A Comsol Multiphysic using for Designing a Hybrid Electromagnetic Launcher

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Abstract: The paper presented examples of using the Comsol Multiphysic for designing the hybrid electromagnetic launcher with pneumatic assist. In the article electro-magnetic model of coil (with results verification on laboratory stand) and a rail module shown, for the rail stage presented also a mechanical model. Besides presented a construction of a laboratory stage.

Keywords: electromagnetic launcher, coilgun, railgun, MES.

1. Introduction

The electromagnetic launcher is a kind of an electromechanical converter. An electric energy charged from a current source is converting into a mechanical energy of linear motion.

This kind of a devices is characterized by high speed of moving part (a projectile), which may achieve several kilometers per hour [3].

The electromagnetic launcher is divided on two type:
– a coilgun – a moving element (the projectile) is placed in a coil electromagnetic field,
– a railgun – the moving element (the projectile) is placed between two rails, connected with current source.

In the Mechatronics Department of the Silesian University of Technology designed and manufactured the laboratory stand of the hybrid electromagnetic launcher.

2. The laboratory stand

The laboratory stand of the electromagnetic launcher (Fig.1.) is divided on three parts. The first one is a supporter structure of the electromagnetic launcher, the second one is using for measurement velocity, and the last one is for stopping the projectile and for measurement a velocity and a energy.

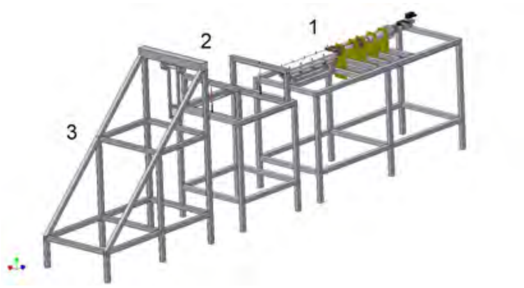

Figure 1. The laboratory stand, 1 – the supporter structure, 2 – the velocity measurement system, 3 – the stopping projectile system

1.1 The construction of pneumatic module

The pneumatic module is used for giving to the projectile a initial velocity, it is very important because in this case the energy is not lost to overcome static friction.

Figure 2. The construction of the pneumatic module

1.2 The construction of the electromagnetic launcher

The construction of the hybrid electromagnetic launcher with pneumatic assist is also divided on three parts, the first of them is the pneumatic module, the second is the coil module and the last is the rail module (Fig.2.).

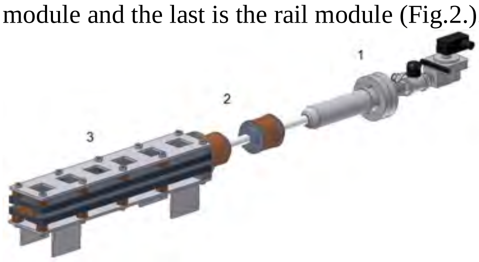

Figure 3. Construction of the hybrid electromagnetic launcher with pneumatic assist:, 1 – pneumatic module, 2 – coil module, 3 – rail module

1.3 The construction of the coil module

The coil module contains: a carcass made from cotton – phenol composite on which a copper winding is wounded. The carcass shape is suitable for connected the coil module with the rail module. Below shown view of the coil module:

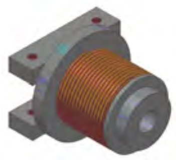

Figure 4. The construction of the coil module

1.4 Construction of the rail module

The rail module consist of the following components [1]:

1 – a rail made from copper (500 mm length),
2 – a construction element made from silicon – glass composite,
3 – a nonmagnetic element using for location of a permanents magnet,
4 – a construction element made from an epoxy – glass composite,
5 – a construction element made from an iron using for connected the rail module with the supporter of laboratory stand.

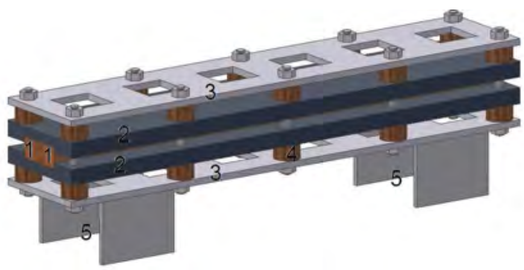

Figure 5. Construction of the rail module

3. The field model of the coil module

The field models (two and three dimensional) for the coil module created with using the Comsol Multiphysic ver. 3.3. For created simulation models assumed:

- the winding made from cooper
- the coil length equal 28,8 mm
- the coil internal diameter equal 9,8 mm
- the coil external diameter equal 17,7 mm
- the number of turns equal 472
- the projectile made from iron
- the projectile length equal 23 mm
- the current value: 1; 1,5; 2; 2,5; 3 A

The two dimensional model created with using symmetry of a magnetic circuit. The coil module in simulation surrounded by the air. On figure 6 shown a magnetic flux distribution and a magnetic flux density for the coil current 2 A.

a) b)

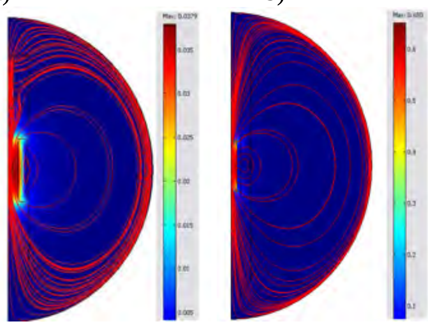

Figure 6. The magnetic field distribution and the magnetic flux density a) the projectile is outside the coil b) the projectile located exactly in the center of the coil.

The simulation performed for 80th different the projectile positions. For each of them determinated value of a force acting on the projectile (Fig.7.). On a horizontal axis is distance between center of the projectile and centre of the coil.

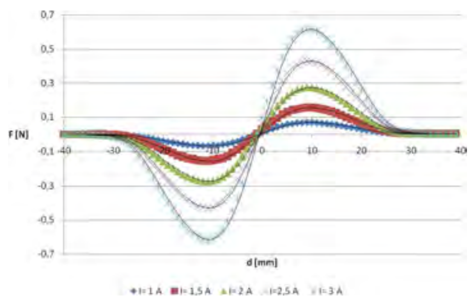

Figure 7. The magnetic force acting on projectile for different current values and for different projectile positions.

Like shown on a picture above, the magnetic force is symmetrical about a zero point. By the zero point we mean that center of the projectile is exactly in the same point like the center of the coil. When the distance between the center of the coil and the center of the projectile equal 9 mm on the projectile acting the maximal force.

For verification the 2D model created the 3D model below shown view of the 3D model.

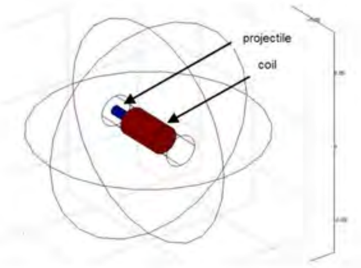

Figure 8. The 3D model view of the coil module

In a table number one shown the results comparison.

Table 1: The results comparison between the models

I [A]	Maximal force acting on projectile	
	model 2D	model 3D
1	0,069	0,074
1,5	0,155	0,167
2	0,275	0,296
2,5	0,429	0,463
3	0,619	0,656

4.The laboratory stand using for verifications results obtained in simulations way [2]

The laboratory stand (Fig. 9) allows the force measurement acting on the projectile located into electromagnetic field of the coil, the force is measured with an accuracy equal 0,01 N. The projectile is moving step by step (one step equal 1 mm).

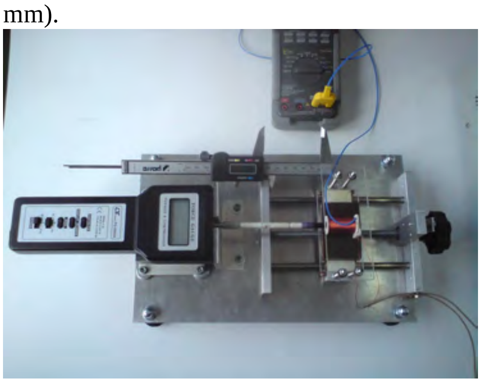

Figure 9. The laboratory stand using for comparison results

Below shown a graphical comparison results obtained in simulation and measurement way for current 1A.

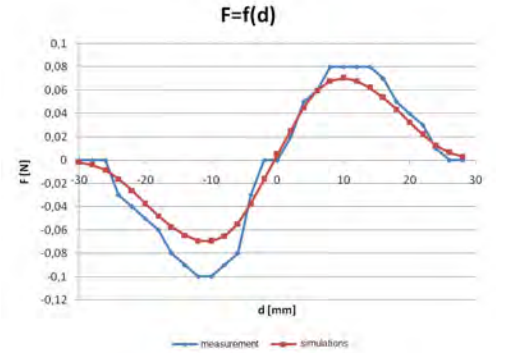

Figure 10. Measurement and simulation results

5. Field models of the rail module

For the rail module performed two models:

- an electromagnetic model
- a mechanical model

5.1 The electromagnetic model of the rail module

A static electromagnetic model of the rail module performed with using an AC/DC module (“Conductive Media DC” and “Magnetostatic Vector Potential”). The model contains only that parts of real stand which have impact on electromagnetic field distribution, the last parts were omitted. The simulation research made for the rail current equal 50 kA, assumed that the rails are made from the cooper, the projectile is made from the iron. By the simulation determined a value of force acting on the rail in a transverse direction and a force value acting on projectile in a longitudinal direction (direction of the projectile motion). On the picture below shown the magnetic filed distribution and the magnetic flux density for case where the projectile is on the end of the rail module (the maximum force value acting on the projectile), and the power is connected to the beginning of the rails.

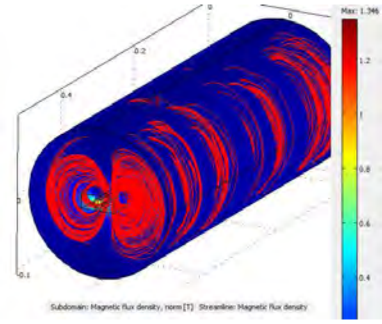

Figure 11. The magnetic field distribution and the magnetic flux density of the rail module

The force value acting on the rail equal 8,31 kN, and on the projectile 0,21 kN.

5.2 The mechanical model of the rail module

The mechanical model of the rail module performed with using a “Structural Mechanics” module (Solid, Stress – Strain). The forces value obtained through the electromagnetic simulation, transferred to the mechanical model. Below shown a module deformation, a stress distribution (Fig.12.) of the material and a distribution of total displacement (Fig.13.).

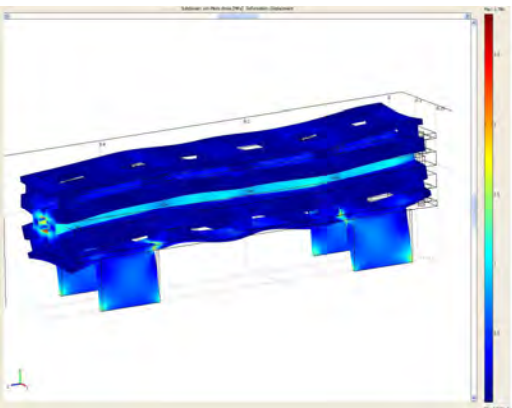

Figure 12. The rail module deformation with the stress distribution

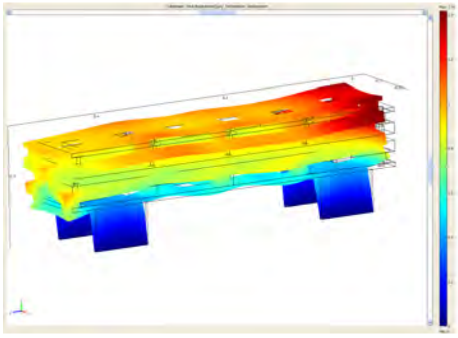

Figure 13. The rail module deformation with the values of displacements.

6. Conclusions

In the paper presented short view of modeling the hybrid electromagnetic launcher with using the Comsol Multiphysic program. The results obtained in the simulation way are similar to the results obtained on the laboratory stand or in the another program. One of the encountered problems was executed the simulation electro – magnetic and mechanic together. It is planned in future executing a dynamic simulations for each step separately and for all steps, also is planned using a thermal and a plasma module in the future.

In the Mechatronics Department, Comsol Multiphysic is using also for modeling anther kind of devices like:

- a force transducers
- a voice coil motors
- a hard drive platters etc.

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8. References

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