International Journal of Engineering, Science and Metallurgy

(Research article)

Study and FE Analysis of Eddy Current Losses of Double Sided Linear Induction

Rakesh Kumar*[a], Manpreet Singh Manna[b], Sanjay Marwaha[b]

[a]Department of Electrical and Electronics Engineering, JCDMCOE Sirsa Haryana
[b]Department of Electrical and Instrumentation Engineering, SLIET (Deemed-to-be-University), Longowal, Distt. Sangrur(pb.), India

Accepted 18 July 2012, Available online 1Sept 2012

Abstract

Linear drive technologies are steadily expanded in various applications, especially in industry, where high precision electrical direct drive systems are required. In this paper a double-sided permanent magnet linear motor is presented. Its characteristics are computed by means of 2D FEM magnetic field analysis. The analysis model taking into account the EM Losses and secondary moving is proposed. The Magnetic force is calculated at various triangles using Maxwell. The simulation results are found to be a good prediction to the total Energy Error and total Power Loss.

Keywords: *Finite Element Method, Magnetic Force, Total Power Losses, Maxwell (Ansoft), Double sided linear induction motor.*

1. Introduction

Nowadays, Linear Induction Motors are widely used in many industrial applications, including transportation, conveyor systems, actuators, material handling, pumping of liquid metal, sliding door closers, with satisfactory performance. The most obvious advantage of linear Motors is that they have no gears, and require no mechanical rotary to linear converters when translation of payload is concerned. The Linear Induction Motor has many advantages such as simple structure in place of the gear between the Motor and the motion devices, reduction of mechanical losses and the size of motion devices, silence, high starting thrust force, easy maintenance, repairing, and replacement. But for high precision motion performance, the friction problem is one of the significant limitations.

Three-phase linear drive is used more often in industry because it is characterized by greater power and efficiency; however, connection requires a three-phase feeding network. Single phase drive has less efficiency, but can be utilized where there is a single-phase feeding network. Therefore, single phase drive is more widely applied for domestic appliances; they can be used as controlled servomotors in automatic system. The Single Sided Linear Induction Motor is proven as a better drive for urban transit vehicles, Comparing to Rotary Induction Motor drive system, it could achieve more propulsive thrust independent on friction between wheel and rail. Furthermore, it has smaller turn circle radius, smaller sectional area of a tunnel, stronger climbing ability, lower noise, bigger acceleration and so on. Classification of Double Sided Linear Induction Motor

1. Long Primary and short Secondary DLIM
2. Short Primary and Long Secondary DLIM

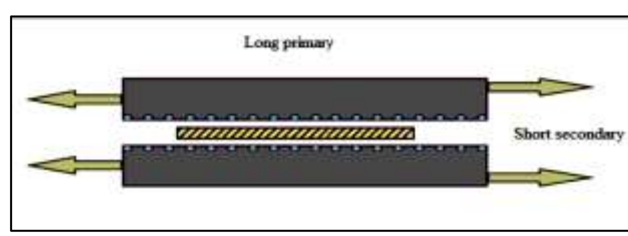

Fig. 1 Long Primary and Short Secondary Double Sided Linear Induction Motor

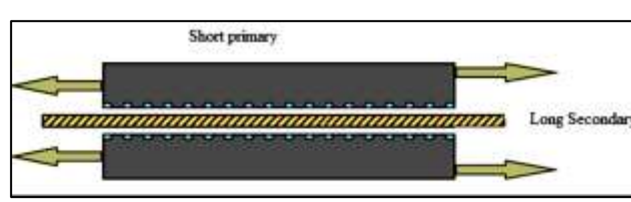

Fig. 2 Short Primary and Long Secondary Double Sided Linear Induction Motor

*Corresponding author's email: rakeshkamboj87@gmail.com

2. Double sided linear induction are studied

The Double Sided Linear Induction Motor is two primaries and one secondary region. The primaries are either finite or infinite length. In present work Double Sided Linear Induction Motor with infinite length of primary and finite length of secondary is used. The short secondary laminated core with conventional one phase winding mounted under the carriage is in motion. While primary region capped with permanent magnet is stationary part. To ensure safe operation, mechanical clearance between two parts is larger than that of the rotary motor. Magnetic flux excited by the secondary windings passes through the air-gap and ferromagnetic stainless-steel and closes by the ferrite magnetic material. The synchronous traveling magnetic field moves in the opposite direction relative to the moving secondary.

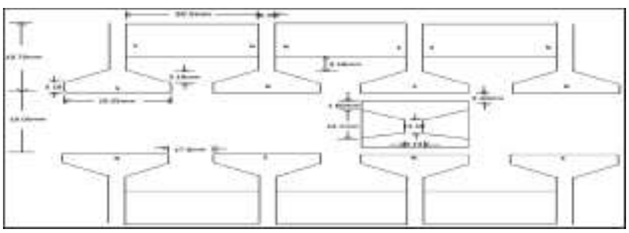

Fig. 3 Model of Double Sided Linear Induction Motor

The Model of Double Sided Linear Induction Motor used for the High speed application is analyzed using Finite Element Method. The structure Model Specification of Double Sided Linear Induction Motor and the coordinate system are shown in Table 3.1. The secondary is moving and composed by secondary core laminated by silicon steel sheet and winding coil. The primary with teeth and rectangular pole is installed with given air-gap with secondary.

Double sided linear induction motor simulation model

When a medium moves into an electromagnetic field, a kinetic electromotive force equal to V × B will be induced [31]. If the medium velocity is much smaller than the light speed, the total induced electromotive can be expressed by

$E_{Total} = E + V \times B$

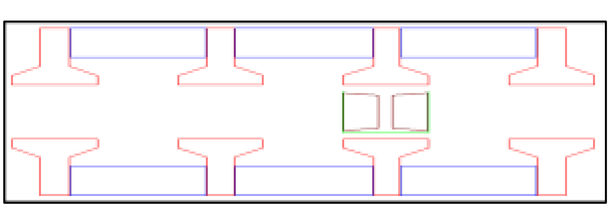

Fig. 4 Double Sided linear induction motor

The Starting Electromagnetic force in Linear Induction Motor is given by

$$F_{st} = \frac{m_1}{V_s}\left(I_{2st}^2 R_{2st} + \frac{E_1^2}{R_{ref}}\right)$$

Some Linear Levitation Motor develop two mutually perpendicular forces one in the direction of motion and the normal to the direction of motion. The normal force may be an attraction or a repulsion force between the primary and secondary [16]. A Machine in which the net normal force is such that the secondary tends to the suspended over the primary may be used mainly for suspension and called a Linear Levitation Motor. The electromagnetic phenomenon of machine is study for the Model under consideration. The air-gap field is produced by the primary, travels at the synchronous speed which is related to slip and the speed of the secondary.

$$s = \frac{U_s - U}{U_s}$$

In Linear Induction Motor analysis is carried out in the term of electromagnetic field equation. The slotted structure is replaced by a smooth surface and the current carrying winding is replaced by fictitious, infinitely thin current element called current sheet, having linear current densities. The current density distribution of the current sheet is the same as that of the slotted-embedded conductor configuration, such that the field in air-gap remains unchanged. The amplitude of the current sheet is given by relation.

$$J_m = \frac{\sqrt{2}\, m W I K_w}{p'}$$

The definition of the optimum goodness factor is based on the idea that it is possible to design a linear Induction Motor. So that it's predicted thrust at synchronous speed is zero [37]. The basis for this conjecture is that a Rotary Induction Motor develops no torque at synchronous speed, and an ideal Linear Induction Motor (Having no end effects) may be obtained. The goodness factor is a useful index in preliminary design of Linear Induction Motor, however the large goodness factor does not necessarily ensure maximum thrust and efficiency for high speed Linear Induction Motor. Certain modification to the goodness factor must be made in such case and it may be preferable to use the optimum goodness factor. Goodness factor is given as

$$G = \frac{2f\mu_0\sigma\tau^2}{\pi g}$$

Finally, the fundamental definition of the goodness factor for the secondary, in term of equivalent circuit is given as.

$$G = \frac{X_m}{R_2}$$

3. Result of field simulation

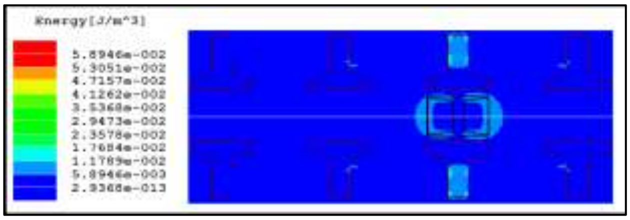

Fig. 5 Energy of DLIM

In Analysis of Double Sided Linear Induction Motor Energy Produce at Different part of The DLIM structure is study.

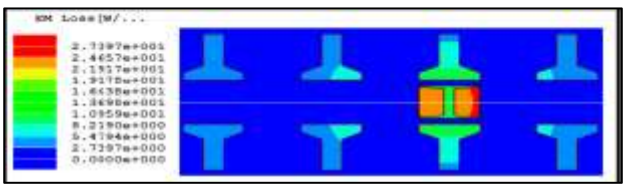

Fig. 6 EM Loss of DLIM

In The Double Sided Linear Induction Motor Secondary is force generated part of Motor. The winding is provided at secondary region to produce magnetic force. The Magnetic Force is in the form of Electromagnetic wave. The Electromagnetic wave passed through different region of the Motor and produce Magnetic Force. The Magnetic Force is directly proportional to Current Density. In the simulation of double Sided Linear Induction Motor value of Current Density is take about 10A and Frequency of operation about 50 HZ. The total losses of the Motor are depend upon frequency. Measurements of iron losses in magnetic material are traditionally made with sinusoidal flux density of varying frequency and magnitude. The total iron-loss density is commonly expressed in the following form for sinusoidal varying magnetic flux density with angular frequency

$P_{iron}= P_h+P_e$

$P_h = K_h B^{\beta} W_s$

$P_e = KeB^2 W_s^2$

Meshing refinement data of DLIM

Triangles	Total Energy	Energy Error	Magnetic Force (N)	Total Power Loss (W)
1290	3.14393E -005	0.8626	1.04107E -006	1.30546E- 002

In Double Sided Linear Induction Motor Structure breaking up a physical domain into smaller sub domains or elements in order to facilitate the accurate numerical

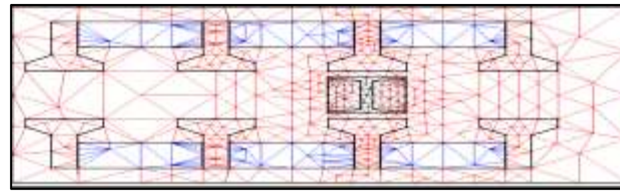

Fig. 7 Mesh around the air-gap

solution of a partial differential equation. The representation of a given domain by a collection of simple geometric shapes requires engineering judgment on the part of practitioner. The number, shape (i.e. triangular and rectangular), size and density (i.e., mesh refinement) of elements used in a given problem depend on a number of considerations.

Conclusion

The Electromagnetic Field Characteristics of DLIM is investigating at different part of Motor without air-gap. The accurate value of Electromagnetic Field are study at various part such that tooth pole, rectangular pole, secondary core are also. Finally result obtain from the Meshing refinement data is also study to analysis of FEM. The Maxwell (Ansoft) is provided accurate result for given Model of DLIM.

References

1. Tiejun Zhou, Yumei Du, Junfei Han Wei Xu, ―Performance Analysis of a Linear Induction Motor Based on the Finite Element Method,‖ Proceedings of IEEE, Applied Superconductivity and Electromagnetic Devices, 2009, pp 163-166.
2. Tong Yang, Libing Zhou, Langru Li, ―Performance Calculation for Double Sided Linear Induction Motor with Short Secondary‖, IEEE Conference on Electric Machine and System, 2008, pp 3478- 3483.
3. Tong Yang, Libing Zhou, Langru Li, ―Finite Element Analysis of Linear Induction Motor for Transportation Systems‖, IEEE Conference on Vehicle power and Propulsion, 2008.
4. T. Sadauskas, A. Smilgevicius, Z. Savickiene, "Distribution of Magnetic Field of Linear Induction Motor‖, ISSN 1392 – 1215, Electronic and Electrical Engineering Elektronika IR Elektrotechinika, 2007. Nr. 4(76), pp 63-66.
5. T. Chevalier, A. Kedous-Lebouc, B. Cornut, C. Cester, ―Estimation of Magnetic Loss In an Induction Motor Fed with Sinusoidal Supply using a Finite Element Software and a New Approach to Dynamic Hysteresis‖, IEEE Transaction on Magnetics, Vol. 15, No.5, Sep. 1999, pp 3400-3402.
6. T. W. Preston, A. B. J. Reece, ―Transverse Edge Effects in Linear Induction Motor‖, IEEE Proc., Vol. 118, No. 12, Dec. 1971. pp 1820-1821.
7. Wei Xu, Jianguo Zhu, Youguang Guo, Longcheng Tan, Shuhong Wang, ―Analysis on Performance of Linear Induction Motor Basing on Winding Function Method,‖ ICIEA 2009, pp 3639-3642.
8. Wei Xu, Guangsheng Sun, Yaohua Li, ―Research on Performance Characteristics of Linear Induction Motor‖, IEEE Conference on Industrial Electronic and application, 2007, pp 86-89.
9. Yang Jia-xiang, Ma Feng-lian,Yang Yan-hua, ―Numerical Analysis of Starting Characteristic of Tubular Linear Induction Motor Based on Finite Element Method,‖ International Conference on Electrical and Control Engineering, 2010, pp 3921- 3924
10. Zbigniew Gmyrek, Aldo Boglietti, Andrea Cavagnino, ―Estimation of Iron Losses in Induction Motors: Calculation Method, Results and Analysis‖, IEEE Transaction of Industrial Electronic, Vol. 57, No. 1