3D Modeling of Double Sided Linear Synchronous Motor for EMALS

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***Abstract*—Electromagnetic aircraft Launch System is integrated system used for launching naval aircraft. To accelerate the aircraft to launch speed; EMALS uses linear motor. At this state, Double sided linear synchronous motor (DSLSM) looks to be a far better as well as an improved alternative owing to higher potency and better power issue, which might plainly scale back the capability of power offer and facilitate the ability electrical converter design. DSLSM is made with long stator coil and short moving permanent magnet rotor. Owing to the specific generation and storage capability supply voltage is restricted to certain limit. This paper describes the basic design of DSLSM using finite Element Method (FEM).**

***Keywords*—Double Sided Linear Synchronous Motor (DSLSM), Electromagnetic Aircraft Launch System (EMALS), Permanent magnet(PM) and Ansys Maxwell, Finite Element Method (FEM).**

I. INTRODUCTION

Since the invention of flight, researchers are investigating various techniques to power assist aircraft into flight. The evolution of the catapult system has gone from large rocks to weighted luggage in ancient era, to spinning flywheels then the hydraulic driven systems. Presently, Steam driven catapults are getting used to meet this purpose. EMALS (Electromagnetic launch system) has many advantages over the presently inducted Steam primarily based Launch system (Steam Catapult) such as it offers feedback due to which controlling acceleration is possible along with 30% more launch energy [1]. EMALS is low maintenance system since its moving part never touches the stationary part of the system which reduces the mechanical wear; it improves reliability of the system as well as enhances overall efficiency of ship [2].

With the recent development in EMALS; the Indian navy desires to use this state of art to enlarge 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.

II. STRUCTURE OF EMALS

EMALS working is generally based on four main subsystems:

1. Power source subsystem
2. Power conditioning subsystem
3. Launch motor subsystem
4. Closed-loop control subsystem

The arrangement of EMALS with modular DSLSM is shown in Figure. 1.

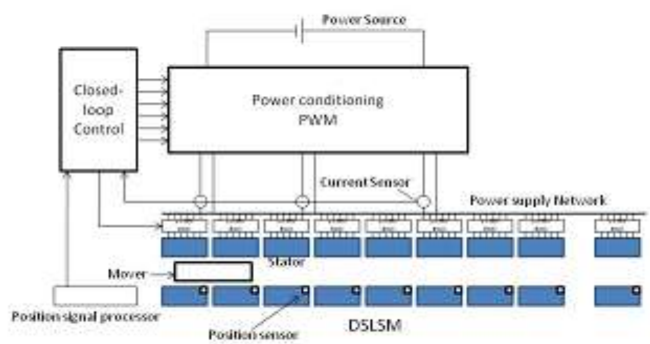


Figure 1: The basic structure of *EMALS*

The current design of EMALS revolves around a linear synchronous motor. In EMALS, rotors of the disk alternators stores prime energy generated by an independent source on the host platform. The stored kinetic energy operates dual stator four disk alternators and spins its rotors in 45 sec during launch of aircraft. High frequency power released in pulses and transferred to the cycloconverter. Cycloconverter operates EMALS in most efficient way by allowing running the coils which impacts the launch at a particular time. It produces high voltage and raised frequency to power the linear synchronous motor in order to accelerate the aircraft for launch.

A. EMALS Requirement

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

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

Sr. No.	*EMALS Requirement*	
	Parameters	***Value***
5.	Maximum braking distance	10 m
6.	Cycle time	45 s

III. 3DMODELLING OF LINEAR MOTOR

The Figure.2 shows Double sided iron core surface permanent magnet linear synchronous motor with long primary (stator) and short secondary (rotor) has been chosen for EMALS application as it has much better power factor, which simplifies the power inverter design. So it improves overall efficiency of the system and would have great positive impact on electric ship.

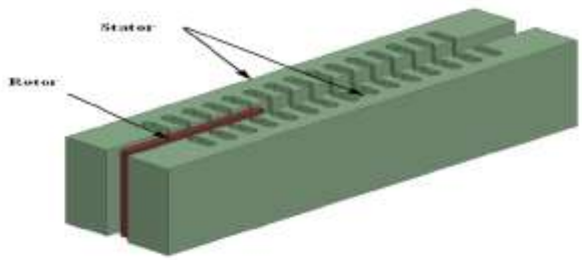


Figure 2: *Construction of DSLSM*

A. Stator Unit

The stator construction of DSLSM is based on the concept of 'modular stator segments' where all stator units are identical & electrically connected in parallel. M19_24G (M19 is a type of steel with 24 gauge thickness) material type has been chosen for stator construction as it has several benefits such a low average core losses, minimal eddy current circulation, superior permeability at high inductions, good gauge uniformity & excellent flatness with high stacking factor.

B. Rotor Unit

Rotor is made up of permanent magnets where PM's are inserted into the rotor frame. Rare earth materials, neodymium iron-boron (NdFeB) has selected since it provides high flux density, high coercive force, high energy product and linear demagnetization curve and low temperature coefficient.

C. Armature Winding of slotted cores

The machine is modeled with full pitch distributed winding and semi-opened slot structure to provide better cooling arrangement. Copper conductor material with rectangular shape is used.

IV. BASIC DESIGN

A. Design Parameters of DSLSM

The physical parameters described in Table II are calculated manually by neglecting certain parameter to improve the simplicity of other circuitry.

TABLE II. DESIGN PARAMETERS OF DSLSM

Sr. No.	**Design Parameters**	
	Parameters	***Value(unit)***
1.	Stator Unit Length	231 cm
2.	Stator Width	54 cm
3.	Stator Thickness	45 cm
4.	Rotor length	60 cm
5.	Rotor width	54 cm
6.	Rotor Thickness	40 cm
7.	Airgap	0.5 cm
8.	No. of Slots	18

B. Operational Parameter of DSLSM

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

TABLE III. ELECTRICAL PARAMETERS OF DSLSM

Sr. No	**Electrical Parameter**	
	Parameter	***Values(Unit)***
1.	System Phase Voltage	1905 V
2.	No. of Phases	03
3.	Weight of the aircraft carrier	1500 kg
4.	No. of Poles	06
5.	Current Density	30 A/mm^2
6.	Power Factor	0.7
7.	Frequency	200 Hz
8.	Efficiency	0.8

V. FINITE ELEMENT METHOD FOR DSLSM

Electrical machine modeling is crucial and important as it saves time and is economical. Consequently, it is regularly difficult to calculate and analyze the motor overall performance with consistent accuracy through the classical circuital methods. Therefore numerical techniques are found more fascinating and advantageous. Because of the various requirements of high speed linear motion, now-a-days DSLSM is becoming popular. Hence for Electromagnetic designs, the finite element method (FEM) has shown its reliability and accuracy.

A. FEA for 2.31 Meter Stator Unit

The design of motor was achieved by using RMxprt and Maxwell 3D. In order to analyze 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 Figure 3.

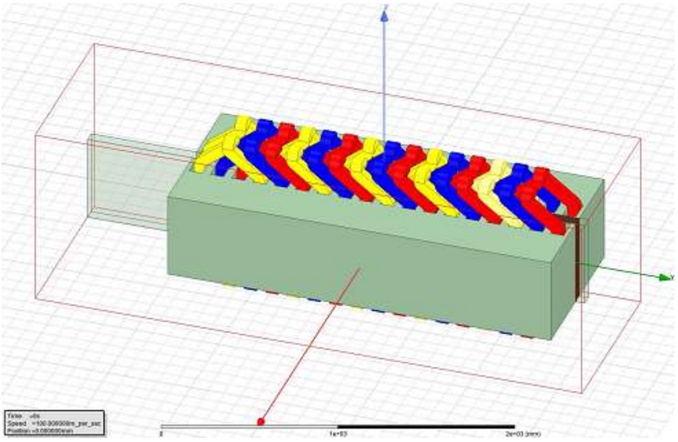
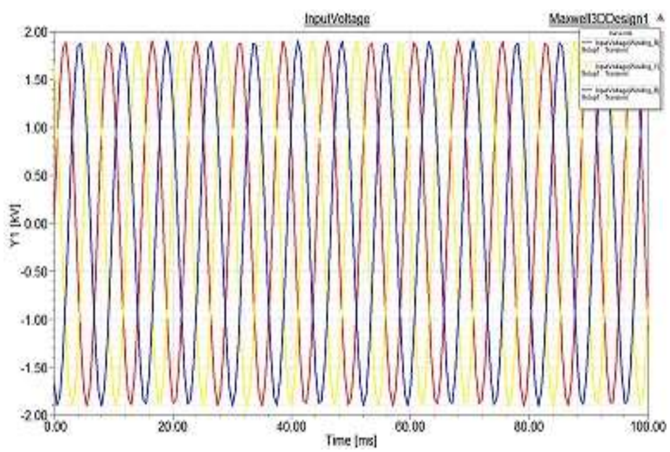


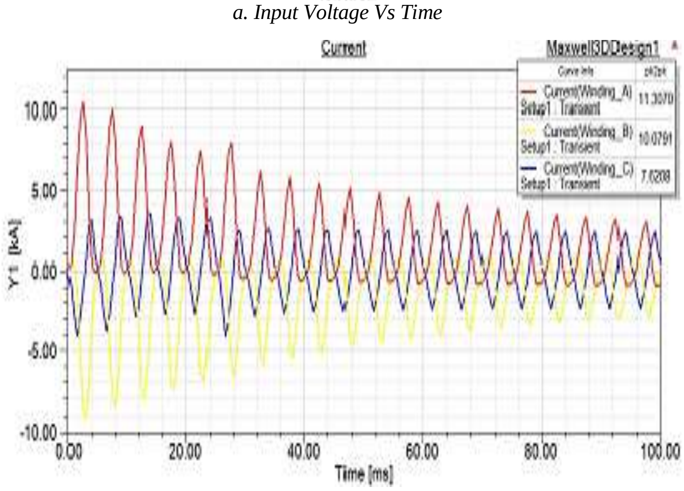
Figure 3: 3D Model of *DSLSM in Maxwell*

VI. SIMULATION RESULTS

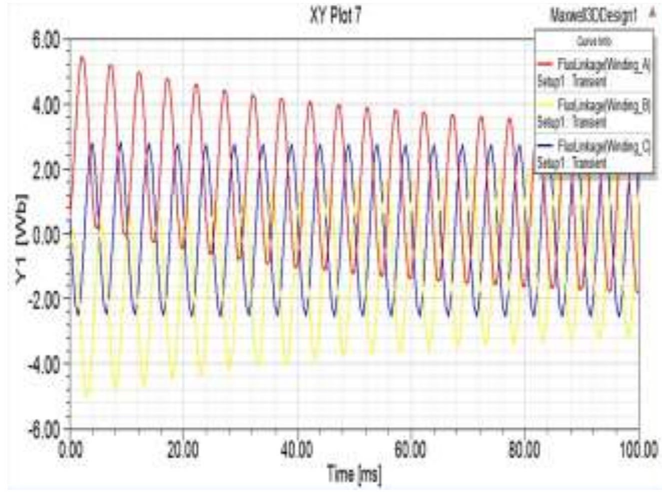
The Model of DSLSM has been analyzed and studied for loading conditions with a weight of 15000 kg on rotor. Graphs for the different characteristics are shown in Figures 6.1 a) to f)



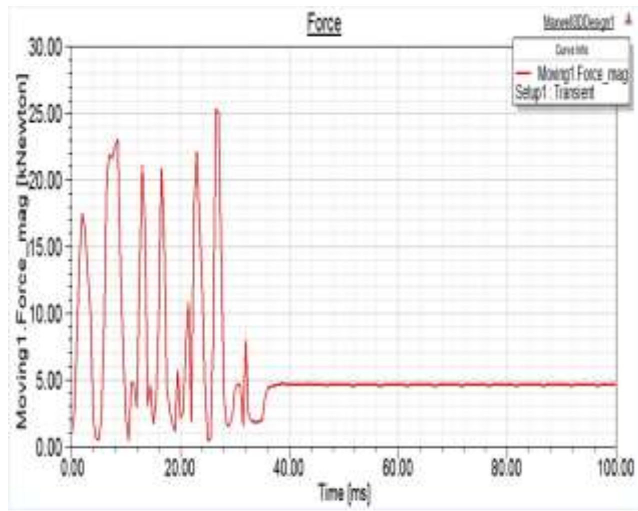
a. Input Voltage Vs Time



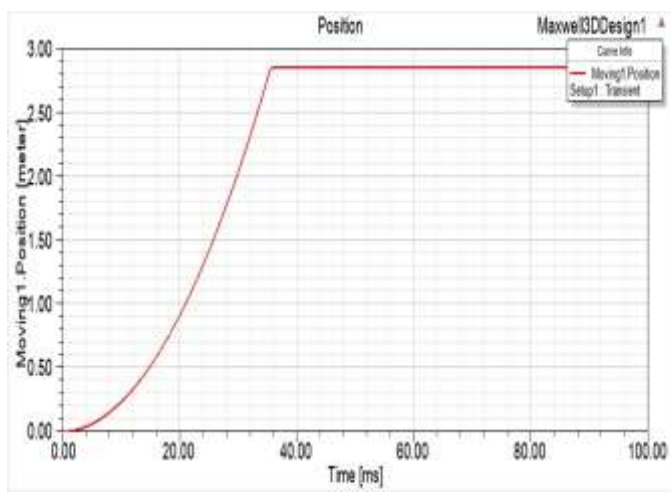
b. Current Vs Time



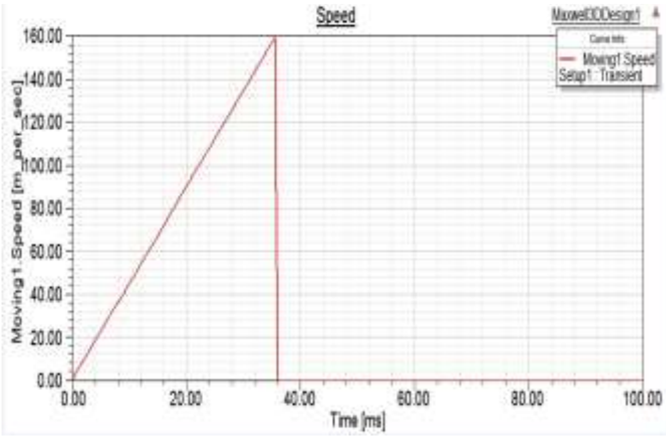
c. flux linkages Vs Time



d. Force Vs Time



e. Position of rotor Vs Time



f. Speed Vs Time

Fig 4: *DSLSM with long Stator*

Three phase, 1905 V supply is given to the DSLSM for field excitation as shown in Figure 4.a.Initially, current wave form and flux linkage starts from zero as obtained in Figure 4.b. and 4.c. respectively due to absence of residual flux then after some time it settles down and reaches to steady state. During transient period, t<80ms, maximum current I is 11kA. Figure 4.d shows that because of the magnetization effect of permanent magnets, motor runs on constant speed. Figure 4.erepresents the displacement of the rotor and speed varies linearly with respect to time shown in Figure 4.f. Table IV describes the value obtained from the results.

TABLE IV. RESULTS FOR LOAD-CONDITION

Sr. No.	Output	
	Parameter	***Load condition***
1.	Maximum Force	Nearly 27 kN
2.	Speed	Variable 0 – 180 m/s
3.	Position	Varies parabolically
4.	Transient Current	T<80ms; 11kA

VII. CONCLUSION

The design of DSLSM has been done analytically and then dynamic performance of the DSLSM is analyzed and verified. The 3D MAXWELL software simulation results shows that DSLSM is more efficient & fulfills all the requirements of EMALS. Hence DSLSM is suggested as the best suitable choice for EMALS.

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