Safety Assessment of Electromagnetic Exposure of Superconducting Magnetic Levitation Track

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Abstract: At present, there are few researches on the electromagnetic exposure of superconducting maglev train to passengers. In order to supplement these deficiencies, the finite element simulation software COMSOL is used to model the Halbach track and the superconducting maglev train and guide rail of the Federal University of Rio de Janeiro in Brazil. The simulation results show that the train can get off the train when it is stationary on the straight track Electromagnetic exposure of customers. The results show that: when the train is stationary and the suspension height is 5 mm, the maximum values of magnetic flux density in the body of the three passengers are 527μT, 240μT and 77.7μT respectively, and the farther the passenger is from the guide rail, the magnetic flux density in the body tends to decrease. These values are lower than the public electromagnetic exposure limit recommended by ICNIRP, which indicates that the magnetic field generated by the superconducting magnetic levitation permanent magnet track will not pose a health risk to the passengers in the vehicle.

1. Introduction
In recent years, the new superconducting maglev train technology has become the focus of the world. In 2014, the Federal University of Rio de Janeiro in Brazil built a 200m high temperature superconducting magnetic levitation train line, which began operation in 2015; in June 2014, Southwest Jiaotong University successfully built a new generation of vacuum tube high temperature superconductive magnetic levitation test-bed "super maglev" [1]. With the rapid development of maglev train, the research on electromagnetic environment of maglev train has become a hot spot. In reference [2], R Kircher studied the magnetic induction intensity in different positions of JR maglev train in Japan under static and running conditions. In reference [3], Du Yumei and others from Institute of electrical engineering, Chinese Academy of Sciences, took Tangshan medium and low speed maglev line as the research object, and used finite element method to analyze the leakage field around the magnet and linear motor of maglev train under different operating conditions. In reference [4], Qi Hongfeng simulated the leakage magnetic field distribution of suspension electromagnet and linear traction motor of cms04 medium and low speed maglev train using electromagnetic field finite element method.

Using the finite element simulation software COMSOL Multiphysics, the magnetic field and electric field in the passenger body and head exposed to the magnetic field of the permanent magnet guideway in the train are analyzed respectively with the permanent magnet track under the high temperature superconductor maglev train as the electromagnetic exposure source and under the conditions of the static and moving states of the train. The calculated results are compared with the public electromagnetic exposure limits recommended by the International Commission on non-ionizing protection (ICNIRP).
2. Simulation model
In order to simulate the real riding state of passengers, two kinds of human models, standing posture and sitting posture, are placed in the train.

![Mannequin figure](image1.png)

**Figure 1.** Mannequin figure.

The model refers to an adult human model with a general height of 1.75m [5], in which the sitting height is 1.304m. The head is made of three-layer ball model. The sphere with radius of 0.092m simulates the scalp, the sphere with radius of 0.085m simulates the skull, and the sphere with radius of 0.08m simulates the human brain. The human body model is shown in Figure 1:

![Front view of track magnetization direction](image2.png)

**Figure 2.** Front view of track magnetization direction.

The HTS Maglev works normally on the permanent magnet track, as shown in Figure 2. The commercial 35m NdFeB is used for the permanent magnet, the coercivity is 903 Ka/m, and the residual flux density is 1.198T [6-7]. The relative permeability of soft iron is set to 4000.

![Train model diagram](image3.png)

**Figure 3.** Train model diagram.

The car body refers to the HTS Maglev train of the Federal University of Rio de Janeiro, Brazil, with a height of 2.5 m, a width of 2.3 m and a length of 6 m. There are 16 suspension modules (8 on each side) under the car body. The car body is connected with the suspension module through metal support, and the suspension device is 5mm away from the track (full load state). The car body material is aluminum [8-9]. The track laying length is 10m. This is shown in Figure 3.

3. Description of safety standard ICNIRP
The International Commission on non-electric protection has formulated the relevant exposure limits for electromagnetic fields. This standard is generally used as a reference for the study of exposure levels in complex electromagnetic environments. When the vehicle is stationary, it is a static magnetic field problem. Refer to the relevant provisions of ICNIRP [10] on the exposure limit of static magnetic field, and the specific provisions are shown in Table 1:
| Exposure characteristics | Magnetic flux density |
|--------------------------|----------------------|
| Occupational exposure    |                      |
| Head and trunk Limb      | 2.0 T                |
| Public exposure          | Body parts           | 0.04 T               |
|                          |                      |

4. Result analysis

When the train is stationary and the suspension height is 5mm, the maximum value of magnetic flux density in human body appears in the foot.

As shown in Figure 4-6, the highest level of electromagnetic exposure was found in the body of sitting passengers right above the track, with the maximum value of 527μT, mainly concentrated in the ankle area. The results show that the distance between the seated passenger and the permanent magnet track increases, and the magnetic flux density in the body decreases significantly, with the maximum value of 240μT. Since the left heel is close to the track, it mainly concentrates on the left heel of the passenger. The maximum flux density in the passenger body has been reduced to 77.7μT. The maximum value of electromagnetic exposure level at different positions in the train varies greatly, but the maximum value of magnetic flux density in passenger organization is far less than the exposure limit of 40mT recommended by ICNIRP international standard, accounting for 1.3%, 0.6% and 0.19% of the recommended limit respectively.

Figure 4. Magnetic flux density of sitting human body above the track

Figure 5. Human body magnetic flux density in aisle side sitting posture

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Figure 7. Magnetic flux density of human head in sitting position above track

Figure 8. Magnetic flux density of human head in aisle side sitting posture

Figure 9. Magnetic flux density of human head standing in aisle

Figure 7- Figure 9 shows the distribution of magnetic flux density in the head of each passenger. The head is far away from the permanent magnet guide rail, and the maximum value of the head flux...
density is smaller than that of the human torso. The maximum magnetic flux density of the scalp of the passengers in the sitting position above the track is 3.04μT, mainly under the head; the maximum flux density of the scalp of the passengers sitting in the aisle side is 4.42μT; the maximum flux density of the scalp of the standing passengers in the aisle is 2.27μT. The maximum values of the three are far less than the 40μT exposure limit recommended by ICNIRP international standard, accounting for 0.007%, 0.011% and 0.005% of the standard limit respectively.

**Figure 10.** Magnetic flux density section of human head in sitting position above track  
**Figure 11.** Magnetic flux density section of human head in aisle side sitting posture  
**Figure 12.** Magnetic flux density section of human head standing in aisle

Figure 10-12 show a section of the human head. From the section, it can be concluded that the maximum value of scalp of sitting passengers above the track and standing passengers in the aisle is directly below the head; the maximum magnetic flux density of the scalp of sitting passengers on the aisle side is mainly concentrated on the left side away from the track side.

5. Conclusion

Taking the permanent magnet guide rail of superconducting maglev train as the radiation source, the electromagnetic exposure of passengers in different positions inside the vehicle under static state was analyzed. Because the passengers above the track are close to the track, the internal magnetic flux density is the largest; in the aisle, the standing passengers are far away from the track, and the internal magnetic flux density is the smallest. Therefore, the distribution of the magnetic flux density in the human body is directly related to the distance between the human body and the guide rail. The farther away from the guide rail, the magnetic flux density in the passenger's body tends to decrease, and the magnetic flux density distribution in the head is also the same as that of the permanent magnet the orbit space position is related. After comparative analysis, the exposure values of the passengers in the vehicle are lower than the exposure limits recommended by the International Commission for non-electric power protection (ICNIRP).

6. References

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