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Design and Fabrication of Rope-Less Elevator

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ABSTRACT: Rope-less Elevator is similar to maglev train. It can be imagined as a Maglev train moving vertically. It is unlike conventional elevator that uses steel ropes and traction motor to lift the load, but it uses magnetic levitation and propulsion to perform lift operation. In this model, permanent magnetic strips are used to create a levitation effect and a diametrically oriented ring or disc magnet along with alternately arranged bar magnets are part of propulsion system. A rack and pinion assembly is used guideways. Here the levitation effect produced is not lifting something but is actually helping in maintaining a gap between cabin and the shaft.

KEYWORDS: Rope-less elevator, Maglev, Rope free elevator, Magnetic propulsion

I. INTRODUCTION

In metropolis and large urban settlements due to high population density limited spaces are available for construction. Therefore real estate developers are investing in skyscrapers and high-rise multi storied buildings, with intent to full fill the high demand of residential, commercial and office spaces. Such solutions will pose big engineering and logistical challenges. Construction of such structures requires application of technologically advanced materials, methods and construction techniques.

Elevator is the only [1] element of a skyscraper design and construction that [1] remained unchanged since its inception. Though the present elevator differs in terms of shape, fit and finish, aesthetics, noise level during operation, drive and have become more precise as compared to the first [2] invented design of [2] 19th century. However, the [2] fundamental principle of operation remains unchanged. In this principle, a cabin or car moves in a shaft (vertical plane) between the storeys of the building with the help [3] of load-bearing member like chains, steel rope etc.

To enhance the transportation capability of elevators in multi-storeyed buildings and skyscraper a combination of shafts are designed to meet the requirements. In case of very tall skyscraper the present system prove insufficient to meet the demand. Even the most efficient and capable [4] system can rise up to a height of 180m only. In order to ease movement and to increase reach in very tall billings, the designers and engineers follows a zoning [5]. In [5] zoning a particular elevator or a set of elevators operates [5] between a certain numbers of floors. Zoning is proved beneficial but it also increases the complexities for designers and engineers.

Considering above limitations of the present systems, it seems purposeful to design an elevator that can transport both humans and objects vertically without any limitations on height.

II. LITERATURE REVIEW

1. **SelmiSivrioglu et al. [22]** ('Design and simulation of a model maglev vehicle '):In this paper the author has presented a conceptual model of a Maglev vehicle. The authors have presented the [7] concept of magnetic levitation using HTS (High Temperature Superconductor) as superconductors can levitate passively without any external energy source. The model contains a maglev cryostat and a magnetic guideway. Maglev cryostat is a closed container which contains liquid nitrogen and is well insulated and unpressurised to maintain the superconducting behaviour of the superconductor. The superconductor is dipped in liquid nitrogen. The authors have also established a [8] mathematical model to figure out the levitation force between HTS and permanent magnet. They have also conducted the dynamic analysis on lab scale maglev vehicle. In their proposed design the authors have used three- surface levitation with cryostat.

In this paper a [3] cryostat is developed with the objective [3] to increase the stiffness or load bearing capacity of vehicles of superconducting maglev system. A new type of guideway with three permanent magnet surfaces is also developed. An H-formulation model is used to calculate the variation of levitation force.

2. **Markus Jetter et al. [23] ('A next generation vertical transportation system')**: This is a conference proceeding paper. In this the authors have presented the concept of the world's first rope free elevator called Multi. They named the concept as multi as in this system multiple cabin can be transported in horizontal shaft in both horizontal and vertical directions. Possibility of transporting multiple cabins in limited number of shaft will increase the transportation capacity of elevators and will reduce the average waiting time. It will also reduce the complexities of the architects. Linear induction motor is used to propel the vehicle in multi system. This [3] paper also presented a comparison between multi and the presently available elevator technology.
3. **Roman Trochimczuk et al. [24] ('Rope-free multi-cabin elevator system for vertical and horizontal transportation and simultaneous integration of movement in two directions')**: In this article the author has presented a detailed description about the rope free multi cabin elevator system for horizontal transportation and vertical transportation of load across a building and evaluated the possibility of integration of simultaneous bidirectional movement of cabin. The author has explained in detail the design and [5] components of the cable [5] free elevator system. To maintain the accuracy hall sensors are used.

III. SYSTEM DESIGN

The suggested system is composed of mainly two sub-assemblies, when these are put together, they constitute a [2] system. For this system to deliver the desired [2] result it is essential that these system sub-systems or sub-assemblies should work in cohesion. These sub-assemblies are as follows:

- **Elevator Shaft:** An elevator shaft is [1] a vertical hollow section in a building [1] in which the elevator cabin travels to raise or lower the load. It houses all the systems and components of an elevator system. Shaft of the rope-less elevator system contains a magnetic track.



Fig. 1: Elevator Track



Fig. 2: Elevator Shaft

The track is made up of wood. The magnetic track consists of a two long permanent magnet rails which is pasted on the two extremes of the shaft and it runs throughout the shaft in vertical plane. These magnets are meant for levitation purpose. These magnets are arranged with same poles facing each other. The shaft also has [2] a set of permanent magnets [2] placed with opposing poles facing each other, at the centre of the [14] shaft. These magnets are the part of propulsion system. Two sets of rack and pinion assembly are also the part of elevator track assembly. Two racks are installed on each end next to the levitating magnet. In the model rack and pinion system is used to hold the cabin and prevent it from falling.

The shaft also had a magnetic buffer. A magnetic buffer is made by a set of permanent magnets placed at the bottom of the [10] shaft. The magnets are placed with same pole facing each other. The magnetic buffer is used in place of regular buffer which absorbs jerk at the lowermost level. It uses the property of magnetic repulsion to perform above operation.

- **Elevator cabin-** It is the most important subassembly which is responsible for transporting load from top to bottom. Generally, the elevator cabin is of cubic shape [12]. It can [12] be imagined as a room [12] made up steel. It contains electronics, propulsion system and braking system.

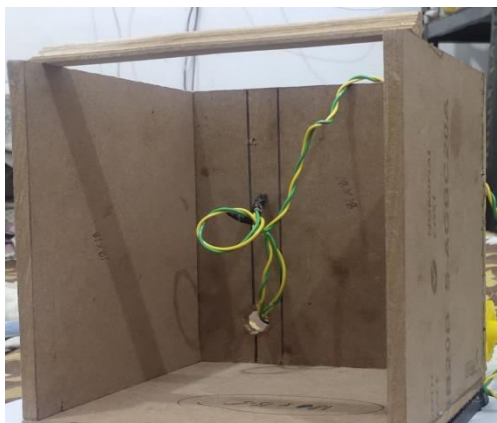


Fig. 3: Elevator Cabin



Fig. 4: Elevator Propulsion Assembly

The propulsion system of [15] the rope-free elevators consists of a DC [15] motor with a ring magnet mounted on it. The propulsion is obtained by alternate attraction and repulsion of between ring magnet of motor and bar magnet which is mounted on the track. When the elevator is stationary, the opposite poles of the ring or disc magnet and bar magnet will face each other. In order to set elevator in [1] motion, the motor is rotated which in turn [1] will rotate the ring magnet. This ring or disc magnet will get attracted by the magnet next in the series because of opposite polarity while the previous magnet will repel the ring magnet mounted on motor because of reverse polarity. Hence a linear motion in the vertical plane is obtained.

IV. COMPONENTS AND MATERIALS

- Battery:** A battery is an electrochemical device that transforms chemical energy into electrical energy [16]. It can also store electrical energy and can supply the same when electrical power is needed. In this project lead acid batteries are used [17] as a power source [1], since it easily available at an affordable price. Some of drawbacks of this battery technology are that it offers lowest energy density among all types of [1] batteries and for the [1] same quantity of electrical consumption the size and weight of lead acid batteries is quite big as compared to other technologies like Li-ion batteries. At present Li-ion batteries are the best battery technology available, though it is not used in this machine because Li-ion batteries are not readily available in India and they are quite expensive as compared to lead acid batteries.



Fig. 5: Lead-acid battery

- ii. **DC geared motor:** It is a simple DC motor with gear assembly attached to output shaft of the [6] motor. The advantage of using gears is that it [6] increases the torque and decreases the speed. Motor speed is measured in revolution per minute or rpm.



Fig. 6: DC geared motor

In this project DC motor is used to propel the cabin. It indirectly propels the cabin, actually ring shaped permanent magnets are mounted on it which when rotated will experience an alternate attraction and repulsion from alternately arranged magnet pieces of the track. Due to this alternate attraction and repulsion a linear motion is obtained.

- iii. **Ceramic magnet:** is also called ferrite magnet. It was invented in 1960's as low cost alternative of regular metallic magnets. These magnets in whole contain two major compounds i.e. iron oxide and strontium carbonate. The hard and brittle characteristic [18] of permanent magnet and its low energy content makes it unfit for some applications. These magnets are widely used because of their low cost [19] and high corrosion and demagnetization resistance properties. These magnets are the most widely [13] used magnets and accounts for more than [20] 75% of the total magnet consumption globally. Preferentially these magnets are used in motors, separators, sensors etc.

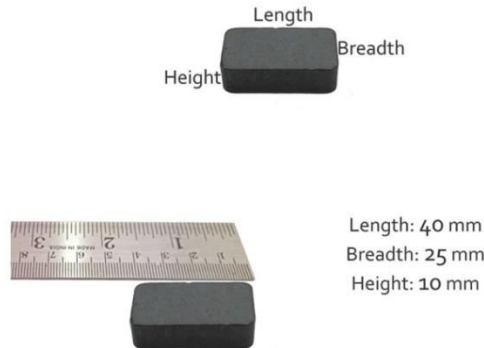


Fig. 7: Ceramic magnet

In this project a ceramic magnet of rectangular bar shape having dimensions 40mm X 25mm X 10mm is used of propulsion system and is mounted on the track [1]. Another ring shape magnet of an outer [1] diameter of approximately 40mm is also [5] used and is mounted on the motor [5] shaft.

- iv. **Rubber magnet:** is an extruded form of thermoplastic magnet. These magnets are formed by mixing ferrite in vinyl or rubber. These magnets have comparatively lower absorption power in comparison to the conventional ferrite magnet. In this project magnetic rubber strip of dimensions 195mm X 20mm X 6mm (L X B X H) is used for levitation purpose.



Fig. 8: Rubber magnet

- v. **MDF board-** Medium- Density-Fibre board is being abbreviated as MDF board. It is type of engineered wood. It is manufactured by tearing down the residues of wood (hard wood & soft wood) into fibres. This wood fibre is then mixed with the resin binder and wax and is then moulded into panels of different size and thickness. These boards are generally denser than plywood and it can be used [21] as an alternative of ply wood. In this project MDF sheets are used for making shaft structure and elevator cabin.

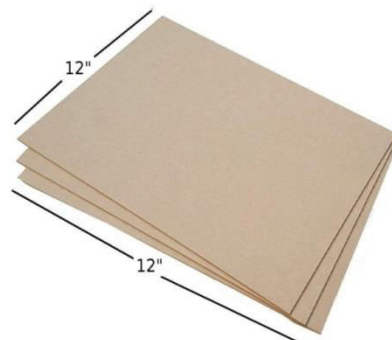


Fig. 9: MDF board

- vi. **Rack and pinion assembly-** It is type of a gear system that converts rotational motion into translational motion. Rack is a long linear toothed rectangular bar on which [9] the pinion translates. Pinion is the circular [9] gear that slides over the rack. Both helical and straight teeth can be used in this drive but helical teeth are preferred often because of their quieter operation and greater load bearing capacity. The maximum force transferred by this drive is dependent on the pitch of tooth and pinion size.



Fig. 10: Rack



Fig. 11: Pinion

In this project rack and pinion assembly is used to guide and support the elevator cabin.

- vii. **Ply board-** It is type [11] of wooden board which is manufactured [11] by stacking up thin layers of wood slices of thickness of 3mm. Several such layers are glued together with wooden grains in between them to get the ply of desired thickness. In this project it is used to make walls of elevator shaft.

V. CONCLUSION

The design proposed in this project has the tendency to completely revolutionize the vertical transportation. The ropeless elevator system designed in this project has three sub-assemblies which are track; elevator cabin and elevator shaft and among these three assemblies track and cabin are the prominent one. The track is made up wood and permanent magnets are fixed on its corners with same pole and also a set of ceramic magnet is fixed at the middle of the track with alternate pole facing each other along the length of the of the track. The cabin consists of a ring magnet attached to a DC motor. This combination is used to propel the cabin. This is similar to the linear induction motor in which the linear feed is obtained by alternate variation of polarity.

This prototype is developed for demonstration and testing purpose and has limitations related to maximum height up-to which it can lift the load, maximum payload that it can lift up-to maximum height and maximum operation speed. In this model we have used rack and pinion assembly which can be replace by wheels and guideways and suitable braking and levelling system. Moreover the precision and accuracy of the braking and levelling can further be improved by using advanced electronics and control system.

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