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Study and Design of a Double Sided Linear Induction Motor

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Abstract : *Linear induction motors are under improvement for a variety of demanding applications including high speed ground transportation and specific industrial applications including transportation, conveyor systems, actuators, material handling, pumping of liquid metal, and sliding door closers, etc.. These applications require machines that can produce large forces, operate at high speeds, and can be controlled precisely to meet performance requirements. In this project, a double sided linear induction motor prototype has been designed and constructed to identify and study the different concepts and parameters of the motor which are different from other types of electrical machines. The DLIM equations and design procedures are developed and its performance is predicted using equivalent circuit models. The DLIM design choosing various design parameters like the primary voltage, frequency, number of poles, number of phases and many more parameters are considered. Optimum design parameters are obtained by the iterative procedure of the design calculation. The performance curves of the DLIM i.e., thrust and efficiency are drawn and then analyzed for different target thrust values and rated slip. The effect of varying parameters of the DLIM such as air-gap, thickness of aluminum sheet and the number of poles on the performance of DLIM are analyzed and the results are discussed. The linear induction motor is very beneficial at places requiring linear motion since it creates thrust directly and has a simple structure, easy maintenance, high acceleration/deceleration. (1) The most obvious benefit of linear motor is that it has no gears and requires no mechanical rotary-to-linear converters.*

Keywords: *AC motor drives, Transportation System, Conveyer System, linear magnetic field.*

I. Introduction

The linear induction motors for transport vehicles such as urban vehicles or trains, or for linear drives where they can replace the rotary electric machines, hydraulic or pneumatic equipment with linear movement. A Double-sided Linear Induction motor (DLIM) is a special type of induction motor which gives linear motion instead of rotational motion, as in the case of conventional induction motor. It works on the principle of which a conventional induction motor operates. In contrast with its rotary counterpart, a DLIM may have a moving primary (with a fixed secondary) or a moving secondary (the primary being stationary). In our project stator of DLIM act as primary and rotor acts as secondary. DLIM can be a short primary or short secondary, depending on whether the primary or secondary is shorter In each situation, either primary or the secondary can be the moving member in our project, secondary is short. In addition, the LIM may have two primaries face to face to obtain a double-sided LIM (DLIM) from the figure 1.1. If the LIM has only one primary, it is called as single sided LIM. The secondary of the DLIM is normally conducting plate made of either copper or aluminum in which interaction currents are induced. In a single primary system a Ferro magnetic plate is usually placed on the other side of the conducting plate to provide a path of low reluctance to the main flux. However the ferromagnetic plate becomes attracted near the primary on energization of the field and this causes uneven gap distance on the two sides of the conducting plate. Depending on the size and ratings of DLIM they can produce thrust up to several thousand Newton's .The speed of the DLIM is determined by winding design and supply frequency. Conceptually all types of motors have probable linear configurations (dc, induction, synchronous and reluctance).The dc motor and synchronous motor requires double excitation (field and armature). As in a rotary motor, a LIM may have one/two/three phase. The primaries of these all LIMs are essentially similar to stator winding of rotary machine. DLIM can have various configurations like the air gap can be flat or cylindrical, and the flux can be longitudinal or transverse. The primary goal is to analyze a small laboratory sized linear induction motor for educational purpose. This project describes the design and construction of DLIM. It describes implementation of the stator component of DLIM. The completion of the stator design is necessary in order to analyze LIM. This project also focuses on the advantages and drawback of DLIM along with comparison with conventional rotary motor. LIM belongs to the group of special electric machine that converts electric energy directly into mechanical energy of linear motion. A DLIM is a non-contacting, high speed, linear motor that operates on the same principal as a rotary, squirrel cage, induction motor. Progress in power electronics and ac variable speed drives has had a tough impact on the improvement of linear induction drives.

Linear electric machines are direct drives, they allow accelerations, and velocity and position-accuracy far better than their rotary counterparts; however, they are usually more expensive. LIM is conceptually a rotary motor is cut and unrolled. It can be thought to be basically a rotating squirrel cage induction motor opened out flat. Instead of creating rotary torque from a cylindrical machine it creates linear force from a flat one. Depending upon the size and rating of the linear induction motors they can produce thrust up to several thousand Newton. The speed of DLIM is determined by the winding design and supply frequency unrolling of stator of rotating induction motor.

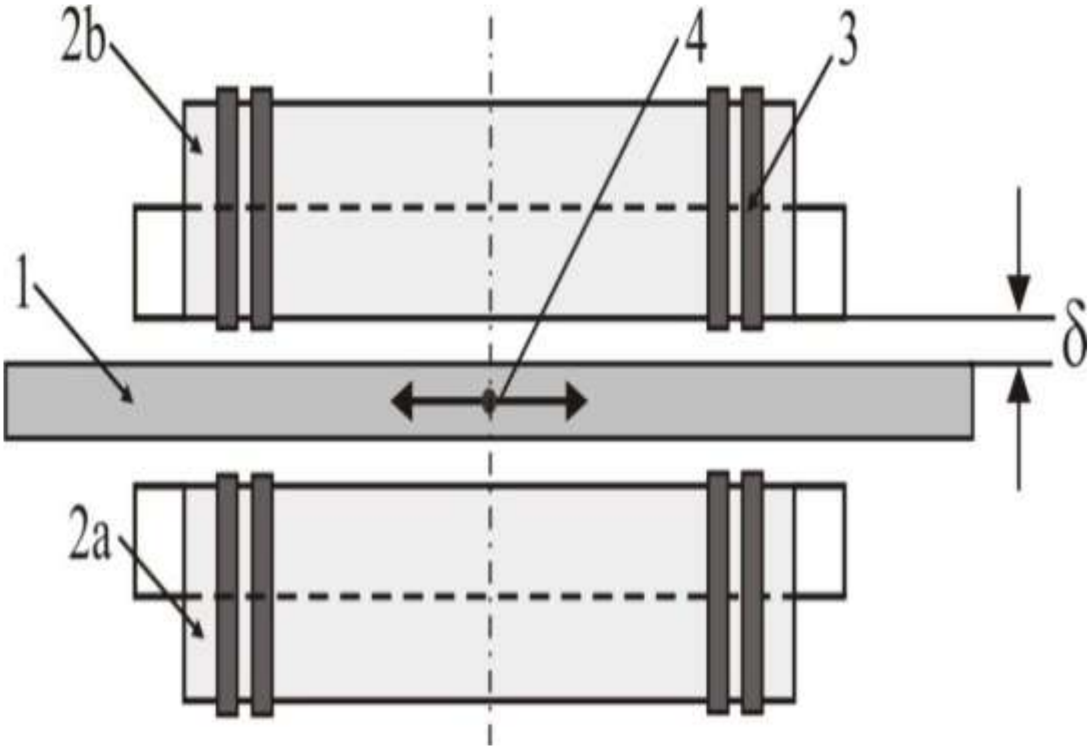

Fig.1: Double-sided Linear Induction Motor (DLIM)

The linear motor considered (Fig. 1) is a three-phase, double sided, with a vertical plate mobile armature (1) from copper. On the two inductors (2a and 2b), there are located the ring windings in 24 slots, yielding the coils (3). The air gap δ is to be establish on the both sides of the plate armature, the total air gap presence 2·δ.

II. History Of Dlim

The history of LIM extends as far back as the 19th century. Although these machines have been practically forgotten for the last 30 or 40 years, there appears to be a genuine revival of the interest in them. The idea of the DLIM is maybe contemporary with the invention of the rotating field machine by the scientists Tesla, Dolivo-Doborovolsky, and Ferrari sometime after 1885. However, some of the authors give additional dates for the finding. The clue of a linear electric motor is almost as old as that of a revolving electric motor. The first linear motor was a reluctance machine built by Charles Wheatstone in 1845, to be nearly followed by a like machine by Henry Fox Talbert. Nicola Tesla invented the induction motor in 1888. The first patent in linear induction motors was obtained by the mayor of Pittsburg in 1895. The first electromagnetic gun was undoubtedly Baekeland’s cannon of 1918, again a reluctance device, but possibly the first tubular motor using a row of simple coils energized in sequence with DC. In 1946, scientist Westinghouse built a full-scale aircraft launcher, the “Electropult”, which was an induction motor with a moving primary. It was this machine that motivated E.R.Laithwaite to begin his own work on linear motors in the 1950‟s. Since from 1950, there have been rapid advances in linear induction machines for producing standstill forces, for propelling high- speed vehicles and as accelerators for producing kinetic energy.

III. Literature Survey Of Dlim

First of all declarations linear induction machines in 1890, only two years after the discovery of the rotary induction principle. Mostly the concept of the linear device consists in conception a rotary machine to be cut along a radial plane and 'unrolled' so that the primary member then consists of a only row of coils in slots in a coated steel core. The changes between rotary and linear motors are outlined and reasons for the slow application of linear motors. A linear electric motor's primary usually involves of a flat magnetic core with transverse slots which are regularly straight cut with coils laid into the slots, with every phase giving an alternating polarity and so that the dissimilar phases physically overlap. The secondary is regularly a sheet of aluminum, often with an iron backing plate. Some LIMs are double sided, with one primary either side of the secondary, and in this case no iron backing is needed. Two sorts of linear motor exist, short primary, where the coils are truncated smaller than the secondary, and a short secondary where the conductive plate is lesser. Short secondary LIMs are often wound as parallel connections between coils of the similar phase, whereas short primaries are typically wound in series. Both works are primarily apprehensive with theoretic analysis of single and double-sided linear induction machines. There is a wealth of literature on the analysis of Double sided linear induction motors, but very few papers that focus directly on the design of a DLIM, which is the main subject of this project. In order to begin modeling and developing Double-sided linear induction motors for different applications, it is necessary to have a modular test bed. The modular DLIM test bed will allow customization in order to accommodate several applications and designs. Some of the designs contain air gap manipulation, stator tooth, and a quad stator topology. The design of the linear induction motor is mostly dependent on a combination of two items. First, the team has accomplished an extensive literature review surveying designs of linear induction motors for a multitude of applications. The purpose of this literature review is to define baseline parameters for this design so that they may be optimized. The second determining cause in the design is the analysis and optimization of the design.

IV. Operating Principle Of Dlim

Whenever there happens a relative speed between the field and short circuited rotor, current is persuaded in rotor which results in electromagnetic forces and under the influence of these forces according to Lenz’s law the conductor tries to move in such a ways so as to eliminate the induced current. In the simplest form of DLIM, it consist of field system having three phase double layer windings placed in slots while the secondary can be a reaction plate of aluminum or copper, in which interaction current are induced.

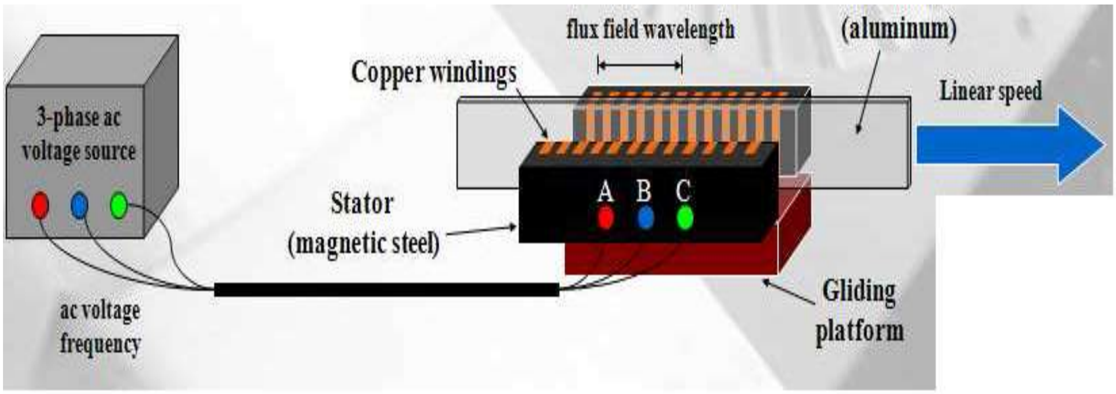

Fig. 2: DLIM Operation

The DLIM operates on the same principal as a rotary squirrel cage induction motor. The rotary induction motor becomes a LIM when the coils are laid out flat; the reaction plate in the LIM becomes the equivalent rotor. This is made from a non-magnetic extremely conductive material. The induced field can be maximized by backing up, the response plate with an iron plate.

If three phase supply connected to both primary side of Double Sided Linear Induction motor a travelling flux is induced in the primary instead of rotating 3 φ flux, which will travel along the entire length of the primary, electric current is induced into the aluminum plate due to the relative motion between the travelling flux and the conductors . This induced current interacts with the travelling flux wave to produce linear force or thrust F.

V. Components Of Dlim

V.1 Stator of DLIM: It consists of 3 phase windings that are wound on a steel laminated core. These laminations are protected from one additional with very fine materials such as paper or adhesive glue. The whole assembly can be encapsulated with thermally conductive epoxy for insulation and strength. The core will involve some mounting to ensure its stability during operation. The core is provided with semi surrounded slots to house the conductors.

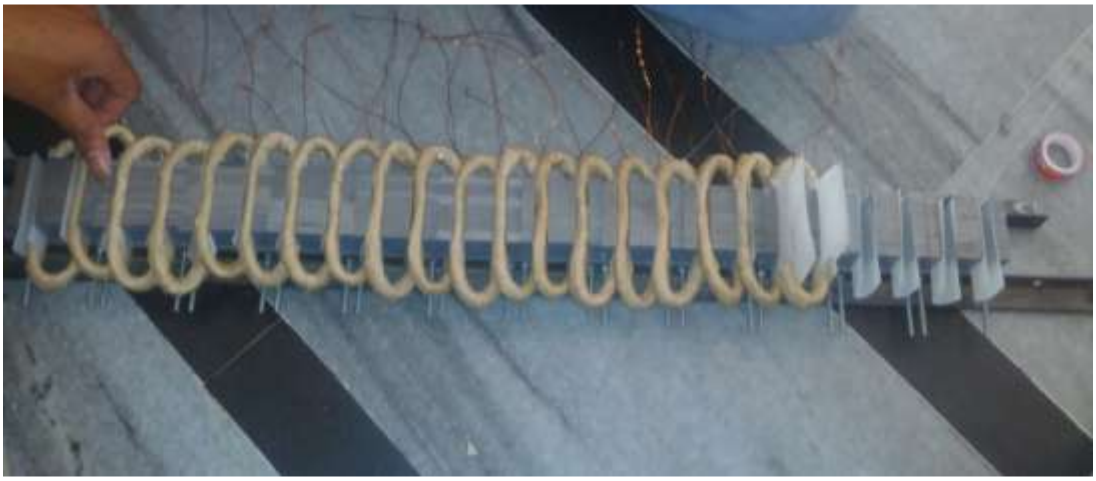

Fig.3: stator coils assembly

V.2 Rotor: A suitable reaction plate is required for proper operation of the DLIM. The reaction plate is made up of standard steel, Aluminum, and or Copper. For double sided operation, the length of reaction plate consists of a 1.7m and .6mm thick .Aluminum or a .080" [2 mm] thick Copper plate that is backed by a .25" [6mm] thick ferrous steel plate. The steel plate can be omitted but the strength will be dramatically reduced.

VI. Figures And Tables

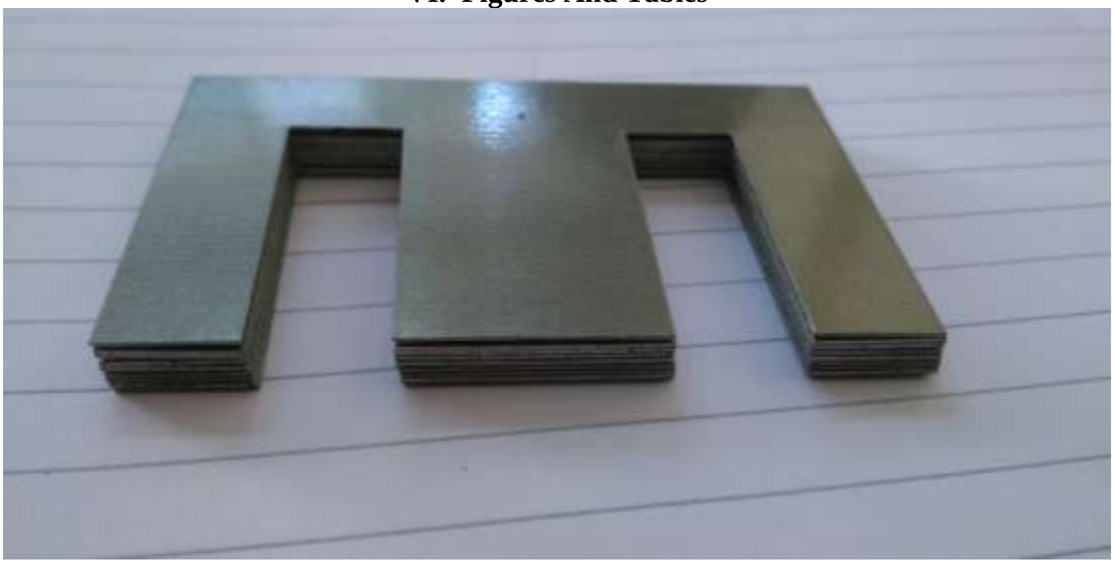

Fig.4 Shape Stamping CRGO Material

Fig.5: Copper Winding

Insulation Paper: We are using excellent insulating materials like Nomex, press pan paper, craft paper, Miler paper Glass Film etc which are strong enough and better in dielectric strength, as a result we can increase the maximum allowable temperature resulting the overload strength is strong specially in case of Dry type Transformer. We are sustaining the maximum temperature rise limited to the earlier class of insulation ,such as if we claim class of insulation “H” , temperature rise will be limited to class of “F” (generally we consider ambient temperature as 45 Deg.C. if not indicated by the client).As per IS and other International Standard

Table 1: Temperature classes

Sr. No	Tempt. Class	Max. Total Temperature Of Insulation
1	A	105 ° Centigrade
2	E	120 ° Centigrade
3	B	130 ° Centigrade
4	F	155 ° Centigrade
5	H	180 ° Centigrade
6	C	180 ° Centigrade above

VII. Construction Of Dlim

Slot Design In AutoCAD**:** Slot designing in AutoCAD before coil placing and after coil placing. Here the slots are designed such that the core material is utilized in an optimum manner as shown in the figure 6.

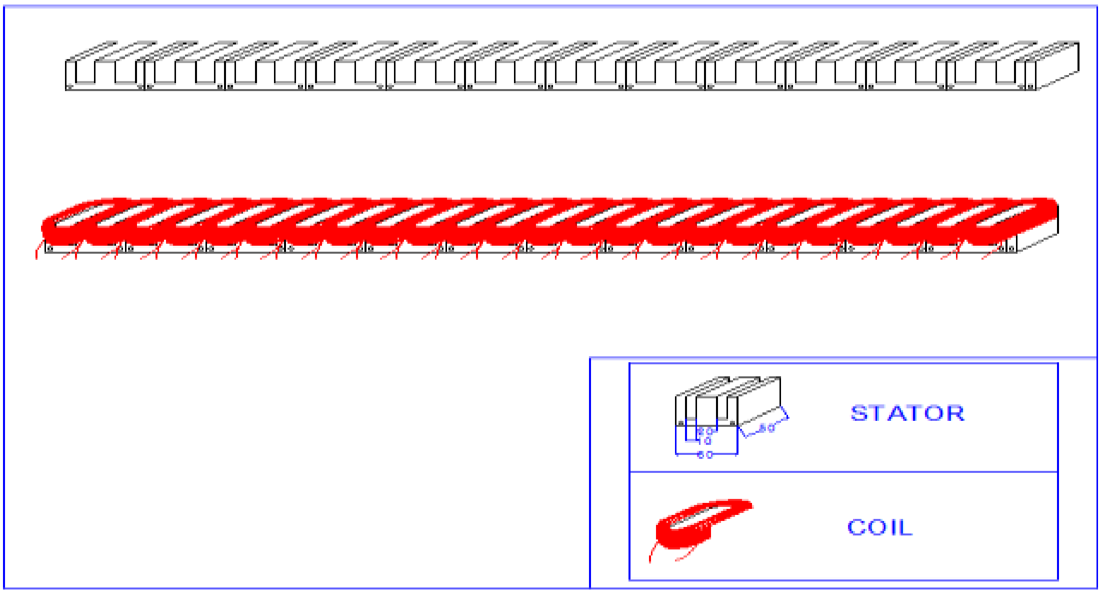

Fig. 6: AutoCAD Design of Stator

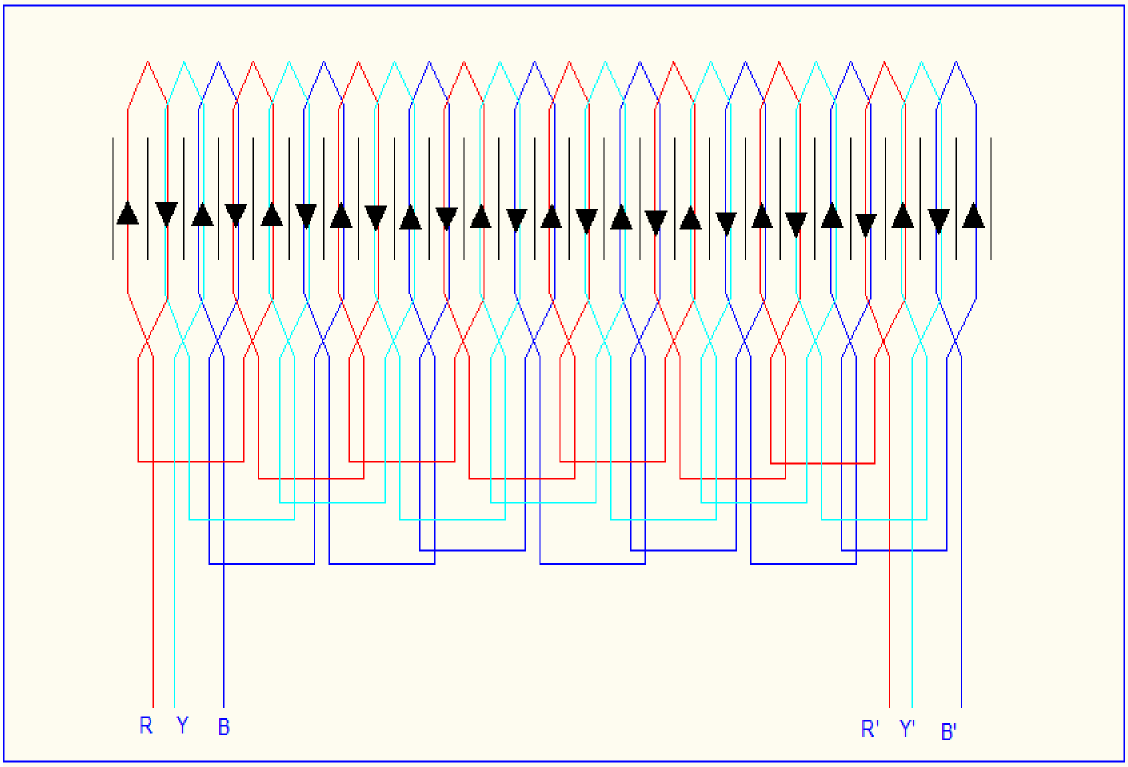

Fig. 7: AutoCAD design of winding

VIII. Advantages Of Dlim

1. Low maintenance cost because of absence of rotating parts.
2. Simplicity.
3. No limitation of tractive effort due to adhesion between wheel and the rail.
4. No limitation of maximum speed due to centrifugal forces.
5. Cost is less as we use less lamination and less winding.

IX. Disadvantages Of Dlim

1. Larger air-gap and nonmagnetic reaction rail need more magnetic current resulting in poor efficiency and low power factor.
2. Difficulties encountered in maintaining adequate clearances at points and crossing.

X. Applications Of Dlim

1. Sliding doors
2. Metallic belt conveyers
3. Travelling cranes
4. Electromagnetic pumps
5. Catapults to accelerate warplanes
6. Linear accelerators
7. Flywheel welder
8. Capsule felling machine
9. Air craft technology

XI. Conclusion

Thus the project concludes showing the working model of Double sided linear induction motor. The direction of the reaction plate can be changed by using limit switch. From this Double-sided linear induction motor with reduced mechanical losses and Constructed DLIM with high starting thrust force and easy maintenance. So double sided linear induction motor is very well suitable for industrial applications like conveyer system and very useful for transportation in future.

XII. Future Scope Of Dlim

Linear induction motor has potential to revolutionize how we travel. The trains themselves are less expensive and loud than conventional trains and they need less maintenance due to their levitation removing most of the friction. Maglev trains use far less energy than conventional trains and release no impurities. High speeds allow for maglev trains to be a realistic substitute to flying, and they can help decrease air and road congestion as more people are moving around the world. So far DLIM has been controlled with few classic controllers in future various latest control methodologies are upcoming which will have effective control of LIM in terms of the efficiency and performance of the machine.The U.S. Navy plans to start launching future naval stable aircraft using linear induction machine. The scientists are altering the shape of stator to flat, and the vehicle is to use in place of the rotor. This vehicle will move in straight line and will attain high acceleration quickly.

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