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Numerical Analysis for the Electromagnetic Sealing of Mechanical Structure*

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***Abstract*—Slots are inevitably presented in actual enclosure of electronic equipment due to assembly process. These slots break the integrity of the enclosure and are considered to be the main reason for electromagnetic energy leakage. Conductive gasket and metal reed are the important sealing structure to improve the shielding effectiveness (SE) of enclosure with good elasticity and conductivity. In the paper, the transmission-line matrix method is employed to investigate the electromagnetic shielding performance of enclosure which is sealed with conductive gasket and metal reeds. As shown by the numerical results, the SE of enclosure with conductive gasket and metal reeds will be greatly improved. The greater the width of conductive gasket and the smaller the finger gaps, the higher the SE of enclosure. The conclusions can be used for electromagnetic shielding design of the enclosure with slots.**

***Keywords*—electromagnetic sealing, conductive gasket, metal reed, shielding effectiveness, Numerical Analysis**

I. Introduction

With rapid development in high-speed electronics and wide application of wireless technologies in recent years, the electromagnetic environment is becoming more and more complex, which may lead to fatal damage to sensitive electronic device. The increasingly complicated electro-magnetic environment makes it vital important to study how to reduce the impact of electromagnetic interference and achieve the electromagnetic compatibility in the whole or partial region[1-2].

Slots are inevitably presented in actual enclosure of electronic equipment due to assembly process which break the integrity of the enclosure and are considered to be the main reason for electromagnetic energy leakage, and therefore slots must be well sealed for electromagnetic shielding in engineering. With good elasticity and conductivity, conductive gasket and metal reed can be used for electromagnetic shielding to improve the SE of enclosure with slots.

Several analytical and numerical techniques are proposed to calculate SE of an enclosure with slots. Experimental test[3] is the most accurate while the test site is very demanding. Analytical methods[4-5] are accurate but can just be applied to very simple geometries with some approximations. Numerical techniques such as method of moments, finite-difference time-domain, finite element, transmission-line matrix and hybrid methods [6-9] are widely utilized to calculate the SE of an enclosure with slots which can offer good accuracy over a broad frequency. In the paper, the transmission-line matrix method is employed to investigate the electromagnetic shielding performance of enclosure which is sealed with conductive gasket and metal reeds.

II. Electromagnetic sealing mechanism

A. Selecting a Template

In the shield case, seam welding can be used for the permanent slot in an electromagnetic seal while the slots produced by assembly process is inevitable. However, the gap of these slots break the integrity of the enclosure and block the induced current flowing which is considered to be the main reason for electromagnetic energy leakage and directly influence the SE of the enclosure.

The electromagnetic sealing effects of conductive gasket and metal reed are reflected in two aspects. On one hand, a metal spring or a resilient can guarantee a good contact with both walls of the gap and provide a conductive path for the induced current around the slit which increases the SE of enclosure. The schematic is shown in Figure 1.

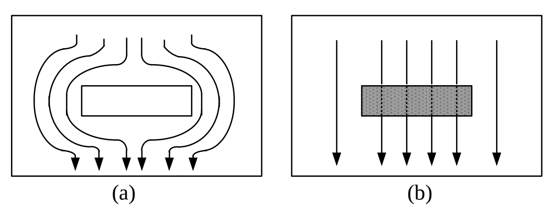

Figure 1. *The electromagnetic sealing of conductive gasket and metal reed(a)the induced currents steer around slot (b) the induced currents traverse the gasket.*

On the other hand, a metal spring or an elastic conductive gasket makes it possible to compensate for the original deformation of the shield wall of the contact surface, further weakening the magnetic leakage at the gap to ensure a good electromagnetic seal. The schematic is shown in Figure 2.

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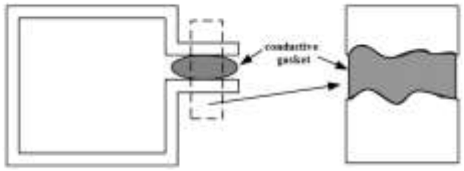

Figure 2. *The influence of the presence of conductive gasket on the shielding effectiveness of cavity.*

III.The electromagnetic sealing characteristics of conductive gasket

The common installation method of conductive gasket in engineering is shown in Figure 3. In the paper, the influence of width of the conductive gasket on SE is discussed. (The length and thickness needn't to be analyzed because they depend on the slot parameters).

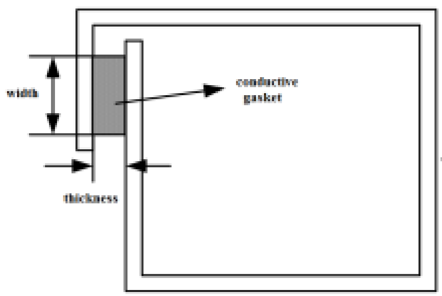

Figure 3. *Installation of conductive gasket in a lap joint.*

A. *The influence of the conductive gasket*

Firstly, the shielding effectiveness of enclosure with the conductive gasket is compared. The size of enclosure is 220mm×140mm×80mm and thickness is 1mm. The material is aluminum and the observation point locates in the center of enclosure. The configuration of conductive gasket is shown in Figure 3. The parameters of conductive gasket are as follows: the thickness is 0.8mm, width is 3 mm , the conductivity and the relative permeability are 100 Siemens/m and 1000 h/m, respectively. The simulation results are shown in Figure 4.

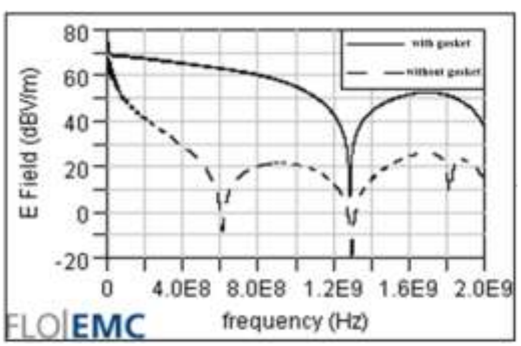

Figure 4. *The influence of the presence of conductive gasket on the shielding effectiveness of an enclosure.*

As shown in Figure 4, the SE of enclosure can be improved obviously with conductive gasket. Meanwhile, the first aperture resonance point is disappeared.

The reasons of this phenomenon are: Firstly, conductive gasket is equivalent to fill in the capacitance of the equivalent circuit of waveguide the conductive medium, which reduces the capacitive reactance and decreases the equivalent impedance of the slot. With the decrease of gap leakage, shielding efficiency significantly increases. Secondly, conductive gasket provides the electric contact on both ends of the gap, which greatly reduces the resistor component of the gap impedance.

B. *The electromagnetic sealing of conductive gasket*

1) *The width of the conductive gasket*

Keep the electrical parameters and the thickness of the gasket the same. Then compare the SE of different widths of 4mm, 2mm and 1mm respectively. Figure 5 shows the SE of enclosure.

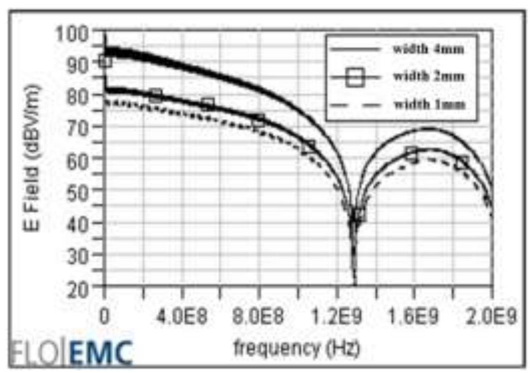

Figure 5. *The shielding effectiveness of conductive gasket with different widths.*

As shown in Figure 5, the greater the width, the higher of the shielding effectiveness of the enclosure. And the SE of enclosure with gasket's width of 4mm is 15dB higher than that of 2mm and up to 20dB than that of 1mm on average. The reasons are: on one way, the increase of width of the conductive gasket leads to much more wastage of the electromagnetic energy through the gasket into the cavity. On the other way, the density of the induced current flow increases because the wider gasket provides more pathways for induced current in the conductive gasket.

2) *The installation of gasket*

The installation of conductive gasket will directly impact the contact of gasket with enclosure wall as well as the shielding effectiveness of gasket. In the paper, three installations of conductive gasket are analyzed. Figure 6 shows the three installations and Figure 7 shows the simulation results.

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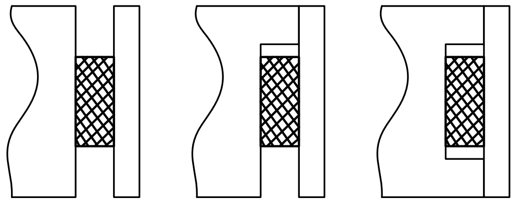

Figure 6. *Three installations of the conductive gasket.(a) method 1;(b) method 2;(c) method 3*

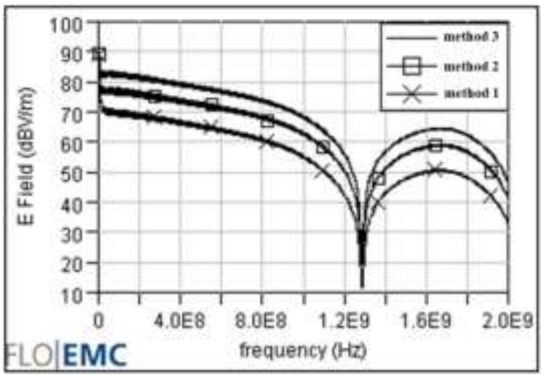

Figure 7. *Shielding effectiveness of different installation methods of conductive gasket.*

Figure 7 shows that the shielding effectiveness of method 2 and method 3 are better than method 1 and the shielding effectiveness of method 3 is a little bit better than method 2. This is because method 2 and method 3 not only ensure the reliable compression degree of the gasket, but also further hinders the penetration of the electromagnetic wave through the gasket for its structure, which provides additional shielding effect for shielding enclosure.

IV. The electromagnetic sealing characteristics of metal reeds

A. *The structure and model of reeds*

Finger metal reed is another electromagnetic sealing devices which often used to reduce the electromagnetic leakage of the slot and improve the shielding efficiency of enclosure. They are widely used in shielding enclosure or cover plate that often require to be disassembled. Figure 8 shows three kinds of commonly used reeds with different structures and installation methods.

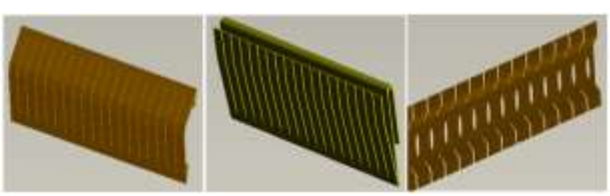

Figure 8. *Three kinds of metal reeds(a) Paste structure (b) Cassette structure (c) Lock attached structure.*

The model of reed structure in Figure 8(a) is shown in Figure 9 with a length of 218mm, a height of 2mm, a width of 10mm, finger width of 10mm, finger gap of 1.5mmand a thickness of reed of 0.4mm.

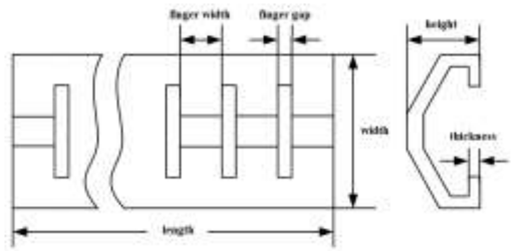

Figure 9. *The parameters schematic of metal reed.*

B. *The influence of the metal reeds*

In view of the reed model in Figure 8(b), the shielding effectiveness with and without the reed of enclosure is compared. The simulation result is shown in Figure 10.

Figure 10 shows that the shielding efficiency of enclosure increases greatly with the metal reed which makes the electric contact on both ends of the gap and greatly reduced the resistor component of the slot impedance. With the decrease of the electromagnetic leakage from the gap, shielding efficiency significantly increases. In addition, the slot resonance point disappears with the presence of the metal reed. However, the influence of reed to hinder the electromagnetic wave in high-frequency is significantly lower than that in low-frequency with the existence of many tiny gaps in reed fingers. In contrast, the increase of shielding efficiency in high-frequency is not obvious.

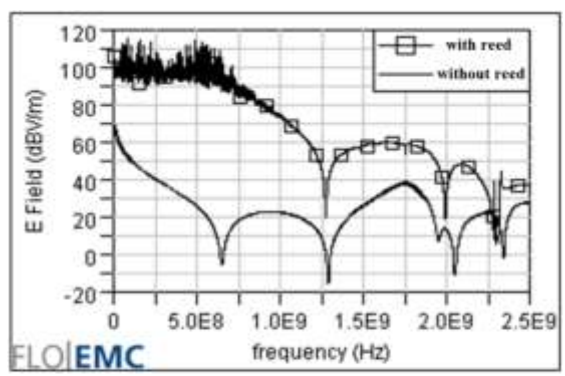

Figure 10. *Simulation result of the influence of the reeds.*

C. *The electromagnetic sealing of metal reed*

1) *Comparison of three different structures*

Three kinds of reed structures are shown in Figure8 with the same structure parameters and the installation of reed is shown in Figure 11. The simulation excitation source is the plane wave with the frequency range is 0-2.5GHz. The simulation results are shown in Figure 12.

(a) (b) (c)

Figure 11. *The three installations of metal reed (a)paste type; (b)cassette type; (c)lock attached type.*

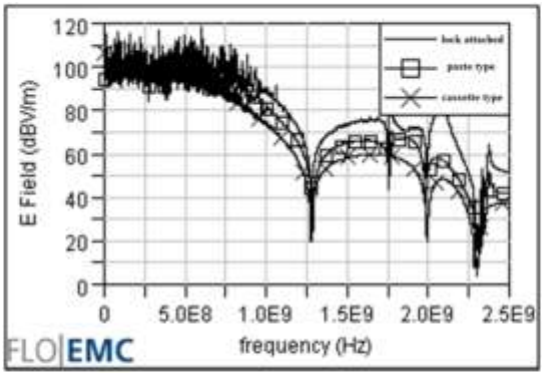

Figure 12. *Comparison of the shielding efficiency of the three kinds of metal reed.*

Figure 12 shows the lock attached structure with the highest shielding efficiency and the cassette structure with the lowest. The shielding efficiency of lock attached type is 12dB higher on average than the cassette type. Furthermore, the shielding efficiency of all three types of reeds in high frequency declines obviously compared with low frequency, which is due to the shorter wavelength of electromagnetic waves of high frequency that can penetrate through the gaps much more easily in the spring fingers.

2)The influence of gaps between the spring fingers

The gap width between the spring fingers is an important parameter of the metal reed to make each finger of better elasticity. Figure 13 shows the shielding efficiency curves of different finger gaps width of 1.5 mm, 1.0 mm and 0.5 mm, respectively. In the simulation we assume that the reeds are in good contact with the enclosure wall.

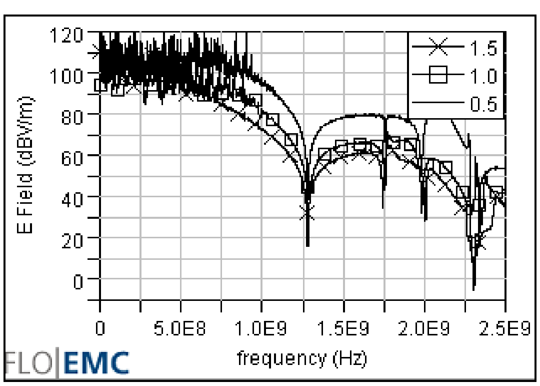

Figure 13. *Comparison of the shielding efficiency of different gap widths*.

Figure 13 shows that the smaller the finger gaps, the higher the shielding efficiency of the enclosure and the shielding efficiency increases obviously. When the width of the finger gaps reduces from 1.5mm to 1.0mm the efficiency of shielding effectiveness improves about 6 dB on average, while increases by an average of 12 dB when reduced from 1.0 mm to 0.5 mm. The reason for this is that, with the metal reed, the electromagnetic leakage of the main channel refers to the gap between reeds. And when the gap decreases the electromagnetic leakage reduces, then the shielding efficiency of cavity increases.

3) The influence of the finger width

The finger width is another important factor to affect the shielding efficiency of the metal reed. Figure 14 shows the influence of different finger widths to the shielding efficiency.

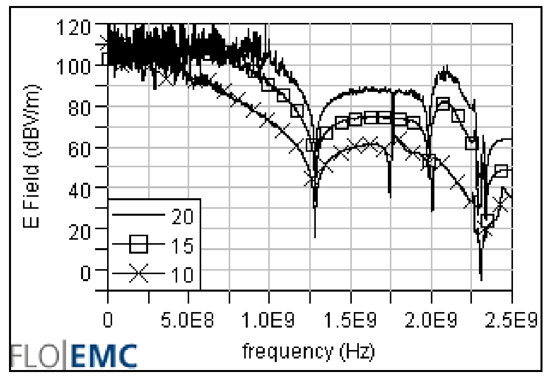

Figure 14. *Comparison of the shielding efficiency of different finger widths*.

Figure 14 shows that different finger widths have significant influence on shielding efficiency. The shielding efficiency increases obviously when the finger width increases gradually. The shielding efficiency of the finger width of 20mm is about 11dB higher than that of 15mm and 25dB higher than that of 10mm. The reason for this is that the increase of the width means the decrease of the gap width. The smaller gap width, the less electromagnetic leakage, resulting in higher shielding efficiency .

V. Conclusion

In the paper, the electromagnetic sealing performance of enclosure with conductive gasket and metal reed is investigated. The following conclusions is obtained which can provide the basis for the electromagnetic shielding design of the enclosure with slots.

(1) The greater the width of conductive gasket, the higher the shielding efficiency of enclosure.

(2) Installing a conductive gasket should maintain good electrical contact with the enclosure wall. Trough structure wrapped liner can be used to improve the shielding efficiency.

(3) The lock attached structure has the highest shielding efficiency and the cassette structure has the lowest.

(4) The smaller the finger gaps, the higher the shielding efficiency of the cavity.

(5) The greater the finger width, the higher the shielding efficiency of the cavity.

(6) After the installation of the conductive gasket or metal reed, the slot resonance point disappears which can improve the shielding effective of enclosure.

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