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COAXIAL LINEAR MOTOR FOR ELECTROMAGNETIC LAUNCHERS

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Abstract. ***This paper deals with a new coaxial linear permanent magnet motor. For a designed physical model of this motor, the representative magnetic spectrums are determined: the spectrum of the excitation field provided by cylindrical permanent magnet, and the spectrum of total magnetic field given by superposition of permanent magnet field and of energizing coil field.***

Keywords: coaxial linear motor, electromagnetic launchers.

1. INTRODUCTION

Electromagnetic launchers or electromagnetic catapults have received great attention in the last decades because of their potential application to a variety of mass transportation.

The electromagnetic launchers use the electromagnetic field to produce propulsive force, and these can overcome many of the disadvantages of chemical launchers such as velocity limitations and difficulty of acceleration control. The electromagnetic launchers are relatively cheap when compared with conventional chemical launchers since they are reusable, could project almost pure payloads, and the used electricity has a relative low cost.

Throwing force of electromagnetic launchers or electromagnetic catapults is produced by linear electric motors of various types. An electromagnetic launcher is composed of an accelerating electric motor, an electrical energy storage unit, a power supply and a electronic control device. Acceleration electric motors can be of various types: asynchronous, synchronous permanent magnet or synchronous switched reluctance motors [1]. Electrical energy storage units may be mechanical flywheels, called also impulse generators, or ultra-capacitors batteries. Figure 1 shows the structure of a proposed coaxial linear motor electromagnetic launcher utility highlighting three elements: load system and its hook device, coil stationary system and magnet moving system of the launcher.

Unlike other types of launchers where the throwing force is produced by purely mechanical or chemical means, electromagnetic launchers offer many advantages: a reduced size, an increased operating safety control for the speed and acceleration of the launched object. The electromagnetic launchers are relatively cheap when compared with conventional chemical launchers since they are reusable, could project almost pure payloads, and the used electricity has a relative low cost.

These systems are a class of mass drivers that use a direct adaptation of linear electric motors to accelerate various useful loads to high speeds.

The linear electric motors that operate through the reaction between stationary coils and a coaxial mobile armature that is attached to a useful load are essentially coil guns that magnetically accelerate, along a path, a package consisting of a holder containing the payload. Once the payload has been delivered, the holder is slowed down and recycled for another charge.

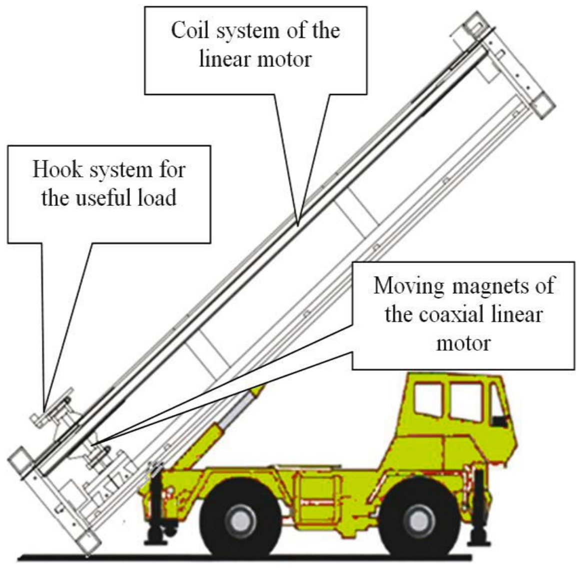

Figure 1. Coaxial linear motor application proposal with its elements: hook system for the useful load, coil system and the moving magnet system of the linear motor.

An initial 3D model design of the coaxial motor marks the basic four elements of the functional assembly: motor's rail system, linear bearings for guiding and support, magnet moving system and coils stationary system as presented is Figure 2.

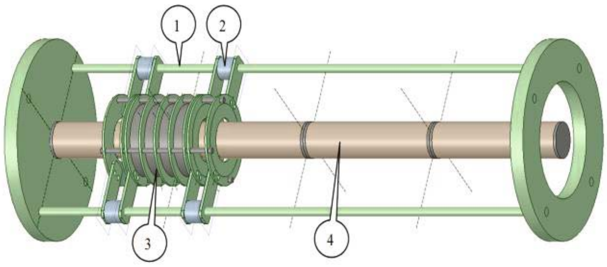

Figure 2. Coaxial linear motor 3D model with basic elements:
1- rail system;
2- linear bearings for guiding and support;
3- magnet moving system;
4- coils stationary system.

In recent years, permanent magnet linear motors have been more and more used in applications showing a significant advantage in terms of efficiency, thrust control, position accuracy, and reliability. Rare-earth magnets, such as SmCo or NdFeB magnets, improve the performance of the permanent magnet linear motor drives, making slotless motors interesting solutions [1–6].

This paper describes a new slotless coaxial linear permanent magnet motor with the principle electromagnetic launch arrangement shown in Figure 3 [7]. A physical model was designed for future experimentation. For this physical model, two specific magnetic field spectrums have been determined:

a) the spectrum of the excitation field provided by cylindrical permanent magnet;

b) the spectrum of total magnetic field given by superposition of permanent magnet field and of energizing coil field.

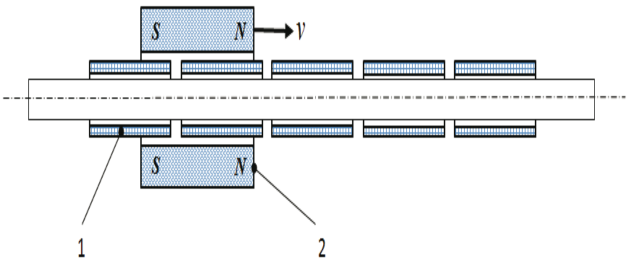

Figure 3. Principle structure of coaxial linear permanent magnet motor:
1 – energizing coils (stationary armature);
2 – permanent magnet (mobile armature).

2. PHYSICAL MODEL OF THE NEW TUBULAR LINEAR PERMANENT MAGNET MOTOR

In Figure 4 appears the longitudinal section of the physical model of the proposed coaxial linear motor. The interior stator consists of an array of coils with 40 mm length, disposed on a barrel with a 28 mm diameter.

The exterior mobile armature consists on a cylindrical NdFeB permanent magnet with 13 mm length and two iron magnetic flux concentrators with 16 mm, and 32 mm length, respectively. The mobile armature is of a length that spans one and half of stator coils and the stators' coils may be switched on and off as the rotor progresses.

Polyphase excitation of the coils constituting the barrel is designed to create an electromagnetic wave packet, which travels with increasing velocity from left to right.

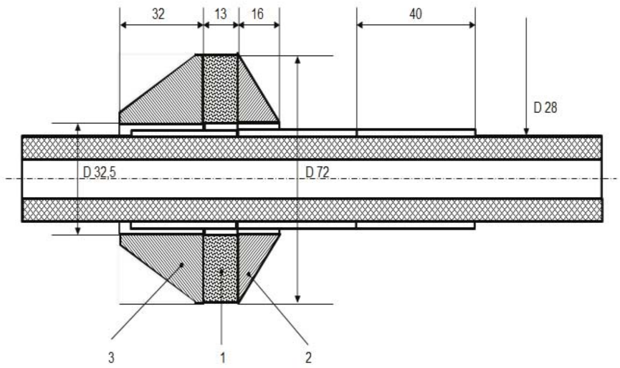

Figure 4. Physical model of the proposed coaxial linear motor:
1 – cylindrical permanent magnet;
2 – front magnetic flux concentrator;
3 - rear magnetic flux concentrator.

The mobile armature is a cylinder piece (sleeve) carrying the payload within it. If a proper system of currents, able to produce a travelling wave of magnetic flux density in the region between the permanent magnet sleeve and the coils, is used to feed stator coils, a further thrust force on the armature itself will be produced.

Once the launch has been performed it is necessary to stop the payload holder in reasonable space and time. In this paper, we propose an electrical braking system. To reduce the stopping distance in the braking phase, the launcher itself can operate as a break.

For this purpose, we must reverse the speed of the traveling magnetic field provided by the last coils. In this case, the kinetic energy of the holder is converted in electrical energy, which can be dissipated or stored into a separated electrical circuit.

3. SPECIFIC MAGNETIC FIELD SPECTRUMS

Two kinds of magnetic field spectrums for the proposed coaxial linear motor were calculated by using Maxwell® program.

Figure 5 illustrates the geometry and materials of the coaxial linear motor armatures edited in Maxwell program.

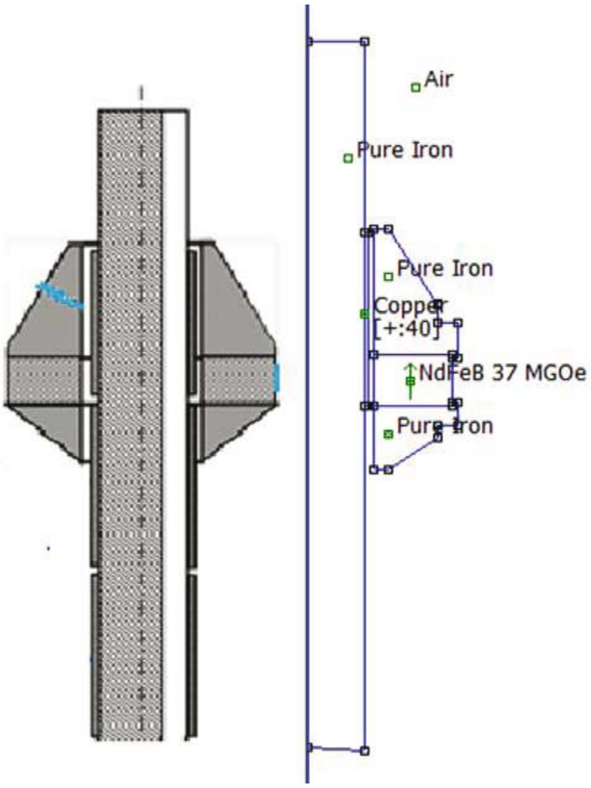

Figure 5. Coaxial linear motor geometry and materials edited for the magnetic fields' calculation.

The calculated magnetic field spectrums are shown in Figure 6 and Figure 7. As we can see, the maximum value of the magnetic flux density, of 2.17 T, is obtained in the case of Figure 6. This value can be accepted if we want to have a not too heavy electromagnetic launcher.

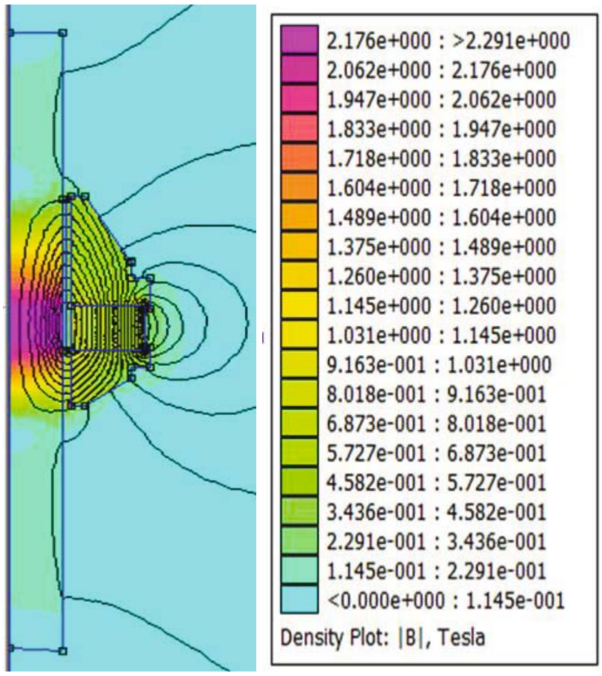

Figure 6. The magnetic field spectrum of mobile armature's permanent magnet.

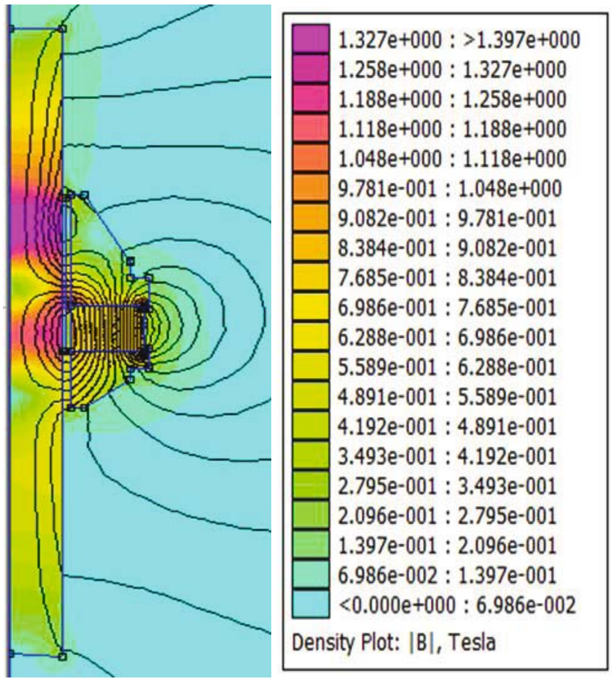

Figure 7. The magnetic field spectrum of the resultant magnetic field after the superposition of permanent magnet field and energizing coil field.

4. CONCLUSIONS

A new slotless tubular permanent magnet linear motor has been proposed. A physical model for this new coaxial linear electric motor was designed. For this physical model, two representative magnetic spectrums are determined: the excitation field spectrum provided by cylindrical permanent magnet, and the total magnetic field spectrum given by superposition of permanent magnet field and of energizing coil field. The calculated values of the magnetic flux density in the magnetic circuit of the designed physical model are under recommended limits. A high power switching circuits used to power the individual stator coils and the appropriate control system will be the subject of a future paper.

5. ACKNOWLEDGMENTS

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