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Simulation of a linear oscillating tubular motor

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Abstract: *Still continuing our study of tubular linear oscillation motors (LOTM), the work presented in this paper shows a simulation of a tubular linear motor oscillating, the latter is that a coil iron nucleus C.I.N.C. Determining the inductance of the coil turns the model in mathematical equations that govern the operation of (LOTM) in order to know the performance of the motor. Note that it is very difficult to calculate the inductance of such a motor type by classical methods because the coil is magnetically saturated is to say the system is not linear, so the necessity of use computer tools.*

Key words: *linear motor; Ferro-resonance, oscillating motor, inductance, coil.*

I. Introduction:

The linear oscillating tubular motor consists of an iron bar moving inside a coil [8], figure 1.

The displacement of the nucleus in direct-reverse movement can lead to a Ferro resonance phenomena which affect all the circuit parameters; hence it is called parametrical motor. This type of motor which is based on the inductance periodical variation operating in linear oscillating regime leads to a change in the behaviour of the electrical circuit. This behaviour is accompanied with electromechanical phenomena which make the mathematical approach and simulation delicate [9].

Its operating particularity needs an adequate conception of a starting circuit as well as another circuit for breaking. They need to understand that the Starter motor requires manual pulse, and when we want to stop the motor by turning off the power, the nucleus is ejected outwards as a pitcher. So two solutions are possible to solve these two important problems and we propose:

1 – Strengthen the two ends of the coil turns (of Excitation winding) for the motor starts easily figure 2.
2. a– The nucleus must be held by two springs at both ends figure 3.
2.b – Put a capacity parallel with the motor so that the kernel not eject in the area figure3.

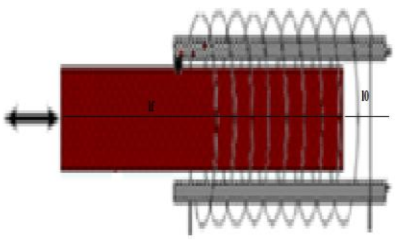

Figure1. Linear oscillating tubular motor

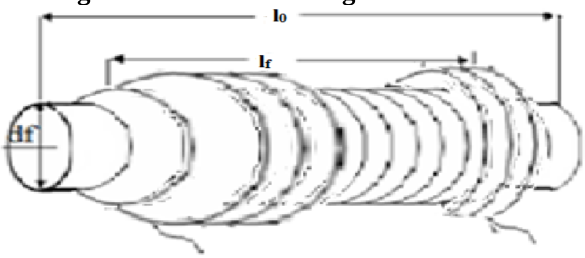

Figure 2. Reinforcement of both ends of the coil windings Exciter

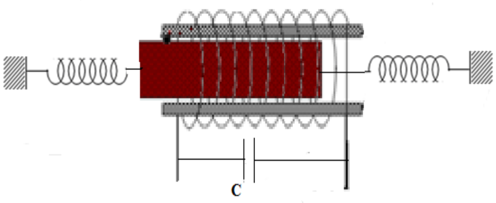

Figure 3 LOTM with return springs and the ability to stop by electrical damping

II. Setting Of The Equation LOTM

LMTO inductance L is a function of displacement [1] is given by the following formulas:

$$L = L_0 + L_f + 2.M \qquad (1)$$

With:

$$M = k\sqrt{L_0.L_f} \qquad (2)$$

And,

$$L_0 = \mu_0 . \frac{N^2}{l^2} s_0 . l_0 = \mu_0 \frac{N^2}{l^2} s_0 \left(l - l_f\right) \qquad (3)$$

$$L_f = \mu_0 . \frac{N^2}{l^2} [s_0 . + (\mu_f - 1) s_f] l_f \qquad (4)$$

L0: inductance of the coil without iron nucleus.
Lf: inductance of the nucleus.

And we know that the magnetic force is the derivative of the magnetic energy [1], and it is magnetic force that causes the oscillation of the nucleus:

$$\mathrm{Fm} = \frac{dw}{dt} \qquad (5)$$

As magnetic energy is defined by the following formula [2]:

$$w = \frac{1}{2} L_0 i_1^2 + \frac{1}{2} L_f i_2^2 + M i_1 i_2 \qquad (6)$$

Therefore, the magnetic force will be equal to:

$$\mathrm{Fm} = \frac{1}{2}\frac{dL_0}{dt} i_1^2 + \frac{1}{2}\frac{dL_f}{dt} i_2^2 + \frac{dM}{dt} i_1 i_2 \qquad (7)$$

And even:

$$\mathrm{Fm} = \frac{1}{2}\frac{dL_0}{dx}\frac{dx}{dt} i_1^2 + \frac{1}{2}\frac{dL_f}{dx}\frac{dx}{dt} i_2^2 + \frac{dM}{dt} i_1 i_2 \qquad (8)$$

On the other we have:

$$\frac{dx}{dt} = v \qquad (9)$$

With v: the speed of the nucleus

So :

$$\mathrm{Fm} = \frac{1}{2}\frac{dL_0}{dx} v . i_1^2 + \frac{1}{2}\frac{dL_f}{dx} v . i_2^2 + \frac{dM}{dt} i_1 i_2 \qquad (10)$$

Determining the speed V will be after the resolution of the mechanical equation that governs the functioning of LOTM [9].

The superposition of the two curves lf = f (x) (coil length), and l0 = g (x) (nucleus length) shown in Figure (4) shows the evolution of the gradual penetration of the nucleus in the coil chasing air that above.

l0 : coil length
l_f : nucleus length

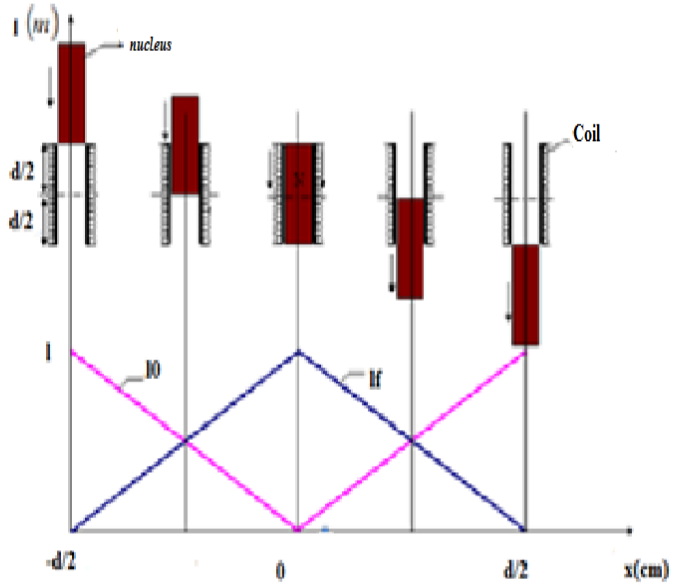

Figure 4. Progressive evolution of the nucleus

III. Simulation

The system of equations reflecting the operation of parametric oscillating motor is solved according to the block diagram of Figure 5

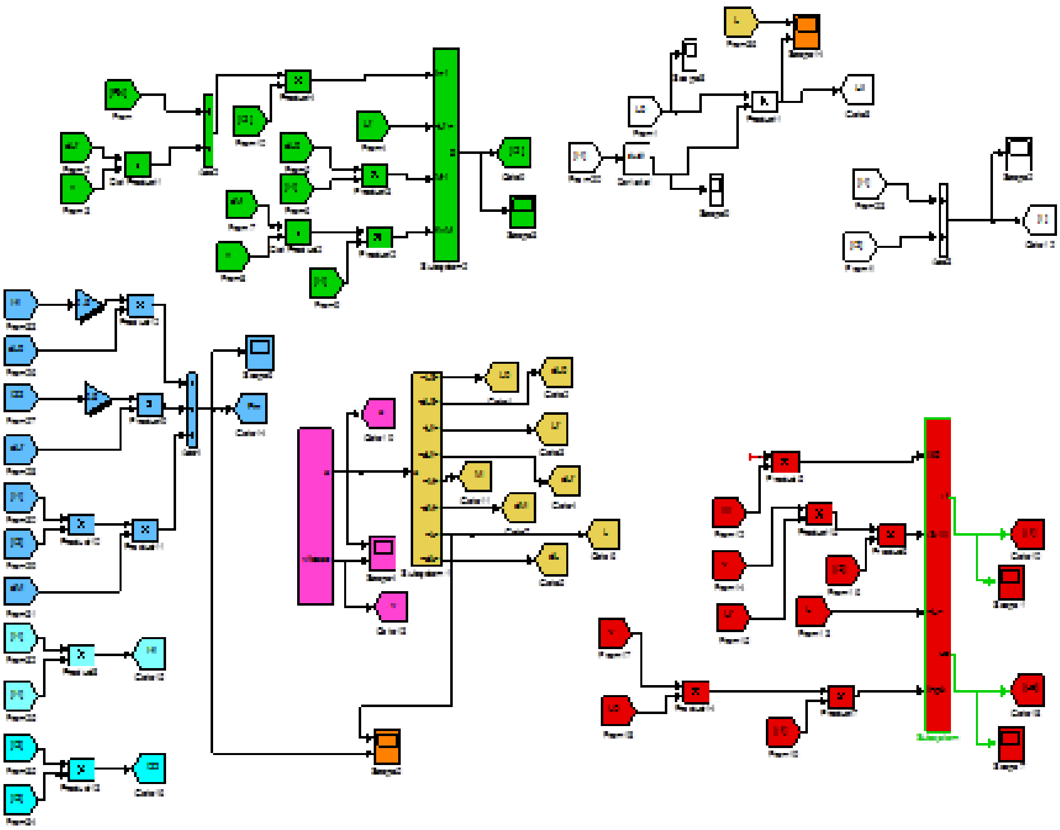

Figure 5. Block diagram of a simulation LOTM

The electrical part figure 6.a and figure 6. b, is a set of blocks representing the different parameters of electrical equations that govern the operation of the motor made above.

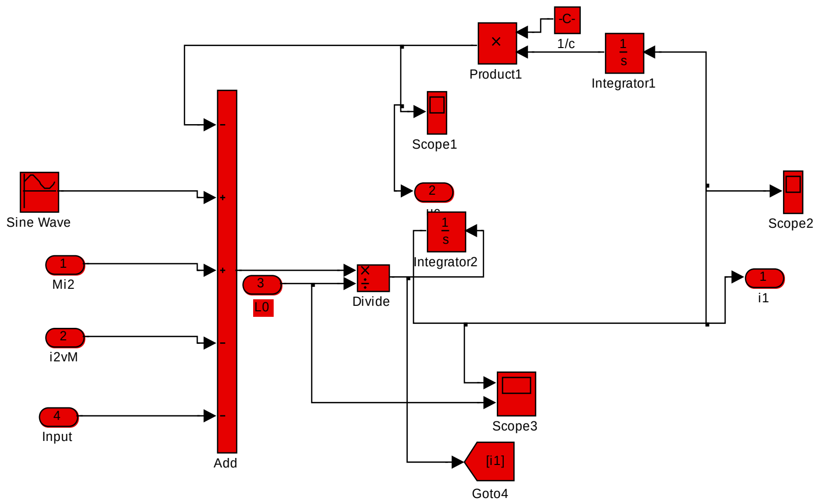

Figure 6.a SUB-SYSTEM electrical part

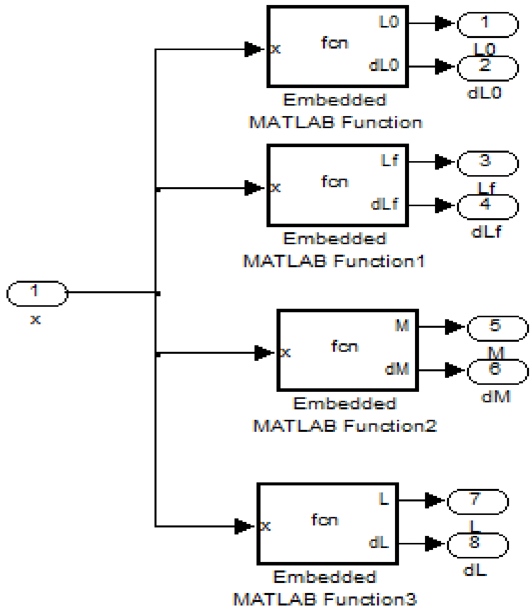

Figure 6.b SUB-SYSTEM electrical part

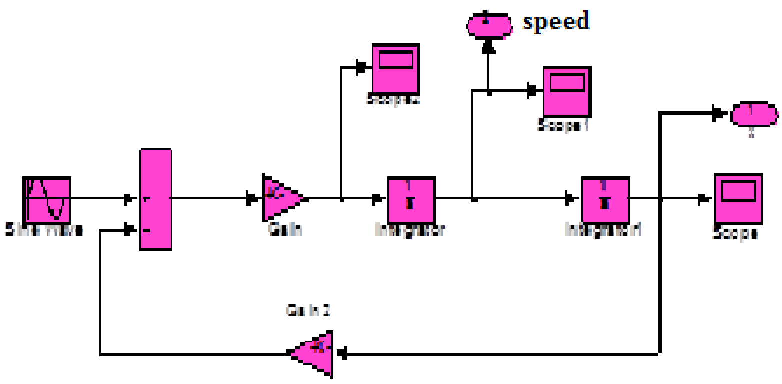

Figure 7. SUB-SYSTEM mechanical part.

below, the graphical results, whether those obtained in MATLAB (figures (. a) shown in the left column), or those obtained by simulation figure (b) shown in the right column.

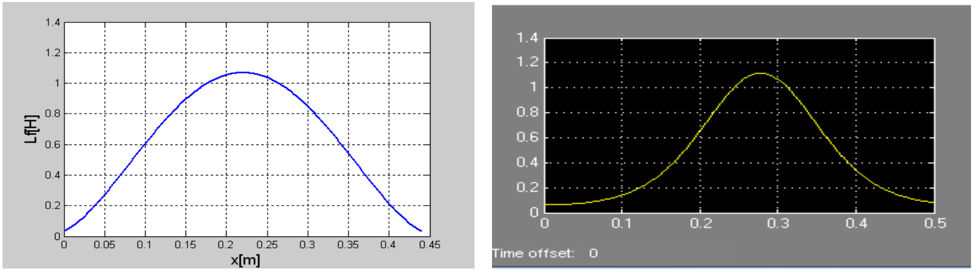

Figure (8.a, 8. b) Variation of the inductance of the nucleus L_f in function of time and displacement.

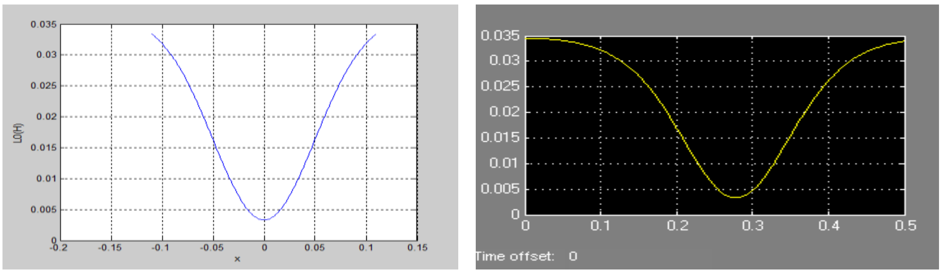

Figure (9.a, 9. b) Variation of the inductance of coil without iron nucleus L_0 in function of the displacement and time.

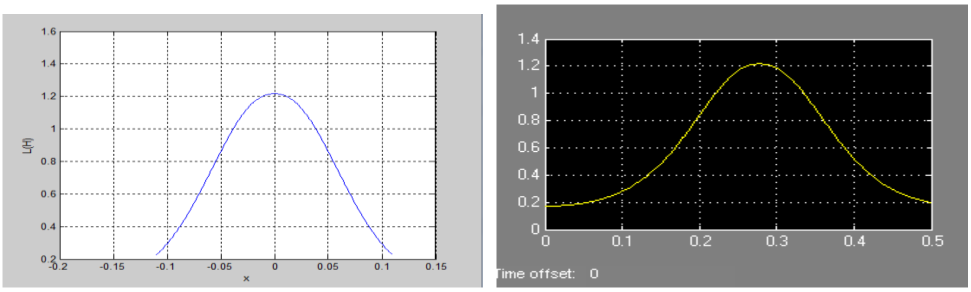

Figure (10.a, 10. b) Variation of the total inductance L in function of the displacement and the time

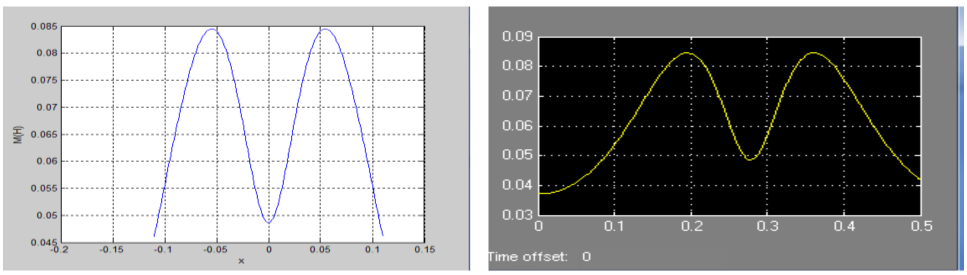

Figure (11.a, 11. b). Variation of the mutual M in function of the displacement and the time

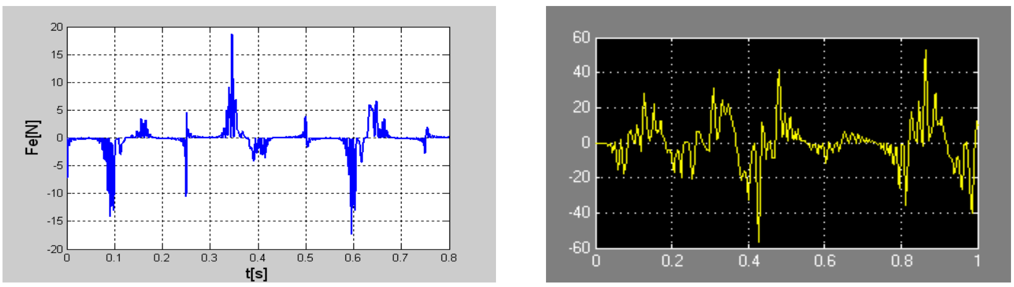

Figure (12.a, 12. b) variation of the magnetic force in function of the displacement and the time

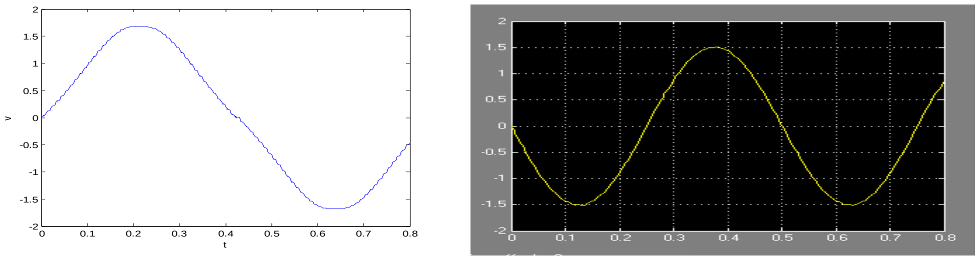

Figure (13.a,13.b) variation of the speed in function of the displacement and the time.

IV. Conclusion:

Faced with these comments and looks of results, interesting perspectives that can contribute to improving the functioning of the device MLTO are possible: The study of other configurations and optimization of the magnetic circuit may contribute to the improvement of motor LOTM. The stability and control of this type of motor may facilitate its integration in several industrial applications. The possibility of a storage system and technical and economic optimization of the electro-mechanical conversion chain integration. The study of the magnetic perturbations inherent coupling reaction LOTM overlooked imbalances and voltage dips and fluctuations.

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