

Design and Analysis of an Electromagnetically Propelled Elevator System

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Abstract — *An elevator is a vertical transportation system designed to efficiently move people and goods between the floors of a building. Conventional elevators operate using electric motors, traction cables with counterweight systems, or hydraulic mechanisms that pump fluid to raise a piston. They are also widely used for transporting materials in factories, warehouses, and mines. However, traditional elevator systems present several disadvantages: they occupy large floor areas, require frequent repairs and regular maintenance, and face operational challenges in high-rise structures. This study aims to address these limitations by replacing conventional mechanical systems with an electromagnetic propulsion mechanism. The proposed design utilizes electromagnets aligned along the elevator shaft walls and permanent magnets attached to the cabin. By controlling the polarity of the electromagnets, a synchronized push-pull force is generated to enable smooth vertical movement of the cabin. The report includes the design methodology, analysis of key influencing factors, force calculations, and the detailed design of critical components.*

Keywords— *Electromagnetic Force, Elevator, Maglev Train*

I. INTRODUCTION

An elevator or lift is a type of cable-assisted, roller track assisted, or hydraulic cylinder-assisted machine that vertically transports people or freight between floors, levels, or decks of a building, vessel, or other structure. They are typically powered by electric motors that drive traction cables and counterweight systems such as a hoist, although some pump hydraulic fluid to raise a cylindrical piston like a jack. In agriculture and manufacturing, an elevator is any type of conveyor device used to lift materials in a

continuous stream into bins or silos. Several types exist, such as the chain and bucket elevator, grain auger screw conveyor using the principle of Archimedes' screw, or the chain and paddles or forks of hay elevator. Languages other than English, such as Japanese, may refer to elevators by loanwords based on either elevator or lift. Due to wheelchair access laws, elevators are often a legal requirement in new multistory buildings, especially where wheelchair ramps are not possible. Some elevators travel laterally in addition to the usual vertical motion.

An elevator is essentially a platform that is either pulled or pushed up by a mechanical means. A modern-day elevator consists of a cab (also called a "cabin", "cage", "carriage" or "car") mounted on a platform within an enclosed space called a shaft or sometimes a "hoist way". In the past, elevator drive mechanisms were powered by steam and water hydraulic pistons or by hand. In a "traction" elevator, cars are pulled up by means of rolling steel ropes over a deeply grooved pulley, commonly called a sheave in the industry. The weight of the car is balanced by a counterweight. Sometimes two elevators are built so that their cars always move synchronously in opposite directions and are each other's counterweight. The friction between the ropes and the pulley furnishes the traction which gives this type of elevator its name. Hydraulic elevators use the principles of hydraulics (in the sense of hydraulic power) to pressurize an above ground or in-ground piston to raise and lower the car (see Hydraulic elevators below). Roped hydraulics use a combination of both ropes and hydraulic power to raise and lower cars. Recent innovations include permanent magnet motors, machine room-less rail mounted gearless machines, and microprocessor controls. The technology used in new installations depends on a variety of factors. Hydraulic elevators are cheaper but

installing cylinders greater than a certain length becomes impractical for very-high lift hoist ways. For buildings of much over seven floors, traction elevators must be employed instead. Hydraulic elevators are usually slower than traction elevators.

II. LITERATURE REVIEW

Onat and Gürbüz (2013) conducted foundational research on ropeless elevator systems, demonstrating the feasibility of using linear motors for multi-car vertical transportation and proposing an active position-sensing method for improved stability.

Markon et al. (2010) explored the application of electromagnetic propulsion in elevator shafts and highlighted the advantages of contact-free movement in reducing mechanical wear and maintenance requirements.

Lim (2005) presented a detailed study on electromagnetic actuation for vertical transportation, emphasizing the need for precise control algorithms to manage the dynamic behavior of magnetically driven elevator cabins.

Lobo (2019) evaluated the performance of linear induction motors (LIMs) in elevator systems and reported significant improvements in torque control and thrust generation compared to traditional traction drives.

Krishnan (2014) investigated permanent-magnet linear synchronous machines (PMLSMs) for high-rise elevators and identified their potential for high thrust density, smooth acceleration, and regenerative braking.

Wang, Xu, and Du (2013) analyzed the interaction forces between shaft-mounted electromagnets and permanent magnets attached to the elevator cabin, proposing optimized magnetic pole arrangements to enhance lift capacity.

Feng and Wang (2012) studied active magnetic suspension systems for elevator guidance and demonstrated that electromagnetic levitation can significantly reduce vibration, resulting in improved ride quality.

Albert So (2018) reviewed the development of linear-motor-based elevator technologies and emphasized that permanent-magnet synchronous systems offer superior efficiency and reduced operational noise.

Tan, Li, and Gu (2017) developed simulation models for electromagnetic elevator propulsion and showed that controlled polarity switching can generate stable push-pull forces suitable for vertical lifting applications.

Mingyi Wang (2017) contributed to the optimization of electromagnetic coil placement along elevator shafts, highlighting the importance of magnetic field uniformity for safe and efficient cabin motion.

III. WORKING PRINCIPLE

When the north pole of a magnet is brought closer to the south pole of another magnet, there is an attractive force that brings the magnets together. If the magnet is turned so that two north poles or two poles are brought closer, they will repel each other.

Coulomb's Law of Magnetic Force Known as Coulomb's Inverse Square Law of magnetic force or Coulomb's Law of magnetic force. He represented the quantitative expression of force for two isolated point poles.

Mathematically,

$$F \propto m_1 m_2 \text{ and } F \propto 1/r^2$$

$$F = K(m_1 m_2) / \mu r^2$$

Inspired the principle and technology of the maglev trains, the elevator mechanisms can be made based on principles of propulsion of maglev trains.

The mechanism is vertical consisting of a shaft, support rails, guide rails on to which magnets of alternate polarity are arranged linearly, the cabin (load), electromagnet mounted on cabin, the position sensors, the power unit and a control unit which will process and execute the mechanism.

The idea is to generate opposite poles, one at the electromagnet-net which is same as adjacent ma

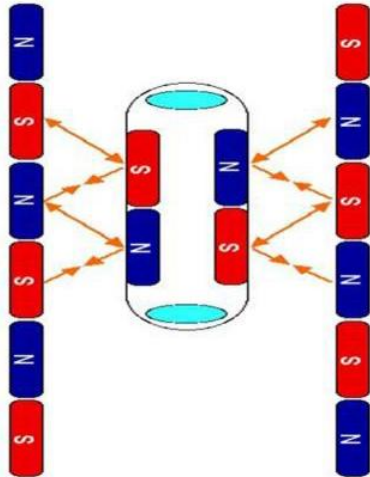


Fig. III.I: Working of maglev train

For electromagnet magnitude of that force by plugging the dimensions and other properties of the magnet based into a simple equation:

$$F = (n \times i)^2 \times \text{magnetic constant} \times a / (2 \times g^2)$$

Passing an electrical current through the solenoid results in a magnetic field that exerts force on nearby ferromagnetic objects, such as pieces of iron or steel.

$$F = (n \times i)^2 \times \text{magnetic constant} \times a / (2 \times g^2)$$

Where, F = force, i = current, g = length of the gap between the solenoid and a piece of metal, a = Area, n = number of turns in the solenoid, and the magnetic constant = $4 \times \pi \times 10^{-7}$

For wire we will be using a Standard Wire Gauge (SWG) table to find the gauge of suitable wire.

AWG	Dia mm	SWG	Dia mm	Max Amps	Ohms / 100 m
11	2.30	13	2.34	12	0.53
12	2.05	14	2.03	9.3	0.67
13	1.83	15	1.83	7.4	0.85
14	1.63	16	1.63	5.9	1.07
15	1.45	17	1.42	4.7	1.35
16	1.29	18	1.219	3.7	1.70
18	1.024	19	1.016	2.3	2.7
19	0.912	20	0.914	1.8	3.4
20	0.812	21	0.813	1.5	4.3
21	0.723	22	0.711	1.2	5.4
22	0.644	23	0.610	0.92	6.9
23	0.573	24	0.559	0.729	8.6
24	0.511	25	0.508	0.577	10.9
25	0.455	26	0.457	0.457	13.7
26	0.405	27	0.417	0.361	17.4
27	0.361	28	0.376	0.288	21.8
28	0.321	30	0.315	0.226	27.6
29	0.286	32	0.274	0.182	34.4
30	0.255	33	0.254	0.142	43.9
31	0.226	34	0.234	0.113	55.4
32	0.203	36	0.193	0.091	68.5
33	0.180	37	0.173	0.072	87.0
34	0.160	38	0.152	0.056	110.5
35	0.142	39	0.132	0.044	139.8

IV. CALCULATIONS AND RESULTS

Selection Of Wire For Electromagnet

Material of wire –copper

Max. amp. Limit of wire –1.5 A

Selection of wire from std wire gauge(SWG) chart

Grade of wire –2 i.e. with medium coating

req. wire of gauge –21

Wire dia. –0.8120mm

ohms/100m –4.3

Selection of Core Of Electromagnet

Type of core –Iron core

Selected shape of core –cylindrical for circular winding

Diameter of core –20mm

Length of core –15mm

Calculation of turns on electromagnet

Weight of cabin of elevator, W = mg = 300g approx. = 3 N

So we have to design an electromagnet which can develop the force greater than 3 N

For finding force (F) at a distance (g) we have the formula

$$F = (n \times I)^2 \mu A / (2 g^2)$$

$$\mu = \text{magnetic constant} = 4 \times \pi \times 10^{-7}$$

$$\text{Area} = A = \pi r^2$$

$$= 314 \text{ mm}^2$$

so,

$$F = (n \times I)^2 \mu A / (2 g^2)$$

$$3 \leq (n \times 1)^2 \times 4 \times \pi \times 10^{-7} \times 314 / (2 (5)^2)$$

$$n \geq 617$$

Hence, we have to take the no. of turns greater than 617 consider as 620v

For electromagnet: - diameter of wire: - 0.8120mm
gauge number of wire: - SWG 21 number of turns of coil: - 620 the size of electromagnet is determined.

V. CONCLUSION

An alternative mechanism for vertical lift, based on the principles and applications of electromagnetism is developed that can replace mechanical systems of conventional elevators to eliminate their disadvantages. Based on these findings, the proposed design using shaft-mounted electromagnets and cabin-mounted permanent magnets aligns closely with modern advancements in rope less elevator technology. By generating synchronized electromagnetic forces, the system minimizes mechanical components, reduces maintenance, and improves operational reliability. However, the literature also emphasizes the need for careful attention to thermal management, electromagnetic interference (EMI), safety redundancy, and control robustness.

In conclusion, electromagnetic elevator systems represent a technologically viable and future-oriented approach to vertical transportation. While further experimental validation, optimization of magnetic configurations, and safety analysis are required, the research collectively supports the feasibility and long-term advantages of adopting electromagnetic propulsion in next-generation elevator designs.

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