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Deformation Analysis of High Speed Maglev Track Beam under Temperature Effect

Jing Yu Huang*[1a], Wei Nan Xu[2], Xiong Zhou[3], Dong Zhou Wang[4], Zhe Wei Wu[5] and Xiang Yun Kong[6]

[1,2,3,4,5,6]*Department of Civiling-Engineering, Tongji University, Shanghai, China*
[1] *National Maglev Transportation Engineering R&D Center, Tongji University ,Shanghai, China*
huangjingyu@tongji.edu.cn

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Abstract. Based on the thermal-structural coupling analysis method, a high-speed maglev track beam model was established by using finite element analysis. The temperature loads of track beams were calculated and analyzed under five temperature conditions: vertical linear temperature difference load, vertical exponential temperature difference load, transverse linear temperature difference load, transverse exponential temperature difference load and bidirectional exponential temperature difference load. The results show that the mid-span deflection under bidirectional exponential temperature difference load is less than that under unidirectional exponential temperature difference load, and the mid-span deflection under exponential temperature difference load is less than that under linear temperature difference load. The method of calculating the temperature deformation of track beam by using linear temperature difference load is conservative.

Keywords: high-speed Maglev, track beam, effect of thermal, gradient temperature difference

1. Introduction

Maglev rail transit system is a non-contact ground rail transit system. Maglev vehicle is different from traditional wheel-rail vehicle. It mainly relies on strong electromagnetic force to lift the vehicle and drive it forward by linear induction motor, which has strict requirements for the position of maglev track functional surface. Therefore, in order to meet the design requirements of train operation safety and comfort, it is necessary to study the deformation and response of track structure under train load, temperature load and sudden change load. At present, there were many studies on the dynamic response of track beam under the load of maglev train, but less on the temperature effect of high-speed maglev track beam.

Combining with Shanghai High Speed Maglev Demonstration Line Project, this paper calculated and compared the temperature effect of maglev track beam under different temperature gradient modes, and obtained the temperature deformation and law of track beam under different temperature difference conditions. These results can provide reference for the structure design of high speed maglev track beam.

2. Temperature Load of Track Beam

Under the action of sunshine, the temperature on the surface of concrete box girder will rise rapidly due to its poor thermal conductivity, while the temperature inside the box girder will not change significantly, so a large temperature gradient will be formed in the beam body.

When simulating the temperature gradient of normal section, the double-fold line model was adopted in the design code of highway bridges and culverts in China, the design code of American highway bridges and the European code; the design code of New Zealand highway bridges adopted the 5th power function model; and the exponential function model based on natural logarithm *e* was adopted in the design code of railway bridges and culverts in China. At present, there is no uniform standard for the temperature gradient model of maglev track beams. Therefore, the exponential curve in the design code of railway bridges and culverts in China is used to simulate the temperature gradient load on the section of high-speed maglev track beams.

In this paper, the temperature loads of bridges were divided into linear and exponential temperature difference loads, and only the case of temperature rise was considered. According to the regulation of TB10002.3-2005, the gradient temperature load was calculated along the beam height and width direction, and the formula was as follows:

$$T_y = T_{01} e^{-ay} \tag{1}$$

$$T_x = T_{02} e^{-ax} \tag{2}$$

in which T_y, T_x is the temperature at point *y* and *x*; T_{01}, T_{02} is temperature difference between high direction and width direction of box girder, and for standard designs, values can be taken in Table 1; *y* and *x* are the distance from the calculated point to the outer surface of the box girder; a is the calculation parameter and the values are given in Table 1.

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[*] Corresponding author, Ph.D.Professor
E-mail: huangjingyu@tongji.edu.cn

The exponential temperature difference load curve was shown in Figure 1.

Table 1. T_{01} and a values of sunshine temperature difference curve

Gradient temperature load direction	T_{01} or T_{02} /℃	a /m^{-1}
Along the beam height	20	5
Along beam width direction	16	7

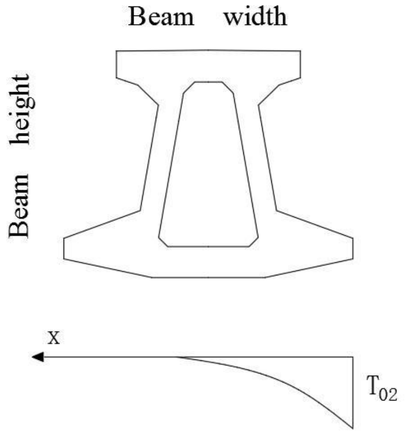


Fig. 1. Exponential Temperature Difference Load Curve

3. Computational Model

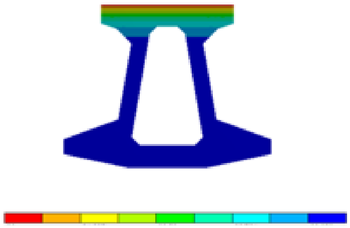
Taking Shanghai Maglev Demonstration Line as an example, this paper established a three-dimensional solid model and compared the temperature field distribution and temperature deformation of track beams under different temperature gradient modes by finite element analysis. According to TB10002.3-2005, the parameters of track beams were selected as follows: density ρ was 2500kg/m^3; elastic modulus E_c was 3.6×1010N/m^2; Pine ratio ν_c was 0.2; thermal conductivity K_x was 2.34W/(m·℃); thermal expansion coefficient ALPX was 1.18×105m/℃ and specific heat capacity c was 1046J/(kg·℃).

Fig. 2. Finite Element Model of High-Speed Maglev Track Beam

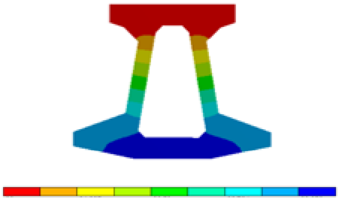
4. Computational Analysis

4.1 Vertical Temperature Effect

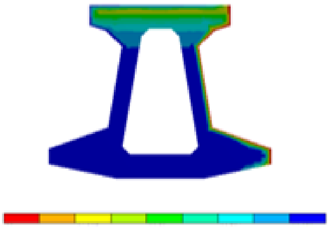
As shown in Table 2, three vertical temperature conditions were considered.



a. Temperature condition 1



b. Temperature condition 2



c. Temperature condition 3

Fig. 3. Temperature Distribution of Rail Beam Section under Three Temperature Conditions

The temperature field distribution of the maglev track beam was obtained by finite element calculation as shown in Fig. 3. It show that the temperature changed under exponential temperature difference load mainly concentrates on the upper half of the track beam, while the temperature change under linear temperature difference load was more uniform.

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Table 2. Vertical Temperature Difference Loading Conditions

Temperature condition 1	Temperature condition 2	Temperature condition 3
Exponential thermal load at 20℃	Linear thermal load at 20℃	Bi-directional exponential temperature difference load, vertical temperature 20℃, transverse temperature 16℃

The temperature field distribution of the maglev track beam was obtained by finite element calculation as shown in Fig. 3. It show that the temperature changed under exponential temperature difference load mainly concentrates on the upper half of the track beam, while the temperature change under linear temperature difference load was more uniform.

Fig. 4 show the distribution curves of vertical deflection along the beam length under three temperature conditions. Under vertical heating conditions, the deflection curves of the three temperature conditions were parabolic. Table 3 list the vertical deflection values of track beams in mid-span under three working conditions. The mid-span deflection under temperature condition 2 was obviously larger than that under temperature condition 1 and temperature condition 3, which indicated that the linear temperature difference load was conservative, and it can be seen from Fig. 4 that the vertical deflection under vertical heating condition can be reduced by applying a certain transverse temperature difference load.

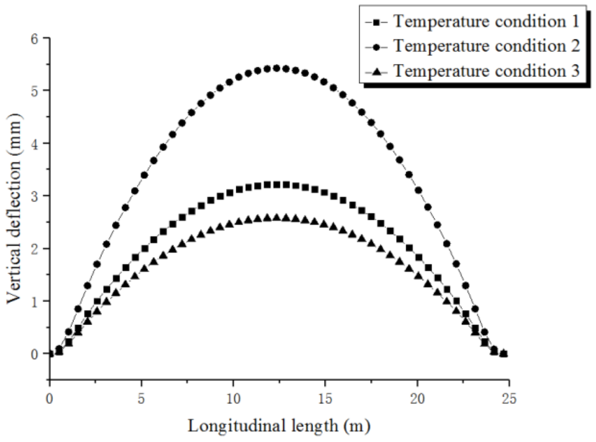


Fig. 4. Vertical Deflection Curve of Track Beam under Vertical Heating Condition

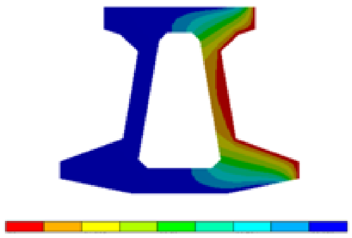
Table 3. Mid-Span Deflection of Track Beams under Vertical Heating Conditions

Condition	Temperature condition 1	Temperature condition 2	Temperature condition 3
Vertical deflection /mm	3.22	5.43	2.58

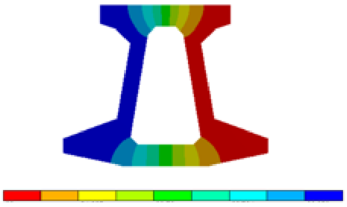
4.2 Transverse Temperature Effect

As shown in Table 4, three transverse temperature conditions were considered.

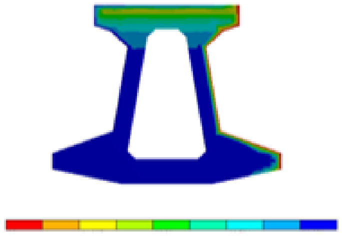
Fig. 5 show the temperature field distribution of maglev track beam obtained by finite element analysis. Fig. 3 show that the temperature change under exponential temperature difference load was mainly concentrated on the higher side of the track beam. The temperature change is irregular due to the influence of cross-section type, while the temperature change under linear temperature difference load was more uniform.



a. Temperature condition 4



b. Temperature condition 5



c. Temperature condition 3

Fig. 5. Temperature Distribution of Rail Beam Section under Three Temperature Conditions

Fig. 6 was the distribution curve of the transverse deflection of the track beam along the beam length under three temperature conditions. Fig. 6 show that the deflection curves of three temperature conditions were parabolic under transverse heating conditions. Table 5 list the transverse deflection values of track beams in mid-span under three working conditions. The mid-span deflection under temperature condition 5 was obviously larger than that under temperature condition 4 and temperature condition 3, which indicated that the linear temperature difference load was still conservative under transverse temperature condition, and it can be seen from Fig. 6 that the two-way temperature difference load can reduce the transverse deflection under transverse heating condition.

Table 4. Transverse Temperature Difference Loading Conditions

Temperature condition 4	Temperature condition 5	Temperature condition 3
Exponential thermal load at 16℃	Linear thermal load at 16℃	Bi-directional exponential temperature difference load, vertical temperature 20℃, transverse temperature 16℃

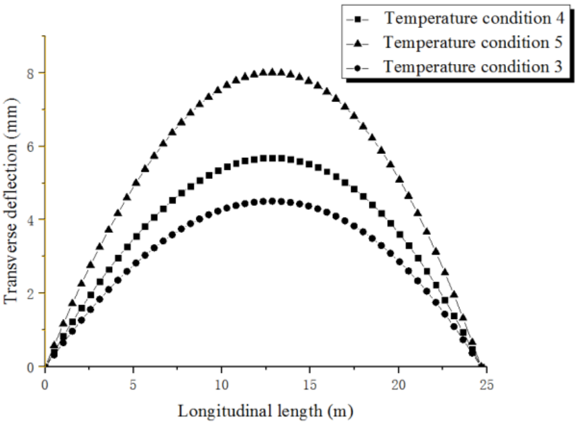


Fig. 6. Vertical Deflection Curve of Track Beam under Transverse Heating Condition

Table 5. Mid-span Deflection of Track Beams under Transverse Heating Conditions

Condition	Temperature condition 4	Temperature condition 5	Temperature condition 3
Transverse deflection /mm	5.70	8.01	4.51

5.CONCLUSION

(1) Under bidirectional heating condition, the mid-span deflection of the maglev track beam was smaller than that of the one-way heating condition, which indicated that the bidirectional heating condition was easier to meet the temperature control requirements.

(2) Under the condition of vertical heating, the vertical deflection curve of track beam was parabolic; the linear temperature difference load was too conservative compared with the exponential temperature difference load, and the mid-span deflection values were 5.43 mm and 3.22 mm, respectively. It can be seen that using linear temperature difference load to calculate temperature deformation will not meet the requirements of vertical temperature deformation control of Shanghai maglev track structure.

(3) Under the condition of transverse heating, the transverse deflection curve of the track beam was parabolic, and the linear temperature difference load was still too conservative compared with the exponential temperature difference load. The mid-span deflection values of the two loads were 8.01 mm and 5.70 mm, respectively, which do not meet the requirements of the transverse temperature deformation control of the maglev track structure of Shanghai Line.

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