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DESIGN OF LINEAR INDUCTION MOTOR WORKS AS CONVEYER

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ABSTRACT

This paper suggests and described the methodology for the design of linear induction motor and performance of the motor works as conveyer.The design equation of the single sided linear induction motor and the equivalent circuit model are studied and discussed in detail. The SLIM of specified parameters are designed using a user – interactive MATLAB programme and then compared to a simular tabular linear induction motor (TLIM).The SLIM equation and design procedure are developed and its performance is predicted using equivalent circuit models.End effects and edge effects are neglected in this study. The performance of single sided linear induction motor for different value of thrust, rotor acceleration, rotor thickness and slip value is analyser.The effect of such parameter variation on the performance of is discussed.

Keywords: Single sided linear induction motor (SLIM), Rotary Induction Motors (RIM), rotor acceleration, slips, conveyer.

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I. INTRODUCTION

Now a days, the linear induction motor (LIM) has been used in a various applications such as transportation, conveyer systems, actuators robot base movers, office automation, drop towers, elevators, etc. as well as linear induction motor has many advantages like as high starting thrust, alleviation of gears between motor and the motion devices, simple construction, pollution less, less friction, and suitability for low speed and high speed applications. [1]

The history of the Linear Induction Motors (LIM) goes back to 19th century, a few years after the invention of the Rotary Induction Motors' (RIM) principle. In general, the operation of a RIM is defined by the interaction of two main parts: the stator (or primary) and the rotor (secondary).The stator consists of a cylindrical slotted structure formed by a stack of steel laminations. The relative motion between the rotating magnetic field and the conductors of the rotor induces a voltage in the rotor producing currents flowing through the conductors which also generates its own magnetic field. The interaction of these two magnetic fields will produce an electromagnetic torque that drags the rotor in the same direction of the magnetic fields.

From the RIM principle, the operation of the LIM can be explained if one imagines the cylindrical slotted structure and the rotor to cut open and rolled flat causing the magnetic fields to travel in a rectilinear direction instead of rotating. However, contrary to the RIM, the LIM has leading and trailing edges.

Single-sided linear induction motor is used in transportation. The reason why it is selected is that the LIM for transportation has the low energy consumption, high speed, and low pollution. Electrical energy is converted into mechanical energy and linear motion is achieved. In recent years, there have been more than 20 urban transportation lines propelled by single-sided linear induction motors (SLIM) all over the world, such as the Kennedy air line in America, linear metro in Japan, Vancouver light train in Canada, Guangzhou subway line 4 in China, and so on.[4]

II. THEORETICAL STUDY

A. Working principle

It's operates on the same principle of the rotary induction motor i.e. "whenever there occurs a relative motion between the field and the short circuited conductors, currents are induced in them which result in electromagnetic forces and under the influence of these forces, according to Lenz's law, the conductor try to move in such way as eliminate the induced current .in case of rotary induction motor , movement of field is rotary about an axis so the movement of the conductor is also rotary. But in case of linear induction motor (LIM), the movement of the field is rectilinear and so the movement of the conductors.[2]

In its simplest form, a linear induction motor consists of field system having a 3 phase distributed winding placed in slots.

The field system may be a single primary system or double primary system .the secondary of the LIM is normally conducting plates made of either copper or aluminum in which interaction currents are induced. Either member can be the stator, the other being the runner in accordance with the particular requirement imposed by the duty for which motor is intended.

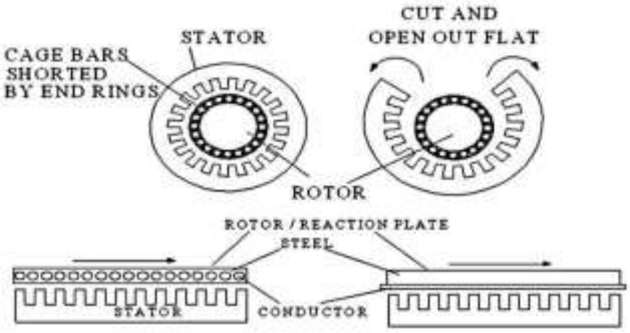

Figure 1: Single-sided LIM. [2]

The structure diagram of a single-sided linear induction motor (SLIM) is shown in Fig.1.[2]

The SLIM drive system has the following merits compared with the RIM drive

1. It can achieve direct propulsive thrust, which is not dependent on the friction between wheel and rail.
2. It has smaller turning radius, smaller cross-sectional area for requirement of a tunnel, larger acceleration, and stronger climbing ability. By investigations from some Japanese exporters, the typical SLIM system has 40-60 m turning radius, 22 m2 cross-sectional tunnel area, 1.2 m/s2 acceleration, and 6-8% gradient ability compared with the 80-120 m turning radius, 41 m2 cross-sectional tunnel area, 0.8 m/s2 acceleration, and 3-4% gradient ability in a typical RIM system. It has lower noise and lesser maintenance.
3. Hence, the SLIM drive system is very suitable for the transportation in large cities. However, the SLIM, which can be considered as evolved from the RIM, has a cut-open primary magnetic circuit. As the primary moves, a new flux is continuously developed at the primary entrance side, while the air gap flux disappears quickly at the exit side. By the influence of sudden generation and disappearance of the air gap penetrating flux density, an amount of eddy current in anti-direction to the primary current will be induced in the secondary sheet, which corresponding affects the air gap flux profile along the longitudinal direction (*x*-axis) as illustrated in Fig. This phenomenon is called "longitudinal end effect" of SLIM, which can increase the copper loss, and decrease the mutual inductance as the velocity goes up. In the end, the effective electromagnetic thrust will be reduced because of the attenuating air gap average flux linkage.

B. Block diagram

The block diagram of the LIM system consists of the following components

1. The first component of the drive system is the three phase supply (440v) which is required for the working of the linear induction motor.
2. The dimmer stat or variac (0v.to440v) is the second component of the system and it is used to control the voltage across the LIM.
3. A reverse forward switch is the third component that is used for applying the direction to the drive system. The system being a linear drive the direction i.e. forward or backward is decided the reverse forward switch.
4. The load is the conveyor belt that is connected to the drive and contains object to be transported along the drive system.
5. And the main component of this drive system being the linear motor itself which is used as a drive medium for the load connected.[4]

All these components together comprise of the LIM drive system.

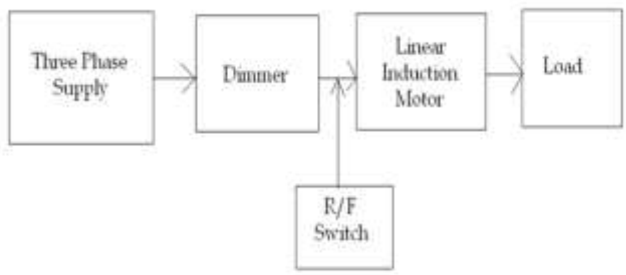

Figure 2: The block diagram of LIM drive system

C. LIM components:

It consists of mainly two important parts

a. 3 phase coil assembly:

The coil assembly consists of a 3 phase winding that is wound into a steel lamination stack. These lamination are insulated from each other with fine materials, such as paper or adhesive glue. The coil assembly will require some form of mounting to ensure stability during operation. The single side configuration consists of a single coil assembly that is used in conjunction with an Aluminum or copper plate backed by a steel reaction plate. The coil assembly can be directly connected to AC line for single speed application.

b. Reaction plate:

A suitable reaction plate is required for proper operation of LIM. The reaction plate for single sided operation is made from standard steel(3 mm), aluminum(2 mm), and or copper(6 mm) thick ferrous steel plate. The steel plate can be omitted but the force will be dramatically reduced.[5]

III. METHODOLOGY

A. Properties of LIM:

Followings are the different properties of Linear Induction Motor (LIM)

a. Linear synchronous speed:

Linear synchronous speed is equivalent to synchronous speed of rotary induction motor. The linear synchronous speed is given by

$$Vs = 2 * pf$$

Where

Vs is the linear synchronous speed (m/s), p is Width of one pole pitch (m), f is Frequency (Hz)

It is important to note that the linear speed does not depend on no. of poles but only depends on the pole pitch width. By this logic, it is possible to for a 2 pole linear machine to have the same speed as linear synchronous speed of a 6 pole linear machine, provided that they have same pole pitch width.

Consider two machines where the radii are R & 2R respectively. The rotational field speed for is w for both of them, While the linear speeds are different.

It clearly indicate that linear synchronous speed does not depends on the number of poles, but depend on pole pitch. as show in table 1

Table 1: various case of linear synchronous speed

Case (a)	Case (b)
Vs = Wr = 2πfR = 2f* pole pitch	Vs = 2wR = 4πfR = 2f* pole pitch

To increase synchronous speed of LIM designer could:

a. Design a longer pole pitch
b. Increase the supply frequency

***b. Slip*:**

The slip formula for LIM is identical to RIM. Per unit slip is expressed by:

$$S = \frac{(V_s - V)}{V_s}$$

Where, S is a Slip, Vs is the Synchronous linear speed (m/s), V is the Speed of rotor (m/s)

c. Forces:

The main forces involved with the LIM are thrust, normal and lateral.

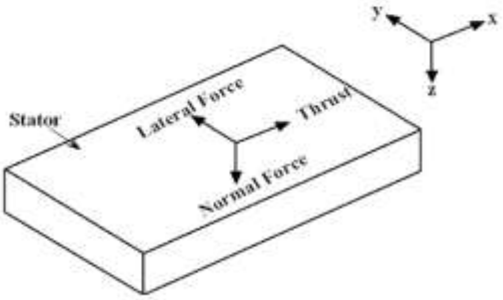

Figure 3: Force directions

Thrust:

Under normal operation, the LIM develops a thrust proportional to the square of the applied voltage and reduces as the slip is reduced.

The amount of thrust produced by LIM as follows:

$$F = \frac{P_1}{V_s}$$

Where,

F is the Thrust Force, P1 is the power transmitter to the rotor (W), Vs is the linear synchronous speed (m/s)

Normal:

The normal force is force between the stator and reaction plate. It is large in SLIM this is because of asymmetrical topology. At synchronous speed, the force is an attractive force and its magnitude is reduced as the speed is reduced. At certain speeds the force will become repulsive, especially at high frequency operation.

Lateral:

Lateral forces moves in the y direction. These occur due to asymmetric positioning of the stator in a LIM. Any displacement from the central positioning will result in an unstable system. Generally small displacement will only result in very small lateral force. At high frequency the lateral forces are quite chaotic. A set of guided mechanical wheel tracks is sufficient to eliminate small lateral force.[4]

B. Equivalent diagram of LIM:

The equivalent diagram of LIM is exactly the same as of a conventional 3 phase RIM.

Output equation:-

$$\text{KVA input } Q = C_0\, D^2 Ln$$

Where, Co is Output coefficient, n is speed in rps, D is diameter of motor, L is length of stator

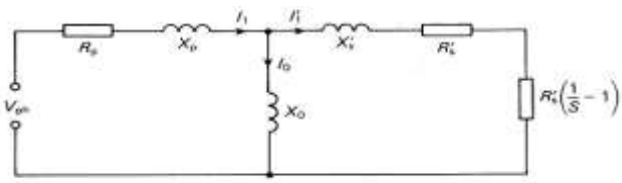

Figure 4: Linear motor equivalent circuit

C. Design Specification of LIM:

a. Output equation

$$\text{KVA input } Q = C_0 D^2 Ln$$

$$Q = \frac{KW}{n\cos\phi}$$

Where, Co is Output coefficient, n is speed in r.p.s., D is diameter of motor, L is length of stator

b. For overall good design

$$\frac{L}{\zeta} = 1$$

$$\frac{L}{\frac{\Pi * D}{P}} = 1$$

$$\frac{L}{D} = \frac{\Pi}{P}$$

Where, L is a length of stator, D is a diameter of motor, P is a number of poles, ζ is a pole pitch

c. Flux per pole

$$\phi_m = B_{av} * \zeta * L$$

Where, B is the flux density, ζ is a pole pitch, L is a length of stator.

d. Stator voltage per phase

$$V_{ph} = \frac{V_L}{\sqrt{3}}$$

Where, V_{ph} is phase voltage, V_L is the line voltage.

e. Slot dimension

Space required for bare conductor in slots =Zsq*as

$$\text{Slot pitch } \lambda = \frac{\zeta}{mq1}$$

$$\text{Slot width Ws=Tooth width Wt} = \frac{\lambda}{2}$$

$$\text{Let, slot depth (hs)} = \frac{\text{Total slot area}}{\text{slot width}}$$

Where, λ is the slot pitch

f. Depth of stator core

$$\text{Area of stator core ACS} = \frac{\Phi m}{\text{flux density in core}}$$

Assuming, 1.2wb/m^2 Flux density

g. Net iron Length

Net iron Length =0.9*L

$$\text{Depth of stator core} = \frac{Acs}{\text{net iron length}}$$

Outer diameter of stator=D+2hs+2dcs

IV. EXPERIMENTAL STUDY

Show in fig.5 experimental set up of SLIM .there is check the performance of the SLIM, under this motor how its work and also check the R/F switch. A reverse forward switch it is used for applying the direction to the drive system. The system being a linear drive the direction i.e. forward or backward is decided the reverse forward switch.

Figure 5: Experimental set up of SLIM

Show in fig.6 experimental setup of SLIM testing the performance of the motor .In this measure the current between the each phase (R, Y, B) with the help of clip on meter .Clip on meter which is the device measure the high voltage using low range ammeter (0-5A)

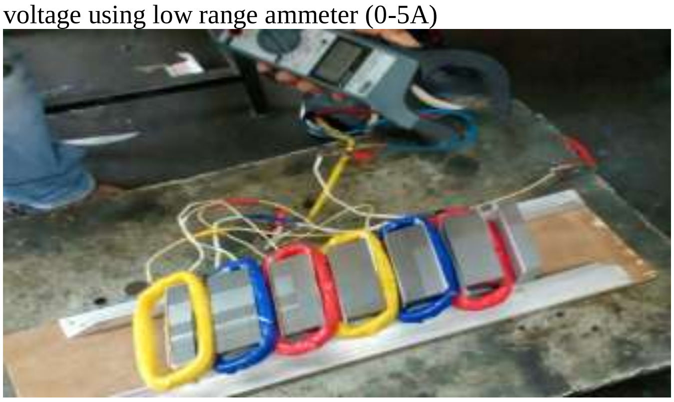

Figure 6: Experimental set up of SLIM testing the performance of the motor

V. RESULT AND DISCUSSION

Table 2: At constant voltage

SR.NO	INPUT VOLTAGE	LOAD IN GRAM	CURRENT IN AMPS	SPEED
1	100	0	8.24	↓ decreases
2	100	500	8.18	
3	100	1000	8.20	
4	100	2000	8.00	
5	100	3000	8.04	

Shows in table no. 2 there are input voltage are constant at range 100volts. The load are gradually increase by 0 to 3000 Gram. The load are in weight (0 to 3000gm) .but there voltage at all condition constant and load are vary and current are nearly equal are decreases and speed also decreases.

Table 3: At constant load

SR.NO	INPUT VOLTAGE	LOAD IN GRAM	CURRENT IN AMPS	SPEED
1	100	3000	8.16	Increases ↑
2	110	3000	8.91	
3	120	3000	9.35	
4	130	3000	10.26	
5	140	3000	11.21	
6	150	3000	12.05	

As shown in table 3.In this table input voltage are vary from 100volts to 150volts.but there are load are (weight in gram) constant at range 3000gm. But in this case current are gradually increases from 8amp to 12.05amp.

VI. CONCLUSION

In this work the experimental and theoretical study of a Conveyer using linear induction motor (LIM) was presented. A prototype model of conveyer using LIM was built and taking a regarding test, for controlling there are used a R/F switch (drum switch).

The air gap is very important role in linear induction motor. Performance improvement of linear induction motor (LIM) this parameter are considered characteristics, structure of winding, properties of material used. And the find the equation of design of LIM

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