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A polymer bonded gridded box EMI shielding method based on FEM for high speed railway

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Abstract– When there is current passing through the air, the electromagnetic field occurs, which could interfere with the other apparatus nearby or even damage it. In this way, the electromagnetic sources could also be a victim. Therefore, the equipment need to be designed to both blocking and tolerated the electromagnetic radiation. The electromagnetic interference could be mitigated or minimized by many techniques like filtering, earthing, or enclosure. Especially in high speed railway, enclosing dc and ac system, high power and lower power system into a limited area requires the equipment generates less EMI and could perform against the interference by the other apparatus. Metal box shielding is a method when the circuit design alone cannot satisfy the requirement that the equipment could stand against the environmental EMI or emanating from the equipment. This paper presents a polymer bonded gridded box shielding method which is light, flexible, material saved and suitable for high and low frequency shielding by employing polymer material.

Keywords–Shielding, EMI, HSR

I. Introduction

The normal electromagnetic interference reduction technique is earthing, shielding, and filtering which could reduce the most interference level within the range of standard.

However, the power electronics equipment, control, and traction communication system are becoming more and more complicated, more interference reduction method should be adapted and even complicated control filtering and earthing techniques should be used to reduce especially conducted interferences which to eliminate the source of the electromagnetic emissions.

In the high speed railway [1], the electromagnetic radiation [2-3] consists both high frequency and low frequency. High frequency electromagnetic emission is mostly generated by the signal, communication or portable computers, mobile phones, RFID system, or even implanted medical cardiac pacemaker, which is venerable and easy to be affected. Since in the traction system, most equipment are power electronics for example the machine, motor drive and utility power supplies are all power electronics converters. Any high dv/dt through capacitor or high di/dt could generate EMI noise. This is usually a frequency which varies from 1kHz to 40kHz depending on the different conversion stages and the possible noise is from the fast switching such as switching devices, hard-switching, acing in the catenary and also the high power cables. That equipment especially the low frequency need to be magnetic isolated from the environment since low frequency electromagnetic field must be investigated, which may harm the other equipment or human health [4-5]. For high frequency EM sources, it should work well and cannot be affected by the environmental electromagnetic radiation. The electromagnetic shield can work in two ways which block the outside environmental electromagnetic interference or mitigate the EM radiation. The traditional EM shielding box is made of metal which could successful block the EM radiation from or to the equipment. In most places, the metal box could solve the EMI problem, however, in high speed railway, the voltages and currents are usually high power and at high level, it is very possible to create an eddy current or induced a voltage on the box, which could produce extra power losses and will be very dangerous if the equipment occurs earthing fault.

The EMI shielding method has attracted researchers' attention for many years [6-11] from 1960s. Many researchers are focused on the evaluation the metal electromagnetic shielding shapes [6-10], electromagnetic field shielding effectiveness could be calculated in a certain or arbitrary shapes shielding mats [6], however, the shielding material is very important especially in the circumstance of both high frequency and low frequency meanwhile with high voltage or current. Recently, Prof. Eric Cheng [11] has put forward that The Polymer Bonded magnetic shielding, which investigated the characteristic of the material shielding effectiveness under high frequency ac and dc excited fields, which indicated that the material is capable and suitable of providing the electromagnetic field in the high speed railway traction system.

In this paper, the polymer material is used for the gridded shielding box, which greatly reduces the shielding box's cost, weight, induced current, voltage and power loss. It also can be manufactured easily and in flexible shapes. The shielding effectiveness is first investigated in the following sections.

II. 2. The EMF scattering and the shielding effectiveness

In this paper, the electromagnetic field is simulated by Maxwell software, which is calculated by FEM. Since the polymer bonded gridded shielding box is a symmetry structure, 2D's model is established.

A. EMF formulations

The electric magnetic field calculation is based on the Maxwell's equations, which is illustrated as followed.

$$\nabla \times \mathbf{H} = \mathbf{J} \tag{1}$$

$$\nabla \times \mathbf{E} + \frac{\partial B}{\partial t} = 0 \tag{2}$$

$$\mathbf{B} = \mathbf{B}(\mathbf{H}) \tag{3}$$

$$\mathbf{J} = \sigma \mathbf{E} \tag{4}$$

where, E is the electric field, B is magnetic field, J is current density.

magnetic flux density B can be calculated based on the following equations [12],

$$\mathbf{B} = \sqrt{\mathbf{B_x}^2 + \mathbf{B_y}^2} \quad (5)$$

$$\frac{\partial}{\partial x}(v\frac{\partial \mathbf{E}}{\partial x}) + \frac{\partial}{\partial y}(v\frac{\partial \mathbf{E}}{\partial y}) = -\mathbf{J} \quad (6)$$

B. Shielding efficiency

According to ref [3], the shielding efficiency is defied that the ratio of the magnetic field outside the shielding box to the magnetic field passing through the shielding.

$$SE_e = 20\log_{10}\left|\frac{\vec{E_o}}{\vec{E_i}}\right| dB \quad [3] \quad (7)$$

$$SE_h = 20\log_{10}\left|\frac{\vec{H_o}}{\vec{H_i}}\right| dB \quad [3] \quad (8)$$

where, SE_e , SE_h are the shielding efficiency of electric field, and magnetic field respectively. The shielding efficiency represents the blocking magnetic and electric field characteristic of material, which is used to evaluated the shielding effectiveness of the material.

where E is the electric filed, $\mathbf{B}_x = \frac{\partial \mathbf{E}}{\partial y}$, $\mathbf{B}_y = \frac{\partial \mathbf{E}}{\partial x}$.

III. THE SIMULATION OF THE POLYMER-BONDED GRIDDED BOX SHIELDING EFFECTIVENESS

In order to investigate the shielding effectiveness of the proposed polymer bonded gridded magnetic box, two pieces of polymer bonded gridded magnetic walls are firstly placed next to radiation source which is an electromagnetic wave ball to study the shielding efficiency of the material as shown in Fig. 1. Then two different gridded box with different size are installed next to the source of the electromagnetic wave ball to investigate the electromagnetic radiation outside the shielding box and inside the shielding box. The simulation result is shown in Fig. 2-3. To compare the shielding effectiveness of the proposed gridded box with metal box, the shielding effectiveness of the magnetic enclosure box are simulated in Fig. 4. The simulation with two dimensions are calculated. Parameter of the different shielding components are illustrated in Table. 1.

As we can see from Fig. 1, magnetic wall shielding effectiveness with two dimensions is presented. The magnetic and electric field are blocked from the first magnetic wall, there are very few electric field and magnetic field could penetrate the wall especially the magnetic field.

From Fig. 1 (b), the electric field on the first wall is around 1.23*102 A/m, part area is 1.85*102 V/m second wall is 2.8*101 V/m, which presents the electric field decreases greatly after passing through the wall.

From Fig. 1 (c), the magnetic field outside of the first wall is around 4.55 A/m, 1.25*10-2 A/m on the wall, and 1.3*10-4 A/m on second wall. Therefore, the shield efficiency of the magnetic field could be roughly calculated by equation (8), which would be about 80.34 dB.

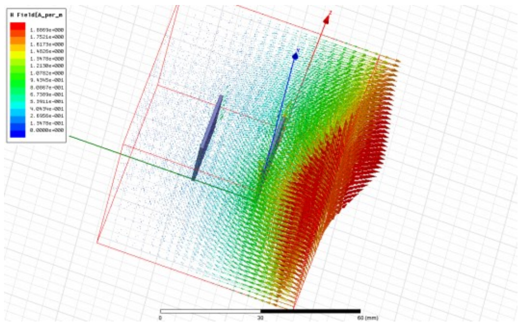
Compare with grid box 1, 2, and magnetic enclosure box, the shielding efficiency could be roughly calculated by equation (8), from Fig. 2 and Fig. 3, which is about 66.56dB, 78.29dB 88.03 respectively.

As we can see from Fig. 3 (b) and Fig. 4(b), the magnetic field attenuated significantly after penetrating through the shielding box.

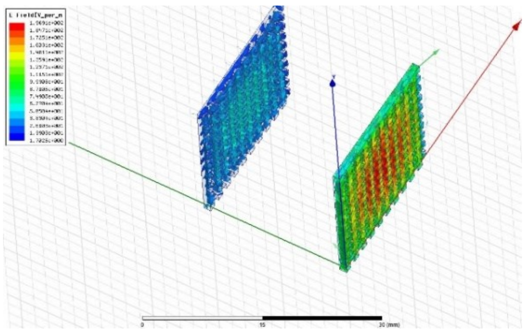
The simulation result from Fig. 1 to Fig. 5 shows that both electric and magnetic field decrease significantly after passing through the proposed shielding material. Therefore, the polymer bonded magnetic gridded box could be used to blocking the magnetic field in a certain place. The electromagnetic field is weak inside of the shielding box.

Table 1: The parameter of the shielding components

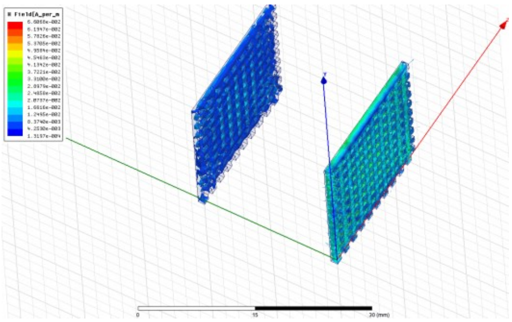
Shielding components	Line width	Line height	Line length	Grid interval	Distance between two walls
Magnetic sheet	1mm	1mm	20mm	1mm	20mm
Gridded box 1	1mm	1mm	20mm	1mm	20mm
Gridded box 2	1mm	0.5mm	20mm	0.5mm	20mm



(a) Polymer bonded magnetic walls shielding effectiveness

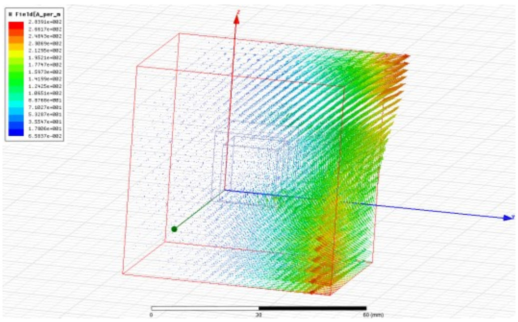


(b) Electric field shielding effectiveness

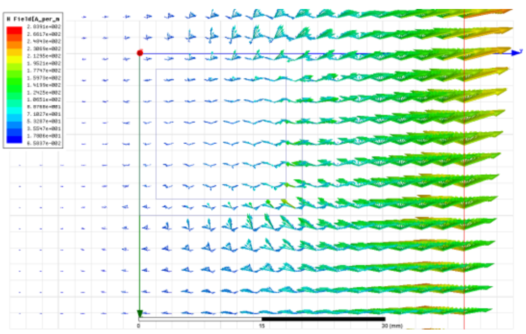


(c) Magnetic field shielding effectiveness

Fig. 1 Polymer bonded magnetic walls shielding effectiveness

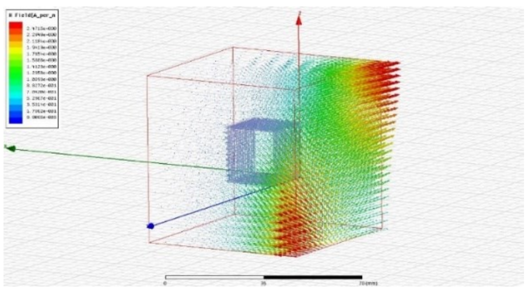


(a) Magnetic field shielding effectiveness

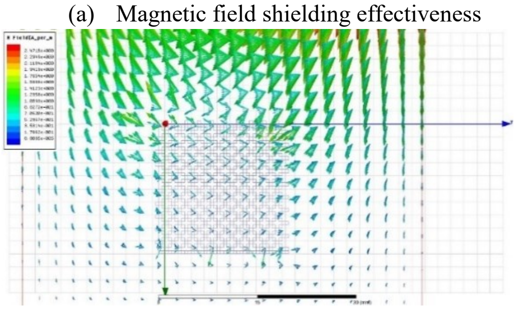


(b) Magnetic field shielding effectiveness (zoom in)

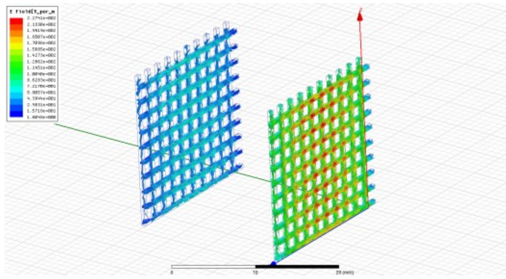
Fig. 2 Gridded box 1 shielding effectiveness



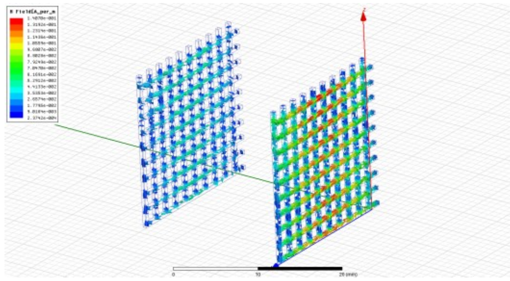
(a) Magnetic field shielding effectiveness



(b) Magnetic field shielding effectiveness (zoom in)

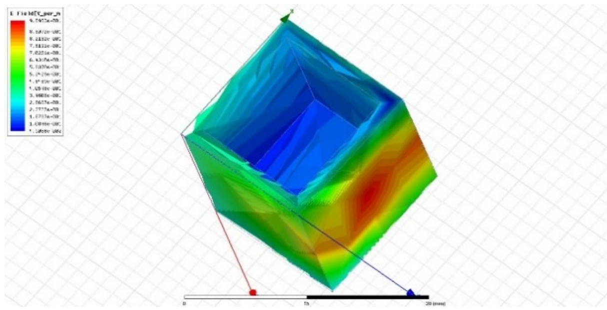


(c) Electric field shielding effectiveness

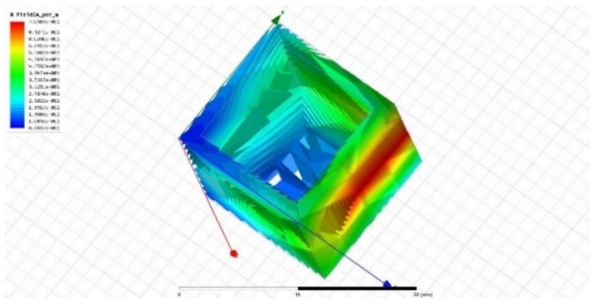


(d) Magnetic field shielding effectiveness

Fig. 3 Gridded box 2 shielding effectiveness



(a) Electric field shielding effectiveness



(b) Magnetic field shielding effectiveness

Fig. 4 Metal box enclosure shielding effectiveness

IV. CONCLUSION

A polymer bonded gridded magnetic box is proposed as a shielding method. A two dimensions' medal based on FEM is present and simulated. The result shows that the proposed polymer bonded gridded magnetic box could block most of the electromagnetic penetration. Meanwhile, it is light, size flexible and could save half of material than conventional metal box. Because the permeability could be designed, it is suitable for both high frequency and low shielding efficiency.

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