Maglev Program in Korea

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Abstract
Maglev Project Team at KIMM has been leading development of attraction type urban transit maglev for the past 10 years. In this paper current status of maglev program in Korea - what has been done so far, efforts to improve technical problems we have – is reported.

1. General

Maglev Project Team at KIMM has been leading development of EMS type urban maglev for the past 10 years under the sponsorship of the ministry of science and technology. In June 1998 we, in cooperation of Korea Railway Manufacturing company, introduced two vehicle consisted maglev train - UTM-01. Running test of UTM-01 for the past three years confirmed the basic performances of the maglev train but showed many improvements yet to be made for commercial applications. Overall system reliability falls short of expectations and refinements of each sub-systems have to be made. It was the first maglev train we made and these were expected. We believe that as far as the EMS system is concerned once the levitation can be secured, it can be one of the promising urban transportation systems and that many of the commercial maglev lines appear worldwide in the near future.

Recently the Korean government granted us a 4 year project to build a new version of two vehicle consisted maglev train. In this paper we report what we are doing to develop an improved maglev model UTM-02.

2. UTM-01

Fig 1 shows UTM-01 under test. The representative vertical gap records are shown in Fig. 2. Peak to peak of gap fluctuations is 2.5 mm at 40 km/h. It measured in the car when accelerating at the rate of 0.8 m/s. Maximum noise level was about 72 dbA.

Figure 1. UTM-01 under running test

Figure 2. Representative vertical gap

Running tests for the past 3 years identified many improvements yet to be made. They are:

1. Need to reduce peak to peak of gap fluctuations occurring when dual gap sensors pass the rail joints. Also fail safe of the levitation controller has to be provided through dual mode.
3. Development Plan of Light Rail Type Maglev UTM-02

In what follows we describe what we have been doing to improve UTM-01.

Levitation Controller

Levitation controller in EMS systems is a key to commercialization. It is an inherently unstable system, so there is no way to maintain nominal gap clearance for all cases. There could be a moment for the magnet to hit the rail due to unusually big gap fluctuations when mechanically braking on 7% downslope with high speeds. We think the controller will suffice so long as it is robust enough to return to normal control immediately after the magnet hits the rail. Aside from the robustness, we need to secure the levitation for possible hardware failures related to the levitation—failure of part of gap or acceleration sensors, magnet drivers, and controller itself. Duality of magnet drivers is provided. Duality of controller is not yet done and we have to do for the coming years. Figure 3,4 shows the test data of the fault tolerant control (FTC) against part of the gap or acceleration sensor failures[1]. It is seen that stable levitation is maintained even if part of the gap or acceleration sensors fails.

Carbody

Present car's cabin floor height above the reaction plate is 1080 mm. In UTM-02 it is reduced to 870 mm to give a low center of gravity for better running performance against external disturbances. Carbody consists of three bogies and is supported by 6 air springs—one for each side frame of the bogie just like conventional wheel on rail bogies. It is simple but has difficulty in negotiating tight curve less than 50

Figure 3. Gap signal when part of the gap sensors fails

Figure 4. Gap signal when part of the acceleration sensors fails

m radius of curvature. In UTM-02, the air spring at the center bogie is designed to be connected to the carbody via linear bearing so that the carbody and the center bogie slide through each other to avoid excessive deflection of the air spring in the lateral direction.

Bogie

The length of the bogie in longitudinal direction is reduced from 3.5 m to 3.0 m for better curve and up/down grade running performance. The weight of the newly designed bogie is 2.2 tons compared with 3 tons previously. The emergency landing roller was modified so that the train can be returned to the maintenance shop or sideway by the LIM or another tugging car when the levitation fails on tight curve.

Linear Induction Motor
The efficiency of the newly designed LIM was somewhat improved as follows.

- by allowing larger current density.
- by using smaller slip frequency than ever.

In doing so, design optimization was done with current density, temperature, and weight of the LIM as parameters. Figures 5 shows test data of the LIM at the rotary LIM tester.

Table 1. Major Specifications of UTM-01 and 02

<table>
<thead>
<tr>
<th>Description</th>
<th>UTM-01</th>
<th>UTM-02</th>
</tr>
</thead>
<tbody>
<tr>
<td>maximum thrust</td>
<td>3.3 KN</td>
<td>4.5 KN</td>
</tr>
<tr>
<td>max. current density</td>
<td>4.1 A/</td>
<td>5.5 A/</td>
</tr>
<tr>
<td>operating slip frequency</td>
<td>12.5 Hz</td>
<td>10 Hz</td>
</tr>
<tr>
<td>material</td>
<td>AL</td>
<td>AL</td>
</tr>
<tr>
<td>Length</td>
<td>2.3 m</td>
<td>2.3 m</td>
</tr>
<tr>
<td>max. acceleration</td>
<td>0.8 m/</td>
<td>1.0 m/</td>
</tr>
<tr>
<td>weight</td>
<td>250 kgf</td>
<td>190 kgf</td>
</tr>
</tbody>
</table>

Major power supply equipments

Major power supply equipments such as VVVF Inverter, DC/DC converter, Magnet Drivers, and L&G Controller are being developed with the following points in mind.

1. All of these use natural cooling to reduce fan noise.
2. Carrier switching frequency above 2 KHz to reduce noise drastically.
3. Reduce weight of each equipments by 30% or more and ease of maintenance.
4. Operating temperature range between -25 and +80 degrees in Celsius.

Figure 6 shows test data of the noise level of the VVVF Inverter with different switching frequencies.

Figure 6. Experimental data of the noise level of the VVVF Inverter at different switching frequencies.

VVVF Inverter at different switching frequencies. It is seen that at switching frequency 2.5 KHz, the noise level is 59.4 dBA. The VVVF and DC/DC converter are being developed with switching frequencies to be above 2 KHz.

Magnet

UTM-01 used general structural steel for both magnet yoke and poles. In UTM-02, pure iron was used for yoke and general structural steel for poles. Anodized aluminium sheet was used for coil. The magnet was made smaller and lighter resulting in ratio of levitation force vs. magnet weight from 8.46 previously to 9.86 with increased nominal current from 19 A to 24 A. Figure 7 shows experimental data on levitation force with increasing magnet current.
Figure 7. Levitation force with magnet currents

Power Collector

Figure 8 shows the newly designed power collector. Test confirmed smooth operation with much lower contact noise and good power collecting capabilities.

Figure 8. Newly designed power collector

Test Track

Maglev test track is located at our institute (KIMM) in city of Daejeon. The length is 1.3 km. It has 6% gradient, 60 m radius of curvature curve, and switching facility. Allowable maximum speed on the 650 m straight section is 70 km/h. The switching facility is of a parallel moving type, which also needs redesigning with shorter switching time in less than 25 seconds. Right now it takes 80 seconds.

Table 2 shows major specifications of UTM-02 compared with those of UTM-01.

<table>
<thead>
<tr>
<th>Major Spec.</th>
<th>UTM-01</th>
<th>UTM-02</th>
</tr>
</thead>
<tbody>
<tr>
<td>dimension</td>
<td>13.6m<em>3m</em>3.96m</td>
<td>13m<em>2.8m</em>3.6m</td>
</tr>
<tr>
<td>empty weight</td>
<td>22 tons</td>
<td>14 tons</td>
</tr>
<tr>
<td>maximum capacity</td>
<td>80 persons</td>
<td>64 persons</td>
</tr>
<tr>
<td>max. speed</td>
<td>100 km/h</td>
<td>100 km/h</td>
</tr>
<tr>
<td>Levitation gap</td>
<td>11 mm</td>
<td>10 mm</td>
</tr>
<tr>
<td>No. of bogies</td>
<td>3/car</td>
<td>3/car</td>
</tr>
<tr>
<td>max. acceleration</td>
<td>0.8 m/s, in emergency</td>
<td>1.0 m/s, in emergency 1.25 m/s</td>
</tr>
<tr>
<td>/deceleration</td>
<td>1.25 m/s</td>
<td></td>
</tr>
<tr>
<td>vvvf switching frequency</td>
<td>500 Hz</td>
<td>2000 – 2500 Hz</td>
</tr>
<tr>
<td>dc/dc switching freq.</td>
<td>400 Hz</td>
<td>2000 Hz</td>
</tr>
<tr>
<td>curve negotiability</td>
<td>60 m radius of curvature</td>
<td>less than 30 m radius of curvature</td>
</tr>
<tr>
<td>power supply</td>
<td>DC 1500 V</td>
<td>DC 750 V</td>
</tr>
<tr>
<td>ATO</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

Table 2. Major specifications of UTM-02

Time Schedule of the light rail type Maglev UTM-02

Time schedule for UTM-02 is

By the end of 2003:
- finish development of major power supply equipments
- secure more robustness of L&G controller and find a way to manipulate double gap sensor signals at 45 mm rail joints maximum.

By the end of 2004:
- finish designing prototype maglev, hopefully to be accepted as a commercial model.

By the end of 2005:
- finish manufacturing two vehicles
- finish developing ATO
In 2006:

Performance test and evaluation

Conclusion

Though small in scale, maglev project in Korea has been progressing continuously for the past 11 years.

By virtue of the commercialization of Nagoya and China transrapid lines, the Korean government and several regional states are beginning to show strong interest in maglev. Korea is a very populated country. The traffic is very much congested in every big cities. Subway system costs too much, and so the government declared that they wouldn't construct subway any more and that all the public transportation systems to be built from now on would be light rail systems. Therefore commercialization of maglev is thought to be a matter of time, once we can assure maglev is a safe, environmentally friendly alternative.

References
