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Double Sided Linear Induction Motor Modelling in 3D for EMALS

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ABSTRACT: Electromagnetic Aircraft Launching System (EMALS) is a technology that improves the performance, reliability and highly flexible. It is an emerging technique for launching aircrafts which utilizes a fully united system and can effectively accelerate naval aircraft from the deck of its carrier to its take-off speed. This paper describes the basic design of Double Sided Linear Induction Motor (DSLIM) using Finite Element Method (FEM) which provides more flux as compared to Single Sided Linear Induction Motor owing to its double stator unit.

KEYWORDS: Double Sided Linear Induction Motor (DSLIM), Electromagnetic Aircraft Launch System (EMALS), Ansys Maxwell and Finite Element Method (FEM).

I.INTRODUCTION

Researcher has analysed different techniques to power-assist an aircraft into flight. Steam Catapult system is one of the ancient launching technique which serves to be very useful for launching the naval aircraft. But recent development in this system reached to a technical end. The advancement in the aircraft demands more energy for launching purpose and steam catapult is unable to meet this necessities. EMALS has several advantages over the former steam catapult system; it offers feedback due to which controlling acceleration is possible. EMALS is low maintenance system as its moving part never touches the stationary part of the system which reduces the mechanical wear Ref [1, 2].

Electromagnetic aircraft launch system (EMALS) is an united system that accelerate the naval aircraft from the deck of aircraft carrier in about 300 ft (100m) to its "wind-over-deck" takeoff speed of more than 100 m/sec so that the aircraft can literally take flight as it reaches the end of the carrier deck. EMALS is an age old technology, whose initiation in development started long back in 1946 by Westinghouse engineers but still under development. This system is only developed by U.S army with help of General Atomics (GA) for newest Gerald ford aircraft [3]. The Indian navy desires to use this state of art to increase the capability and efficiency of launching. EMALS utilize linear motor (LM) for launching purpose as well as it serves the purpose of braking and retracting, thereby reducing all the auxiliary elements and reducing the complexity of the general system. The hazards from compressed gas, hydraulic oils etc. which are released with every shot in atmosphere would be eliminated.

This paper is structured in the following schematic way Section II deals with basic block diagram of EMALS. Section III describes the 3D modelling of Double Sided Linear Induction Motor. Section IV mainly concentrates on parametric evaluation of machine design. Section V includes the brief idea about the method used for designing purpose that is Finite Element Method. Section VI will provide the simulation results, conclusion the future directions.

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II. EMALS STRUCTURE

EMALS as a whole system consist of four main subsystem; which are Power source subsystem, Power conditioning subsystem, Launch motor subsystem and Closed-loop control subsystem [1]. The schematic of EMALS with modular DSLIM is shown in fig. 1.

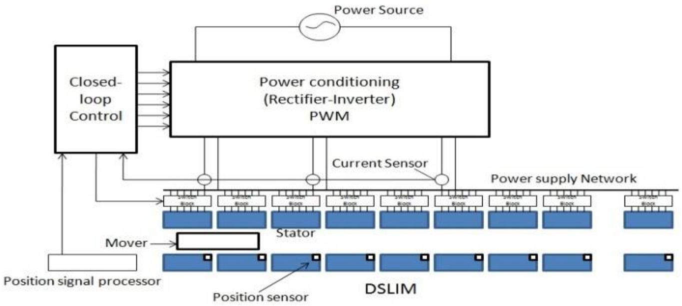

Fig. 1 The basic structure of EMALS

A. Power Source Subsystem

The power requirement of the launch motor exceeds the continuous power supplied by the ship. Thus demand for more power is then accomplished by the four flywheel arrangement. Flywheel is used for storing energy during launching of aircraft. 4 flywheels of same size and weight are used, two will rotate in clockwise direction and other two will rotate in anticlockwise direction. Speed of rotation of flywheel is 4000-5000 rpm. Other options are ultracapacitors, SMES (Super Conducting Magnetic Energy Storage).

B. Power Conditioning Subsystem

The power from power source subsystem is then converted to power of variable frequency and variable voltage with aid of cycloconverter. Since Launch motor operates at high frequency 70-200 Hz and voltage in kV. The cycloconverter provides a controlled rising frequency and voltage to the LIM.

C. Launch Motor

The power from power conditioning subsystem is then feed to launch motor using block feeding method. According to this method, it energies only the small portion of stator coils that affect the launch carriage at any given moment. The launch motor considered in this research is linear induction motor (LIM).

D. Closed-loop Control System

Power is controlled through a closed loop system. Operation on the track is monitored by Hall Effect sensors, allowing the system to make certain that it provides the desired acceleration. The launch stresses on the plane’s airframe is reduced due to the closed loop system which allows the EMALS to maintain a constant tow force.

E. EMALS Requirement

The basic parameter requirement for EMALS to launch aircraft from carrier deck to is take off speed is mentioned in table I.

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TABLE I. BASIC PARAMETRS OF EMALS

Sr. No.	*EMALS Requirement*	
	Parameters	***Value***
1.	End Speed	28-103 m/s
2.	Launch energy	122 MJ
3.	Maximum length	≈100 m
4.	Maximum thrust	1.3 MN
5.	Maximum braking distance	10 m
6.	Cycle time	45 s

III. 3D MODELLING OF LINEAR MOTOR

Here in the modelling process of 3D linear motor, only the designing consideration of one stator module is assumed which of length 2.31meter. Accordingly the length of the mover is considered. The fig. 2 shows the designing of DSLIM with long stator and their physical parameters are also mentioned**.** It is the most desirable choice for EMALS, due to the reason that flux linkage is more in rotor as it is surrounded by two stator fields which in turn produce more thrust.

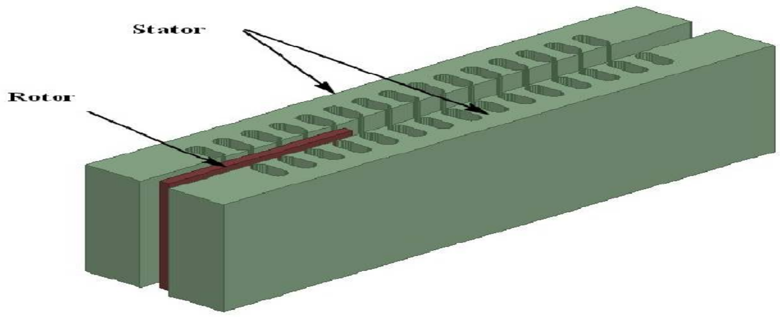

Fig. 2 DSLIM with long Stator

A. Stator Unit

The whole launch motor is consisting of numbers modular stator segment which make easy replacement of faulted part. Each stator segment is made of silicon steel. Double layer winding is employed by DSLIM.

B. Rotor Unit

Rotor is solid material made of copper sheet on both side of iron plate. The arrangement looks like sandwich which is used to improve strength and bearing capacity.

IV. BASIC DESIGN

A. Physical Parameters of DSLIM

The physical parameters described in table II are calculated manually by neglecting certain parameter to reduce the complexity.

TABLE II. PHYSICAL PARAMETERS OF DSLIM

Sr. No.	**Physical Parameters**	
	Parameters	**Value(unit)**
1.	Stator Unit Length	231 cm
2.	Stator Width	54 cm
3.	Stator Thickness	45 cm

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Sr. No.	Physical Parameters	
	Parameters	Value(unit)
4.	Rotor length	60 cm
5.	Rotor width	54 cm
6.	Rotor Thickness	6 cm
7.	Airgap	0.3 cm
8.	No. of Slots	18

B. Operational Parameter of DSLIM

The electrical Parameter described in table III are obtained by applying certain constraint as per the EMALS requirement mentioned in table I and design criteria.

TABLE III. ELECTRICAL PARAMETERS OF DSLIM

Sr. No	Electrical Parameter	
	Parameter	Values(Unit)
1.	System Phase Voltage	1905 V
2.	No. of Phases	03
3.	Weight of the aircraft carrier	15000 kg
4.	No. of Poles	06
5.	Current Density	25 A/mm^2
6.	Power Factor	0.48
7.	Frequency	136 Hz
8.	Slip , S	0.046
9.	Efficiency	0.6

V. FINITE ELEMENT METHOD FOR DSLIM

The mathematical formulation is tedious and usually not possible by analytical methods in complex engineering design problems. Therefore using numerical techniques is attractive and useful. Operating DSLIM is becoming trendy and it is necessary as well because of necessity of high speed linear motion. Therefore the finite element method (FEM) is usually considered to be the ideal approach to operate Double sided linear induction motor.
For using software based FEM there are three steps

1. Preprocessing - Consumes maximum time out of the three steps. This deals with software based geometry, meshing (or discretisation to convert infinite degree of freedom to finite one) and boundary conditions.
2. Processing (or solution) – just click on “analyze” and the software does the job. Internally software carries out many processes like matrix formations, inversion, multiplication and solution for unknown.
3. Post processing – It consist of viewing the result, interpretation of the data, verification, conclusion and critical thinking for improving design.

A. FEA for 2.31 Meter Stator Unit

The Motor design is carried out using RMxprt and Maxwell 3D. In order to analyse the magnetic field distribution created by the stator windings; a six poles, 18 slots 3D model is demonstrated for 2.31 m. The symmetry and periodicity of the model is considered as shown in fig. 3.

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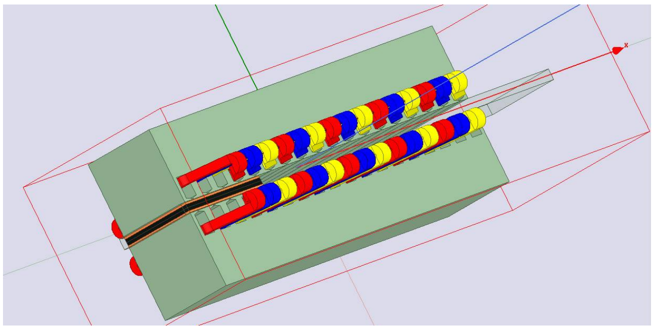

Fig. 3 3D Model of *DSLIM in Maxwell*

VI. SIMULATION RESULTS

The DSLIM model has been analyzed and studied for loading conditions where rotor (mover) is loaded with payload as aircraft of weight 15000kg and graphs for the different parameters are shown in fig. 4.1 to 4.5.

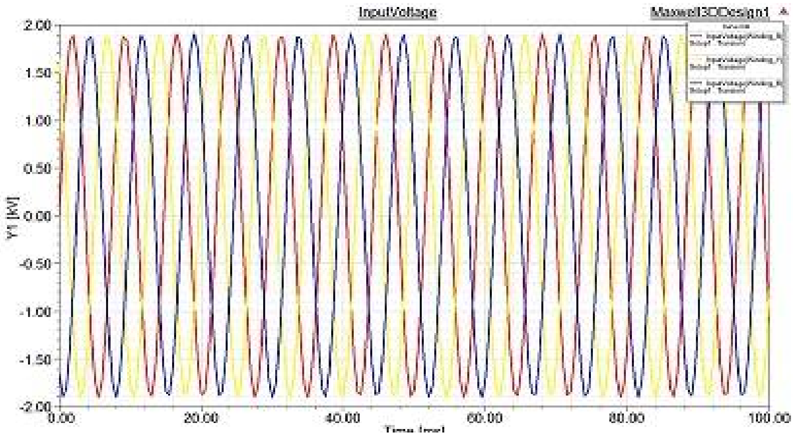

Fig. 4.1 Input Voltage Vs Time

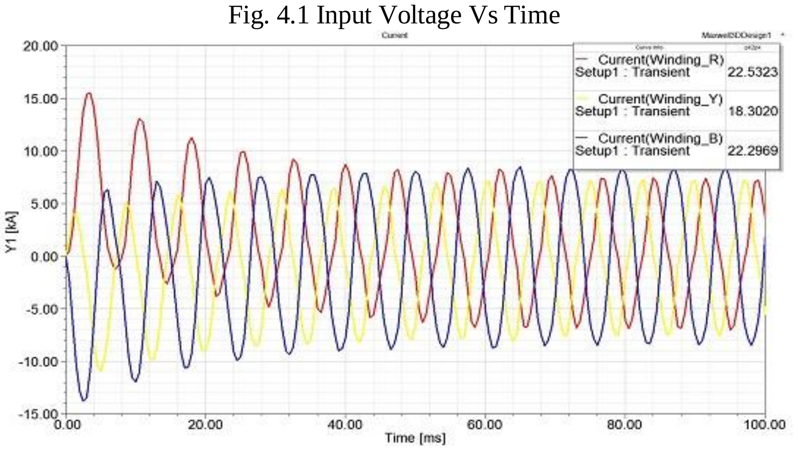

Fig. 4.2 Current Vs Time

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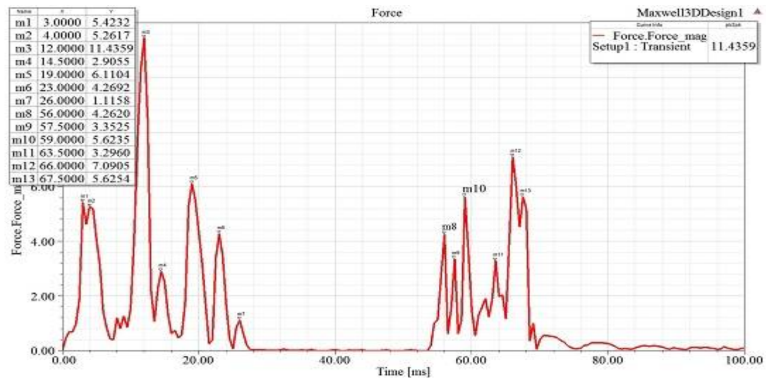

Fig. 4.3 Force Vs Time

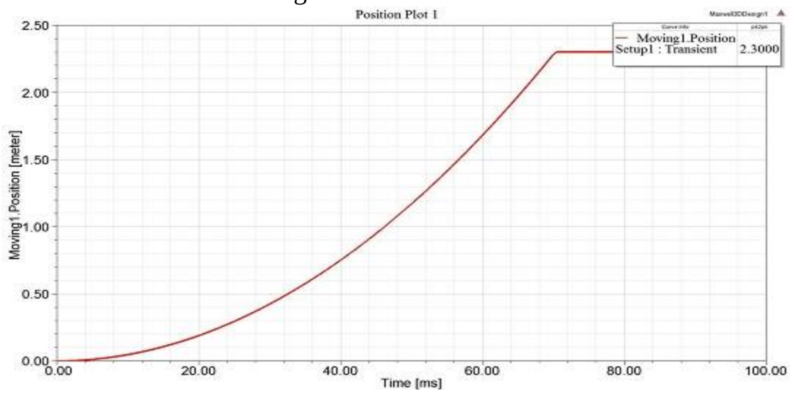

Fig. 4.4 Position of rotor Vs Time

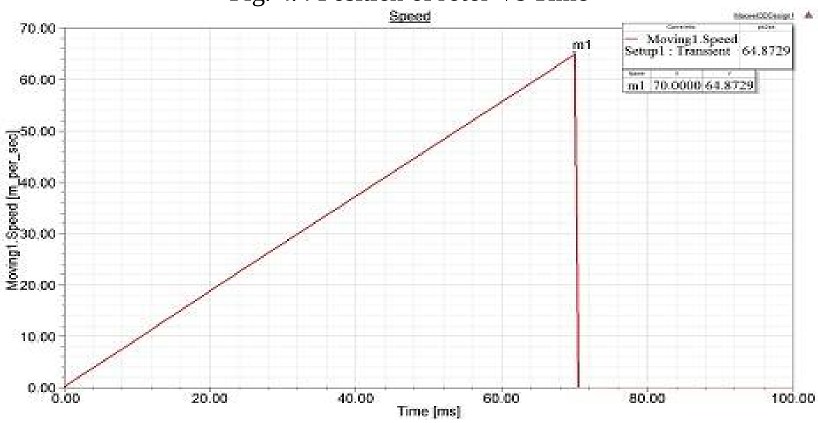

Fig. 4.5 Speed Vs Time

DSLIM is excited with 3 phase sinusoidal supply of 1.905 kV as shown in figure 4.a. Initially, due to absence residual flux and high inductances the current wave form starts from zero as obtained in figure 4.b. During transient period, t<80ms, maximum current I is 22kA. Figure 4.d and 4.e respectively shows the displacement of the rotor is of parabolic nature due to inertia acting on rotor for loading condition and speed varies linearly with respect to time. Table IV describes the value obtained from the results.

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TABLE IV. RESULTS FOR LOAD-CONDITION

Sr. No.	**Output**	
	Parameter	***Load condition***
1.	Maximum Force	65 kN
2.	Speed	Variable 0 – 180 m/s
3.	Position	Varies parabolically
4.	Transient Current	T<80ms; 22kA

VI.CONCLUSION

3D model of DSLIM for stator module of 2.31 lengths is designed and studied. The basic designing and parameter determination is discussed. The FEM model was build using Ansys Maxwell software to analyse the electromagnetic behaviour. The results show the DSLIM operation for loading condition with payload of 15000 kg.

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