A SUPERCONDUCTING MAGNETIC LEVITATION TRAIN PROTOTYPE IN CLOSED LOOP TRACK

(*) R.M.Stephan, A.C.Ferreira, M.A.Cruz Moreira, M.A.P.Rosário, O.J.Machado, R.de Andrade Jr., M.A.Neves, L.G.B.Rolim, R.Nicolsky.
(*) UFRJ, LASUP (Laboratory of Applied Superconductivity)
P.O. Box 68553 , 21945-970 Rio de Janeiro, Brazil
Tel/fax: 55-21- 2642 8088, e-mail: rms@ufrj.br
http://www.lasup.dee.ufrj.br

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Abstract

This paper describes a reduced scale MAGLEV vehicle prototype, which is under development at UFRJ (Federal University of Rio de Janeiro) since year 2000. The basis for the vehicle levitation is the diamagnetic response of HT_cS (High Temperature Superconductor) blocks that produce a repulsive force against permanent magnets distributed on the rail. A closed loop laboratory prototype is now available and tests are being conducted to better understand the advantages and limitations of this technology.

1. Introduction

The need of high speed non-polluting transportation systems has drawn the world attention to MAGLEV trains, that can travel at speeds of 500km/h and use electricity as energy source. In Brazil, for instance, more than 90% of electric power is generated in hydroelectric power stations that are renewable energy sources. This paper describes a reduced scale MAGLEV vehicle prototype, which is under development at UFRJ since year 2000 [1-2].

The development of YBCO blocks in 1984 made feasible the construction of a new concept of MAGLEV trains, based on high temperature superconductors diamagnetic response, that causes a repulsive force between such blocks and permanent magnets distributed on the rail [3].

The strong pinning force in these blocks leads to self-stability, as already reported [4-5-6], and this fact represents an advantage in comparison with other levitation schemes, but, up today, there is not a real scale prototype of this train in the world. This technological opportunity must be studied and analysed for practical applications. Many groups around the world pursue such application [7].

A laboratory prototype, that reproduces in reduced scale such solution, is now available at UFRJ, and tests are being conducted to better understand the advantages and limitations of this technology. Design considerations and experimental results are presented in this paper.

2. The Laboratory Prototype

In order to test the performance of both traction and levitation systems, the vehicle runs in a double rail closed loop track with an oval-like perimeter of 30 meters, as shown in Fig.1.

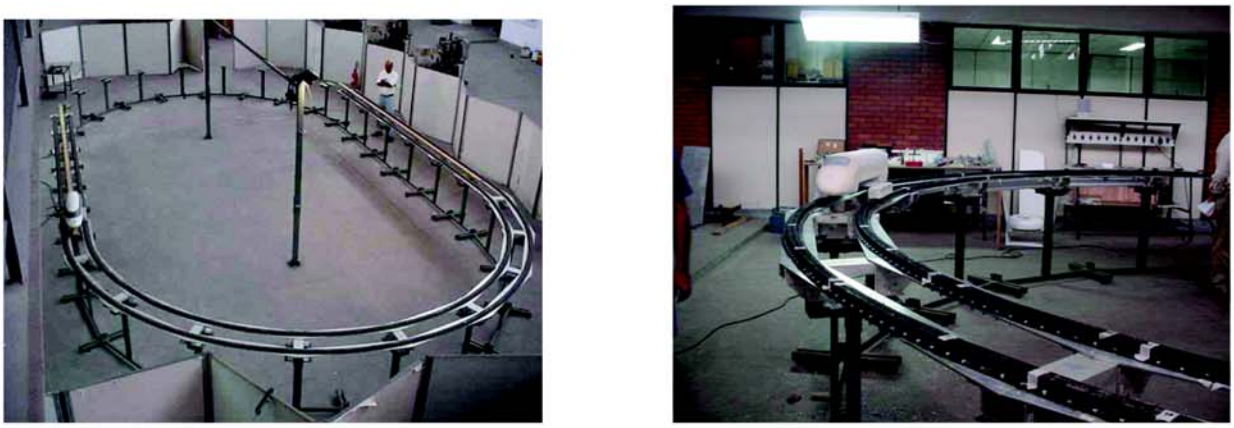

Fig. 1 - Oval-like closed loop track

The vehicle contains four poles of NdFeB magnets as presented in Fig.2 and behaves as the rotor of a synchronous machine.

Fig. 2 - MAGLEV vehicle

The absence of any mechanical means for force transmission suggests the use of linear motors for the propulsion of magnetically levitated bodies. The inconvenience of sliding contacts at high speeds may be overcome with linear motors with long armature windings. After this choice, the linear synchronous motor (LSM) has advantages over the linear induction motor (LIM) since LSM can work with bigger air-gaps, is simpler to control and both have the same windings configuration. The armature windings are shown in Fig.3. The flux density produced by these windings was obtained with 3-D FEM (Finite Elements Method) simulations (Fig. 4)

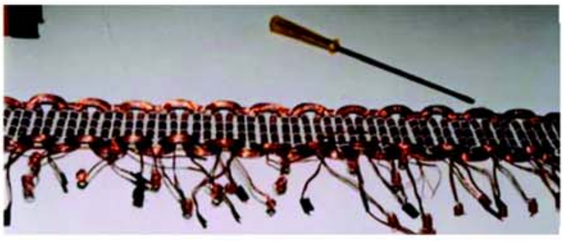

Fig. 3 - Armature windings

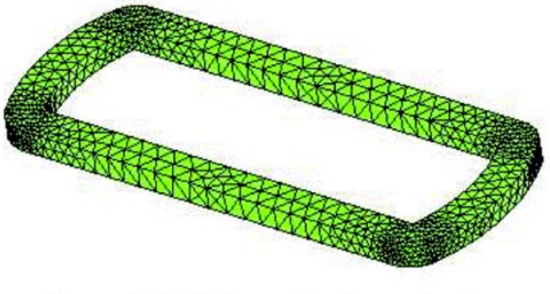

Fig.4 - 3-D FEM model of one winding.

The traction force is calculated by FEM considering a 3-D model where the conductors are fed with a time-varying three phase set of currents (Fig. 5). Sequential solutions are calculated for successive time intervals in such a way that the spatial displacement between the magnetic field produced by the permanent magnets on vehicle and the field produced by the armature changes with time, thus simulating the variation of load angle δ. The force was calculated over the conductors on track using

$$F = J \times B$$

and

$$F_{track} = -F_{vehicle}$$

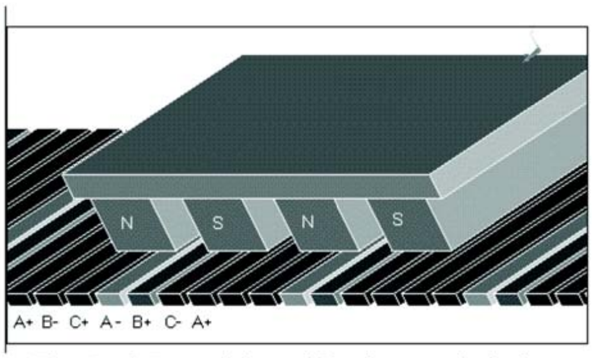

Fig. 5 - 3-D model used for thrust calculation

These FEM simulation were compared with measurements of traction forces and analytical equations showing good agreement (Fig. 6).

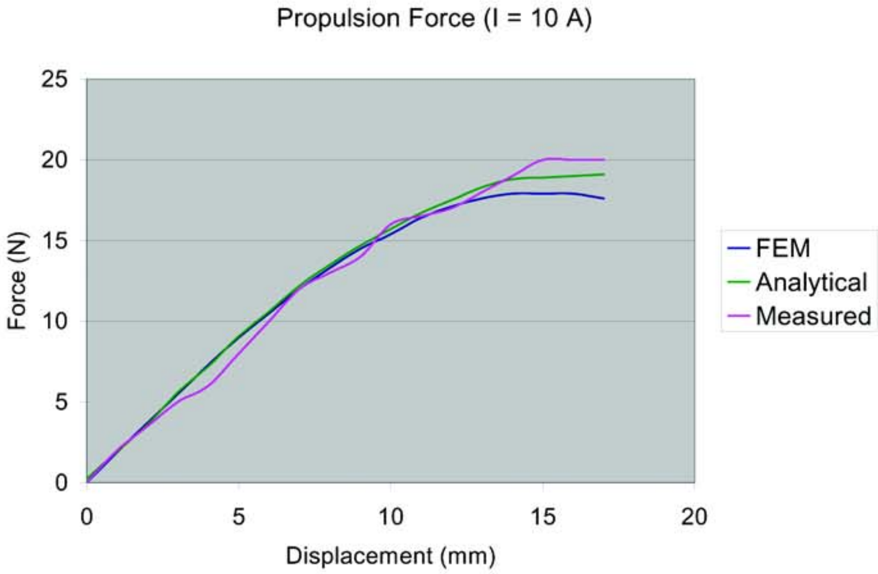

Fig.6 - Force for I=10.0 A

The levitation rails use NdFeB magnets assembled in opposite dipole symmetry, separated and sided by flux concentrators of steel as shown in Fig. 7.

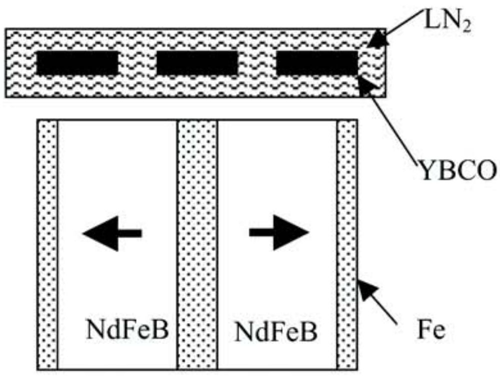

Fig. 7. (a) NdFeB levitation rails and linear motor. (b) Cross section of one levitation rail.

3. Power Supplies

The linear synchronous motor is divided in two segments and, for each segment, the power is supplied by an inverter (Fig. 8).
The operation of these two inverters must be synchronised according to the vehicle speed and position.

Fig. 8 Inverters

4. Experimental Tests and Future Work

Experimental tests are under development and include:

- maximal acceleration/ deceleration time,
- lateral stability in curves,
- synchronisation,
- field cooling air gap influence on vehicle dynamics.

For the next two years horizon, improvements on the closed loop reduced scale prototype will be carried out.

An economical analysis of the connection between Rio de Janeiro and São Paulo, the two largest cities in Brazil, with a traffic of 20 million passengers foreseen for the year 2010, will be conduced. Financial support for the construction or a real scale vehicle is also expected.

5. Conclusion

Many technological aspects of a MAGLEV superconducting train can now be studied with the reduced scale prototype described in this paper. The feasibility of this technology can be now realistically established.

6. Acknowledgments

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7. References

[1] R.Nicolsky, R.M.Stephan, R.de Andrade Jr., A.C.Ferreira, "The Brazilian Project for a Superconducting Magnetic Levitation Train", *MAGLEV'2000*, Rio de Janeiro, pp. 179-182

[2] R.Nicolsky, R.M.Stephan, A.C.Ferreira, R.de Andrade Jr, M.A.Cruz Moreira, L.G.B.Rolim, M.A.Neves, M.A.P.Rosário, "The Current State of the Brazilian Project for a Superconducting Magnetic Levitation Train", *MAGLEV'2002*, Lausanne, CD-ROM.

[3] F.C.Moon, S*uperconducting Levitation.* John Wiley & Sons, Inc. New York, 1993.

[4] W. Gawalek, W. Schüppel, R. Hergt, W. Andrä, K. Fischer, and P. Görnert. "Evidence of Strong Pinning in Peritectic Grown $YBa_2Cu_3O_{7-x}$ Single Crystals", *Physica C: Superconductivity*, vol. 185-189, pp. 2261-2262, December 1991.

[5]R. Nicolsky, Y. Gorelov, A.S. Pereira, D. David, A. Santisteban, R.M. Stephan, A. Ripper, R. de Andrade Jr, W. Gawalek, T. Habisreuther, and T. Strasser, "Superconducting Axial Bearing for Induction Machines with Active Radial Magnetic Bearings". *IEEE Trans. Applied Superconductivity*, vol. 9, pp. 964-967, 1999.

[6]R. Nicolsky. R. de Andrade Jr., A. Ripper, D.F.B. David, J.A. Santisteban, R.M. Stephan, W. Gawalek, T. Habisreuther, T. Strasser, "Superconducting-electromagnetic hybrid bearing using YBCO bulk blocks for passive axial levitation". *Superconductor, Science and Technology,* vol. 13, pp. 870-874, 2000.

[7] J. Wang Editor, International Workshop on HTS MAGLEV – ISMAGLEV, Chengdu, China, 2002.