A Study on Energy Efficiency Analysis by Changing Maglev Train Slip Frequency

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Abstract. Today, urban maglev train has a number of advantages. It is eco-friendly and cost-effective system because it generates little vibration, noise and dust compared to other systems. In the aspects of vehicle characteristics of propulsion, braking and levitation, however, the energy efficiency of the Maglev train is relatively low compared to other vehicles. In this paper, we analyzed and compared the energy efficiency of the electric braking by applying changing slip frequency to the current vehicle when control braking.

Keywords: Maglev, Energy Efficiency, Propulsion Control

1 Introduction

Today, we face a global warming and find that today's environmental overwhelming public transport should be a train. At this point, Research on energy efficiency around the new transportation means has been conducted recently. In the aspects of vehicle characteristics, the energy efficiency of the Maglev train is relatively low compared to other vehicles. In other words, the Maglev train has a relatively large power consumption, compared with the other vehicle systems-Steel wheel electric vehicles, K-AGT (rubber wheel electric vehicles) etc. To improve the energy efficiency of the Maglev train, we demonstrate the way to increase the electrical utilization during braking through the test of changing the propulsion braking control pattern.

2 Electric braking

2.1 Electric Braking pattern analysis

The operation of the train braking device of the braking action is performed by mixing the electric brake and an air brake, which is known as blending braking. Blending braking reduces the energy by supplying the regenerative energy generated during braking in the motor vehicle to the catenary and aims to reduce maintenance...
costs by minimizing the friction braking. Following the development of the train standards in 1999, the next generation of electric vehicles have been developed since 2004. Train braking has been continuously being developed in order to minimize the air friction braking by maximizing the electronic braking in the conventional blending braking. We can achieve the purpose of improving the performance of the motor and the efficiency of the electrical braking through entering into air braking with only a lack of regenerative energy. But, braking characteristics of the Maglev train has a relatively low energy efficiency because its braking system uses the reversed braking in addition to the electronic braking unlike traditional railway vehicle.

2.2 Electrical braking control method

![Fig. 1. Maglev inverter characteristics](image)

Steel wheel train and other vehicles perform the regenerative (electric) braking and air braking. As show in Figure 1, Maglev train, however, uses electric braking and plugging braking in accordance to the characteristic of the train. Electric braking is extinguished completely at the low speed (about 4 ~ 5km/h) of the train and air braking is performed against the brake shortfall at the stop time.

3 Case Study

This paper selected the Urban Transit Maglev in KIMM (Korea Institute of Machinery & Materials) as a test model. As show in Figure 2, the Maglev train has one inverter and LIM (Linear Induction Motor) 4S2P in a car. Inverter control method uses slip frequency control method because of the LIM and the characteristics of Magnetic rise, not a vector control method which has an excellent response unlike the circular induction motor control.
Fig. 2. Configure the inverter and motor maglev train

Slip frequency control method, as shown in Figure 3 gives a lower limit to the most of regenerative extinction point, which affects the injury caused this sudden attraction LIM slip below a certain frequency. And LIM sudden attraction generated in less than a certain part of the slip frequency affects Magnetic rise of Maglev. Therefore, the slip frequency control time in terms of energy efficiency is to be taken fully into account the correlation between the attraction force and driving force.

Fig. 3. Slip frequency and promotion / attraction force of the characteristic curve

3.1 Changing the slip frequency

It is possible to improve the energy efficiency with the regenerative power generated during braking and the time adjustment to the reverse-phase power through the existing Maglev train drive slip frequency change. We changed the existing slip frequency of 13.5Hz to 11.5Hz and measured the inverter current phase transformation point, the regenerative power, and the reverse- phase power. The test
was conducted 10 times totally in the Test conditions, Vehicle propulsion 100%, 100% braking, maximum speed 50Km/h. Table 1 shows the measurement equipment specifications and Figure 4 is the measurement data of an inverter when changing the slip frequency.

Table 1. The measurement equipment specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>DCPT 2516</th>
<th>DCCT 2516</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor Scale</td>
<td>3.000V/10V</td>
<td>3.000V/10V, 1000A/10V</td>
</tr>
<tr>
<td>Rated Voltage</td>
<td>1.800Vdc</td>
<td>Bipolar</td>
</tr>
<tr>
<td>Measuring Instrument</td>
<td>Graphtec WR300</td>
<td>Sampling time : 5ms</td>
</tr>
</tbody>
</table>

![Image of measurement equipment specifications](image)

Fig. 4. The characteristic curve of slip frequency change (Left : 13.5Hz, Right : 11.5Hz)

3.2 Test Results

In terms of actual power consumption when changing the slip frequency, the conversion time of phase current of the inverter was reduced from 20Km/h to 16Km/h, depending on the change in the brake slip frequency 13.5Hz to 11.5Hz. This allows to increase the amount of regeneration and to decrease the energy required to reverse braking relatively. Table 2 shows the actually measured data of power consumed.
Table 2. Measuring results (Top: 13.5Hz, Bottom: 11.5Hz)

<table>
<thead>
<tr>
<th>Brake slip frequency</th>
<th>Remark</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Average</th>
</tr>
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<tr>
<td>13.5Hz</td>
<td>Propulsion</td>
<td>2.96</td>
<td>2.36</td>
<td>2.43</td>
<td>2.38</td>
<td>2.44</td>
<td>2.47</td>
<td>2.43</td>
<td>2.34</td>
<td>2.48</td>
<td>2.39</td>
<td>2.41</td>
</tr>
<tr>
<td></td>
<td>Regenerative braking</td>
<td>-0.12</td>
<td>-0.117</td>
<td>-0.12</td>
<td>-0.109</td>
<td>-0.116</td>
<td>-0.124</td>
<td>-0.111</td>
<td>-0.089</td>
<td>-0.114</td>
<td>-0.094</td>
<td>-0.112</td>
</tr>
<tr>
<td></td>
<td>Plugging braking</td>
<td>0.359</td>
<td>0.362</td>
<td>0.368</td>
<td>0.373</td>
<td>0.373</td>
<td>0.375</td>
<td>0.35</td>
<td>0.38</td>
<td>0.385</td>
<td>0.388</td>
<td>0.374</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2.631</td>
<td>2.507</td>
<td>2.677</td>
<td>2.651</td>
<td>2.698</td>
<td>2.731</td>
<td>2.701</td>
<td>2.605</td>
<td>2.759</td>
<td>2.663</td>
<td>2.672</td>
</tr>
</tbody>
</table>

| 11.5Hz               | Propulsion                    | 0.333| 2.207| 2.367| 2.332| 2.179| 2.358| 2.304| 2.441| 2.229| 2.392| 2.314  |
|                      | Regenerative braking          | -0.155| -0.110| -0.181| -0.135| -0.136| -0.149| -0.135| -0.136| -0.117| -0.148| -0.139 |
|                      | Plugging braking              | 0.305| 0.301| 0.309| 0.311| 0.315| 0.313| 0.312| 0.319| 0.322| 0.320| 0.314  |
|                      | Total                          | 0.483| 2.398| 2.515| 2.499| 2.379| 2.523| 2.489| 2.603| 2.434| 2.564| 2.489  |

4 Conclusion

Since the energy efficiency of the Maglev train is relatively low compared to other vehicles, technology research is underway to improve the efficiency lately. We confirmed energy savings with changing the slip frequency through this study. But the research for the inverter-control system and the optimization of air gap between the LIM and Reaction Plate will have to be in progress in the future.

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