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NEW DESIGN OF AN ELECTROMAGNETIC LAUNCH SYSTEM FOR TACTICAL UAVS

Summary. UAVs in recent times have achieved an increased rate of development, and hence, can cover a large spectrum of missions. Based on the dimensions, we can find UAVs from large dimensions used to operate at the global level through mini UAVs used inside buildings. The large UAVs are operated almost like a manned aircraft. For this reason, it uses the airport infrastructure and a runway for take-off and landing. The mini UAVs can be launched by hand. Between these two extremes, there is a category of UAVs used at the tactical level, which cannot be launched by hand and is not possible to build a runaway. These UAVs are launched using RATO (rocket-assisted take-off) or catapults. To improve the launch system, this should have a few moving parts to reduce maintenance costs and be powered by electric energy to be easily integrated into the automatic control loop. This paper presents a new design of a launch catapult based on electromagnetic energy for tactical UAVs. This technology is under development to launch projectiles with high velocity; however, it has theoretically proved the possibility to equally launch UAVs. The second part presents the theoretical approach necessary to find the expression of force under certain approximation for electromagnetic launch system design.

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1. INTRODUCTION

UAVs in recent times have achieved an increased rate of development, and hence, can cover a large spectrum of missions. Based on the dimensions, we can find UAVs from large dimensions used to operate at the global level through mini UAVs used inside buildings. The large UAVs are operated almost like a manned aircraft. For this reason, it uses the airport infrastructure and a runway for take-off and landing. The mini UAVs can be launched by hand. Between these two extremes, there is a category of UAVs used at tactical level which cannot be launched by hand and is not possible to build a runaway [1,3]. These UAVs are launched using RATO (rocket-assisted take-off) or catapults. These installations are good solutions because:

- the UAVs can be launched without any infrastructure;
- the payload weight or the mission time can be increased as no fuel is used for launching;
- this approach is environmentally friendly.

The catapult installations use different kinds of energy to accelerate the UAVs, these are:

- mechanical energy stored in springs or rubber bungee;
- pneumatic/hydraulic energy produced by cylinders and pistons;
- electromechanical energy produced by electrical motors.

To improve the launch system, this should have few moving parts to reduce maintenance costs and be powered by electric energy as well to be easily integrated into the automatic control loop. This paper presents a new design of a launch catapult based on electromagnetic energy for tactical UAVs. This technology is under development to launch projectiles with high velocity; however, it has theoretically proved the possibility to launch UAVs too.

In this paper, we present the theoretical results obtained during a project aimed to explore new ways to accelerate a mass using electromagnetic energy. The objective of the project is to accelerate a projectile with a mass of 200 kg from zero to 25 m/s using 5 metres of acceleration length. According to this objective, the kinetic energy of the mass is:

$$E_k = \frac{1}{2}mv^2 = 0.5 \cdot 200 \cdot 625 = 62.5 \cdot 10^3 J \quad (1)$$

If we assume the initial speed is zero and the acceleration force acting on the projectile is constant, then the value of the force is:

$$L = E_k = F \cdot d \quad (2)$$

$$F = \frac{E_k}{d} = \frac{62.5 \cdot 10^3}{5} = 12.5\ kN \quad (3)$$

According to our project objectives, the accelerating force acting on the projectile is Lorentz force. The equation of Lorentz force based on current intensities sometimes presented as Laplace force is:

$$\vec{F} = I \cdot \vec{l} \times \vec{B} \quad (4)$$

$$F = I \cdot l \cdot B \cdot \sin\alpha \tag{5}$$

where α is the angle between vectors $\vec{l}$ and $\vec{B}$.

We created a design where the magnetic field is perpendicular on the current caring wire ($\alpha=90^0$) [4,5,6,7].

2. NEW EMLS DESIGN

Our design consists of a static part, which is made by a pair of coils similar to Fig. 1. The coils are square with the outer length calculated at the dimension of 180 mm and the inner length calculated at the dimension of 100 mm. The number of turns *N* depends on the size of the wire. We are looking for a copper wire that is able to sustain a fussing current calculated per Onderdonk for 32 ms up to 1000 amperes. From the table with the American wire gauges, we find AWG 19 with 0.912 mm diameter. At this dimension of wire, we can accommodate *N* =4000 turns in the rectangle cross-section area obtained from calculations. Because only one pair of coils are not enough to accelerate a tactical small UAV, we will use many pairs which form stages of acceleration. For our simulation, we used 4 stages of acceleration. The length of each stage is calculated at the dimension of 100 mm. This acceleration coils provide the current intensity *I* and length *l* of the conductor inside the magnetic field presented in Equation 5.

Because the number of conductors is equal with the number of turns *N*, the Lorentz force will be multiplicate with *N*. Each coil on stage produce an acceleration force so the total net force on each stage is multiplied by 2.

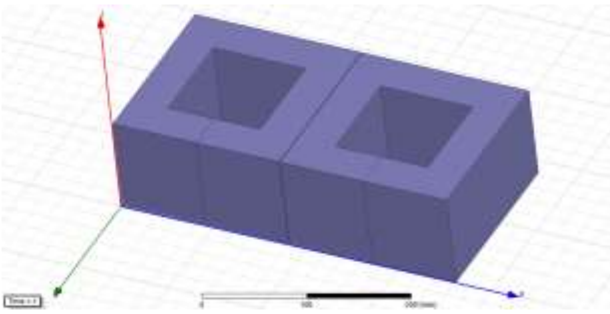

Fig. 1. Static coils for acceleration path

In Fig. 2, we present the 2 coils made to produce the magnetic field B required by the Lorentz force. These 2 coils are in front of the acceleration stator. The coils are square with the outer length calculated at the dimension of 180 mm and the inner length calculated at the dimension of 100 mm. The number of turns *N* is 1600. The length of the coils in axe x direction is 40 mm. These two coils are the moving parts. The magnetic field produced by moving coils and the intensity of the current in static coils create an acceleration force in positive z direction.

To increase the efficiency of the system, we also created a magnetic circuit made by electromagnetic steel. The shape and position of this core is presented in Fig. 3.

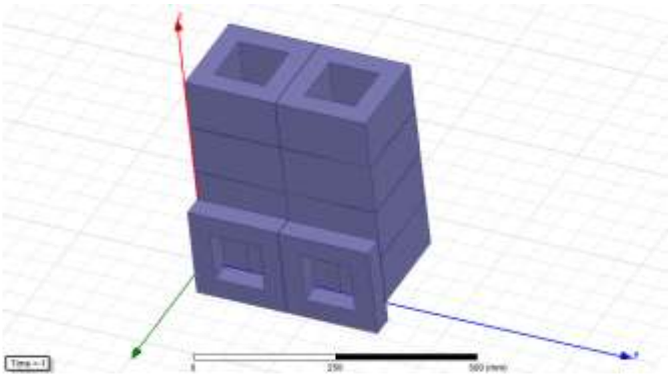

Fig. 2. Moving coils in front of acceleration stages

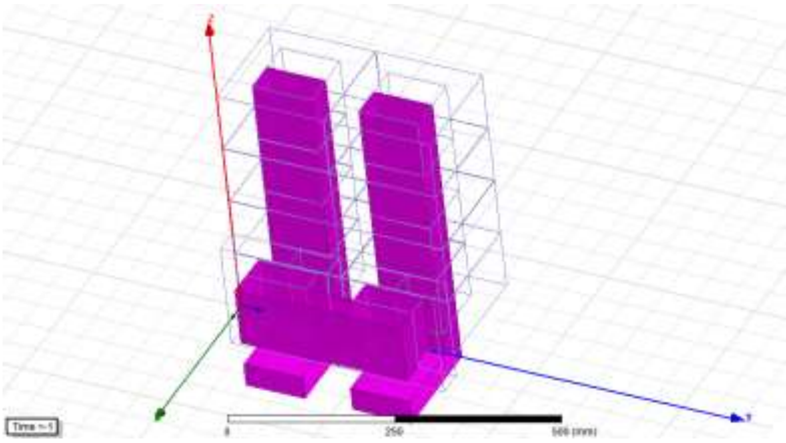

Fig. 3. The magnetic core

The entire design is presented in Fig. 4. The number of acceleration stages can be increased accordingly as needed. For our simulations, we used only 4 stages. We used the same amount of current to power all coils. Because we have moving coils, we can power these coils using moving contacts. This approach is possible given the maximum current used is 1000 A. The acceleration Lorentz force is:

$$F = 2 \cdot I \cdot N \cdot l \cdot B \tag{6}$$

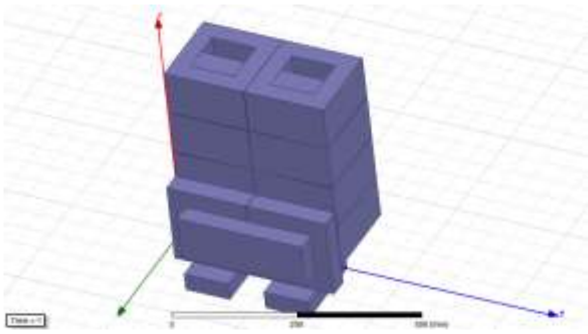

Fig. 4. New EMLS design

3. SIMULATIONS

For simulations, we chose the Maxwell interactive software package that uses the finite element method (FEM) to analyse and solve 3D electromagnetic field problems [2]. First, we built the simulation model with the same dimensions as we used to calculate the theoretical values of current intensity *I*, acceleration force *F*, and muzzle velocity *v*. Because the acceleration length is 5 m and our simulations are for only 0.1 m the value of velocity, we expect from the simulation is 0.5 m/s.

$$E_k = \frac{1}{2}mv^2 = 0.5 \cdot 200 \cdot 0.25 = 25\,J \tag{7}$$

$$F = \frac{E_k}{d} = \frac{25}{0.1} = 250 \;\; N \tag{8}$$

According to theoretical calculus, we need a force of 250 N to accelerate a mass of 200 kg from 0 m/s to 0.5 m/s on a length of 0.1 m. This length is the length of an acceleration stage. From the simulation, we obtained that the necessary value of current intensity to achieve a speed of 0.5 m/s is 4 amperes.

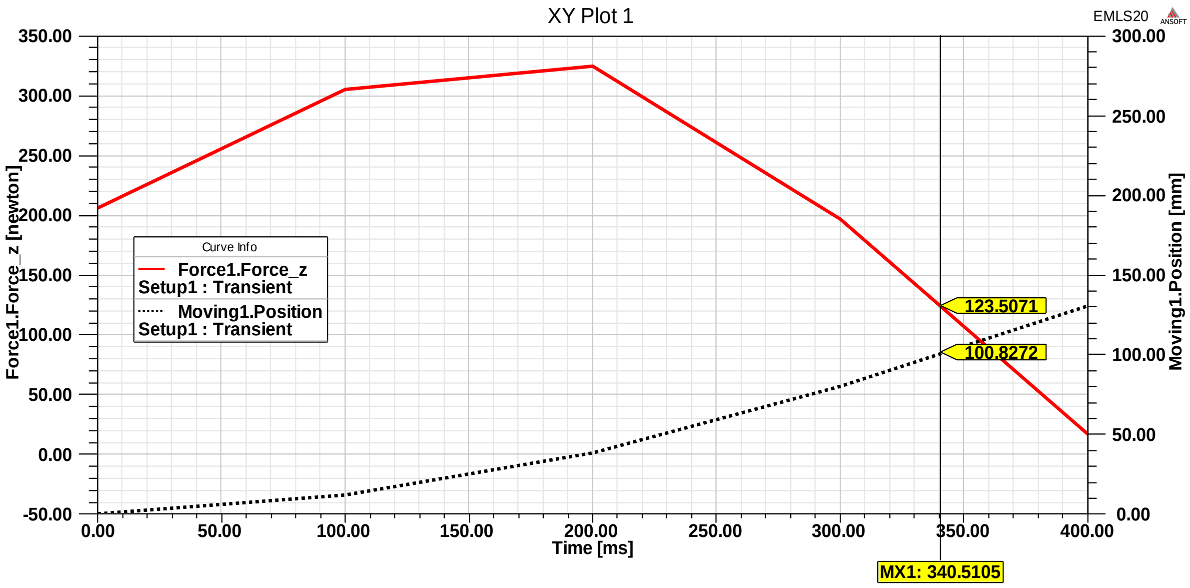

Fig. 5. Variation of acceleration force in time

In Fig. 5 is displayed with a continuous line, the variation of acceleration Lorentz force in time. As expected, the force is not constant as in our theoretical calculus. With dots is displayed the position of mobile coils in time. Based on this acceleration force, the velocity of mobile coils after the first stage is 0.5 m/s in accordance with our goals.

Therein Fig. 6 is displayed with continuous line, the variation of speed in time. At the end of first stage after 0.1 m the velocities of mobile coils achieve the value of 0.5 m/s. With dots is displayed the position of mobile coils in time.

According to the results from this simulation, we can predict that the system is able to accelerate a mass of 200 kg from 0 to 25 m/s on 5m length of acceleration using only 4 amperes current.

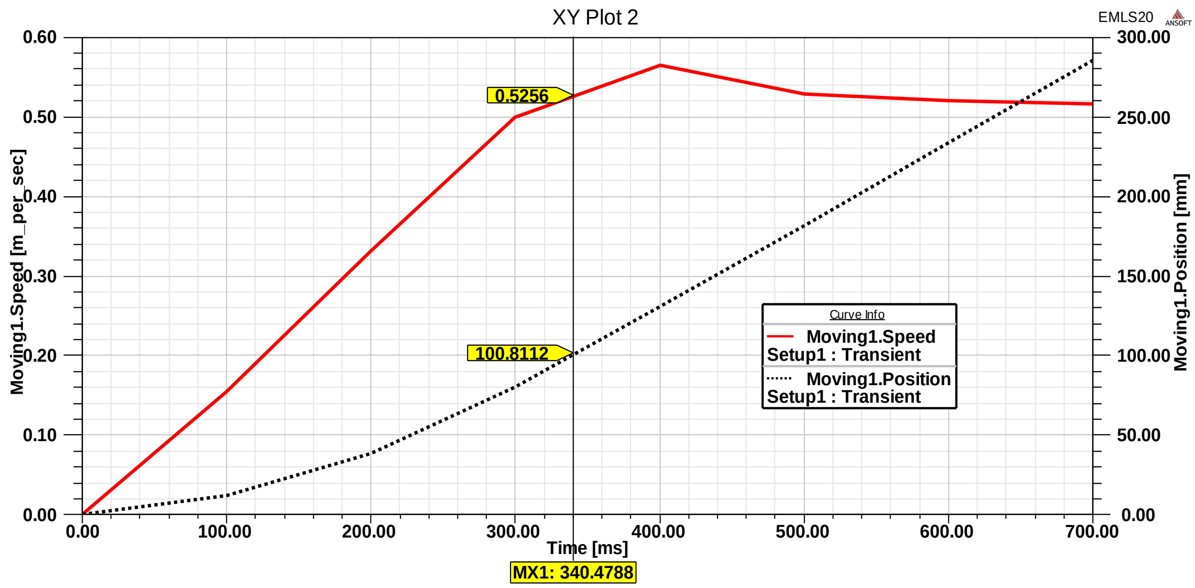

Fig. 6. Variation of speed in time

3. CONCLUSION

In this paper, we proved theoretically though the simulation, the possibility to obtain desired muzzle velocities of a tactical UAV using a current with low intensity of 4 A.

If the acceleration mass is increased, the intensity of the current should be increased to obtain the desired muzzle velocity.

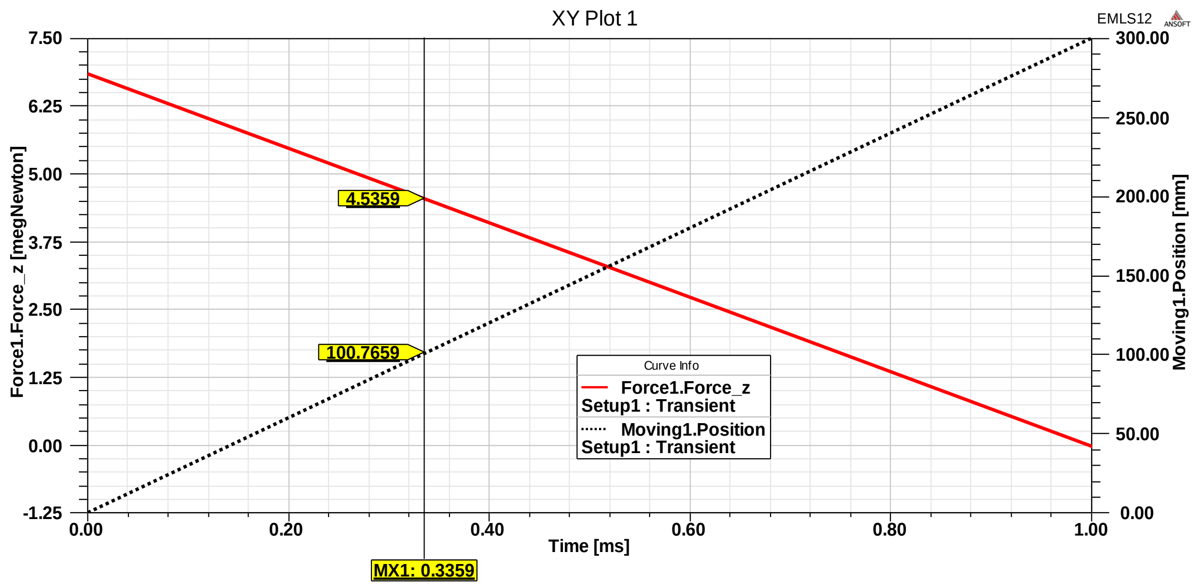

Fig. 7. Variation of acceleration force in time for I=1000A

The great advantage of this design is the adaptability to different applications. If we need to increase the acceleration force, we can increase the current up to 1000 A and increase the number of systems up to 4 as well. According to simulations results, this design can be easily used to accelerate projectiles up to 3000 m/s. This system can be an electromagnetic catapult or a coilgun.

To prove this affirmation, we displayed in Fig. 7 with a continuous line, the variation of acceleration Lorentz force in time for I=1000A and the mass of 1 kg.

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