Load Test Method of Vehicle Body and Bogie Frame for Korean Maglev Vehicle

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ABSTRACT: Maglev vehicle utilizing electromagnetic suspension(EMS) consists of two parts, a vehicle body and a series of bogies which has to sustain the weight of the vehicle body and controls the magnets in the correct alignment to meet requirements of stable running on railway. The vehicle body is seated on the bogie frame subjected to the levitation and guidance forces generated by electromagnets through the air-suspension operating load including vehicle weight and passengers repeatedly during the service life. To ensure the structural integrity of the vehicle, it is necessary to identify a load test method with proper loads that the vehicle is expected to experience while in service. In this paper, a load test method was proposed to verify the structural safety of vehicle body and bogie frame that are applied to an EMS-type Maglev vehicle considering in case of not only running on the ground but also levitated running.

1 INTRODUCTION

Maglev system has two parts a vehicle body and a series of bogies. The vehicle body is connected through a pneumatic suspension on the bogie frame operating loads, vehicle weight and passengers, repeatedly during the service life. The bogie frame plays an important role in sustaining the weight of the vehicle body and controlling the magnets in the correct alignment to meet requirements of stable running on railway. It is also subjected to the levitation and guidance force and propulsion force generated by electromagnets and linear induction motor (LIM) respectively.

In general, the Maglev vehicle has known to be less dynamic effect than rolling stock supported by wheel because of controlling the gap between magnets and railway under running within several millimeters [1]. The vehicle supported with multiple magnets may also have much benefit on vibration behavior. The use of many bogies per vehicle compared with wheel-rail system provides distributed loads on the vehicle body of which may bring a small deflection. On the other hand, it is possible to meet unexpected abnormal conditions like magnet cling or bogie frame drop by the failure of magnet control system or levitation respectively while operating. Accordingly, it needs to determine the static test conditions properly considering the characteristics of Maglev vehicle.

Korean Maglev system utilizing electromagnetic suspension(EMS) will run about 7.0 km exhibition rout around Incheon international airport in 2013. To guarantee this vehicle system, it is necessary to identify a load test method with proper loads that the vehicle is expected to experience while in service. There are many codes and standards to verify the strength of the vehicle body and bogie frames in the case of conventional wheel-rail system [2-4]. However, it is difficult to find a proper test method for Maglev system.

In this paper, a test method was proposed to verify the structural safety of vehicle body and bogie frame that are applied to an EMS-type Maglev vehicle considering in case of not only running on the ground but also levitated running.

2 COORDINATE SYSTEM

2.1 Korean Maglev vehicle

Korean Maglev vehicle supported by four bogies which provide the levitation and propulsion is designed for the maximum speed of 110 km/h with the maximum acceleration of 4.5 km/h/s as shown in Figure 1. Each bogie consists of gap sensors, landing skids, linear induction motors(LIM), electromagnets and hydro-pneumatic braking system. Two anti-roll bars are connect with both side beam installed at the front and rear of the bogie frame. Table 1 shows the general description for Korean Maglev vehicle.

Figure 1. Coordinate system

Table 1. General descriptions of Korean Maglev vehicle

Information	Value
Maximum design speed	110 km/s
Maximum operation speed	100 km/s
Length of vehicle	24.5 m
Train formation	2 Cars

2.2 Coordinate system

The coordinate system is shown in Figure 2. The positive direction of the x-axis and z-axis are in the direction of movement and upwards respectively and y-axis is in the horizontal plane.

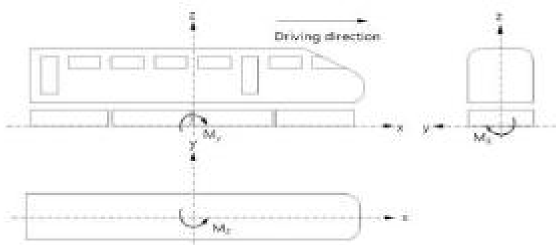


Figure 2. Coordinate system

3 STATIC LOAD TEST

3.1 For the vehicle body

Maglev vehicle body shall withstand the maximum loads consistence with its operational requirements. The principle load path of the vehicle is the floor base level frame, which is resists the axial load transferred through coupler and also transmits payload to bogie via sliding tables and air suspensions. To endure the structural strength of the vehicle, test loads are necessary to define properly considering that the vehicle is expected to experience while in service. In this paper, a vertical, longitudinal and twist load are proposed as static test load cases for vehicle body.

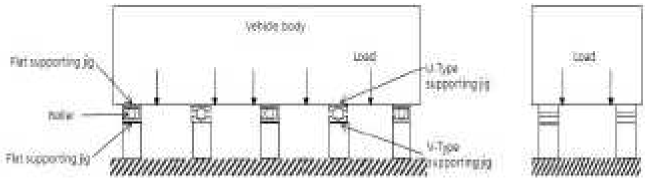
The vertical load defines the summation of vehicle weight including passenger and dynamic load due to vertical vibration under running. It can be calculated as follows;

$$F = k_v(m_v + c_1 - m_b)g - m_f g \quad (1)$$

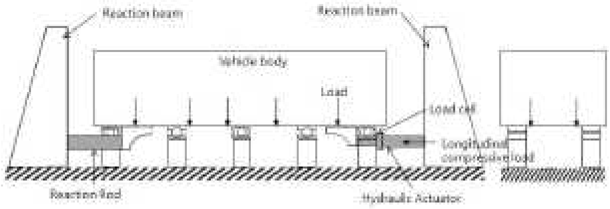
where k_v is a vertical dynamic coefficient , m_v is the empty weight of vehicle in running order, c_1 is passenger weight, m_b is the weight of bogie frame g is acceleration of gravity(=9.8 m/s2) and m_f is a bareframe weight of vehicle body. The coefficient k_v in Equation 1 that represents the vertical dynamic behavior of vehicle can be taken analytically or experimentally.

The longitudinal load is a compressive force reacted at coupler at the opposite end of the vehicle body. The load, applied on a coupler between vehicles, is 392 kN, which corresponds to light duty metro and heavy tramway vehicles in passenger rolling stock [4]. The twist load is applied 39.2 kNm to occur cross-sectional distortion at the center of vehicle body. In addition, three supporting points load is considered with one of the lifting points displaced vertically relative to the plane of the other three supporting points. Table 2 summarizes the calculation equations for each load case. Figure 3 presents the configuration of static test set-up of vertical and longitudinal load for vehicle body.

Single and Rosette strain gages are attached on the vehicle body at all highly stressed points, in particular in zones of stress concentration from stress analysis results. The test loads is applied in steps. Finally, a resonance test is necessary to conduct to avoid a natural frequency under service.



(a) Vertical load test



(b) Longitudinal load test

Figure 3. Configuration of vertical load test for vehicle body

Table 2. Calculation of static load cases for vehicle body

Load case	Symbol	Load Calculation
Vertical load	F_Z	$k(m_v+c_1-m_b)g-m_fg$
Longitudinal load	F_X	392 kN
Twist load	F_T	39.2 kNm
3 supporting points load	F_L	$(m_v-m_b)g-m_fg$

3.2 For the bogie frame

Static test is performed using a test rig that allows the application of the loads. The applied loads consist of vertical load(F_z), lateral load(F_y) including a guidance skid load and longitudinal load(F_x) as main service load case;

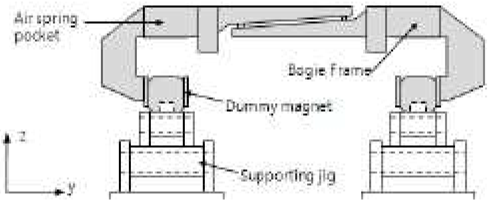
- F_z : W1+Max. vertical dynamic load
- F_y : W1+Max. lateral dynamic load +Wind pressure+Load due to rail cant
- F_x : W1+ max. longitudinal dynamic load

where W1 is the weight of the completed assembled vehicle body with passenger.

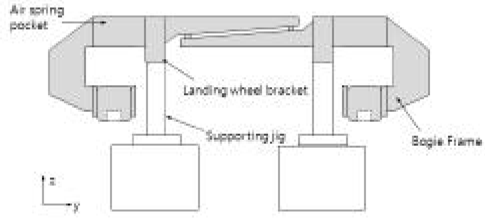
The magnitude of F_z and F_x can be calculated by using a dynamic coefficient due to acceleration of vehicle, k_b with different value accordance with a running condition if levitated running or running on ground.

$$F = k_b(m_v+c_1-n_bm_b) \tag{2}$$

The F_y includes a lateral acceleration of bogie and guidance force by gravity for cant and wind pressure. Electromagnets are replaced with dummy magnets to support bogie to test levitated running condition. Those dummy magnets are fixed on the supporting jig which can rotate with respect to y-axis as shown in Figure 4(a). In the case of running on the ground, the bogie frame should be fixed at the position of emergency landing wheel bracket as shown in Figure 4(b).



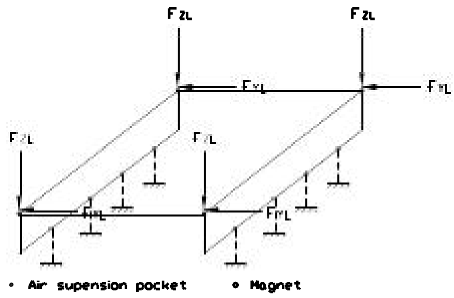
(a) Levitated running condition



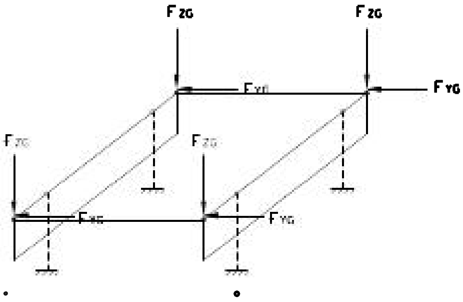
(b) Running on ground condition

Figure 4. Supporting position according to running condition

The loads are applied on four air suspension pockets of secondary suspension in the direction of vertical(z-axis) and lateral(y-axis) as shown in Figure 5. On the other hand, the longitudinal load is applied on the linear induction motor stopper on both side frames and traction rod brackets shall be fixed on the stopper as shown in Figure 6.

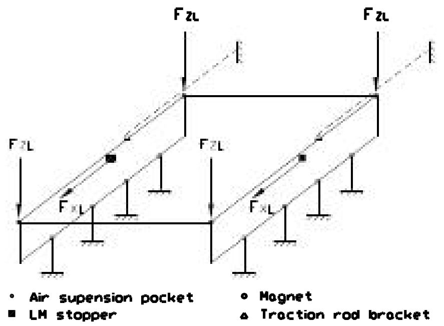


(a) Levitated running condition

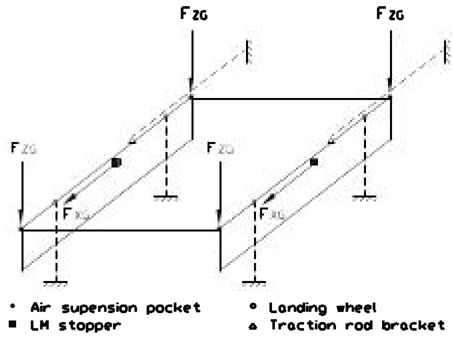


(b) Running on ground condition

Figure 5. Configuration of loading and supporting points of vertical and lateral load for bogie frame



(a) Levitated running condition



(b) Running on ground condition

Figure 6. Configuration of loading and supporting points of longitudinal load for bogie frame

Figure 7 presents an example configuration of test set-up for lateral load test in case of levitated running condition.

The following loads can be considered as exceptional load case.

- Guidance skid load : the maximum load acting at the guidance skid, in particular, taking into account running on curved line
- LIM reaction load : the maximum load corresponding to propulsion and reaction force from LIM, which the load is applied on the LIM stopper
- Braking load : braking load at the bracket installed brake system used when the vehicle is low speed for stop and emergency
- Magnet clinging load : a clinging force between the electromagnet and rail due to the failure of magnet control system, which the load applied to the magnet skid
- Vehicle drop load : an impact load in case of a bogie frame drop on the railway due to levitation failure

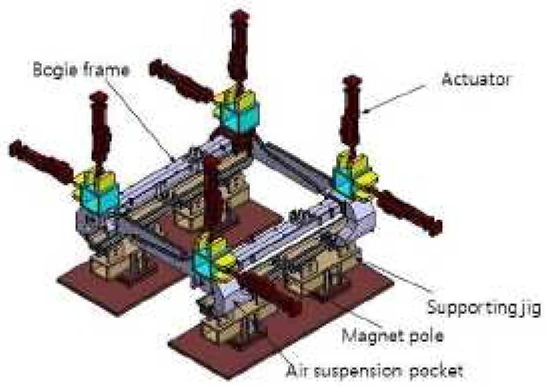


Figure 7. Configuration of lateral load test set-up on levitated running condition

4 CONCLUSIONS

In order to ensure the structural strength of vehicle bogy and bogie for Maglev vehicle utilizing electromagnetic suspension(EMS), we proposed a static load test methods to verify the structural safety of vehicle body and bogie frame, including . The load test of vehicle body consists of four load cases, that is, vertical, longitudinal, twist load and three supporting points load. In case of bogie frame, main service load case and exceptional load case were proposed considering not only running on the ground but also levitated running.

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