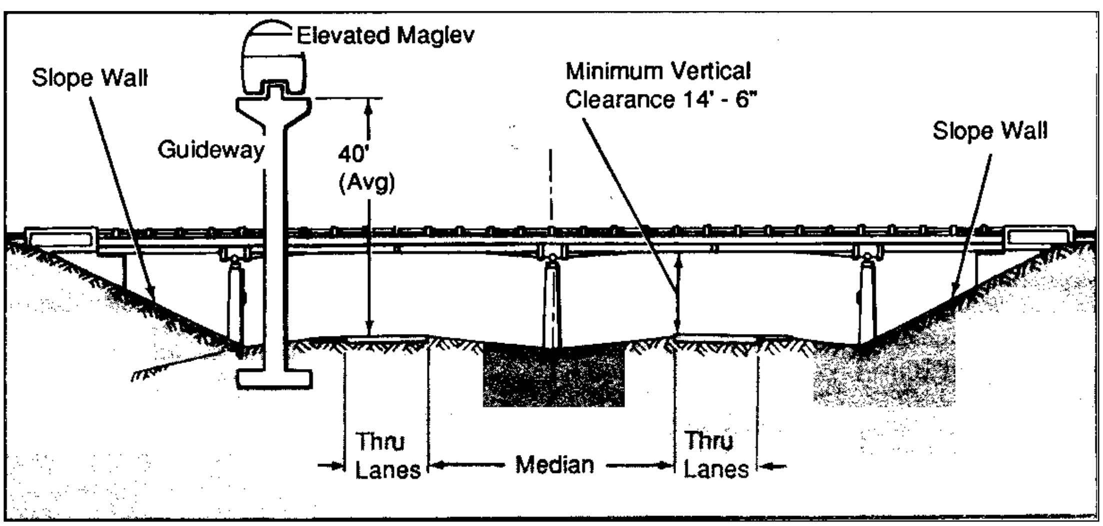


Figure : 25 - Maglev System alongside of Highways [35]

From figure 25 above in looking at the implementation of the system alongside of the highways, capabilities were calculated. It was analyzed that a two-way Maglev system on an existing interstate right of way can easily carry 100,00 passengers per day at speeds of over 200 to 300 miles per hour, not to mention the freight handling ability. The idea here is that major cities are already connected with a network of interstates. This seems to be the most sensible area to implement the idea. One of the areas that they Europeans have had success in was the interconnection the major cities. This is one reason why the rail systems in Europe have been so successful[36].

Not only will it be able to hold a large number of people, but the speed advantages that are associated with it carry a lot of the numbers. To show this type of implementation and with the speed advantages, a 50 foot (2 way) track was researched. For this study, it was shown that this track would be able hold, in volume, the equivalent of approximately ten lanes of speed highway traffic that can be developed on existing right of ways[36]. Building highways to handle such a volume would require new rights-of-ways hundreds of feet wide, which is unreasonable.

A number of benefits can be acquired from the implementation of the Maglev system. The first benefit being improved energy efficiency and security. Currently the U.S. imports over half of its petroleum which results in over 50 billion dollars in that import alone[36].

2.7.2 Propulsion

There are two types of propulsion systems used in current Maglev trains. The Linear Induction Motor (LIM) is used to propel the Japanese EDS system while the Linear Synchronous Motor (LSM) propels the German Transrapid system. Both of the systems are move by the guide ways themselves instead of the actual train car[8] .

Propulsion occurring in the Linear Induction Motor is caused from the sum of four individual linear motors. The motors induce voltages to the four motors. When these voltages are combined they produce a repulsive force that pushes the train car forward. The speeds for Linear Induction Motors is determined by "the ratio of length of the vehicle magnet system to the length of the energized block, the sum of the coupling coefficients between vehicle magnets and the guide way coils, applied voltage, and the current flowing in the superconducting coils [8]."

The speed of Maglev trains in Linear Synchronous motors are determined by the frequency of the alternating current and the magnetic field directions. Propulsion is created when the current is in 'synch' with the frequency allowing for forward propulsion. In order for the train car to brake and slow down, the field simply has to be reversed allowing the train car to brake without the use of friction.

An EDS system can provide both levitation and propulsion using an onboard linear motor. EMS systems can only levitate the train using the magnets onboard, not propel it forward. As such, vehicles need some other technology for propulsion.

A linear motor (propulsion coils) mounted in the track is one solution. Over long distances where the cost of propulsion coils could be prohibitive, a propeller or jet engine could be used.

2.7.2.1 Principle of Propulsion

A linear electric motor (LEM) is a mechanism which converts electrical energy directly into linear motion without employing any intervening rotary components. Linear Induction Motor (LIM) is basically a rotating squirrel cage induction motor opened out flat Instead of producing rotary torque from a cylindrical machine it produces linear force from a flat one. LIM thrusts vary from just a few to thousands of Newtons , depending mainly on the size and rating Speeds vary from zero to many meters per second and are determined by design and supply frequency.

A conventional rotary synchronous motor , is made up of two rings of alternating north and south magnetic poles. The outer ring (the stator) is stationary, while the inner one (the rotor) is free to rotate about a shaft. The polarity of the magnets on one (either) of these rings is fixed; this element is known as the field. The magnets of the other ring, the armature, change their polarity in response to an applied alternating current [8].

I. Linear Synchronous Motor

Linear propulsion for the project will be achieved by using a linear synchronous motor (LSM). In essence this design uses a typical electric motor, unwraps the stator onto the track, and propels the magnets over the track using magnetic fields. By running alternating current through the wires on the track the maglev train will have a force acting on it forward and parallel to the track using the same principals of an electric motor.

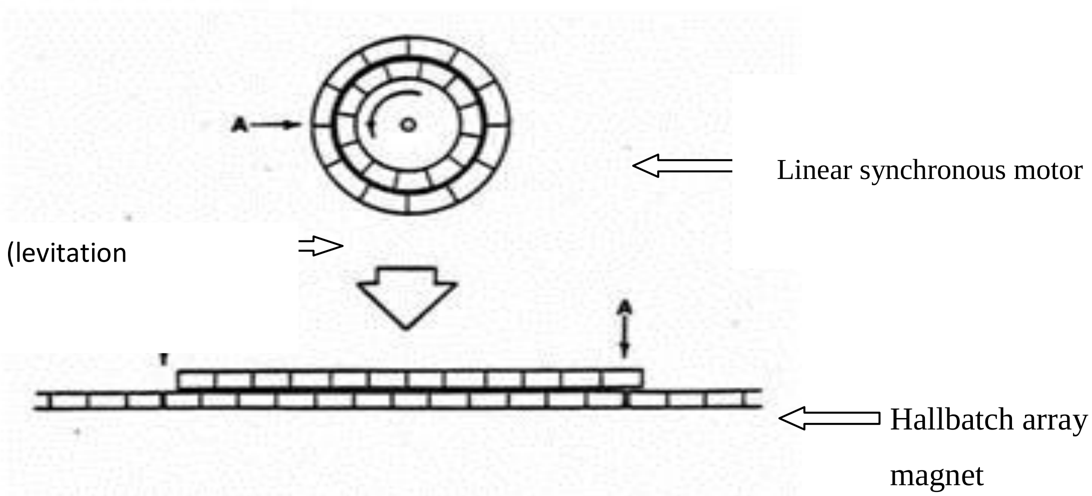


Figure: 26 - synchronous motor operation [23].

From the above figure 26 attractive forces between unlike magnetic poles pull each element of the rotor toward the corresponding element of the stator. Just as the two poles are coming into alignment, the polarity of the armature magnets is reversed, resulting in a repulsive force that keeps the motor turning in the same direction [11].

Linear Motion

A linear synchronous motor will be used in the design. Approximately 30 m of three phase winding will be placed in the center of the track as the motor primary. A specific Halbach array will be constructed as the motor secondary. An AC Drive will control the interactions between the primary and secondary. For braking, inherent magnetic drag force between the track and the train will decrease speed when the frequency of the AC drive is reduced. Exact electrical propulsion specifications are shown in Table 5.

Table 5. Specifications for Linear Motion [25]

Criteria	Design Specification
Class of Motor	Linear Synchronous
Primary	22 Gauge Three Phase Winding Embedded in Track
Secondary	1.25”” x 0.25” x 0.25” Halbach Array
Drive	1/30hp – 1/8 hp AC Drive

2.7.3 Stability

Static stability means that any small displacement away from a stable equilibrium causes a net force to push it back to the equilibrium point.

Earnshaw's theorem shows that any combination of static magnets cannot be in a stable equilibrium. However, the various levitation systems achieve stable levitation by violating the assumptions of Earnshaw's theorem. Earnshaw's theorem assumes that the magnets are static and unchanging in field strength and that the relative permeability is constant and greater than unity everywhere. EMS systems rely on active electronic stabilization. Such systems constantly measure the bearing distance and adjust the electromagnet current accordingly. All EDS systems are moving systems (no EDS system can levitate the train unless it is in motion[8].

Because Maglev vehicles essentially fly, stabilization of pitch, roll and yaw is required by magnetic technology. In addition to rotation, surge (forward and backward motions), sway (sideways motion) or heave (up and down motions) can be problematic with some technologies.

If superconducting magnets are used on a train above a track made out of a permanent magnet, then the train would be locked in to its lateral position on the track. It can move linearly along the track, but not off the track. This is due to the Meissner Effect [8].

Table 6. Specifications for Magnetic Stabilization [25]

Criteria	Design Specification
Vertical Stability	Operating Elevation Height +/- 5 mm
Horizontal Stability	Lateral Variation +/- 3 mm

✓ **Guidance Systems**

Some systems use Null Current systems (also sometimes called Null Flux systems); these use a coil which is wound so that it enters two opposing, alternating fields, so that the average flux in the loop is zero. When the vehicle is in the straight ahead position, no current flows, but if it moves off-line this creates a changing flux that generates a field that pushes it back into line. However, some systems use coils that try to remain as much as possible in the null flux point between repulsive magnets, as this reduces eddy current losses [8].

✓ Lateral Guidance System

The Lateral guidance systems control the train's ability to actually stay on the track. It stabilized the movement of the train from moving left and right of the train track by using the system of electromagnets found in the undercarriage of the MagLev train. The placement of the electromagnets in conjunction with a computer control system ensures that the train does not deviate more than 10mm from the actual train tracks [8].

The lateral guidance system used in the Japanese electrodynamic suspension system is able to use one "set of four superconducting magnets"[8] to control lateral guidance from the magnetic propulsion of the null flux coils located on the guide ways of the track as shown in Figure (18 page 32) . Coils are used frequently in the design of MagLev trains because the magnetic fields created are perpendicular to the electric current, thus making the magnetic fields stronger. The Japanese Lateral Guidance system also uses a semi-active suspension system. This system dampens the effect of the side to side vibrations of the train car and allows for more comfortable train rides [9]. This stable lateral motion caused from the magnetic propulsion is a joint operation from the acceleration sensor, control derive, to the actual air spring that dampens the lateral motion of the train car.

The main task to complete for the system is to levitate the vehicle; otherwise the technology is not breakthrough at all. But on the other hand there are a couple more important things to remember. With magnetic forces there is an unstable force that needs to be contained to act efficiently [9]. So with this known, care must be take to make sure that the vehicle does not slide from side to side. This is done by the principle of Lateral guidance. Refer figure: 18 on page 32.

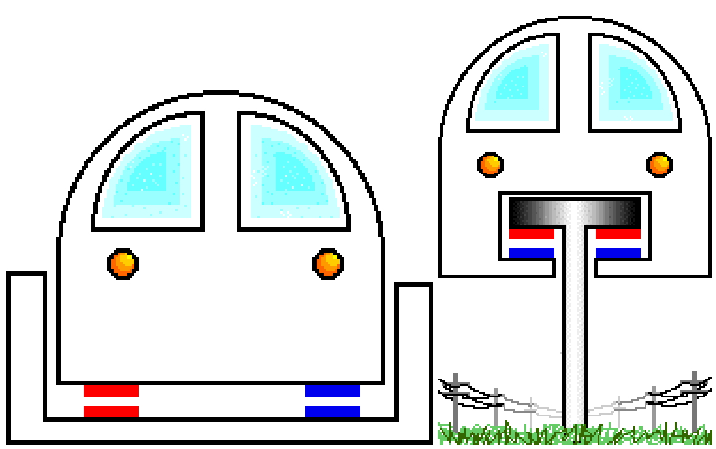


Figure: 27 – Guide way design of the EDS (left) and the Transrapid (right)

✓ Suspension Systems

German engineers had developed Electromagnetic Suspension (EMS) while Japanese engineers had developed Electrodynamic Suspension (EDS), the newest EDS technology is the Inductrack.

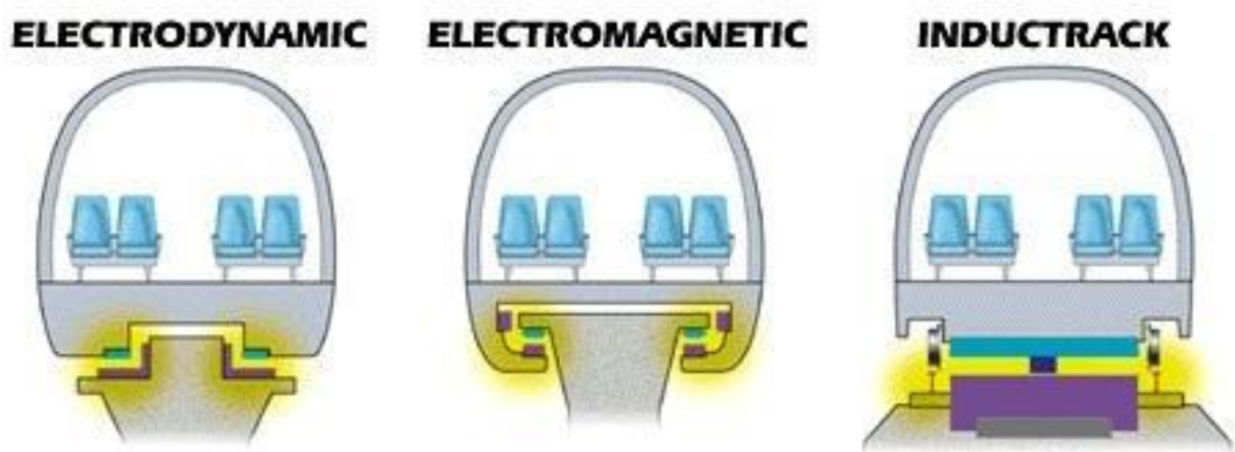


Figure: 28 - The types of Levitation for Maglev Train

From figure 28 above there are three basic different concepts of magnetic suspension have evolved.

1. The attractive Electromagnetic Suspension (EMS) uses electromagnets on the train body which are attracted to the iron rails. The vehicle magnets wrap around the iron guide ways.
2. The Electrodynamic Suspension (EDS) levitates the train by repulsive forces from the induced currents in the conductive guide ways. Electrmagnets on the guide way levitates the train.
3. The Inductrack concept that is permanent magnets levitates over passive coils. In magnetic levitation, basic principles is used to suspend vehicles weighing 40 tons or more by generating a controlled magnetic force.

Table 7. Specifications for Magnetic Levitation [25]

Criteria	**Design Specification**
Ride Height	0 mm : Train Speed < Transition Speed
Ride Height	5 mm - 15 mm : Train Speed > Transition Speed

Power and energy usage

Energy for maglev trains is used to accelerate the train, and may be regained when the train slows down ("regenerative braking"). It is also used to make the train levitate and to stabilize the movement of the train. The main part of the energy is needed to force the train through the air ("air drag"). Also some energy is used for air conditioning, heating, lighting and other miscellaneous systems. The maglev trains are powered on electromagnetism.

At very low speeds the percentage of power (energy per time) used for levitation can be significant. Also for very short distances the energy used for acceleration might be considerable. But the power used to overcome air drag increases with the cube of the velocity, and hence dominates at high speed (note: the energy needed per mile increases by the square of the velocity and the time decreases linearly.

2.8 Economic benefit

- **Track Rail System**

Since the first track system in America was laid down in 1826, trains have been a vital part of life for all. Whether or not it is realized, all people depend on the track and rail system in one way or another. That may be just from traveling, products that are being transported, or fossil fuels being transported. Since the development of efficient cars and planes, though, there has been a decrease in the use of rail systems here in America. The Europeans have long since adapted a unique need for the track and rail system. Because of the close proximity of all cities within the European community, it has been possible to create an efficient interconnected system of track for use. America’s need for the track and rail system has been decreased because of urban sprawl. The distance between major cities in the U.S. is so great in some instances that it would be outrageous to take a train. The distance between the east coast and the west coast is so great, that there is almost no way to take a train that distance without it taking over three days. This is when people decide that the better option would be to take the plain. This is one of the biggest complaints about the current track and rail system. The time that it takes to get anywhere in a train is not worth it. The airport has long been the preferred path because of the short time that it takes to get somewhere[12].

Another complaint with the current track and rail system was noise and chemical pollution that are produced. It is commonly known that the property near the tracks is going to be cheaper then the property away from the tracks. The reason for this is that there is immense noise from the tracks when a train is going by. The current system is just too noisy to place near any city because of the noise. Cities in the U.S. do not like a loud track system running through any residential areas in the city. That is why there are limited track and rail systems in the U.S. and if there are, they are found mostly in the downtown area. The chemical pollution is also a large complaint over the current system. The amount of fossil fuels needed to propel engines on a track system is great. Just like a car, there are also emissions from the running of the car that need to be worried about.

From these complaints there would naturally be a need to create a system that both cuts down the time spent on a train and also cuts down on the emissions that are created. This system is the magnetic levitation system [12].

Airports

The first application of magnetically levitated transportation was found in airports. The reason that it was first started here was because the technology was able to be implemented on a much smaller scale. It would get a lot of used because of the number people that go through the airport, so it seemed like an ideal testing ground. It was also chosen because of the overcrowding that has been seen in the last decade at airports. As noted in the Federal Aviation Administration's (FAA's) 2001 Airport Capacity Enhancement Plan: "In recent years growth in air passenger traffic has outpaced growth in aviation system capacity. As a result, the effects of adverse weather or other disruptions to flight schedules are more substantial than in years past." This is saying that the general population is using air traffic more and more, while airports are staying the same size. This overcrowding is becoming a large problem especially when any delay is becoming more significant because the number of people that it is affecting is growing. From 1995 to 2000, operations increased by 11 percent, enplanements by 18 percent, and delays by 90 percent[12]. With the heightened security that followed the September 11, 2001, terrorist attacks, ground delays have expanded the problem. The obvious ways to reduce delays is to expand airport capacity. Although this sounds easy enough, expansion has encountered determined public opposition and daunting costs. From there, the obvious solution is to begin implementing the magnetically levitating systems to alleviate some of the burden that is put on the airports [12].

2.9 Environmental benefit

❖ Safe for Environment

Maglevs are safer than conventional rail travel, highway vehicles and airplanes. Since the tracks are elevated, there is no risk of any type of collision with automobiles and trucks as compared to conventional trains. There is no possibility of collisions between vehicles on the guide way because the distance between Maglev vehicles on a guide way and the speed of the vehicles are all automatically controlled and maintained by the frequency of the electric power fed to the guide way [12]. There is also no chance for derailment due to the superconducting magnets in the rails.

Also, there won't be much of an effect on the animal life in area. The elevated guide ways allow for small animals and microorganisms to pass underneath [5]. This eliminates animal collisions that occur frequently with normal roadways and conventional rail travel.

Since only electric power is being used, Maglev is also safer for the environment than conventional rail travel. There are no fuels being used so air pollution is reduced because there are no emissions of exhaust gasses [12].

Maglevs operate at low noise levels because there is no mechanical contact with the rails. Aerodynamic noise is reduced by making the Maglevs more streamlined. Maglevs traveling at 250 km/h results in vibrations that are below the human threshold of perception (KB value of .1) [7].

The German Transrapid releases a very low magnetic field. The magnetic field inside a passenger compartment is much less than that of a hair dryer, toater, or even an electric sewing machine. It will therefore have no negative influence on cardiac pacemakers, or magnetic cards such as credit cards. The Japanese version emits only about 4 gauss. Hospitals recommend a maximum of 5 gauss as the maximum permissible exposure for a pacemaker wearer [7].

Maglev will have a positive impact on sustainability. Using superconducting magnets instead of fossil fuels, it will not emit greenhouse gases into the atmosphere [12]. Energy created by magnetic fields can be easily replenished. The track of a Maglev train is small compared to those of a conventional train and are elevated above the ground so the track itself will not have a large effect on the topography of a region [5]. Since a Maglev train levitates above the track, it will experience no mechanical wear and thus will require very little maintenance.

Overall, the sustainability of Maglev is very positive. Although the relative costs of constructing Maglev trains are still expensive, there are many other positive factors that overshadow this. Maglev will contribute more to our society and our planet than it takes away. Considering everything Maglev has to offer, the transportation of our future and our children's future is on very capable tracks.

CHAPTER THREE

3. MATERIAL AND METHOD

This chapter is about the methodology which has been followed and the materials that have been used to meet the objectives of the project work. The study was carried out in Automotive, Manufacturing and Wood Work shop of Adama Science and Technology University (ASTU).

3.1 Description of the project work

There are two main things used for modeling of Maglev Train; These are model of the train and model of the track. The train is controlled by simple switch to propel the train on the truck. Small fan is attached to the DC motor and installed at the back of the train to create the trust force for trust force. Then, the maglev track is made by using thick wood (stock) and a number of high field strength of permanent round bar magnets. A straight track of length 77cm is prepared. Suspension magnet is attached under the model of the train.

The arrangement and position of the magnet at track and train must be with same polarity. This is because of similar polarity of magnets will repels each other and cause the model train to float (levitates) over the model track.

3.2 Practical construction

3.2.1 Materials

Below listed materials are needed materials specifically to construct the model

Table: 8 – list of materials

NO	Materials	Specification	quantity
1	Wood stock for track	77x10x3.5(cm)	1pcs
2	Wood stock for train	15x9.8x3.5(cm)	1pcs
3	Permanent bar magnet for track	22cm long and 1.7 diameter	7pcs
4	Permanent bar magnet for train	15cm long and 1.7 cm diameter	2pcs
5	Guide glass	77cmx12.5cmx4mm	2pcs
6	Cement fluid (glue)	General purpose	1liter
7	Simple motor	Driven by 9v DC	1pcs
8	Small fan	6cm diameter	1Pcs

Tools and equipment

- ✓ Circular saw
- ✓ Thickness planer
- ✓ Nail hummer
- ✓ Back saw
- ✓ Cutter
- ✓ Chisel
- ✓ Screw driver
- ✓ Meter
- ✓ Venire caliper
- ✓ Extension electrical cable

1. **wood stock :**

The purpose of this wood stock is to construct the track on which the track rail magnet is fixed arranged and mounted.

Figure: 29-wood stock for track

2. **wood stock:**

The purpose of this wood stock is to construct the train on which the train rail magnet is fixed mounted.

Figure: 30- wood stock for train

3. **permanent bar magnets:**

Those magnets are important to get the magnetic field which is helpful to levitate the train on the truck. To get the repulsive force the up side pole on the truck and the down side pole on the train must be the same.

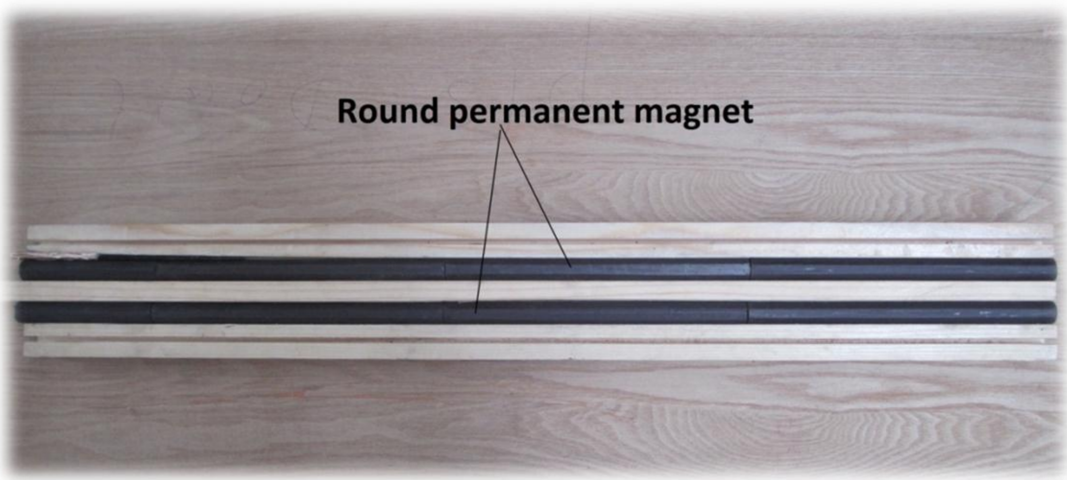


Figure: 31- round type bar magnets for levitation

4. Guide glass:

The glass is used as a guide way for the train during levitating and propelling on the test track.

Figure: 32-glass for guidance

5. Cement fluid(glue)

The purpose of cement fluid (glue) is to fix the permanent bar magnet and the guide glass with the wood stock.

Figure:33- Cement fluid(glue)

1. Simple motor and Small fan:

The motor is mounted on the train and its use is to drive the small fan mounted on it.

The motor can get operating power from 9v dry cell battery .

Figure:34-Simple motor to drive the fan

Figure:35- small fan for propulsion

As the motor gets power, it starts to rotate the fan. The fan is mounted on the motor and the motor is mounted on the train.

Since the train is levitating, the fan starts to rotate on it, the train should expected to move over the truck inside the guide way.

3.2.2 Methodology

The proposed maglev train comprises a combination of hardware components that serve different purposes, software is not as essential because the project is focused on application of EDS or permanent magnetic field principle . This is the main tool regard to enhance the model to levitate, stabilize and propel.

The methodology for the project is literature review study existing experience, practical construction of the model and test of the model for its performance that is levitation, stability and propulsion.

Aactivities' performed to achieve the expected result are listed below

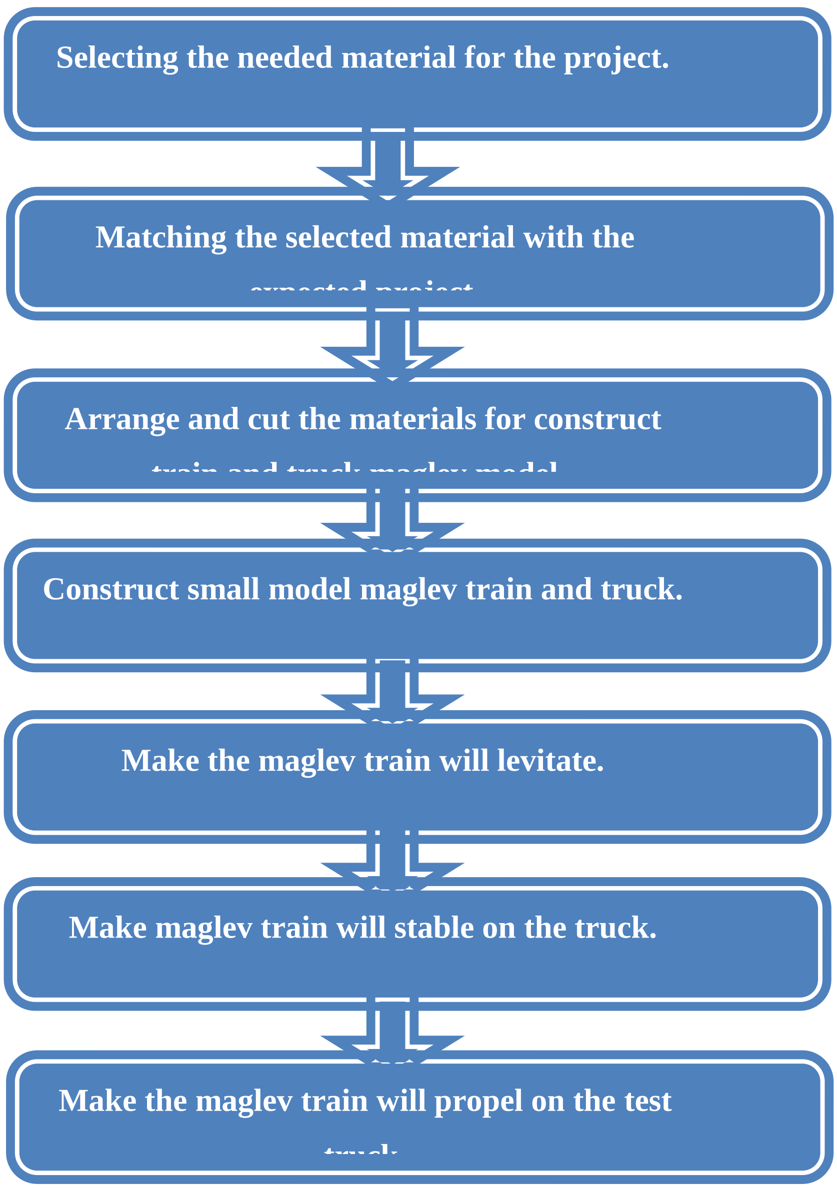


Figure:36 - flow of Activities performed

3.2.2.1 Constructing the model track

To construct the model truck we use the following material and tools which is listed on the following table below:-

Table:9- material for constructing the model of truck

No	Material	Specification	Quantity
1	Wood stock	77 x10x3.5 (cm)	1pcs
2	Bar magnet	22cm long of 1.7cm diameter	7pcs
3	Guide Glass	77cmx12.5cmx4mm	2pcs
4	Cement fluid	General purpose	1 litter

To construct the track we plane and cut the wood stock to its dimension and make a grove on it to hold the bar magnets that are arranged in two row act as a truck rail. On the truck the north pole of the rail magnet is set in upward direction. Since the train is levitating inside the guide, on the wood truck there is also another two groves to hold the guide glass as we illustrated in the figure 37 below:-

Figure: 37- Constructing the model truck

3.2.2.2 Constructing the model train

To construct the model train we use the following material listed below on the table

Table:10- material for constructing the model of train

No	Material	Specification	Quantiy
1	Wood stock	15 x9.8x3.5 (cm)	1pcs
2	Bar magnet	15cm long of 1.7cm diameter	2pcs
3	Cement fluid	General purpose	1 litter
4	Simple motor	Ac 5v and 500mA or 9v Dc	1pcs
5	Small fan	6cm diameter	1pcs

To construct the train we plane and cut the wood stock to its dimension and make a grove on it to hold the bar magnets that are arranged in two row act as a train rail. The same as the truck wood stock this has also a grove to hold the bar magnets that are arranged in two row act as a train rail. On the train the north pole of the rail magnet is set in downward direction. At the back side of the train, the motor and its fan should be mounted on it as a unit. as we illustrated in the figure 38 below:-

Figure: 38- Constructing the model train

CHAPTER FOUR

4. RESULT AND DISCUSSIONS

We have search documents of the existing Maglev train from the internet to know and understand the working principles of the existing maglev train and the materials used to construct a simple model. After this we have collect the available materials which are help full to construct the model. By having those materials like wood stock, permanent round bar magnet, guide glass, simple motor, small fan and cement fluid we have gone to the work shop and start cutting the materials according to the dimension that we gave. Then by using connecting materials like cement fluid and nail the simple maglev train model has constructed.

We use only two bar magnets in two rows:-

- ✓ To make the model size small and compact ,
- ✓ To minimize the weight of the train.

Since the magnets are round bar magnets having 4 poles each 2 north and 2 south, during the installation of those magnet when the side to side are nearby they will attract each other this leads to loose of stability.

The size of our project is given based on the availability of materials and to make simple for handling when transferring from place to place.

4.1 Application test on test track

After the model maglev train has been constructed, we start testing the project for levitation, propulsion and stability. What we have observed from the test was,

4.1.1 Levitation test

- ➢ The train has levitated over the track by the magnetic field since like poles of the magnet are repelling each other. And The train was levitated at a maximum height of 16mm,

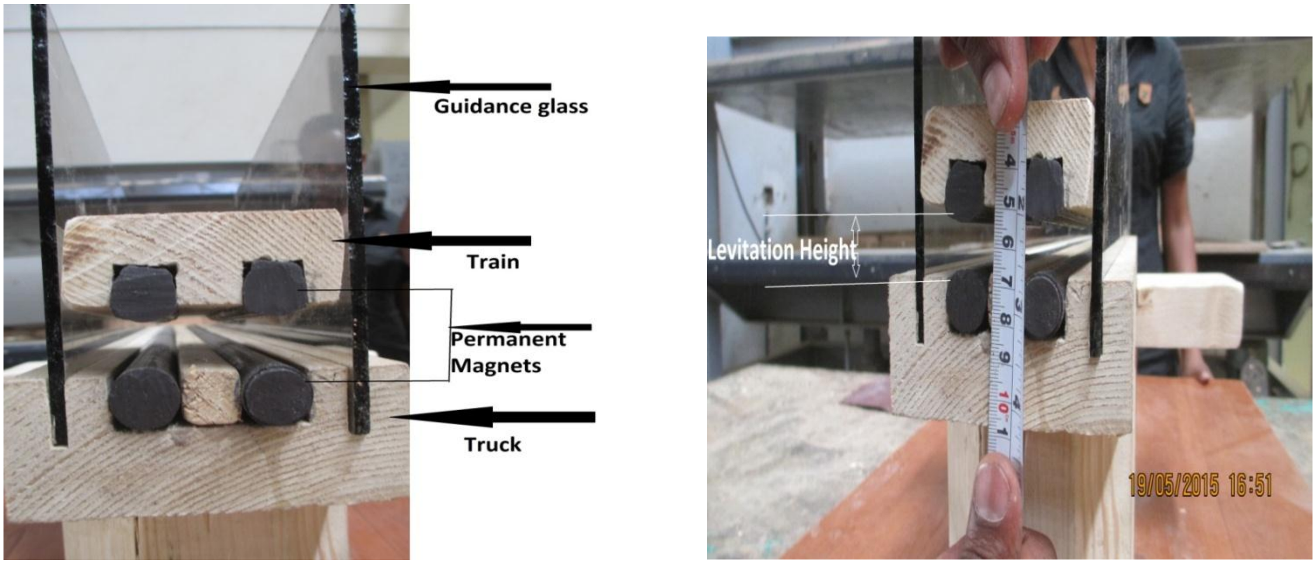


Figure: 39 - Levitation test on the track

4.1.2 Propulsion test

- The train was propelled by the help of gravity, simple motor and fan on the test track.

Figure:40-Propulsion test on the track

4.1.3 Stability test

- And the train was stabled over the track by the help of the guide glass mounted on the two said of the track.

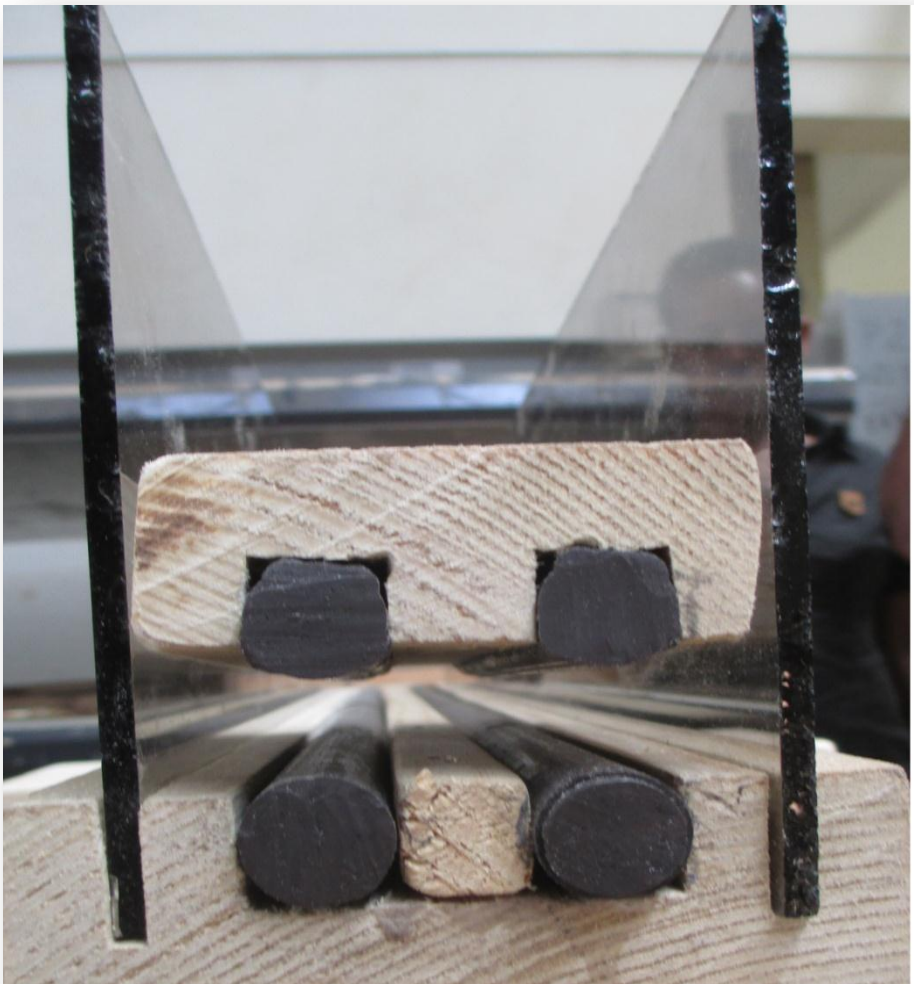


Figure: 41- Stability test on the truck

Finally the achievement what we have got from the project was,

- ✓ We have got knowledge about the existing maglev train working principle,
- ✓ We know how the model can be constructed,
- ✓ We transfer or adopt and provide the knowledge for others about the maglev train,
- ✓ We give some hints about maglev train for future generation researchers in our country.

CHAPTER FIVE

5. SUMMERY, CONCLUSION AND RECOMMENDATION

5.1 Project Summery

The objective of the project is to construct a simple prototype maglev train based on review of the existing experience for a small train model. We have search documents of the existing Maglev train from the internet to know and understand the working principles of the existing maglev train and the materials used to construct a simple model. After this we have collect the available materials which are help full to construct the model. By having those collected hard ware materials we have constructed the small maglev train model and test to know the expected result that are levitating, propelling and stability on the test track.

5.2 Conclusion

On the base of the study practical construction of the model and test result the following conclusion are drawn:-

- ✓ By the knowledge we have got, we successfully constructed the maglev train model according to the size specified before.
- ✓ The train of the project was propelling on the test track by the help of gravitational force as well as the fan which is drive by the motor on the test track and the speed of the train is small and constant because the speed of the motor is not varied. The stability of the train on the track was assured by the guide glass and the levitation of the train is 16cm above the track.
- ✓ As a result of successfully constructed and tested the project of maglev train model, we transfer knowledge as well as technology based on the review study to us and to the next generation.

Even though, there is some limitations like un availability of flat permanent bar magnet and magnetic field tester we construct the maglev train model by round bar permanent magnet.

5.3 Recommendation

We recommended that the

- University and minister of education to prepare educational curriculum on the study of magnetic levitation train.
- The university must have the real model of maglev train and materials and testers for practical work.
- Transportation sector motivates the government and investors to implement the technology as much as possible because it is one of non pollutant technology. As we try to show the exact application in our model, it can be implemented if the government of the country and investors give infancies in the future.
- Researchers to upgrade the study of existing maglev train technology for the future.

5.4 Educational implementation

Since maglev train technology is not available in our country, students will be able to know and grownup with the existing maglev train study from the scratch. Meanwhile, the study of maglev train should be implementing to the education sector like preparatory, college and university by making simple maglev train model. To teach students in different colleges and universities it is important to construct simple maglev model like our project.

CHAPTER SIX

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