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DESIGN OF TUBULAR LINEAR INDUCTION MOTOR

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Abstract: Nowadays, many industrial applications requires a reciprocating motion Including transportation, conveyor systems, actuators, material handling, pumping of liquid metal, and sliding door closers, etc. The rotary-to-reciprocatary converters with rotary motor are used to convert rotary motion into reciprocating motion. Instead of using rotary-toreciprocatary converters the Linear Induction is more advantageous has no gears and requires no rotary-tolinear converters. The reciprocating force is developed by reversing the phase sequence of Linear Induction Motor. The oscillations are inversely proportional to rate of Phase reversal.

Because it provides thrust directly and has a simple structure, easy maintenance, rapid acceleration, and low cost, the Linear Induction Motor (LIM) is highly helpful in situations that require linear motion.

A linear induction motor is a spinning squirrel cage induction motor that is opened flat 'Axially' and then rolled 'Radially.' Instead of generating rotating torque, a machine generates linear torque.

In this project, Linear Induction Motors been designed, equivalent circuit model is studied in detail it is planned to construct a LIM to identify and study the different concepts and parameters of the motor which are different from other types of electrical machines

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I INTRODUCTION

Induction in a straight line since its conception, the motor has been the centre of attention and is regarded the preferred option, therefore it is referred to as the industry's workhorse. Even in specialized and essential applications, it retains its popularity. Its shape can be changed depending on the application demand, allowing rotor motion to be transferred directly into linear motion without any additional processing. Any new mechanism is welcome. Its efficiency and dependability have been improved, and the motor has been renamed Tubular Linear Induction Motor. As a result, the Tubular Linear Induction Motor was created. A linear induction motor (LIM) is a type of induction motor that produces linear motion rather than rotational motion like a regular induction motor. A LIM is a low-speed vehicle. 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 a strong impact on the development of linear induction drives. Linear electric machines are direct drives; they allow acceleration, velocity and position-accuracy far better than their rotary counterparts. Conceptually all types of motors have possible linear configurations (dc, induction, synchronous and reluctance). The dc motor and synchronous motor requires double excitation (field and armature). This makes the hardware applications rather complex. The reluctance motor requires thrust since it has no excitation. This is the reason why most of the attention is diverted to LIM. LIM may have a moving primary (with a fixed secondary) or a moving secondary (the primary being stationary). LIM can be a short primary or short secondary, depending on whether the primary or secondary is shorter. In each case, either primary or the secondary can be the moving member. In our project stator of LIM act as primary and rotor acts as secondary and the primary is shorter than secondary. The secondary of the LIM is normally a conducting plate made of either copper or aluminium in which interaction currents are induced. Depending upon size and rating of the linear induction motors they can produce thrust up to several thousand Newton. The speed of the TLIM is determined by winding design and supply frequency. As in a rotary motor, a LIM may have either three phases or two or one.

Schematic Diagram:

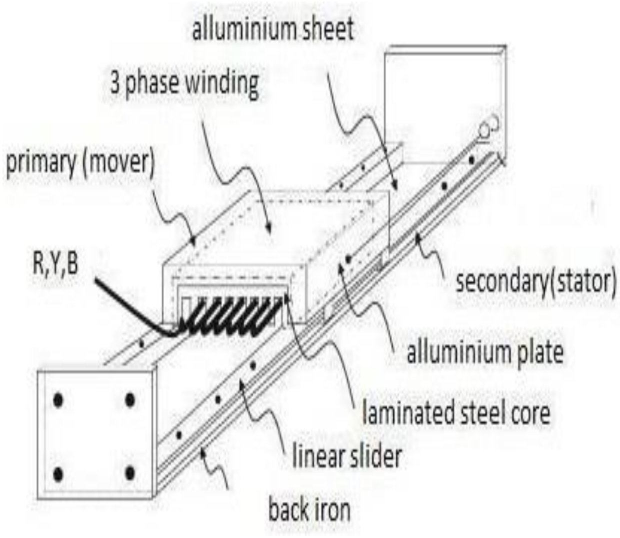


Fig1 Schematic diagram of LIM. **III.**

Principle of operation:

Linear Induction works similar to the Rotary Induction Motor; except that instead of producing Rotating magneticfield the LIM produces Linear Moving Field.

When a three phase supply is given to the three phase stator winding a linear moving field of constant magnitude is produced. The velocity of this Linear Moving field is Synchronous Velocity SV.

At start the secondary is stationary and statorflux is moving. So there occurs a relative velocity between the field and short circuited secondary. The stator field gets cut by secondary conductors, whenever the field gets cut by secondary the e.m.f. gets induced in secondary conductors due to electromagnetic induction called as secondary induced e.m.f. As the secondary forms closed circuit , induced e.m.f. circulates current through secondary conductorscalled as secondary current . Due to this current secondary conductors forms its own flux. So secondary produces its own flux called as secondary flux. Due to interaction between this two fluxes the secondary exerts a force in the direction of moving field.

According to Lenz's law the direction of induced current in the secondary is so as to opposethe cause producing it. The cause of secondary current is induced e.m.f. which is induced becauseof relative velocity present between the moving field and the secondary conductors. Hence to oppose the relative velocity i.e. to reduce the relative velocity ,the secondary experience a thrust in the same direction as that of moving field and tries to catch up the velocity of magnetic field.

In the LIM, it consist of field system having three phase distributed windings placed in slots while the secondary can be a reaction plate of aluminium or copper, in which interaction current are induced.

Forces in TLIM :

The main forces involved with the LIM are thrust, normal force. This project is interested in thrust and its relation to other variable parameters. The normal force is perpendicular to the stator in the z-direction.

Thrust Force:

Under normal operations, the LIM develops a thrust proportional to the square of the applied voltage, and this reduces as slip is reduced similarly to that of an induction motor with a high rotor resistance.

The amount of thrust produced by a LIM is as follows:

Thrust Force =Po (Output Power) Vr (Rotor

Velocity).

Where Po is the mechanical power transmitted to the rotor or the output power and Vr is the linear speed of the rotor.

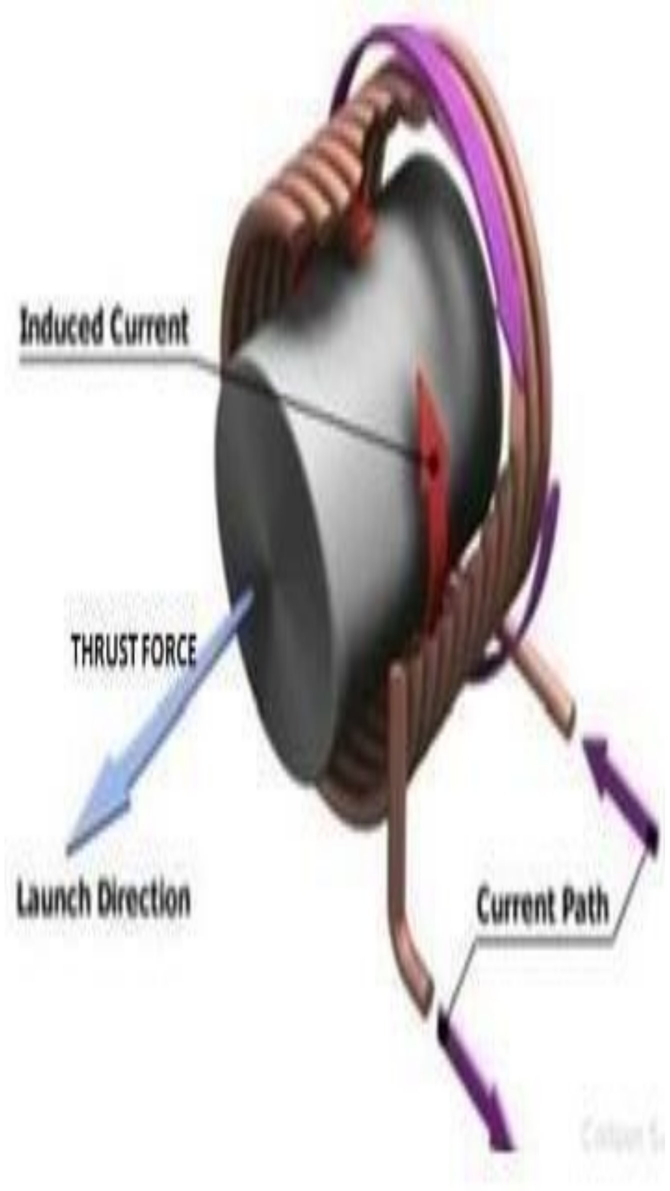


Fig.2Forces in TLIM.

Normal Force:

The normal force between stator and aluminium plate is attractive and its magnitude reduces as speed reduced.at certain speeds force will be repulsive especially at high frequency.

IV.Problem Statement :

Design a 3 phase Tubular linear induction motor with specifications as follows:

1. Output power 1 H.P.

2. 415v

3.4 pole

4.12 slots

5.Linear speed 4.8 m/s

V. DESIGN CALCULATIONS OF STATOR

1. $Number\ of\ slots = p * m * q$

   $= 4*3*1$

   $= 12$

2. $N_s = \frac{120f}{p}$

   $= \frac{120*50}{4}$

   =1500 rpm
   =25 rps

3. $Q = \frac{output}{\eta * \cos\phi}$

   $= \frac{0.746}{0.72*0.75}$

   = 1.381 KVA

4. $V_s = V_r = 4.8$ m/sec

5. Thrust force = Fd

   $= \frac{output\ power}{rotor\ velocity}$

   $= \frac{746}{4.8}$

   = 155.41 N

6. Input electrical power $= \frac{output}{\eta}$

   $= \frac{746}{0.72}$

   = 1036.11 W

7. Input Power=$\sqrt{3}*V_L I_L \cos\phi$

   $1036.11 = \sqrt{3}*415*I_L*0.72$

   $I_L = 1.9422A$

8. $V_s = 2\tau f$

   $\tau = \frac{V_s}{2f} = \frac{4.8}{2*50} = 0.048m.$

9. L= Total length of LIM stator
   = p*ploe pitch
   = 4*0.048
   = 0.192 m =192 mm

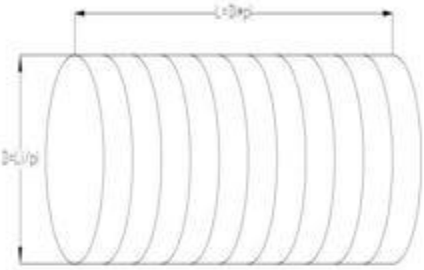


Fig.3.8 Conventional induction motor

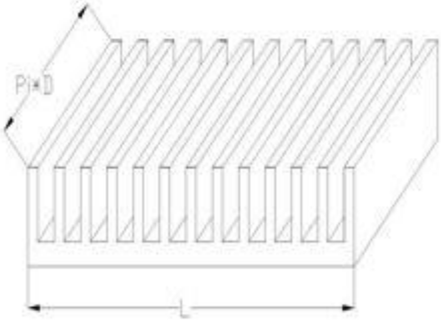


Fig.3.9 Linear induction motor

10.
Length of induction motor =Li= π*D

Stator bore diameter = Di = $\frac{L}{\pi}$ $\frac{192}{\pi}$

=

61.11mm.

11. Pole pitch, $\tau = \frac{\pi Di}{p}$

$$Li = \frac{1.5\pi Di}{P}$$

$$= \frac{1.5\pi * 61.11}{\tau}$$

= 72mm.

12. $= 1.03 * 10^{-3}$ wb

13. inner diameter = $Di = \frac{\phi m}{2 * Bav * Li}$

$$= \frac{0.00103}{2 * 0.3 * 0.072}$$

= 0.02399

= 24mm

14. $Eph = \Phi \quad * K_w \qquad 4.44 * F * Ts *$

$$Tsph = \frac{239.6}{4.44 * 50 * 0.00103 * 0.955}$$

= 1097 = 1100 turns

15. For 3 phase Ts = 1100*3 = 3300
total no of conductor = 3300*2
= 6600

conductor per slot = $\frac{6600}{12}$ = 550

16. Current density, δ = 4 A/mm^2

area of one conductor = $\frac{I}{\delta} \; \frac{1.942}{4}$

= 0.48 mm^2

Total area of 550 conductor
=550*0.48 = 264 mm^2

17. Space factor = 0.7

area of one slot= $\frac{copper\ area}{space\ factor}$

$$= \frac{264}{0.7}$$

= 377.14 ≈ 378 mm^2

18. Slot pitch =Yss = $\frac{L}{Ss} = \frac{0.192}{12}$

= 0.016 m.

Yss = wt + w

19. Maximum flux density of tooth
=1.7 wb/m^2

minimum tooth width = wt_{min}

$\models 0.0026 \approx 0.004$ m.

20. Width of stator slot Ws = Yss – Wt
= 0.016-0.004
= 0.012 m.

21. Depth of slot = $\frac{Aw}{Ws} = \frac{378}{12}$

= 31.5mm.

22. Diameter of slot depth =
inner diameter + 2*depth of the slot
= 24+2*31.5 = 87 mm.

23. Surface area of the tooth =

= Wt*π*D
= 0.004*π*0.0239
= 0.0003 m^2

Sr. No.	Parameters	Symbol	Value	Unit
1	Voltage	V_L	415	V
2	Frequency of supply	F	50	Hz
3	Number of phases	m	3	
4	Output power	Po	1	HP
5	Efficiency	η	0.72	
6	Power factor	ϕ	0.75	
7	Poles	P	4	
8	Slip	S	15	%
9	Rotor velocity	Vr	4.8	m/s
10	Li/Ti ratio		1.5	
11	Number of slots	Ss	12	
12	Specific magnetic loading	Bav	0.3	Wb/m^2
13	Winding factor	Kw	0.955	
14	Current density	δ	4	A/mm^2
15	Space factor	Sr	0.7	
16	Max flux density for tooth	Bt	1.7	Wb/m^2
17	Max flux density for yoke	By	1.3	Wb/m^2
18	Air gap	g	2.5	mm
19	Thickness of aluminium secondary	d	5	mm

Table no. 3.2 Assumptions for calculation

STATOR DESIGN

VI. STATOR WINDING DESIGN :

- P = 4
- Slot = 12
- ∴Pole Pitch=Slot/Pole=12/4=3
- $q = \frac{slots}{pole*phases} = \frac{12}{4*3} = 1$

VII. Distribution of winding:

PHASE	SLOTS			
R	1	4	7	10
Y	2	5	8	11
B	3	6	9	12

Table no.3.3 Distribution of winding

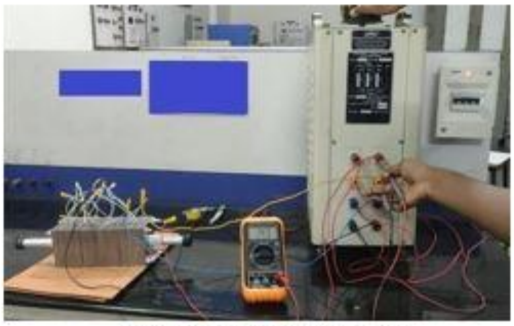
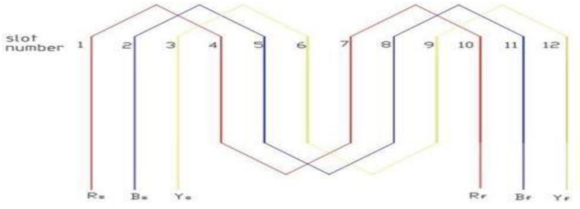


Fig.4.1 Test setup for TLIM



Stator winding design of 3 phase linear induction motor
4 pole , 12 slots ,wave winding, phase sequence – RYB

Fig.4.2 Stator winding design

VIII. TEST RESULTS:

1) Rated Voltage = 415V
2) Minimum Voltage required = 140V
3) Rated movement speed = 4.8 m/

Table no. 4.1 Test Results

Voltage		Current	P.F	Power
230		2.6	0.72	750
220		2.5	0.73	700
210		2.4	0.74	650
Avg	220	2.5	0.73	695

Table no. 4.1 Test Results

IX CONCLUSION:

Hence we designed Tubular Linear Induction Motor and by testing we observed that there is sufficient force is generated for the movement of rotor.

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