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Design of Tubular Linear Induction Motor in ANSYS 3D MAXWELL

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Abstract : Linear Electric Motors belong to the group of Special electrical machines that convert electrical energy into mechanical energy of translator motion. The Linear motors (LM) are very effective drive mechanisms for transportation and actuation systems. Linear induction motors have three main strengths. First, there are no magnetic attraction forces to contend with during the assembly process. Second, long travel lengths are possible. Third, they offer very high continuous force and acceleration ratings.

Linear machines are widely used in various application with effective efficiency. Most of the design equation of linear machines are based on electromagnetic theory. In this the detail study of design and winding technique of linear induction motor (LIM). The purpose of this project is to increase use of LIM in industry for transportation purpose. The low rating LIM are of low cost, low energy consumption, high speed, and low pollution. The linear induction motor develops to use as a conveyer in various industries. It is used for smooth transmission, high speed, high accuracy and precision is required. Such as space canters, defence organization where high accuracy is required. Their main applications will be exposed with specific reference to MAGLEV (Magnetically Levitation) vehicles, urban people movers (such as linear metro, light railway, etc.), X-Y planar motion industrial platforms, launchers, actuators for industry and automotive This project gives idea regarding to use LIM where conventional induction motor used for linear motion drives application.

In this project, procedure is proposed where first an analytical design is carried out to obtain a preliminary geometry. The analytical design is based on approximate equivalent circuits under constrained conditions. In the second step a three-dimensional finite element method (3D-FEM) analysis is performed to validate the accuracy of the analytical models.

Keywords: TLIM, Goodness factor, Finite Element method, EMI.

Introduction:

Today, most motor technologies are set up to run in a rotary fashion. This can be a problem when the need to produce a straight move arises. To get linear output you would be forced to buy and maintain additional components (such as pinion gears, belts, pulleys, etc.), thus wasting precious time and money. To solve this issue, many engineers opt to upgrade their system to use a linear motor. Linear motors run in a straight line and follow your instructions, all with a minimal number of components.

LINEAR movements in mechanical engineering are usually obtained using rotating motors in conjunction with rotation to translation mechanism. Linear electromagnetic actuators are able to provide thrust force directly to the load without mechanical gears and transmission. As a consequence, the control bandwidth and dynamical performance are improved as well as the overall efficiency and reliability

Tubular linear induction motor can ideally be realized by unrolling a rotating induction motor with a radial EMI-plane and by winding the obtained flat single-side linear induction motor off around an axis parallel to the direction of motion, getting to a novel configuration illustrated in Fig. 1

A tubular motor generally has circular transversal section or can have square cross section

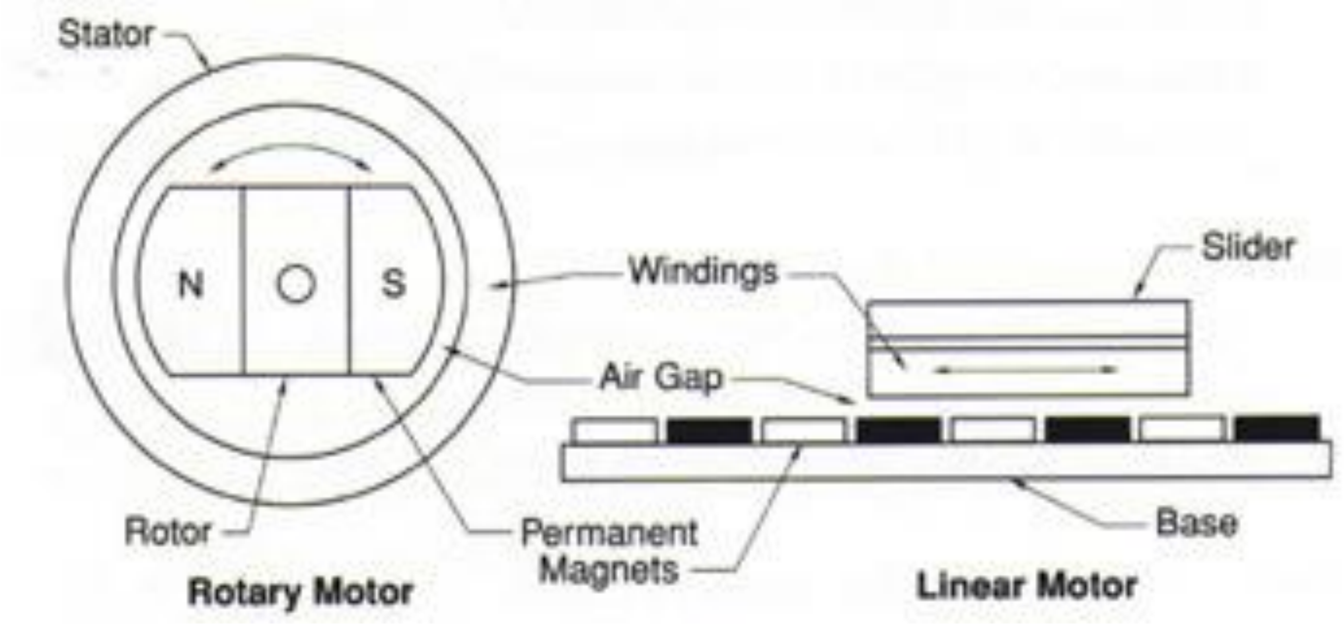


Fig 1: Imaginary process of unrolling a conventional motor to obtain DSLIM

Objectives

The general objective of the study was to get insight of tubular linear induction motor in the Ansys 3D Maxwell. (Simulation software)

- To plot curves of speed vs time in software.
- To plot curve of force vs time in software. (For both the motions of TLIM).
- To plot curves of Induced voltage vs time and also Induced current in the software.
- To observe magnetic flux density at all the points of TLIM and see whether any part is going in saturation or not.
- To plot the magnetic field vector at each point on TLIM.

Structure of TLIM

There are several types of TLIM distinguishable according to the different constructive solutions chosen for inductor and for induced part.

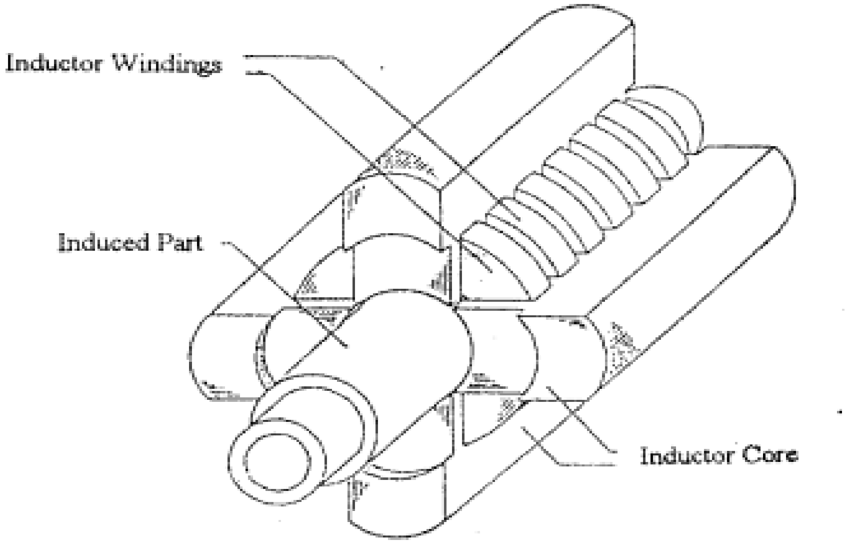
Structure of the TLIM inductor:

The inductor of the TLIM is made up of a laminated magnetic iron-core and of three-phase windings. The magnetic Core is realized with iron-laminated blocks (thin laminations generally wrapped up in number of blocks). This lamination can be longitudinal or transverse with respect of the direction of motion.

For these two types of laminated iron-cores, the drawbacks are as follows: for the former, the practical difficulty to precisely align the laminations of every core, bearing in mind their length; for the latter, the substantial total thickness of the insulations among the laminations which implies a considerable reluctance of the magnetic circuit.

Regarding the inductor winding, the arrangement of one phase of the three-phase winding is shown in Fig.2b. This section of winding can be thought like a sequence of solenoids, alternatively winded in opposite direction, and, for this reason, a tubular motor has been often called **solenoidal motor**.

Among the advantages of the tubular structure, it is evident that the windings of the tubular motor have no end windings, so that the coils of every pole fully contribute to the magnetization of the machine along all their length.[1]



Material and Methods:

Design of TLIM

Consider m phase linear induction motor having one circuit per phase, kVA rating (Q) of m phase conventional rotating induction machine given as

$Q=mEphIph*10-3$ (4.8)

Induced emf per phase given as, $Eph=4.44f\emptyset TphKw$ (4.9)

Substituting value of Ephin from Eqn. (4.9) in Eqn. (4.8), we get

$Q=m*4.44f\emptyset TphKwIph*10-3$ (4.10)

Linear induction motor has flat structure compared to rotary induction motor. Linear velocity of LIM can be calculated as, $Vs=2f\tau$ (4.11)

Equation (4.11) can be derived from the basic equation of linear velocity. We know that, linear velocity in terms of angular velocity given as,

$Vs=\omega m*R$ (4.12)

Angular velocity in terms of electrical can be given as, $\omega e=p2\omega m$ (4.13)

Substituting ωm in (4.12), we get $Vs=2\omega ep*R=2*2\pi f*Rp$ (4.14)

Pole pitch $\tau=2\pi Rp=Lsp$ (4.15)

Substituting Equation (4.15) in (16), we get $Vs=2f\tau$

Frequency of stator voltage can be calculated as $f=Vs2\tau$ (4.16)

From fig.1.1, Length of the stator of LIM given as, $Ls=p\tau$ (4.17)

Therefore, kVA rating equation becomes, $Q=2.22*Vs2\tau*(p\emptyset)*(2mTphIph)*Kw*10-3$ (4.18)

$Q=2.22*Vs2\tau*(total\ magnetic\ loading)*(total\ eletric\ loading)*Kw*10-3$

Specific magnetic loading, $Bav=p\emptyset Ls*W$

Specific electric loading, $ac = IZ*ZLs$

Equation (4.18) becomes

$Q=1.11*Bavac*Kw*10-3*VsLsW\ Co=1.11*Bavac*Kw*10-3$ (4.19)

$Q=CoVsLsW$ (4.20)

Where equation (4.20) is known as the input KVA equation of linear electric machine. Quantity C0 is called the output coefficient.

Assumed values of some of the parameters of SLIM

Parameter	Unit	Values
Power Rating, P	KW	1
Frequency, F	Hz	50
Flux Density, B_{av}	T	0.45
Supply Voltage, V	V	50
Slots/pole/phase, q		1
Current Density, δ_S	A/mm^2	5
Power Factor		0.5
Efficiency,		0.6
Tooth Flux DensityB_t	T	1.5
Yoke Flux density B_{YMAX}	T	1.3
Stator Length, Ls	m	1
Rotor Speed, Vr	m/s	1

Calculated values of some of the parameters of SLIM

Parameter	Unit	values
near Synch. Speed, Vs	m/s	10
Force, F	N	80.32
ase input current , I_{Ph}	A	9.6
Pole Pitch,τ	mm	55
Primary Width, W	mm	224
tor turns per phase, Ts		1020
Stator Slots		54
Stator slot pitch, Yss	mm	18.5
Tooth width, Wt	mm	5.5
Slot width, Ws	mm	13

Depth of the slot, h_s	mm	20
Height of yoke, h_y	mm	9.5
ea of stator conductor	mm^2	261
Power factor		0.53

MAIN DIMENSION

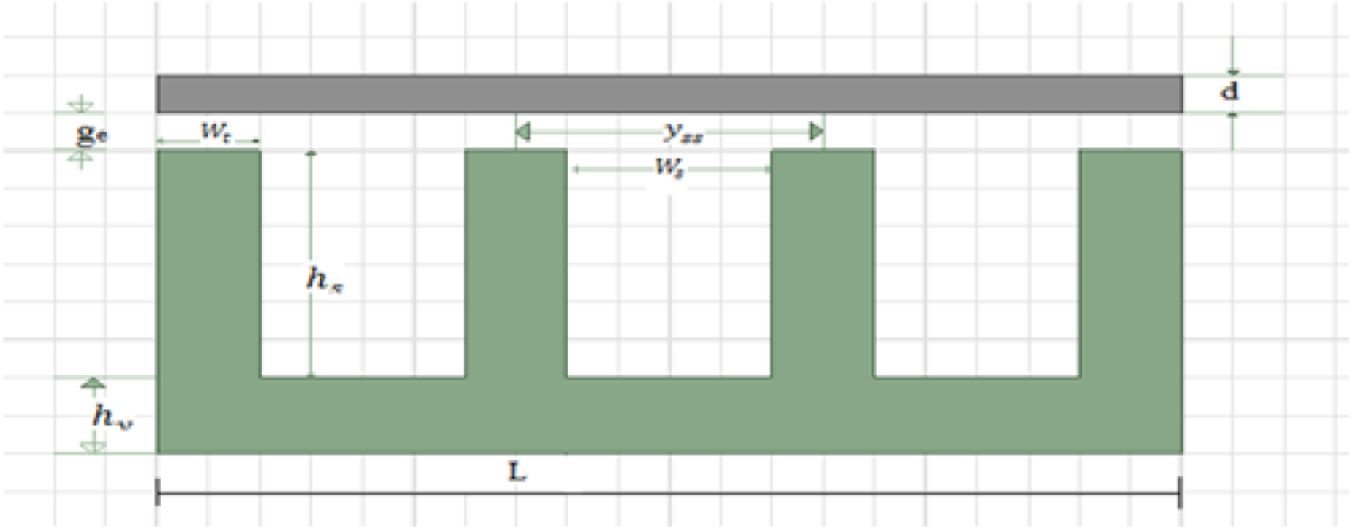


Fig 6.1:[6] Slim geometry

Stator slot pitch $yss=Ls/$.

Conductors per slot $zs=6*Ts/slots$.

Area of conductor, $a= Iph/\delta s$

Diameter of conductor d=$\sqrt{4a\pi}$

Area of stator slot $ASS=Zs/$a*(sp)

Width of stator teeth $wt=\phi m/Bt*sp*W$.

Height of the slot $hs=$ $Area\ of\ stator\ slot/width\ of\ stator\ slot$

Height of yoke $hs=\phi/2Bymax*W$

Width of stator slot $ws=yss-wt$,

Simulation and Analysis in 2-D Maxwell

Ansys develops and markets finite element analysis software used to simulate engineering problems. The software creates simulated computer models of structures, electronics, or machine components to simulate strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Ansys is used to determine how a product will function with different specifications, without building test products or conducting crash tests. For example, Ansys software may simulate how a bridge will hold up after years of traffic, how to best process salmon in a cannery to reduce waste, or how to design a slide that uses less material without sacrificing safety.

Most Ansys simulations are performed using the Ansys Workbench software, which is one of the company's main products. Typically Ansys users break down larger structures into small components that are each modeled and tested individually. A user may start by defining the dimensions of an object, and then adding weight, pressure, temperature and other physical properties. Finally, the Ansys software simulates and analyzes movement, fatigue, fractures, fluid flow, temperature distribution, electromagnetic efficiency and other effects over time.

Ansys also develops software for data management and backup, academic research and teaching.

Designers of electrical machines and generators can enhance ANSYS Maxwell with ANSYS RMxprt, a template-based design tool. Together Maxwell and RMxprt create a truly customized machine design flow to meet market demand for higher efficiency, lower cost machines. Using classical analytical motor theory and equivalent magnetic circuit methods, RMxprt can calculate machine performance, make initial sizing decisions and perform hundreds of "what if" analyses in a matter of seconds.

Finite Element Method [12]

Ansys develops and markets finite element analysis software used to simulate engineering problems. The software creates simulated computer models of structures, electronics, or machine components to simulate strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Ansys is used to determine how a product will function with different specifications, without building test products or conducting crash tests. For example, Ansys software may simulate how a bridge will hold up after years of traffic, how to best process salmon in a cannery to reduce waste, or how to design a slide that uses less material without sacrificing safety.

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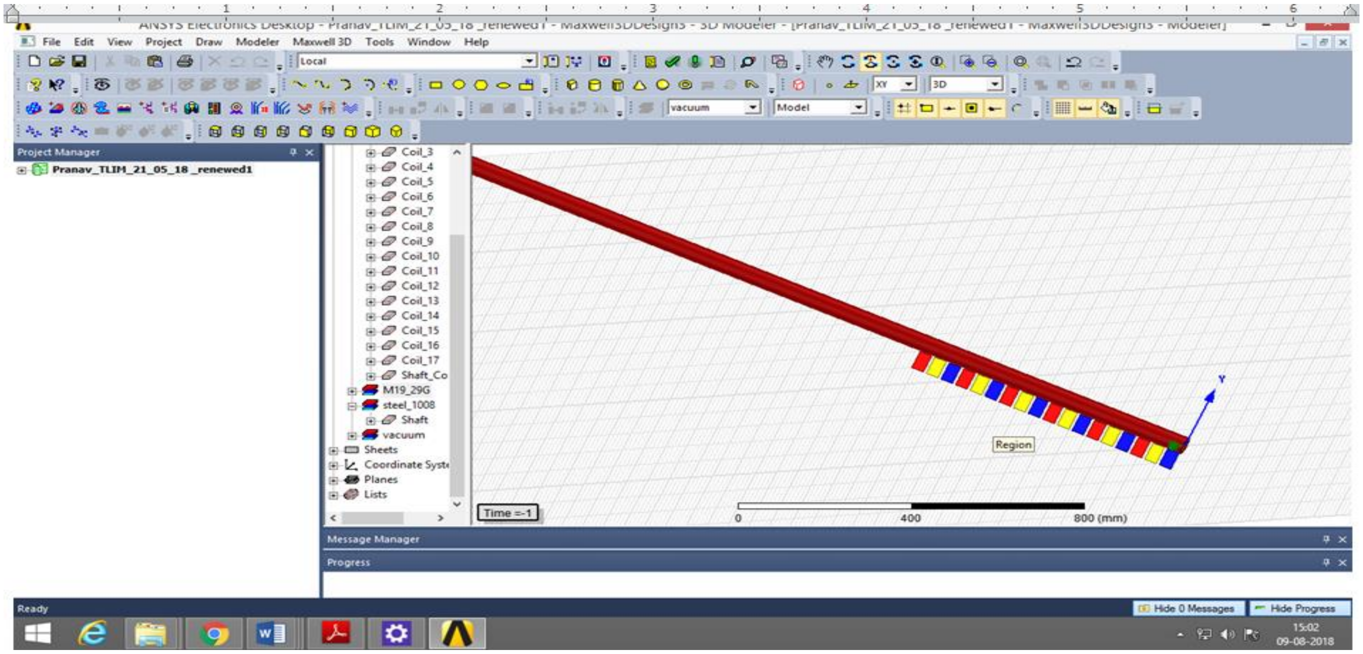

Fig 6.1: Window of Ansys Maxwell

7) Results and Discussion

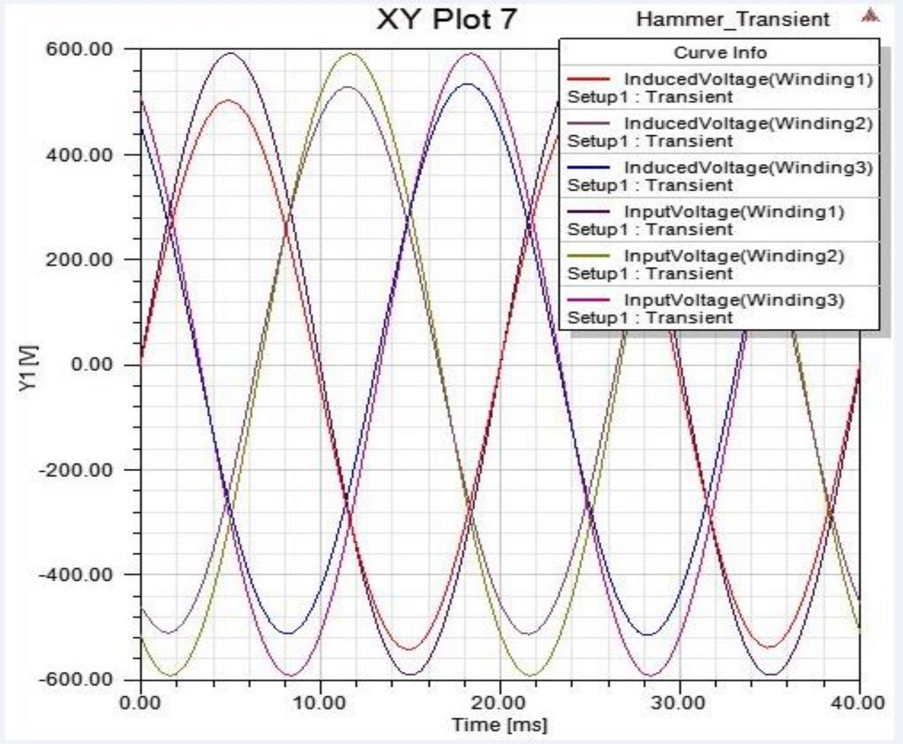

Fig 7.1: Induced voltage and Induced current vs time

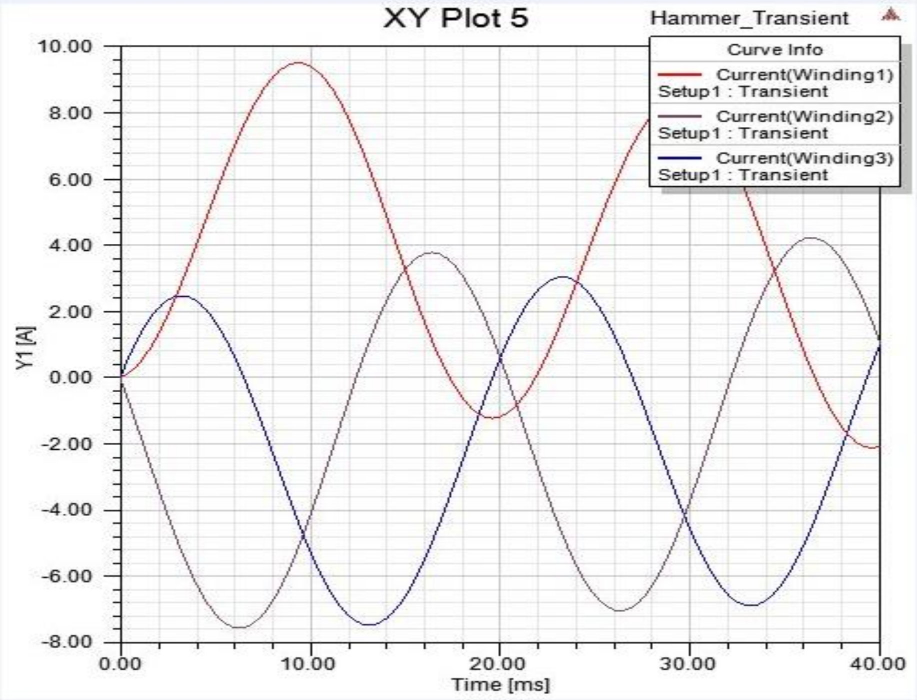

Fig 7.2: Current vs time

CASE 1) When the motor comes down:

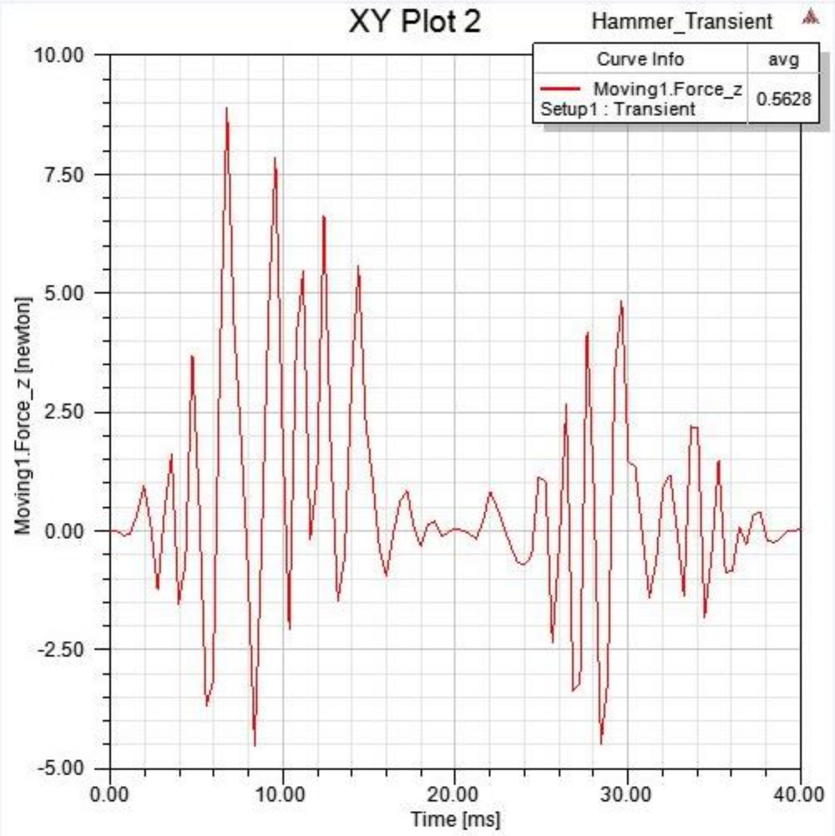

Fig 7.3: Force vs time

CASE 2) When the motor moves up:

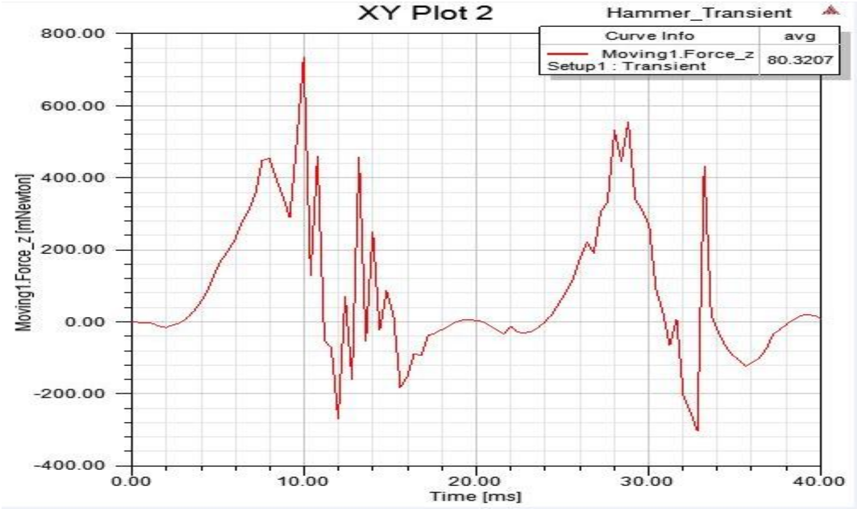

Fig 7.4: Force vs time

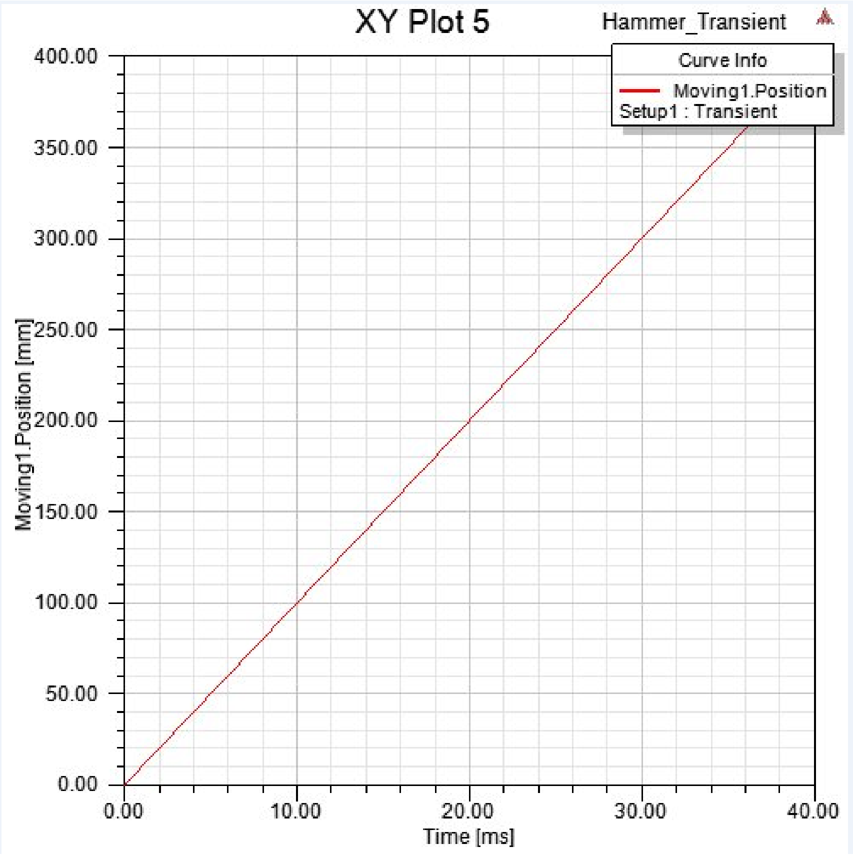

Fig 7.5: Position vs time

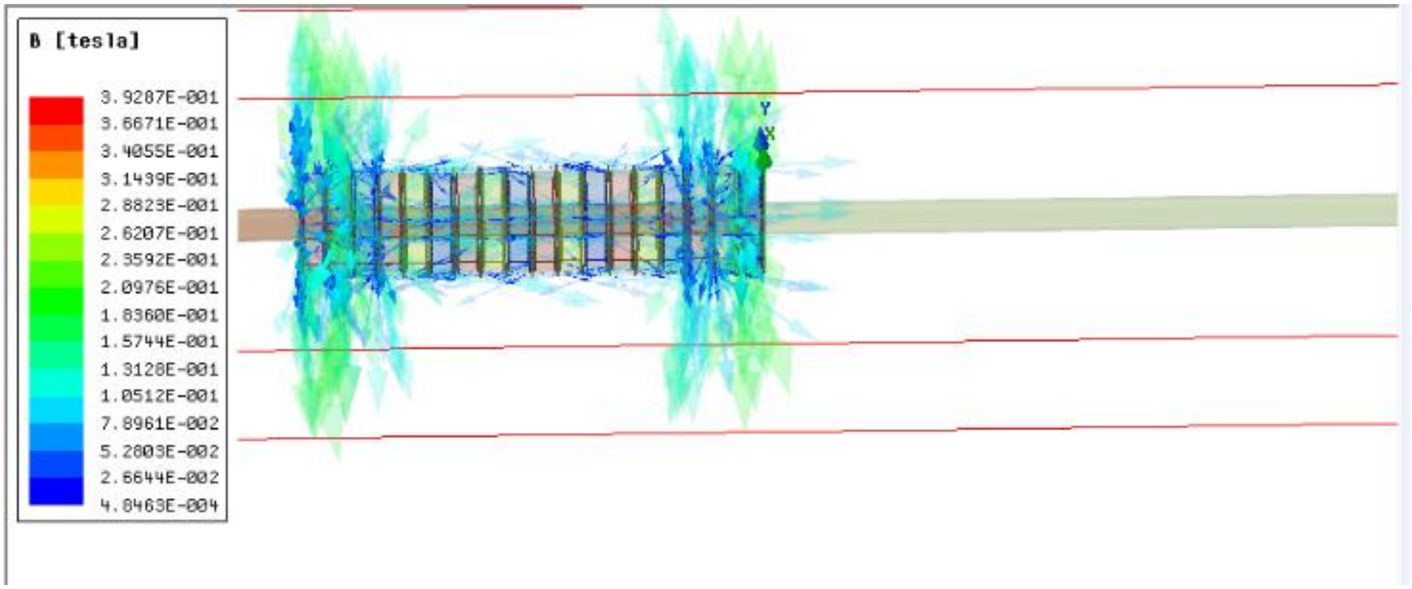

Fig 7.6: Magnetic Flux Density

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