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Design of small scale maglev train by using LIM

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ABSTRACT

The main purpose to introduce this paper is to design a small scale maglev train by using a linear induction motor. The use of maglev train has several advantages such as it has no pollution which is present in case of conventional train. Also it has low noise pollution and has high efficiency than conventional transportation system. In this system we are using a one linear induction motor for propulsion purpose and power magnets are used for levitation purpose. The use of power magnet result in levitation which cause zero friction so we can achieve maximum speed than conventional transportation system.

Keywords: CRGO core, copper winding, power magnets etc

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I. INTRODUCTION

As we know since 18th century the requirement of fast and comfortable transportation is more throughout the history of the world. Until this condition these requirements are satisfied by conventional vehicles. Also conventional vehicles are called as wheel on track system, which causes a friction loss and irregular crashes which result in uncomforting to the passenger. Maglev vehicles are contactless hence there is no wear and tear of rail track which result in high speed of transportation. Maglev train is nothing but a transportation of train from one place to another place with the help of electricity and a magnet (for levitation) through a track.

In maglev train system, we can use basic principle of electric motor i.e. when a current carrying conductor is placed in a magnetic field it experiences a force and starts rotating. We can use linear induction motor (LIM) as well as linear synchronous motor (LSM) for maglev train purpose to propel the train. In a maglev train system rail track act as a stator of motor while train acts as a short circuited rotor. The stator/track design may be of LIM or LSM, but both the system has some advantages as well as disadvantages. According to speed of train it is classified into high speed as well as medium speed. LIM is used for medium speed application and LSM is used for high speed application.

II. BLOCK DIAGRAM AND DISCRIPTION

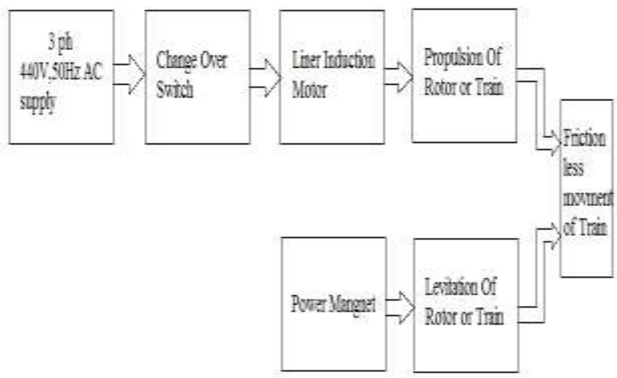

Fig.1 Block diagram of small scale maglev train by using LIM

A. 3-Phase AC Supply:-

When 3 phase ac supply is given to the primary or stator of the LIM a travelling flux is induced in the primary or stator instead of rotating 3 phase flux, which will travel along the entire length of primary, then electric current induced in the aluminium plate due to the relative motion in between the travelling flux and conductors. The induced current interacts with the travelling flux wave to produce linear force or thrust.

B. Linear Induction Motor (LIM):-

As we know there are two types of linear induction motors such as single sided IM and double sided IM. But according to cost consideration point of view we are using a single sided IM for development of small scale maglev train. Whenever there occurs a relative speed between the field and short circuited rotor, current is induced in rotor which results in electromagnetic forces and under the influence of these forces according to Lenz low the conductor tries to move in such direction so as to eliminate the induced current. In the simplest form of LIM, it consist of field system having three phase distributed winding placed in slots while the secondary can reaction plate of aluminium or copper , in which interaction current induced.

The LIM operates on the same principle as a rotary squirrel cage induction motor. The rotary induction motor becomes a linear induction motor when the stator laid out flat.

a) Three Phase Coil Assembly:-

It consists of three phase winding that are wound on the CRGO core material. The core will require some mounting to ensure stability during operation. The whole assembly is mounted on the wooden strip. The type of winding used is the mush winding as this type of winding is simple to do. And also the copper material required for the winding should be less as winding is a single layer mush winding.

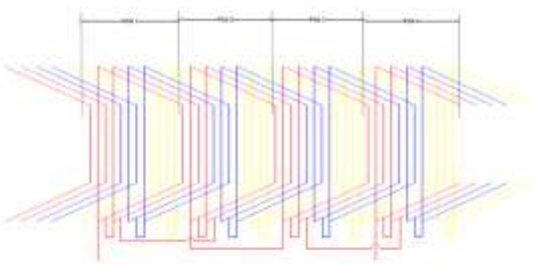

Fig.2 AutoCAD of Winding diagram

b) Primary or Stator Design:-

We designed the maglev train for 120 cm length having height of core is 5 cm and the width of core is 5 cm. The total numbers of slots are 48 which are rectangular in shape. Rectangular slots are also called as an open slot which has advantages of easy winding. The width of each slot is 10 mm and the depth of slot is 15 mm and the cross-section area of each slot is 150 mm^2. The stator teeth are 15 mm throughout except 7.5 mm at start and end of the primary.

Fig.3 AutoCAD of Stator Design

c) Design calculation of LIM:-

Output equation of 3 phase induction machine

$Q = C_o\, D^2 L N_s$

Where Co =11KwBav ac × 10^{-3}

Co = Output Coefficient

Bav= Specific magnetic loading

Kw=Winding factor

Assume:

Bav=0.45 wb/m^2

Ac=5000Amp/m

$\left[\begin{array}{c} The\ Value\ of\ ac\ should \\ be\ in\ Between\ 5000\ to\ 25000\ amp/m \end{array}\right]$

Kw=0.955

$[for\ full\ pitch3\ phase\ machine\ Kw = 3/\pi]$

Speed in RPM

Ns= $\frac{120*f}{P}$ rpm

Ns = $\frac{120*50}{4}$ = 1500 Rpm

Speed in RPS

ns = $\frac{Ns}{60}$ rps

ns = $\frac{1500}{60}$ rps

ns = 25rps

Find the output coefficient

Co = 11* Kw* Bav* ac * 10^{-3}

Co = 11*0.955*0.45*5000*10^{-3}

Co=23.63

We know D^2 L =$\frac{Q}{C0\ ns}$

KVA Input = Q=$\frac{P}{n\ Cos\emptyset}$

Q=3.21 KW

T = $\frac{\pi D}{P}$

Where D = Diameter of Core

P = No of Pole = 4

T = $\frac{\pi*0.3883}{4}$

T =305 mm

L/T= $\frac{0.05*1000}{305}$

L/T = 0.1639

Stator Design

The machine is to be design for star connection

Stator voltage per phase Es= 254.03 volt

Flux per pole = Bav *T*L wb

$\varphi m = 0.45 * 0.305 * 0.05 * 1000$ wb

φm = 6.8653* 10^{-3} Wb

Stator turn per phase =Ts

Ts = $\frac{Es}{4.44*F*\varphi m*Kw}$

Ts = $\frac{254.03}{4.44*50*6.8653*10-3*0.955}$

Ts = 175

Total stator slot = 48

Stator slot pitch = Yss = $\frac{\pi D * 10^3}{Total\ stator\ slot}$

Yss = 25 mm

Total stator conductor = 6*Ts

= 6*175

= 1050

Conductor / slot = Total stator conductor/ total slot

= 1050/48

= 22

Full pitch distributed winding

Kc = 1

β=15˚

slot / pole/phase = m = 4

kd = $\frac{\sin m\frac{\beta}{2}}{m \sin\frac{\beta}{2}}$

kd = $\frac{\sin 30}{4 * \sin 7.5}$ = 0.9576

Stator winding factor = Kd*Kc

Kws = 0.966*1

Kws = 0.9576

No of Coil Required = 24

Each coil total conductor contain = 22

Dimension of conductor

Stator current per phase = Is = $\frac{Kw}{3 * V * Cos\varphi * n}$

Is = $\frac{3.21 * 10^3}{3 * 440 * 0.85 * 0.85}$

= 3.36 amp

Consider current density = 2.3amp/mm^2

$$\partial = \frac{I}{A}$$

Where $\partial = Current\ density$

A = Area of conductor

A = $\frac{3.36}{2.3} = 1.05$

$\frac{\pi d^2}{4}$ = 1.05

d= 1.1562mm

Stator winding Gauge =19

d) Design Calculation of Winding Diagram:-

1. Coil span (Cs)= slots /pole =48/4=12 slots
2. Number of slots /pole/phase=48/ (4*3) =4 slots.
3. Slot angle(ð)=180/(4*3)=15^o
4. Total number of coils required=48/2=24
5. Total no. Of coils /phase =24/3=8
6. Total no. of slots required for 120^o displacement =120/15=8 slots.

C. Copper:-

Copper is the most commonly used electrical conductor as it having a high electrical conductivity with good mechanical properties. And also have immunity from oxidation and corrosion under operating condition. Copper is highly malleable and ductile metal and also can be cast, forged, drawn, rolled, and machined. Hard drawn copper wire is used in a most of the electrical machines. Copper is universally used for winding of electrical machine also it is easily workable without any possibility of fracture. Also copper can be soldered easily which resulting simplification of jointing among the conductors. It has 8900 kg/m^3, melting point 1083 c, specific strength MN/m^2.

D. Aluminium or Short Circuited Rotor:-

The aluminium bar is used as the rotor of the LIM. The aluminium bar acts as a short circuited secondary winding and current gets induced in it and according to Lenz law the aluminium bar start moving linearly. It has density 2700 kg/m^3, specific strength 920 MN/m^2, melting point 660 c. Aluminium has less cost compared with copper.

E. Insulating Material:-

To avoid the eddy current loss we use the insulation over the core and winding. The insulation may be of paper, sleeves, varnish, miller paper or craft paper. Due to the insulation the temperature of the machine is maintained as the I^2R loss in the core is less.

F. Propulsion:-

Propulsion is nothing but a moment of the train or rotor from one place to another place. Due the force or thrust produced by LIM the rotor propels.

G. Power magnet:

Power magnet is also called as a neodymium magnet (NdFeB, NIB or Neo magnet), the most popularly used. It is made up from alloy of neodymium, iron and boron to form $Nd_2Fe_{14}B$ tetragonal crystalline structure. It has mainly two poles such as North Pole and South Pole. The dissimilar pole attracts each other and similar pole oppose each other.

H. levitation:-

When the two similar poles are comes in contact they try to oppose each other such force is used for the levitation purpose .such combination may be south-south or north-north. In our design we placed the power magnet on the wooden strip and also provided on the rotor side insulation.

ADVANTAGES

1) Low maintenance cost because of absence of rotating part.
2) simplicity
3) No limitations of tractive effort due to adhesion between wheel and the rail.
4) Cost is less as we use less lamination and less copper

DISDAVANTAGES

1) More loss as whole track is electrified.
2) Capital investment is more.

APPLICATION

1) Sliding doors
2) Metallic belt conveyor
3) Linear accelerator
4) Electromagnetic pumps

III. CONCLUSION

Hence, from these we conclude that the LIM with reduced mechanical losses and constructed LIM with high starting thrust or force and easy maintenance. It can be used in area such as transportation, conveyor system, and actuators etc.

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