Research on Electromagnetic Environment Safety of High-Speed Railway Catenary

Huijuan Sun, Jun Liu and Can He

Abstract The simulation of electromagnetic fields distribution around high-speed railway catenary on the platform by the finite element method. The research is based on simulation models as classification material properties of human body parts, and presents subdivision mesh sub-model method to calculate and simulate the frequency electromagnetic fields around the human, and giving a comprehensive evaluation on the safety of electromagnetic environment around high-speed railway according to national standard limit.

Keywords Finite element · High-speed railway catenary · Subdivision mesh sub-model method · Frequency electromagnetic fields

1 Introduction

With the increasingly serious environmental problems, traffic transportation and other industry experts believe that high-speed railway as a new transport model in the modern society, has a very distinct advantage. So planning and developing high-speed railway is imperative [1–3]. The development of high-speed railway has caused public concern, therefore it is very important to study the distribution of the frequency electromagnetic field around the high-speed railway platform, and necessary to calculate the electromagnetic radiation on the human body.

Literature [4] measured the electromagnetic changes of the train, there is doubt as to the accuracy due to the impact on the measurement instrument itself; literature [5] studies the relationship between the train material and the low frequency magnetic, but it did not consider the impact of the environment literature [6] by the mirror method to study the different power supply under the contact field of the electric field strength; literature [7] explores biological effects of human under

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L. Jia et al. (eds.), *Proceedings of the 3rd International Conference on Electrical and Information Technologies for Rail Transportation (EITRT) 2017*, Lecture Notes in Electrical Engineering 482, https://doi.org/10.1007/978-981-10-7986-3_16

the high-voltage transmission line, but it cannot replace the original incentive reasonably.

Based on above-mentioned reasons, the finite element method is used to study the electromagnetic field distribution around the high-speed railway catenary, and subdivision mesh sub-model method is proposed to calculate the electromagnetic radiation around human body. Meanwhile, through analysis of numerical simulation results, to make a comprehensive evaluation of the electromagnetic environment of high-speed railway, which provides the basis for the design of the circuit and the evaluation of the environmental impact.

2 High-Speed Rail Platform and Human Body Model

In China, high-speed railway mostly using side platform and AT power supply. Table 1 shows the catenary parameters and the simplified structure drawing of platform is shown in Fig. 1.

In order to investigating whether the electromagnetic field caused by catenary would affect the health of passengers, a more sophisticated human body model is established. The human body are mainly composed of bones, blood, viscera, muscle and other parts, the relative dielectric constant, conductivity and permeability as

Table 1 Catenary parameters

Name	Line type	Radius (mm)	Voltage (kV)	Current (A)
Line of contact	TCJ-120	6.6	27.5	100
Carrier cable	TCJ-110	5.9	27.5	100
Positive feeder	LJ-185	7.7	−27	−192
Guard line	LJ-70	4.7	0.25	−0.972

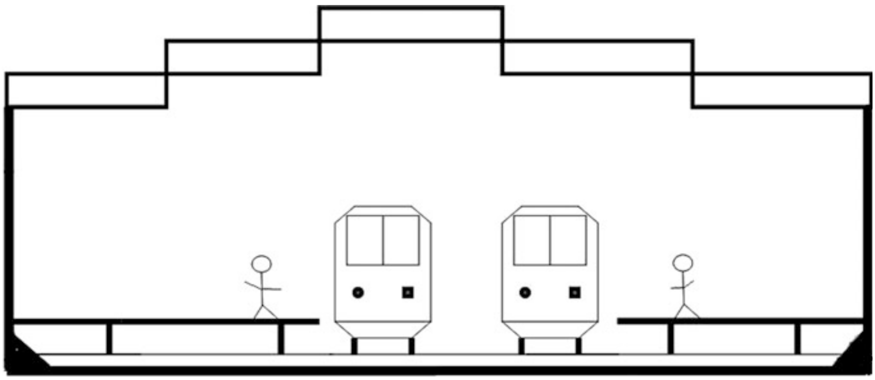

Fig. 1 The simplified structure drawing of high-speed railway platform

Table 2 Properties of the human body material parameters

Name of human tissue	Relative dielectric constant	Conductivity	Permeability
Head	500,000	0.045	1
Trunk	9,570,000	0.11	1
Foot	8867.8	0.02	1
Limbs	8,800,000	0.125	1

shown in Table 2. In this paper, the human body consist of limbs, head, trunk and feet, so the dielectric constant and conductivity of each part are replaced by average value.

3 Numerical Calculation Method of Electromagnetic Field

3.1 Finite Element Method

The finite element method is a combination of discrete solutions domain as a group of elements. The function of whole is replaced by the approximate function of each unit [8]. The finite element algorithm flow chart is shown in Fig. 2:

The finite element analysis method and the algorithm flow can be realized by ANSOFT finite element analysis software.

3.2 Subdivision Mesh Sub-model Method

The subdivision meshes sub-model method is based on the finite element analysis software that the smaller the length of the mesh is, the more accurate the calculation

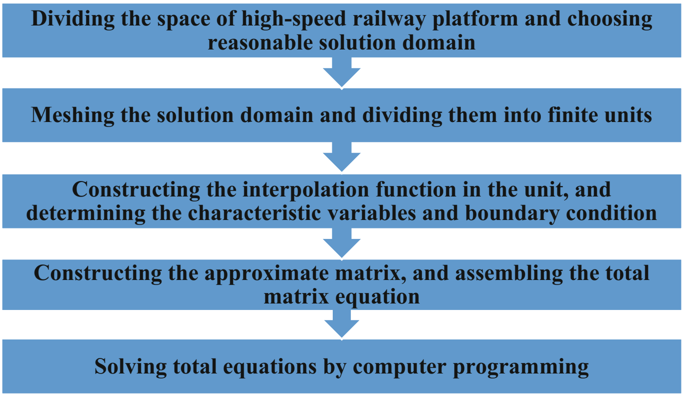

Fig. 2 Finite element algorithm flow chart

result is. Meanwhile, finding out the equivalent excitation around a certain region in the model, and adding the body of the region, and then finite element calculations are performed to obtain more accurate electromagnetic fields around the human body. Figure 3 shows the specific steps in the below flow chart.

4 Numerical Calculation and Analysis of Electromagnetic Fields Around the Human Body

Many countries have their own electromagnetic exposure standards [9]. Table 3 shows the exposure limit of frequency electromagnetic field in China.

4.1 Subdivision Mesh Method for Solving Electromagnetic Fields Around Human Body

Excluding external factors, and we select the site without train. Meanwhile extracting 1.5 m long and 2 m wide solution area around the human body, and then meshing it. The region is divided into three dimensions: the grid length is 5, 0.1 and 0.05 m.

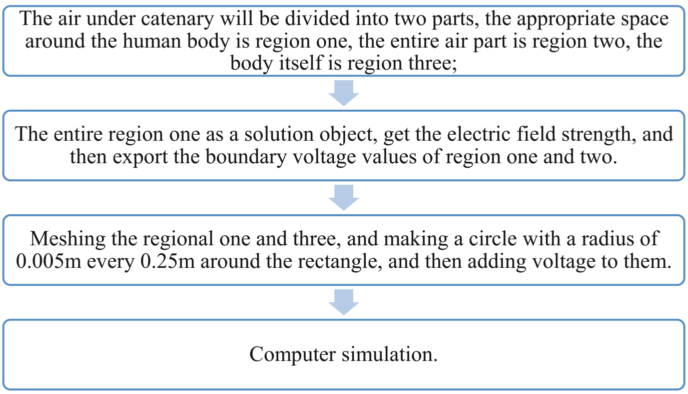

Fig. 3 Sub model process

Table 3 Frequency electromagnetic exposure limit

Name	Frequency (Hz)	E (kV/m)	B (μT)	Contact current (mA)
China	50	4	22	0.5

With the decrease of the length of the mesh, the number of grids increases, and the result of grid focusing on the head and feet more obviously. The corresponding electric field intensity and magnetic field intensity distribution as shown in Figs. 4 and 5, respectively.

Figures 4 and 5 show that the electromagnetic field distribution of high-speed railway catenary around human body has the following characteristics: (1) The head and shoulder is close to catenary, and it is easy to accumulate electric charge and form a high electric field, so the electric field intensity around the body is mainly concentrated on the head, shoulders and feet. (2) The internal magnetic field distribution of the human body is uneven, and is mainly concentrated on the legs and feet, and the magnetic field doesn't gather in the head, so the magnetic field of high-speed railway does not harm to the brain.

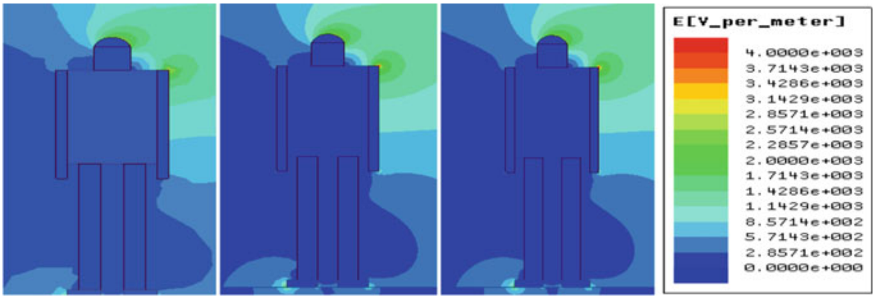

Fig. 4 Distribution of electric field intensity around human body

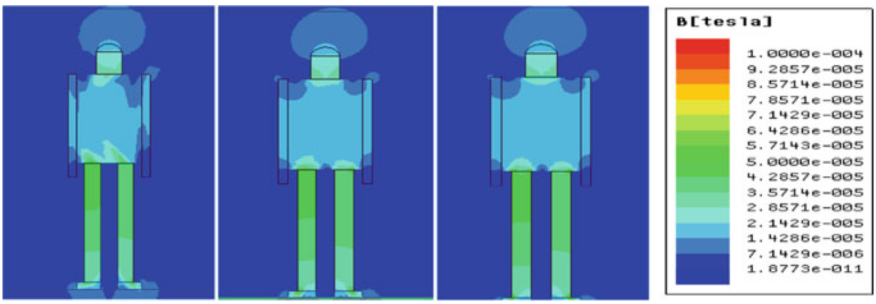

Fig. 5 Distribution of magnetic field intensity around human body

4.2 Subdivision Mesh Sub-model Method for Solving Electromagnetic Fields Around Human Body

Meshing the sub-model in Fig. 4 with grid length of 0.05 m. Calculating the potential for the boundary by analytical method, and according to the accuracy and speed of the request, we add a radius of 0.005 m circles as an excitation every 0.25 m in the boundary.

The intensity distribution of the electric field around the human body is shown in Fig. 6. It shows that the electric field was significantly enhanced on the head. And in order to illustrating the superiority over the proposed method, the numerical simulation results of the two methods are exported. The curve graph is shown in Fig. 7, and the maximum electric field intensity on the head is shown in Table 4.

Figure 7 and Table 4 show that the electric field intensity curve obtained by the sub-model method is similar to that of the subdivision grid method, but the value is significantly enhanced, especially in the area near the head. The reason is that the

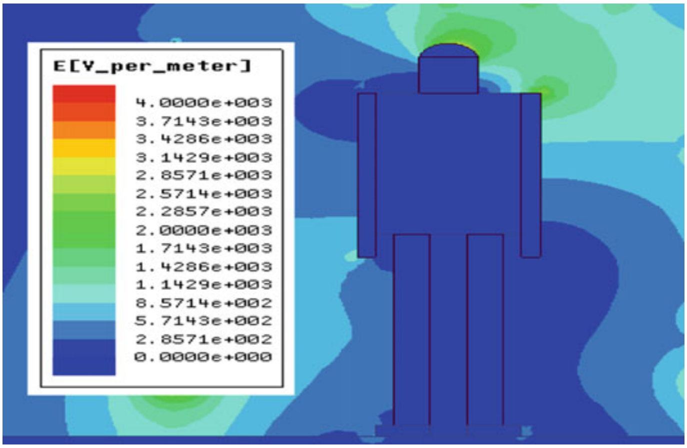

Fig. 6 Distribution of electric field intensity around human body

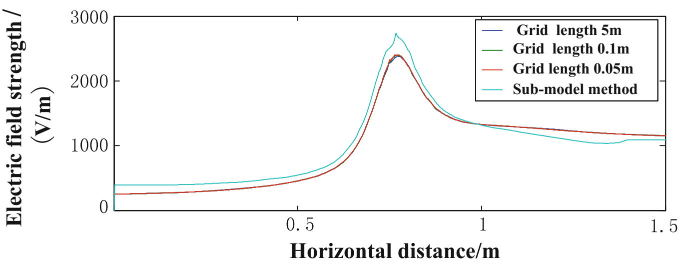

Fig. 7 The electric field intensity at the top of the human body

Table 4 Maximum intensity of electric field at the top of human under different methods

Method	Electric field intensity (V/m)
Grid length 5 m	2383.966
Grid length 0.1 m	2400.993
Grid length 0.05 m	2402.749
Sub-model	2743.32

sub-model method adds incentives around the human body to reduce the loss of transmission, and avoid the interference from other factors. More agglomeration effect on human charge is attracted, so the electric field strength value is more accurate. Comparing with exposure limit of frequency electromagnetic field in China (shown in Table 3), the value does not exceed the standard limit.

5 Conclusion

In this paper, we use the finite element method to calculate and simulate the electromagnetic environment of high-speed railway catenary. The numerical simulation results show that the electromagnetic field generated by high-speed railway catenary does not cause electromagnetic radiation damage to the human. And the subdivision meshes sub-model method proposed to this paper can provide new idea about electromagnetic modeling research in the future.

Acknowledgements This work is partially supported by the Fundamental Research Funds for the Jiangxi Science and Technology Support Project (20142BBE50001), Jiangxi Provincial Natural Science Foundation Project (20152ACB20017, 2015BAB216020) and Jiangxi Provincial Science and Technology Project of Education Department (GJJ160525).

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