Test Method of Linear Induction Motor for Maglev

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ABSTRACT: The linear induction motor for maglev generates the thrust of train and the normal force of vertical direction to rail. When the normal force between LIM and rail is big, we have trouble controlling the force of electromagnets. So it is need to keep having maximum thrust and minimum normal force by controlling the slip frequency of LIM. The performance tests of LIM for maglev can’t carry out, because the LIM doesn’t have its rotor. So we had tested it attached to a car to confirm a performance of LIM and find an optimal slip frequency. In that case, we usually waste time because of beginning test. But if we find an optimal slip frequency in stationary condition, we can reduce the time. This paper explains the test method of LIM for maglev and a way to find the optimum driving point of train. We get a optimum driving point by changing input current from 310A to 330A and air gap from 7mm to 13mm.

1 INTRODUCTION

The linear induction motor (LIM) of maglev generates the thrust of train as well as the attraction of vertical direction to rail simultaneously. In case of using maximum thrust, the train has a good acceleration performance, but the attraction between LIM and rail increases also. Then it is difficult to control the force of electromagnets. Thus, it is necessary to keep having maximum thrust and minimum attraction for maglev by controlling the slip frequency of LIM. The performance tests of LIM for maglev can’t carry out, because the LIM doesn’t have its rotor. So we had tested it attached to a car to confirm a performance of LIM and find an optimal slip frequency. In that case, we usually waste time because of beginning test. But if we find an optimal slip frequency in stationary condition, we can reduce the time. This paper explains the test method of LIM applied to the maglev and derives the optimum driving point of train. The test items are measurements of thrust force and normal force by changing air gap and slip frequency.

2 LIM PERFORMANCE TEST METHOD

Rotating machine consists of stator and rotor which pass on torque. Rotor is supported by stator using bearing. Because of this, Rotating machine can be tested alone and measured RPM and torque by using various sensors after applying load. But LIM have only a line type stator without rotor. For this reason, LIM can't be tested alone. In order to measure performance of LIM, rail should have infinite length. However it is impossible because of lab of limited space. Currently the following two methods are used to predict the performance of LIM.

2.1 LIM test with rotary type small-scaled Model

We can use a small-scaled model to predict performance of LIM like figure1. The small-scaled model has rotary type rail and use to measure torque according to the load by connecting torque sensor at its axle. LIM in the lower secondary winding according to the radius of curvature of the rails were manufactured and fixed. And it have load cell under fixing jig to measure normal force. This method's benefit is thrust, normal force, input current, efficiency and power factor of LIM can be measured dynamic characteristics. As shown in the figure, the small-scaled model is bending structure. But it is impossible because rectangular coil can't be bended. For this reason, round coil should be used, if so, length of coil end is different from real model. This difference occur different leakage of coil end between the small-scaled model and real model, so it is hard to exactly verify design and measure normal force characteristics.

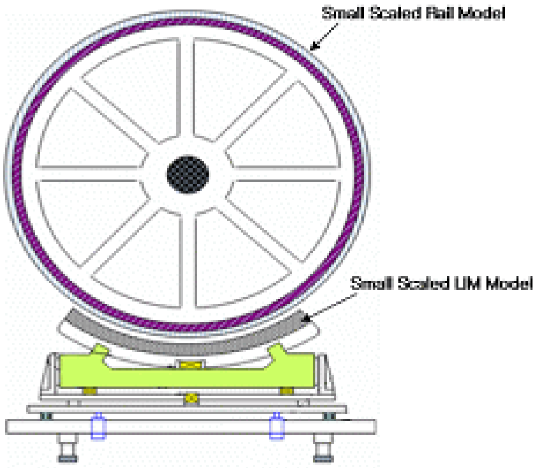


Figure.1 Rotary-Type Small-scaled LIM test equipment

2.2 *Stationary type LIM thrust test*

To estimate the performance of LIM like figure2, we can test LIM in stationary condition using a short secondary rail. This method can't estimate dynamic characteristics unlike ahead of model. But after fixing LIM at test equipment possible to adjust its height, we can measure variations like voltage, current, frequency, temperature, normal force and thrust according to variable voltage and frequency. What measure variations mentioned above can be repeated by changing air gap. This method can find optimum driving point by measuring thrust and normal force when it starts.

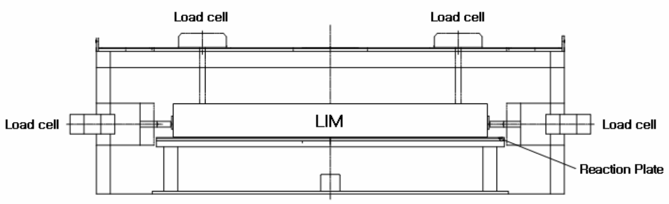


Figure.2 Stationary type LIM test equipment

3 LIM CHARACTERISTIC TEST

3.1 *Stationary type LIM test equipment*

Confirming slip frequency is certainly needed to operate LIM as optimum driving point when it is starting. We choose the latter one mentioned and did test of thrust and normal force of LIM according to air gap and slip frequency to find optimal slip frequency at starting LIM.

This test equipment is composed with inverter part, sensing part, cooling part, panel with meta and test bed.

Figure3 is inverter panel to supply power to test equipment.

Figure.3 Inverter panel

Figure4 is test bed to set LIM and load cell to measure thrust and normal force.

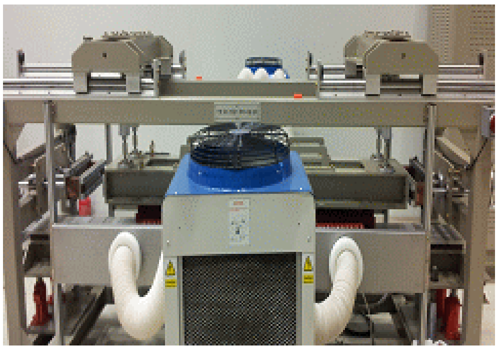


Figure.4 LIM test bed & Measuring device

Figure5 is cooling device to cool LIM and secondary reaction plate.

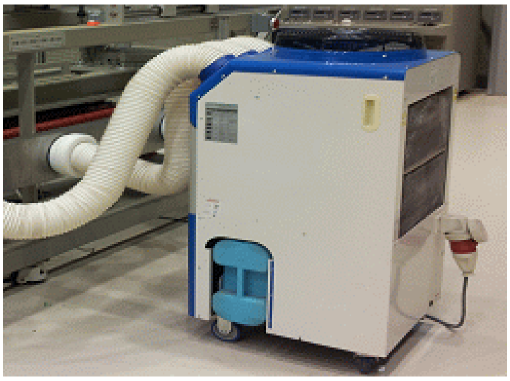


Figure.5 Cooling device

Figure6 is control panel to control a test equipment.

Figure.6 Control panel

3.2 LIM characteristic test result

Table.1 are major specification of LIM model to estimate thrust and normal force. Firgure7 is shown LIM model and firgure8 is secondary reaction plate manufactured to test in stationary condition.

Item	Value
Rate Power	47.2(kW)
Number of Phase	3
Number of pole	8
Start thrust	3775(N)
Voltage	275(V)
Current	275(A)
Slip Frequency	12.5(Hz)
Starting Current	330A

Table1. LIM specification

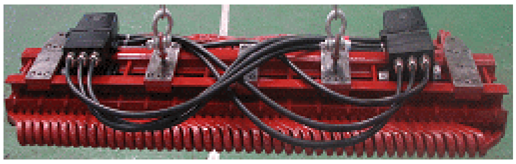


Figure.7 LIM

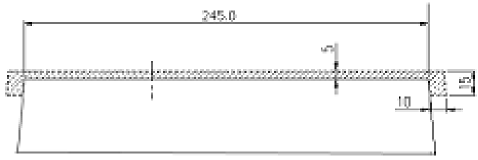
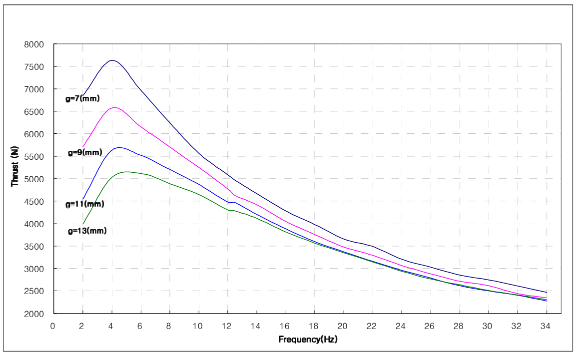
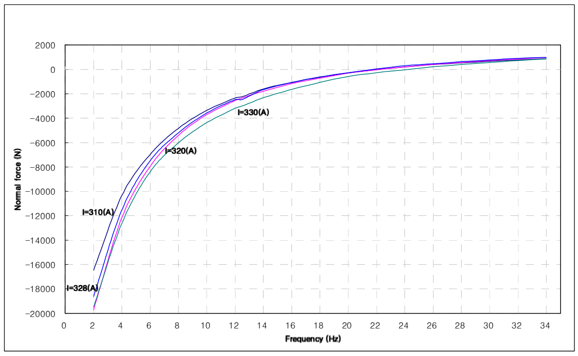


Figure.8 Secondary reaction plate

Figure9 is representing result of thrust and normal force according to input current at 11mm of air gap. As shown in figure, thrust has maximum value at slip frequency, 5Hz. And as normal force is higher, slip frequency is lower.



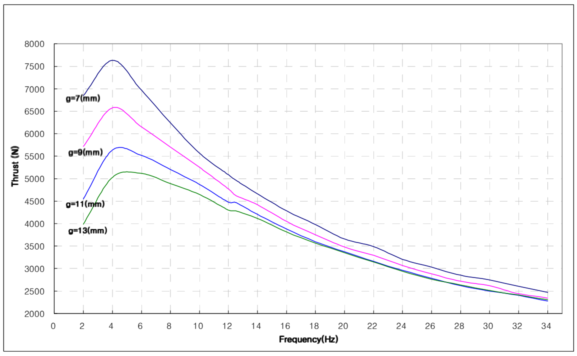
(a) Slip frequency vs Thrust measurement result



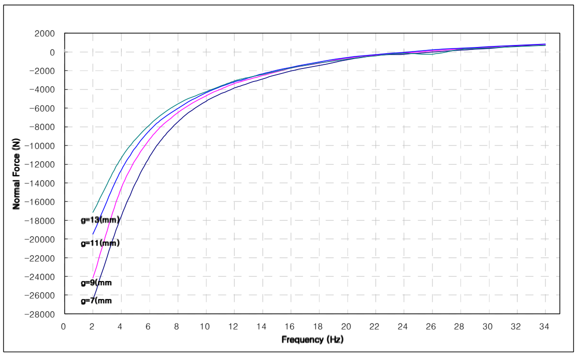
(b) Slip frequency vs Normal force measurement result

Figure.9 Thrust and Normal Force characteristics according to Input current variation

Figure10 is representing result of thrust and normal force according to air gap length when starting current is 330A. As shown in figure, thrust has maximum value at slip frequency, 5Hz. And as normal force is higher, slip frequency is lower.



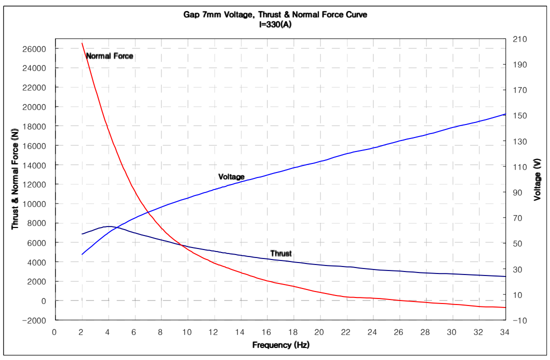
(a) Slip frequency vs Thrust measurement result



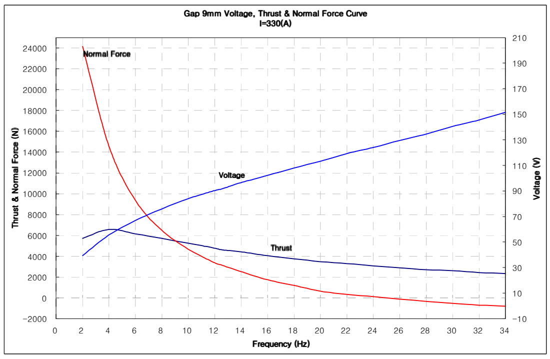
(b) Slip frequency vs Normal force measurement result

Figure.10 Thrust and Normal Force characteristics along with Air gap variation

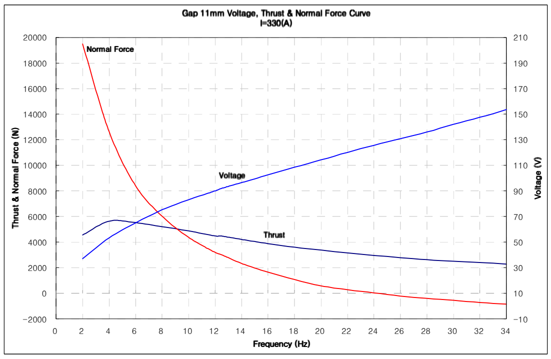
Figure11 is representing result of voltage, thrust and normal force according to air gap length (7, 9, 11, 13mm).



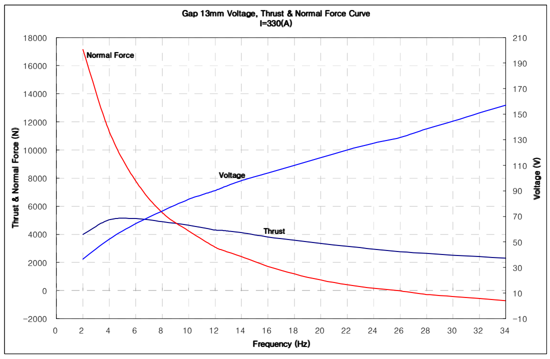
(a) Air gap 7mm



(b) Air gap 9mm



(c) Air gap 11mm



(d) Air gap 13mm

Figure.11 Voltage, thrust and Normal Force characteristics result according to slip frequency variation and air gap length(7, 9, 11, 13mm)

4 CONCLUSIONS

As shown in the characteristic test result, when slip frequency is low area, thrust constantly increases and then decrease. But when air gap is low, thrust continuously increases at low frequency. And normal force is more generated than thrust. Assume air gap of MAGLEV is 11mm. Optimum driving point exist, when slip frequency is from 14Hz to 16Hz. The reason is normal force has the lowest value at the range. Like that, stationary type LIM test method is effective to know optimum driving point and thrust characteristics

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