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Metal Foam for Cooling and EMI Shielding on Vehicle Electronics

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Background:

Electrical and electronic Units (ECUs) transmit and receive signals at different rates and frequency that generate waves and cause interference between the various electronics in the system or the vehicle. The system requirements need to be met while mitigating EM interference (EMI) to specified levels. Adding a metal plate as a shield inside or outside the ECU is one of the typical methods to reduce EMI.

Meanwhile, heat management is another challenge requirement for ECU design, and different controlling approaches used, such as, forced air or liquid, extended fins, and utilized metal foam.

This publication expands the use of the integrating metal foam in ECUs housing and exploits its properties to provide not only thermal management, but also EMI shielding, dual functionalities.

Method:

The system consists of Electrical Control Units (ECUs) made of AL, mag, plastic, composite …etc. An integrated metal foam will be attached to the ECU housing, as illustrated in figure 1 and 2. The metal foam is typically made of aluminum material and shaped to provide optimal cooling and EMI shielding.

Figure 1: Illustration of ECU

When EM waves interact with the metal foam, they will be mitigated (reflected or absorbed). The metal foam will act as a bidirectional shield, namely, reduces the emission of transmitted waves from the ECU to the surrounding and received waves from other sources.

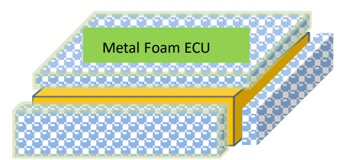

Figure 2: ECU with Metal foam

The metal foam controls the power ratio from within the ECU to the surrounding environment as in the following mathematical concept and illustrated in figures 3 and 4.

The shielding effectiveness (SE), common expression is

SE = 10 log10(Pin/Pout) ……………………..… (1)

Where Pin and Pout are the incoming and outgoing power of the EM wave, when it passes through the metal foam.

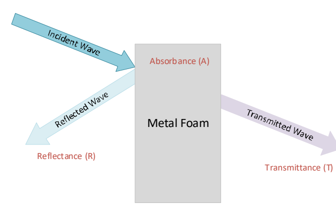

Figure 3: Wave-metal foam interaction

The three main SE forms are reflection (SE_R), absorption (SE_A) and multiple reflection (SE_M). The reflection and absorption are dominant mechanism of open cell metal-foam.

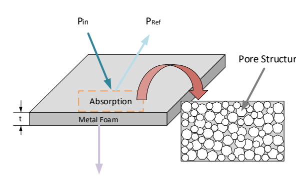

Figure 4: In-and-out coming power of EM wave through metal foam

Thus, the total shielding effectiveness and reflection can be stated as,

$SE_T = SE_A + SE_R$ ……………………………………… (2)

$SE_R = 108 + \log10 (\sigma/f\mu)$ …………………..…… (3)

where μ is the magnetic permeability, σ is the electrical conductivity of the shield materials and *f* is the frequency of electromagnetic wave

$SE_A = - 8.68(t/\delta)$ ………………………………………… (4)

where δ is skin depth of a material which can be defined as the distance up to which EM wave attenuated by *1/e* or 37%, t is thickness of the shield material

$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}} \quad \text{………………………………………………… (5)}$$

where σ is electrical conductivity, ω is angular frequency

$$\sigma = (1 - \left(\frac{\theta}{\theta_M}\right)^S)^t \quad \text{……………………………………… (6)}$$

where θ is the porosity, θ_M is the porosity threshold (the maximum porosity of the foam, usually fixed to one) and s and t are two fitting parameters.

$$S = (5 - n)/4 \quad \text{………………………………………. (7)}$$

$$t = 1 + 0.2536(n - 1)^{1.09} \quad \text{…………………………… (8)}$$

where n had the value 1, 2 or 3, depending on the powder compacting conditions: uniaxial, biaxial or triaxial, respectively.

The magnetic permeability of porous metal foam and electroplated metal is mainly tested by VSM (vibrating sample magnetometer)

$$\mu = B/H \quad \text{…………………………………………………(9)}$$

where, *B* is the magnetic flux density which is a measure of the actual magnetic field within a material and is considered as a concentration of magnetic field lines or magnetic flux per unit cross-sectional area. *H* is the magnetic field strength which is a measure of the magnetizing field produced by electric current flow in a wire or coil.

Based on this described mathematical model, major parameters of metal foam will be defined for each ECU or relevant electronics, such as, thickness (*t*), Porosity (θ), and electrical conductivity (μ).

Then, the system can be optimized accordingly for optimal heat transfer and EM shielding.

Advantages:

This method utilizes metal foam to provide EMI shielding to ECUs and makes it easy to meet the magnetic Interference (EMI) requirements as well as ECUs heat management. Thus, it provides a cost saving opportunity. This method can be applied in general electronics and not limited to vehicular ECUs.

Disclosed anonymously