Feasibility study of an HTS-Maglev line at the Federal University of Rio de Janeiro

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ABSTRACT: The potential application of an HTS-Maglev train has been shown with a small scale prototype developed at the Federal University of Rio de Janeiro (UFRJ) in 2004. The natural following step is the construction of a full scale prototype. This paper presents a study comparing the construction costs of an HTS-Maglev line of 1.0 km inside the Campus of UFRJ with a LRV (Light Rail Vehicle) one.

1 INTRODUCTION

The potential application of an HTS-Maglev train has been shown with a small scale prototype developed at the Federal University of Rio de Janeiro (Stephan et al. 2004, 2005). Other laboratory studies developed in China at the Southwest Jiaotong University (Wang et al. 2002), in Germany at the Dresden Technical University (Haas et al. 2004, 2005) and, more recently, in Russia at the Moscow Aviation Institute (Kovalev et al. 2005) confirm these results.

The next necessary convincing effort to turn this technical option into a real technology is a full scale prototype. Similar steps were followed for the Electromagnetic Levitation Maglev, in Germany (Transrapid), Japan (HSST), U.K. (Birmingham) and South Korea (KIMM), as well as for the Electrodynamic Levitation Maglev, in Japan (RTRI).

This paper presents a study comparing the construction costs of an HTS-Maglev line of 1.0km inside the Campus of the Federal University of Rio de Janeiro (UFRJ) with an LRV (Light Rail Vehicle).

The chosen track has the advantage that no expropriation costs need to be taken into account and that the rail stations can be simple platforms. Nevertheless, the study considers civil, mechanical and electrical engineering costs. Preliminary calculations have already shown that this particular Maglev line can be cheaper than a LRV one.

2 BASIC SPECIFICATIONS

The basic specifications of the Maglev and LVR cars taken as reference for the present study are given in tables 1 and 2, respectively.

Table 1: Maglev specifications

Specification	Units	Value
Passengers density	Number/m^2	4
Passenger weight	kg	70
Internal width	m	2.5
Internal high	m	2.1
Calculation length	m	1.0
Passengers per meter	p/m	10
Passengers weight/m	kgf/m	700
Vehicle tare	kgf/m	150
Security factor (passengers)	%	50
Security factor (vehicle)	%	33
Total weight per meter	kgf/m	1249.5
Vehicle length	m	38.5
TOTAL VEHICLE WEIGHT	kgf	48,106.0

Table 2: LRV specifications

Specification	Units	Value
Passengers density	Number/m^2	4
Passenger weight	kg	70
Internal width	m	2.5
Internal high	m	2.1
Calculation length	m	1.0
Passengers per meter	p/m	10
Passengers weight/m	kgf/m	700
Vehicle tare	kgf/m	300
Security factor (passengers)	%	50
Security factor (vehicle)	%	33
Total weight per meter	kgf/m	1449.0
Vehicle lenght	m	38.5
SUB-TOTAL WEIGHT	kgf	55,787.0
Trucks per vehicle		2
Truck weight inclusive motors	kgf	12,000.0
TOTAL VEHICLE WEIGHT	kgf	79.786,0

The trajectory is depicted in Figure 1. Two curves with 25 m radius are intentionally introduced to better evaluate the vehicle behavior.

Figure 1: The trajectory.

3 MAGLEV LINEAR MOTOR

Although the project aims at a 1 km track, it is expected that greater advantages will be achieved when operating at longer distances and higher speeds. Having this in mind, it was decided to use a linear synchronous motor for the propulsion.

3.1 *Specifications*

For the 1 km track, the following assumptions are made in the design of the linear motor:

Acceleration/deceleration	1 m/s^2
Accelerating distance	100 m
Free running distance	800 m
Braking distance	100 m
Free running speed	50 km/h
Accelerating mass	48,000 kg

3.2 *Linear motor configuration*

The motor design is in its early stage. The prototype will use a single sided linear synchronous motor with a long three-phase armature winding, along the track, with the field excitation fixed to the vehicle as in Figure 2.

The field excitation consists of an assembly of NdFeB permanent magnet blocks, with each block measuring 120 mm x 120 mm x 60 mm, as presented in Figure 3, with a pole pitch of 0.36 m.

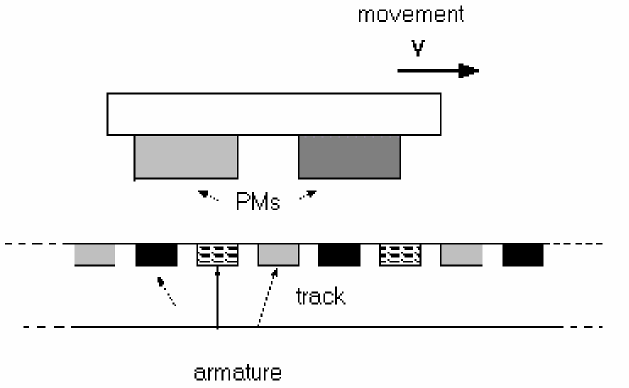

Figure 2: Single sided linear synchronous motor.

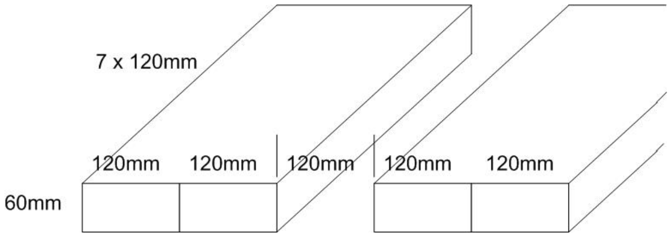

Figure 3: Linear synchronous motor field excitation.

3.3 *Inverters for power supply*

The 1,0 km long track will be divided in three sections of 333 m each. No more than two sections will need to be energized at any instant of time and the switching logic will be controlled digitally. This configuration will allow the operational tests of the power supply using three inverters.

4 MAGLEV LEVITATION RAIL

4.1 *Specifications*

The calculations assume a gap of 10 mm and the same mass used for the linear motor.

4.2 *Simulations and results*

The levitation rail was studied with the help of a Finite Element (FEM) simulation program (Figure 4).

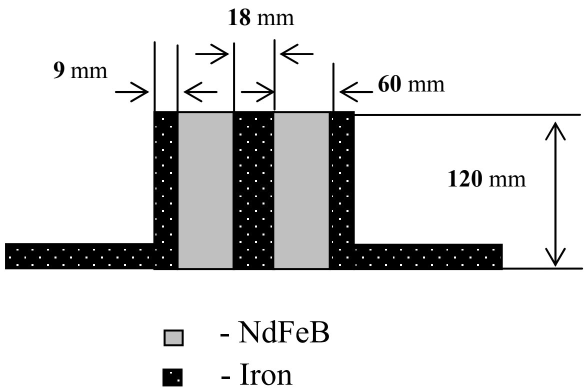

Figure 4: Levitation rail obtained by finite element simulation.

The superconductor was represented in the state of field cooling (FC) using the Bean Model, as shown in Figure 5.

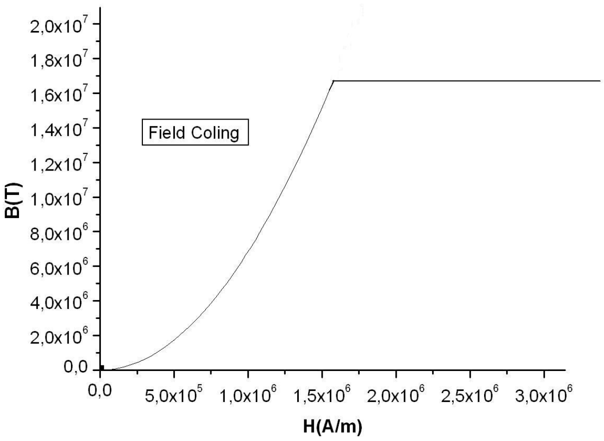

Figure 5: B x H curve for FEM simulation.

5 INFRASTRUCUTRE FOR MAGLEV AND LRV

In transportation systems, the infrastructure costs are much higher than all other ones. Therefore, any economy related with this aspect must be considered.

For urban transportation, the LRV presents well known infrastructure advantages that makes it a reliable reference for comparison with a Maglev line.

5.1 *Vehicle weight and its implications*

An important issue of the elevated structure necessary for the safe operation of trains is the load distribution. For the LRV, the weight is concentrated on the wheels, on the other side, for Maglev trains, the load is distributes along the superconducting blocks.

This fact implies that for the same weight the flexion moments at the elevated structure can be made much lower for Maglev trains in comparison with LVR's. Moreover, as Maglev cars are lighter than LVR' cars for the same number of passengers, the global efforts are approximately 75 % lower.

5.2 *Suporting structure weight*

Being a conventional vehicle, the LVR needs a supporting structure based on sleepers and rails, which weight is circa 1500 kgf/m.

On the other hand, the HTS-Maglev rails are lines of permanent magnets, which weight per meter, for the first approach presented in item 4, is 150 kgf/m. If we add the linear motor weight, the net result will be 70 % leighter than the necessary for a LVR.

5.3 *Structure own weight*

Due to the considerations presented in 5.1 and 5.2, the elevated structure of a HTS-Maglev train can be metalic. For a LVR, a reliable structure must use concrete. Therefore, we can foreseen a reduction of at least 50 % in the structure weight.

5.4 *Vibrations*

The vibrations presented in a conventional rail-wheel system implie in further mechanical considerations that are not so critical for a magnetically levitated system.

5.5 *Movement*

The Maglev does not present friction due to bearings and supporting contacts. Moreover, it is lighter than an equivalent LRV vehicle. Therefore, the power necessary for acceleration and sustained movement is lower. It is also worth mentioning that the linear traction also allows ramps which limit is given by the passengers comfort.

5.6 *Vehicle*

As trucks are not necessary for a HTS-Maglev, it was possible to adopt a completely new concept dividing the train in small modules, easily articulated, as shown in Figure 6. This modular characteristic has two big advantages:

- It allows curves of small radius, so important in urban transportation.
- It makes easier to adapt the train length to the demand, reducing the operational cost.

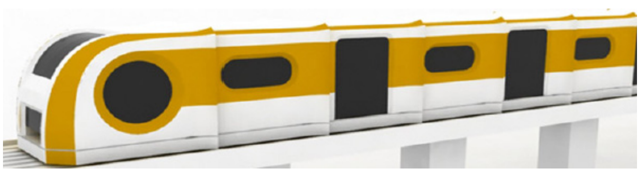

Figure 6: The modular vehicle

5.7 *Cost evaluation*

The considerations presented here were used to estimate the infrastructure costs for the line presented in Figure 1. Table 3 summarizes the results, showing that the investment in infrastructure (the highest part of the total investment) for a Maglev line is much lower that the investment for a LRV one.

Table 3: Infrastructure cost

Specification	Units	Maglev	LRV
TOTAL	US$	1,026,960	1,858,577

6 CONCLUSION

The presented study showed some of the advantages of an HTS-Maglev line in comparison with a traditional LRV line. These initial calculations will be reevaluated and analysed more deeply in the near future. This work will be essential to raise funds to construct a full scale line.

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ACKNOWLEDGMENT

The authors would like to thank the financial support of the Brazilian research and education agencies CNPq and CAPES.