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DESIGN & CONSTRUCTION OF A MAGNETIC LEVITATION VEHICLE

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Abstract*- The word Maglev is a system which uses magnetic levitation to suspend, guide and propel vehicles with magnets rather than using mechanical methods. Magnetic levitation has evolved into an important consideration in designing systems requiring low losses due to friction and low energy consumption. Applications range from high-speed rail transportation systems to various industrial applications (e.g., magnetic bearings). The objective of the Mag. Lev. Vehicle project is to design and implement levitation, guidance, and propulsion for a small scale train. The method has a passive levitation and guidance system that is controlled by the propulsion of the train. The linear motor was built, but due to time and budget constraints, the levitation system was done with permanent magnets. To make the train more efficient in the future, superconducting electromagnets should be used on the train so that a high current could be obtained without losing energy to heat dissipation.*

Keywords: Magnetic levitation, Maglev, EMS, Bullet Train.

1. Introduction

Maglev (derived from magnetic levitation) is a system of transportation that uses magnetic levitation to suspend, guide and propel vehicles from magnets rather than using mechanical methods, such as wheels, axles and bearings. Maglev transport is a means of flying a vehicle or object along a guide way by using magnets to create both lift and thrust, only a few inches above the guide way surface. High-speed maglev vehicles are lifted off their guide way and thus are claimed to move more smoothly and quietly and require less maintenance than wheeled mass transit systems or conventional transportation system – regardless of speed. It is claimed that non-reliance on friction also means that acceleration and deceleration can far surpass that of existing forms of transport. The power needed for levitation is not a particularly large percentage of the overall energy consumption; most of the power used is needed to overcome air resistance (drag), as with any other high-speed form of transport. [3]

In the U S, and in many other countries, growth in demand for conventional, mostly-petroleum-fueled modes of transportation has led to traffic congestion, excessive time delays, environmental issues and energy supply problems. Decades ago, visionaries recognized the solution to be a new mode of transportation - one whose attributes would permit convenient, high-speed, high-frequency, reliable service at competitive costs, that is environmentally friendly, and independent of Petroleum imports. Early on, maglev technology appeared to possess the necessary attributes. It promised high speed, rapid acceleration, smooth, quiet, non-contact, environmentally friendly operation with competitive 66 costs. To what extent have these promises been met?[4,5]

The highest speed record of maglev train is about 540 km/hr. It also may be applied in transportation sector in Bangladesh. The Ministry related with communication sector of Bangladesh also proposed to use maglev train in the transportation sector. That will reduce the transportation time. Now Dhaka to Khulna takes time about 10-12 hours by conventional trains. But the maglev train will reduce this time to an hour.

2. Principle Mechanism

Maglev works very much like the circular electric motor. Here the magnets go in a straight line instead of around a circle. Each magnet on LIM (Linear Induction Motor) is pushed forward from behind and pulled forward from the front causing the vehicle to move forward. Notice again that the magnetic poles on the guide-way must change from S to N and back again to keep the vehicle moving forward. The Figure 1 shows how the vehicle is pushed or pulled by linear induction motor. Motor is a 3-phase LIM (Linear Induction Motor) connected in series. As an added safety feature, the vehicle can travel in a

"U-shaped" guide-way, or wrap around "T-shaped" guide-way. These specially-shaped guide-ways would stop Maglev from falling off the side in an emergency. [1,3]

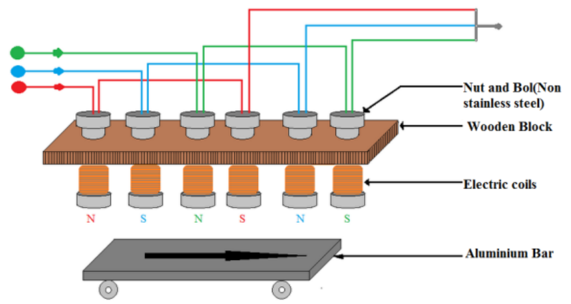

Figure- 1: Propulsion by Linear Induction Motor

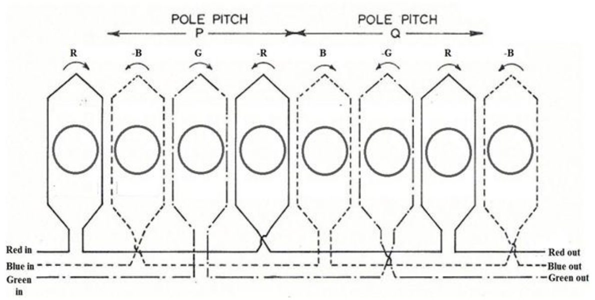

Figure 2: Single layer 3-phase system

3. Linear Induction motors

Linear Induction motor is normally referred as Linear motor. It is a special purpose motor that is used for linear motors. This is interesting development of a conventional induction motor. It performs linear motion instead of rotary motion as in a conventional induction motor.[1]

There are several ways and types of construction of a Linear Motor or Linear Induction Motor. The simplest form of construction of a Linear Motor is as simple as a three phase induction motor. It has three phase winding housed in slots in a field system. It is simply the primary winding on a stator in case of an induction motor. This is obtained if we cut the stator of an induction motor from middle. In case of a moving object like in a train the primary winding is mounted in the middle of the guide ways. The reaction plate is made by aluminum or copper plates in parallel. [1]

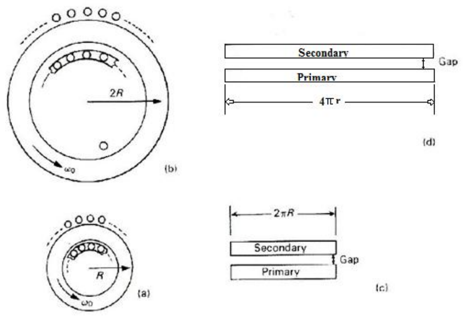

Figure 3: (a) Effective radius R; (b) Effective radius 2R; (c) Travel length 2πR; (d) Travel length 4πR

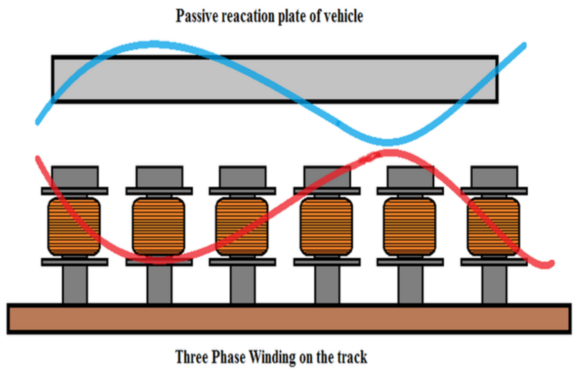

Figure 4: Linear Induction Motor mechanism

4. Equipment Used

- Aluminum Bar.
- 40 Permanent Magnets.
- 3-phase circuit connection.
- A linear Induction motor.
- A reaction bar.

5. Design Consideration:

The purpose of this prototype is for use and testing in a laboratory. The construction and subsequent tests will provide valuable information on this type of electrical machine, and the results, once extrapolated, could serve to design industrial prototypes. This requires some special characteristics that must be taken into account before calculating the different main parameters of the device.

- A low performance motor is targeted. High dynamic performance is not needed in order to study the characteristics of the linear motor in relation to its geometry. Actually, a high performance motor for laboratory testing has some disadvantages, such as the extra protection needed, higher cost, and greater difficulties of working with it.
- As a first approach, an oscillating movement gives enough information to study the motor. The basic electronics should at least generate this type of movement. However, it would also be interesting to supply the motor from commercial regulator to generate more complex types of movements. Therefore, the primary voltage and demanded currents must be compatible with the supply characteristics of a standard regulator.
- The guides, travel and main dimensions of the prototype must be designed to fit in a laboratory and must have an open structure. This last need is important for testing; for instance in order to introduce probes or sensors inside the machine.
- A common sense need is that everything must be as simple as possible, in order to achieve a low cost construction and to avoid problems of mounting and of manipulating the geometry of the linear machine. [2,3]

6. Design and basics of Maglev Vehicle

The basic maglev system design is Guide way, Permanent magnet, Linear Induction motor, vehicle's body, Power supply, Switching System. The maglev will be run frictionless and will run by a liner induction motor. It is quite difficult to construct the liner induction motor, as the suitable electro-magnet coils are not available. In spite of these problems we have to make efficient my maglev system & we concerned on the following matters:

- Track dimension.
- Size of guide plate.
- Shape of the guide-ways.
- Size of permanent magnets.
- Power supply rating.
- Vehicle dimension.
- Propulsion of vehicle by LIM.
- Construction of the prototype.

6.1 Track dimension:

The track of model of the maglev system is the main part of the system. Generally it is made by aluminum frame and stands on beams or pillars. Frame acts as a guide-way of the train. The permanent magnets also are fixed on it. To make the construction more lightly and easily we used aluminum sheets and bars and to support the track we used wooden blocks.

6.2 Size of guide plate:

Guide plates are the main component of the track. It holds up the permanent magnets. In the system we used two guide-plates for maglev system. There were about 18 permanent magnets used on each of the guide plates which interact with permanent magnets of the vehicle.

6.3 Shape of the guide ways:

There are several ways to construct the guide ways of a maglev vehicle. The guide way of the maglev vehicle can be constructed by U shaped, V shaped or T shaped. The shape of the guide ways which is used in this project is of U shaped. The tracks have permanent magnets set on each guide ways.

6.4 Size of permanent magnets:

The permanent magnets for the project are used 1´´x3/4´´ rectangular shape permanent magnet. To sit this magnet on the guide plate, the guide plates are made with easy slots with holders on each side.

6.5 Power supply rating:

The levitation of the train needs high repulsive force. One of the effective matters for this repulsive force is the power supply. Higher the voltage, higher the repulsive force. Moreover high the current supply, high the repulsive force. So a variable 3 phase variable power supply between 150 volt - 220 volt was chosen.

6.6 Vehicle dimension:

Vehicle is made by very light material (Aluminum), as we have to lift up this by magnetic repulsive force. It may be made from light packing material. The linear induction motor is place at the bottom side of the vehicle making the whole vehicle a T shape which will be easier to guide along the U shaped guide plate.

6.7 Propulsion of vehicle by LIM:

As the maglev has no touch to its guide-ways, so it cannot be run by using any wheel or any rotary motor. Maglev should be run by the impulsion and propulsion nature of magnet. It should be run by electro magnets, which can be able to change its pole by only changing their electricity pole. It's the principle of linear induction motor (LIM). So in a word we can say that maglev will be run or propelled by a linear induction motor. In our project a single layer 3 phases linear induction motor is constructed (schematic diagram 2.5-a&b). It is made 12 nut bolts standing on a wooden block. Each bolt has 500 loops of winding and is connected in series. [2]

6.8 Construction of the prototype:

Construction of the prototype is done by constructing a primary winding of LIM attached to the guide ways and a reaction bar or secondary iron attached to the vehicle.

6.8.1 Primary windings:

There is a wide spectrum of types of winding for linear motors. For the design of this prototype, a single layer 3-phase Linear induction motor has been chosen (Fig. 2.5-a). This distribution of windings is simple but very effective, and has been used widely for rotary machines. The winding has single layers, full pitch coils .Each coil is made of 3/4´´ nut bolt each with 500 winding. We used a 3 phase 220V power supply available in our laboratory. The motor consists of a line of electromagnets made by wrapping magnet wire (#32) around 3/4 inch bolts (non-stainless-steel) that were mounted to a wood board. Each one of the 3 phases was wired in series to every 3rd coil, so alternating 1, 2, 3,1,2,3, etc., with 4 cycles. We wired the electromagnets in series in order to reduce the current load. [1]

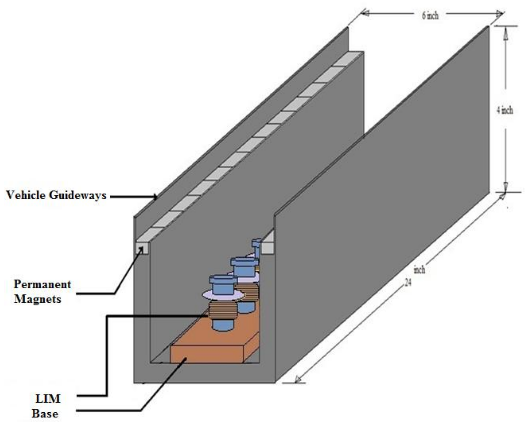

Figure 5: Design of the Guide ways

6.8.2 Secondary iron:

The secondary iron length must be at least the primary length plus the length of travel. The secondary iron is as wide as the primary iron, to maximize the linkage flux. If the same induction level in both irons (primary and secondary) is targeted, the secondary iron must be as high as the back iron of the primary. In the secondary part, a solid core can be tolerated and is preferred to a laminated one, because of simplicity and price.[1]

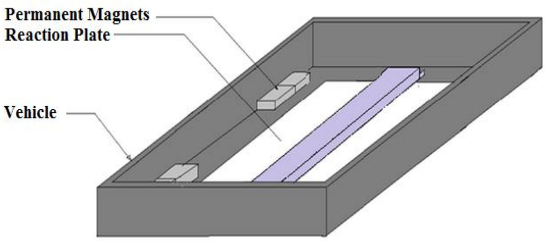

Figure 6: Design of the Vehicle

Figure 7 : Construction of the prototype.

7. Future Development and Discussion

Since, we were finding difficulties to balance the weight of the vehicle with the LIM, we decided to use the LIM on the track. On the tracks and vehicle sideways permanent magnets were used for levitation. In future, we are planning to construct the LIM in more developed way making more lighter and compact so that it can be easily be used on the vehicle. Also, we are also thinking to use electromagnets interacting with ferromagnetic stator which will give more uniform levitation and also will be strong enough to support the weight of the vehicle. In this project LIM used single layer 3-phase of which performance can also be increased by using triple layer 3-phase motor. We are also planning to use sensors and micro controllers on the circuit. As the vehicle comes in each sensor the circuit will change its direction to opposite direction giving the whole arrangement a reciprocating motion. [1]

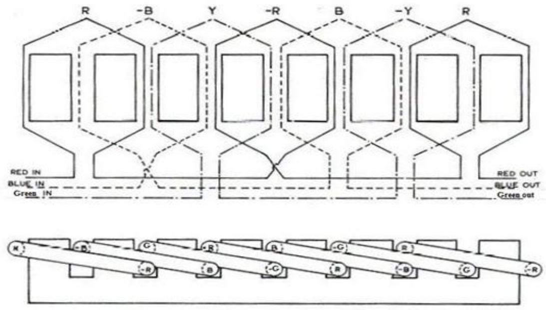

Figure 8: Triple Layer System

8. Conclusion

To improve on this design in the future, as mentioned above, efficiency should be optimized by adding a levitation system and using superconducting electromagnets to prevent any energy loss due to friction or heat dissipation. The microcontroller could tell the electromagnets to turn off once a certain velocity is reached, and turn back on again only when needed to maintain the velocity. Future projects could add these features to the track and train. But the most important and the most difficult improvement that must be made on this project is to cut down on the costs. Unfortunately, permanent magnets are very expensive, and building a linear propulsion system requires a lot of magnets.

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