A Full-Scale Module of the Maglev-Cobra HTS-Superconducting Vehicle

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Richard Stephan, Eduardo David, Rubens Andrade Jr., Ocione Machado, Daniel Dias
LASUP/UFRJ, P.O. Box 68553, Rio de Janeiro, RJ 21941-972, Brazil
rms@ufrj.br, egdavid@pet.coppe.ufrj.br, randrade@dee.ufrj.br,, ocione@dee.ufrj.br
Guilherme G. Sotelo
LASUP/UFRJ and FSMA, Macaé, RJ , Brazil
sotelo@coe.ufrj.br
Oliver de Haas
IFW, Institut für Festkörper- and Werkstoffforschung, Germany
o.dehaas@ifw-dresden.de
Frank Werfel
ATZ, Adelwitz Technologiezentrum GmbH, Germany
werfel@t-online.de

ABSTRACT: This paper discusses the status of the Maglev-Cobra project developed at the Federal University of Rio de Janeiro (UFRJ). This project started in 2000 and, since then, a small-scale prototype has been developed and tested. The present paper describes the first full-scale module of this technology.

1 INTRODUCTION

The status of this project was previously reported in a number of publications at MAGLEV 2000, 2002, 2004 and 2006 conferences [1,2,3,4].

The Maglev-Cobra levitation method is based on the flux pinning properties of High Temperature Supercondutors (HTS) in the presence of magnetic fields, which can be provided by Nd-Fe-B permanent magnets. The proposed vehicle is made of short modules, one meter long each one. When the modules are connected, the vehicle resembles a snake, or 'cobra' in Portuguese, and can follow curves with just 30m of radius [5]. Each module offers space for eight passengers and maximal loaded weight of 800kg.

This paper presents the construction of a real scale test module, levitating above a permanent magnetic railway. The superconductors are accommodated inside four cryostats, specially designed for this application. The magnetic rail uses permanent magnets arranged in a flux shaper (or flux collector) scheme, with iron parts properly located between two Nd-Fe-B with the same magnetic poles. The module has a modern design and light structure of aluminum.

The cryostats, the rail construction and the vehicle design will be explained.

2 THE TRANSPORTATION MODULE

Figure 1 presents the cross section of the vehicle module. The dimensions are in centimeters. The module has a length of 1 meter and space for eight passengers (four seats). The module weight is 240 kg and the total load, considering 8 passengers, is 800kg. This first prototype was built using aluminum, but other materials are being considered for future improvements.

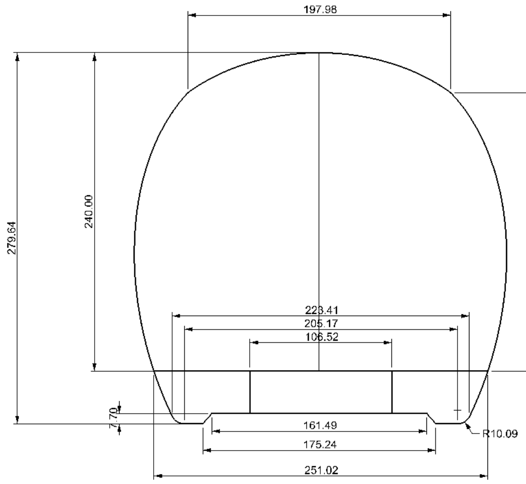

Figure 1. Cross section of the vehicle (dimensions in cm).

An artistic drawing of one module can be seen in Figure 2. The construction of this module has already started, and its picture by the time this paper has been written in is shown in Figure 3. The first tests using this module will be preceded before the end of this year.

Figure 2. Module drawing.

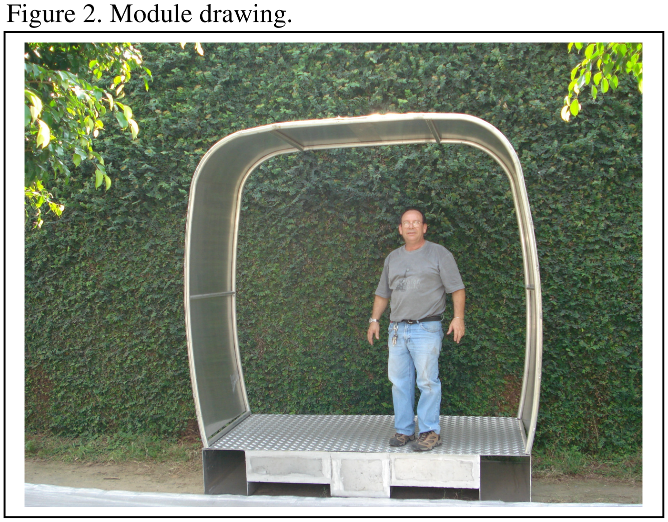

Figure 3. Module picture by September 2008.

3 THE MAGNETIC RAIL

The magnetic rail contains 5x5x10 cm^3 Nd-Fe-B magnets arranged in a flux shaper scheme. The size of the iron between the two permanent magnets is 1.2cm. The optimization of the magnetic rail has also been studied by this group and it is reported elsewhere in this conference [6]. Figure 4 depicts the structure to support the magnets and the reference axis adopted here.

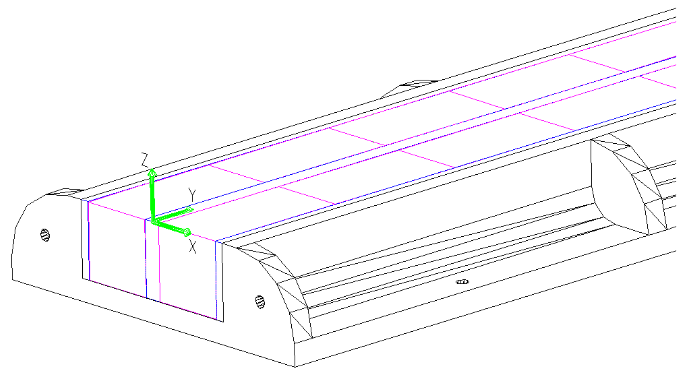

Figure 4. The rail support structure.

Electromagnetic Finite Element Method (FEM) simulations were done to project the magnetic rail and to estimate the field distribution surrounding the track. The FEM results showing the magnetic flux lines and the magnetic flux density modulus can be seen in Figure 5. The soft magnetic bars were made with carbon-steel SAE-1010. The vertical size of these bars was reduced to one half of the size of the permanent magnet, in order to increase the magnetic flux onto the top of the rail. The estimated levitation pressure produced on the vehicle module (where the superconductors are) for field cooling (FC) and at a distance of 1cm is 4 N/cm^2.

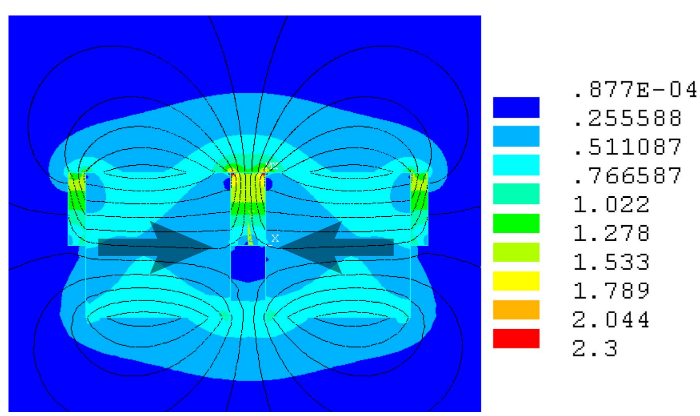

Figure 5. FEM simulation of the magnetic flux density modulus (in T) and the magnetic flux lines.

Due to the balance between the vertical levitation force and lateral stiffness, an optimal FC gap must be chosen. Higher FC gaps allow larger vertical levitation force and smaller lateral restoring force. In other hand, if the FC gap is smaller, the superconductor increases the lateral stiffness but it is not able to support higher loads. The magnetic rail was developed to cool the superconductors in a gap of 15mm, whose magnetic field results are presented in figure 6. After the FC process, it is expected to operate the vehicle with a gap of 10mm.

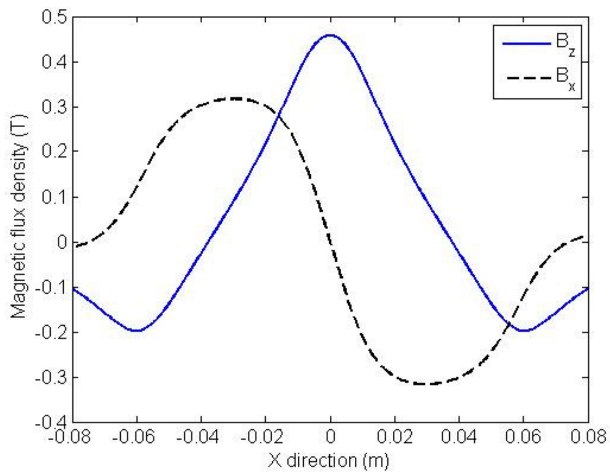

Figure 6. Magnetic flux density above the rail at Z=15mm.

To evaluate the magnitude of the rails' magnetic field along the space and its influence on passengers, the field decay along the space was simulated. Figures 7 and 8 show, respectively, the Z and X components of the magnetic field for three different X positions. The positions X=0mm, X=31mm and X=59mm correspond to the center of the magnetic rail, the center of the permanent magnet and the center of the outer iron bar, respectively. It is possible to observe that both components of the magnetic field are negligible for a vertical distance higher than 10cm.

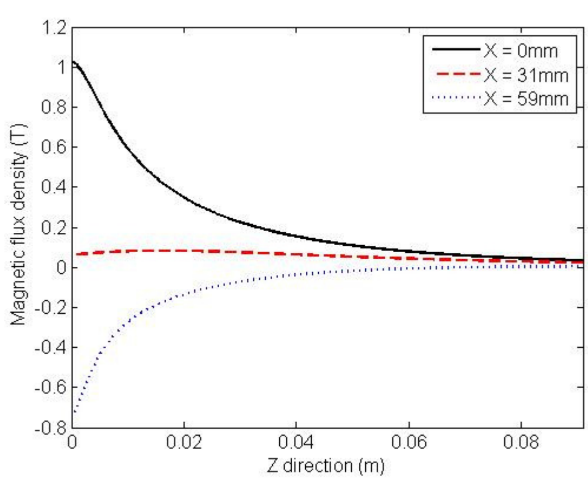

Figure 7. Z component of the magnetic flux density above the rail along Z direction for three values of X.

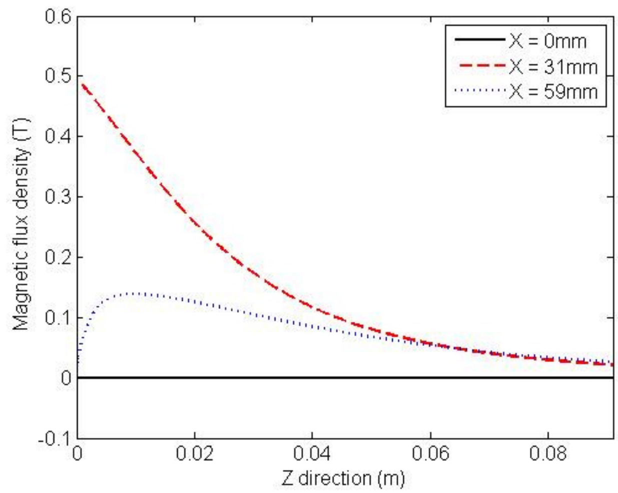

Figure 8. X component of the magnetic flux density above the rail along Z direction for three values of X.

4 THE CRYOSTATS

For ease of refrigeration, the superconductors are put inside cryostats, as suggested in Figure 9.

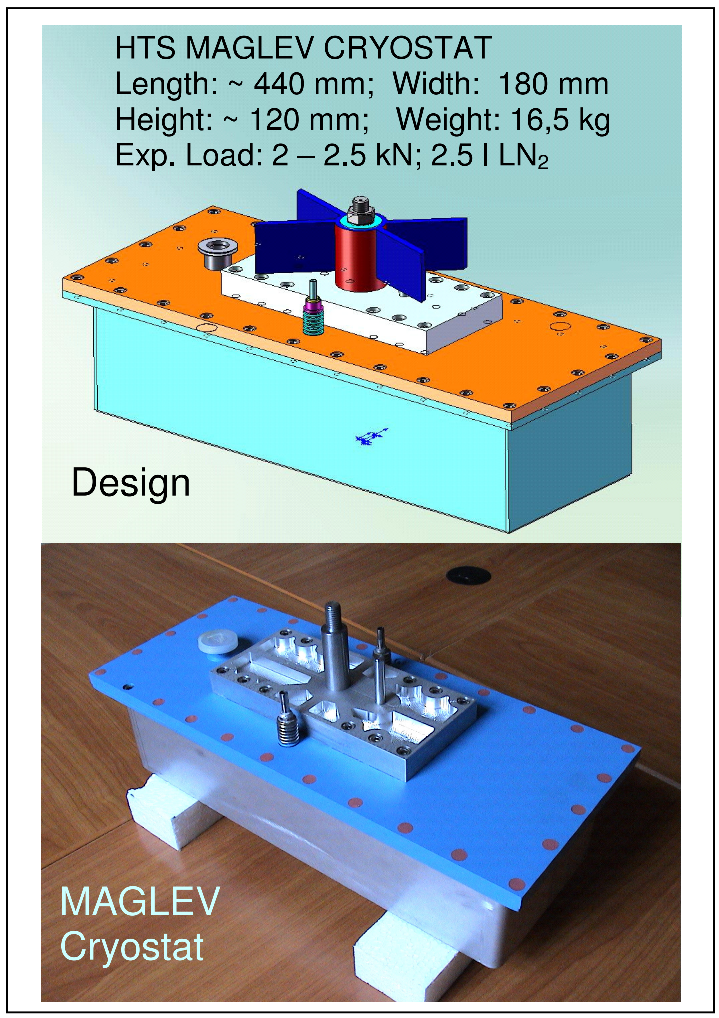

Figure 9 Design and assembled HTS MAGLEV cryostat.

Altogether four vacuum cryostats were fabricated. Each cryostat consists of a stainless steel body with a G-10 plate on the top. A mechanical interface on top is provided to fasten the passenger module. Inside of each cryostat 24 multi-seeded YBCO bulks of the dimension 64mm x 32mm x 12mm are located in a copper holder. The total HTS area is about 490 cm² per cryostat. The superconductors are kept at low temperature by conduction cooling using LN_2. The 2mm distance between the YBCO surface and the cryostat bottom allows high levitation forces and respectively a large load capacity. Due to the 2.5 liter LN_2 storage capacity long operation is ensured. First measurements of the LN_2 consumption under static conditions indicate a one-day operation without refilling.

A great effort was directed to the thermal insulation achieving extremely low heat transfer between the cold YBCO part and the outer cryostat housing. Simultaneously, a compact and robust cryostat design and construction could be obtained.

5 INTEGRATION OF THE PARTS

Figure 10 combines the transportation module, the magnetic rail and the superconductors. The magnetic field inside the vehicle is lower than average Earth's magnetic field, therefore discarding any safety issues.

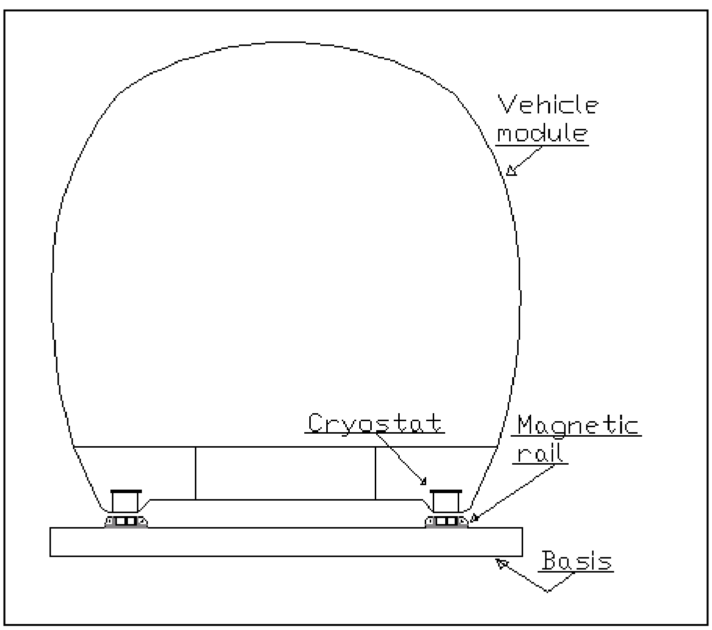

Figure 10. Vehicle, magnets and superconductors.

6 CONCLUSION

The Maglev-Cobra technology for urban transportation has already been tested in small-scale prototypes. The efforts to turn this transportation vehicle into reality need the construction of full-scale units. Similar steps were followed with other technologies like the Transrapid, with the Emsland test track, and the Japanese Maglev, with the test line in Yamanashi.

This paper reported the initial efforts to turn the Maglev-Cobra technology into a full-scale prototype.

7 REFERENCES

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