Status of The General Atomics Low Speed Urban Maglev Technology Development Program

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Key Words

Maglev, Urban Maglev, permanent magnet, Halbach array, Inductrack.

Abstract

This paper presents the status of General Atomics Urban Maglev Program. The development provides an innovative approach for low speed transportation suitable for very challenging urban environments. Permanent magnets arranged in a "Halbach" array configuration produce a relatively stiff magnetic suspension operating with an air gap of 25 mm. The project has progressed from design and prototype hardware testing, to the construction of a 120-meter full-scale test track, located in San Diego, California. Dynamic testing of the levitation, propulsion and guidance systems is being performed.

1 Introduction

The Urban Maglev program is sponsored by the Federal Transit Administration and is currently funded under the Transportation Equity Act for the 21st Century (TEA-21). The Urban Maglev team led by General Atomics has developed an innovative approach using a passive, permanent magnet levitation system with a linear synchronous motor powering the guideway to provide propulsion and guidance. Among the advantages are simplicity, safe and quiet operation, ability to climb steep grades (up to 10%) and negotiate tight turns, and all-weather operation. The system has been designed for driverless operation with a throughput of 12,000 passengers per hour per direction, with a two-minute headway between vehicles. It is envisioned to be elevated, which when combined with the enabling features of maglev technology results in a system which can serve many established urban centers. This technology provides urban planners great flexibility, with corresponding savings in capital and maintenance costs. Depending on the alignment, the elimination of tunneling itself can result in substantial system cost savings.

Overall vehicle design, seen in Figure 1, consists of two chassis units connected via an articulation. Nominal vehicle length is 12 m, although the basic chassis units can be connected to produce a train of longer length. Levitation and propulsion magnets are in the vehicle "wrap-around" structure, resulting in a safe vehicle, which cannot derail under any operational conditions. The vehicles have no active control systems; all the control and train protection systems are in the wayside control room.

Figure 1. General Atomics Urban Maglev vehicle uses permanent magnets arranged in a Halbach array configuration for levitation and propulsion.

The levitation technology referred to as "Inductrack", was developed by Dr. Richard Post of LLNL, and uses high field (1.4 Tesla) NdFeB permanent magnet cubes (~5x5x5 cm^3) arranged in a double "Halbach" array configuration, as seen in Figure 2. One of the notable characteristics of the Inductrack maglev system is that its levitation and drag parameters can be analyzed theoretically and evaluated with high confidence through computer codes. Such levitation codes have been developed at General Atomics, at Carnegie-Mellon University, and at the Lawrence Livermore National Laboratory, using both analytical and finite-element computational approaches. Cross-checked against each other, and bench-marked against the results of measurements made with the General Atomics test wheel and the Livermore Laminated Track Test Rig, these tools have proved to be of high value in designing the test track at General Atomics and in optimizing the design of future systems.

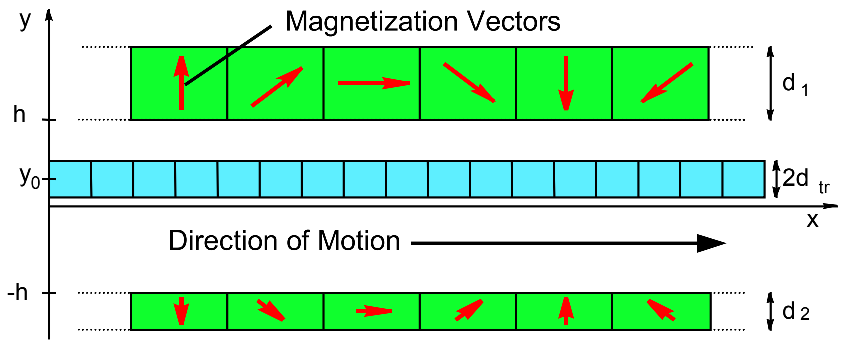

Figure 2. Double Halbach Array Levitation Magnets result in improved lift-to-drag ratio, and a stiffer primary suspension system.

One of the advantages of this configuration is that the field is "focused" on the track, and tends to cancel on the passenger side. In fact, the magnetic field strengths in the passenger compartment are well within recommended allowable values for public safety and below those in existing rail systems without the need for shielding. In addition, because of the nature of the linear synchronous motor operation, all the fields on the vehicle are DC. The array has been configured to provide a nominal air gap of 25 mm, providing the potential for less stringent guideway tolerance requirements. Since this is an Electrodynamic levitation system, the vehicles initially ride on wheels and start levitating at a speed of 3–4 m/s, depending on the weight. With a peak acceleration of 1.6 m/s^2 the vehicles are levitated by the time they exit a station. The details of the technology and potential benefits were discussed in previous papers, including the Maglev 2002 conference in Lausanne, Switzerland [1-6].

Specific accomplishments to date include: concept development, testing of full-scale prototype components (including propulsion and levitation systems), and construction of a full-scale 120-m long test track, vehicle chassis, control and electrical rooms, and all required electrical power systems. The test track is scheduled to be operational in Fall 2004, and will provide validation of the vehicle dynamics and ride quality. Analyses and testing to date give confidence that there are no major technical obstacles.

2 Test Track Construction

In November 2002 we initiated the construction of a 120-meter long test track at the General Atomics Electromagnetics Systems facility in San Diego, California. The test track consists of 8 guideway modules, each 15 meters in length. It has a 50-meter radius curve to demonstrate the guidance system. To save cost for testing, the track is at grade, and consists of a loading ramp for the vehicle, a small test chassis access pit, electrical room, and control room. Figure 3 shows an aerial view of the laboratory, and indicates (in red) the test track site.

Figure 3. Aerial view of Test Track Site

Groundbreaking for the guideway foundation occurred in March 2003, followed by trenching, grading, installation of electrical conduits, and pouring the concrete foundation. The completed 120-m foundation, with the first guideway weldment (prior to turning over) is seen in Figure 4.

Figure 4. Completed 120-m test track foundation, and first 15-m guideway weldment (left). Right picture shows completed guideway module ready for turning over.

The completed chassis unit on the first guideway module is seen in Figure 5. The test chassis has many unique features, specifically focused at being able to vary magnet configurations and gaps, and making changes in the secondary suspension spring constant and damping rates. Variable level water tanks can be mounted on the chassis to simulate the correct center of gravity corresponding to a passenger-carrying vehicle, and the associated shifts in passenger loading.

Figure 5. Completed test chassis on first section of track

The levitation, propulsion, and guidance systems are seen in the end-view of the vehicle and guideway module in Figure 6. The linear synchronous motor (LSM) windings are three-phase and interact with the field generated by the permanent magnet propulsion magnets on the vehicle, with a peak force capability of ~50 kN for a complete vehicle system (~25 kN for the test chassis, which represents ½ length of a full vehicle). The propulsion magnets also provide guidance by interacting with the LSM iron lamination rails.

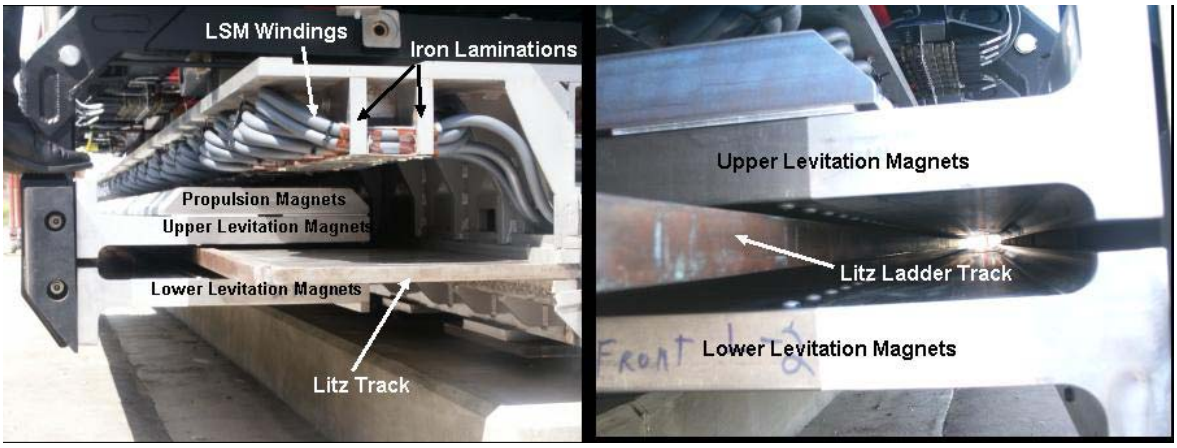

Figure 6. Vehicle levitation, propulsion, and guidance systems

The right side of Figure 6 shows the 3.6-m long levitation magnets and their relation to the cantilevered track, which is a ladder track design consisting of litz cable shorted on the ends with copper. This double-Halbach array combined with the use of litz cable results in significantly reduced magnetic drag forces, for a given lift force. The assembly used for the semi-automated soldering process is shown in Figure 7.

Figure 7. Semi-automated soldering process enables consistent joint resistance

Power to the test track is provided by an IGBT-based, three phase inverter shown in a view of the electrical room in Figure 8, which underwent significant reliability testing during the Spring of 2004. It is sized to be capable of full-scale system operation beyond the test track phase.

Figure 8. View of electrical room, which houses the rectifiers, variable frequency inverter, and train protection equipment

3 Test Operations

The test track is being completed, and is scheduled to start producing test results in the fall of 2004. During a normal testing sequence, the vehicle starts at one end of the test track, accelerates to a maximum speed between 5 m/s and 10 m/s, and decelerates back to zero speed at the other end of the track. The vehicle is expected to levitate at 3-4 m/s and various acceleration and deceleration rates up to 1.6 m/s^2 will be employed. The testing verifies the dynamic performance of the system including levitation, propulsion and guidance. The vehicle motion along the curve and transition section allows us to assess the curve negotiation and guidance characteristics of the vehicle. Test chassis weights between 6,000 kg and 10,500 kg will be tested. Typical expected gap, speed and force profiles are shown in the simulations in Figure 9.

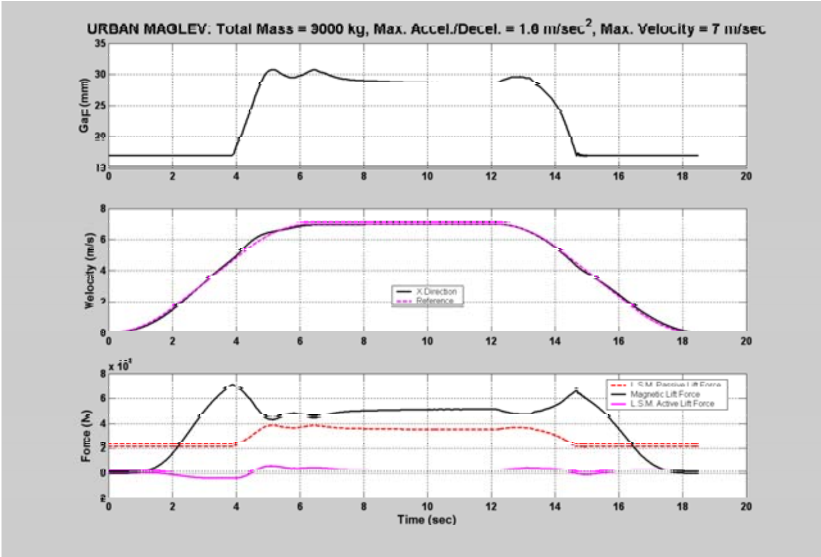

Figure 9. Typical gap and speed profiles during testing will allow vehicle dynamics evaluation

4 Conclusions

The General Atomics Urban Maglev system provides an innovative approach for low speed transportation suitable for challenging urban environments. Analyses and testing of full-scale components to date give confidence that there are no major technical obstacles to successful initial demonstration of the system at the test track, which will validate integrated performance, construction costs, and schedules. The next step beyond the test track will be to construct a demonstration system to refine the system components, and to validate the operational reliability prior to deployment.

5 Acknowledgements

The Federal Transit Administration (FTA), Office of Research, Demonstration, and Innovation is gratefully acknowledged for undertaking this program with General Atomics under Cooperative Agreement No CA-26-7025.

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