Effect of Incident Angle on Temperature Characteristics in Pyramidal Radiowave Absorber

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***Abstract*— A pyramidal radiowave absorber is widely used for anechoic chamber. When high power equipment such as radar is measured in anechoic chamber, a risk that the absorber will catch fire occurs by absorbing the high power. In this paper, effects of incident angle on both electromagnetic absorption and temperature characteristics of a pyramidal radiowave absorber are investigated by using the FDTD method and the heat-transfer analysis for both TE and TM waves.**

I. Introduction

A pyramidal radiowave absorber is widely used for anechoic chamber. When high power equipment such as radar is measured in anechoic chamber, a risk that the absorber will catch fire occurs by absorbing the high power. Therefore, it is important to design a high heat-resistance absorber with consideration of both electromagnetic absorption and temperature characteristics.

Traditionally, both electromagnetic absorption and temperature characteristics of a pyramidal radiowave absorber were investigated for a radio wave radiated from a front side of the absorber [1]. On the other hand, it is important to investigate effects of incident angle for a pyramidal absorber. Therefore, electromagnetic absorption characteristics for oblique incident waves were investigated [2], [3]. However, effects of incident angle on temperature characteristics are not clear.

In this paper, effects of incident angle on both electromagnetic absorption and temperature characteristics of a pyramidal radiowave absorber are investigated by using the FDTD method [4] and the heat-transfer analysis [5], [6] for both TE and TM waves.

II. FDTD Model of Pyramidal Radiowave Absorber

Fig. 1 shows a FDTD model of pyramidal radiowave absorber. Table 1 shows parameters used in this simulation.

The boundary conditions of analysis area in this model are shown in Fig. 1(b). The front and back of absorber used the CPML (Convolution Perfectly Matched Layer) [7] and PEC (Perfect Electric Conductor), respectively. The side of absorber used the periodic boundary. The sin-cos method is used to perform oblique incidence of plane wave in input port [8]. Here, frequency and power of plane wave in input port are set to 2.45 GHz and 100 mW/cm^2 as an example, respectively. The special increment Δ uses 1.0 mm in the FDTD analysis.

The heat-transfer analysis is performed based on the heat transfer equation [5], [6]. Here, both an initial temperature of the absorber and an ambient temperature are set to 30.0 °C. Heat-transfer coefficient uses 30.0 W/m^2/K.

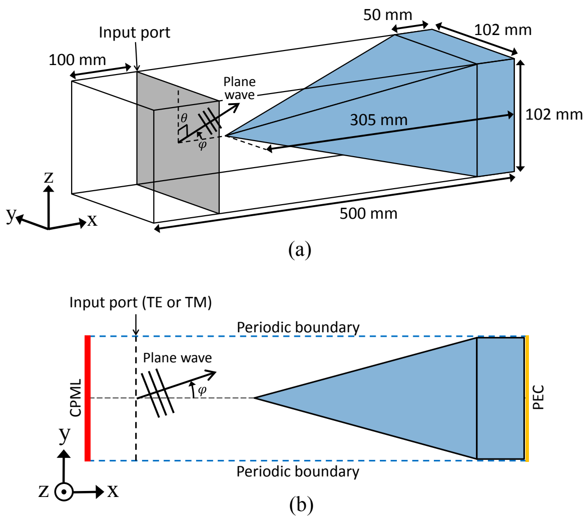

Fig. 1. FDTD model of pyramidal radiowave absorber, θ = 90 deg., φ is from 0 to 80 deg., (a) overall view, (b) boundary conditions and input wave.

III. Numerical Results

Strictly speaking, it is necessary to investigate characteristics for all combinations of incident angles θ and φ. In this paper, at the start of the work, θ is fixed to 90 deg. to know the basic properties of the absorber.

Figs. 2 and 3 show distributions of absorbed power and temperature distributions of the pyramidal absorber for both TE and TM waves, respectively. In these figures, the incident

TABLE I
PARAMETERS USED IN THIS SIMULATION

Input port	Frequency [GHz]	2.45
	Power [mW/cm^2]	100.0
	Polarization	TE, TM
Pyramidal absorber	ε_r	1.6375
	σ [S/m]	0.1738
	Density [kg/m^3]	41.0
	Specific heat [J/K/kg]	1310.0
	Thermal conductivity [W/m/K]	0.074
	Initial temperature [°C]	30.0
Ambient temperature [°C]		30.0
Heat-transfer coefficient [W/m^2/K]		30.0
Special increment Δ [mm]		1.0

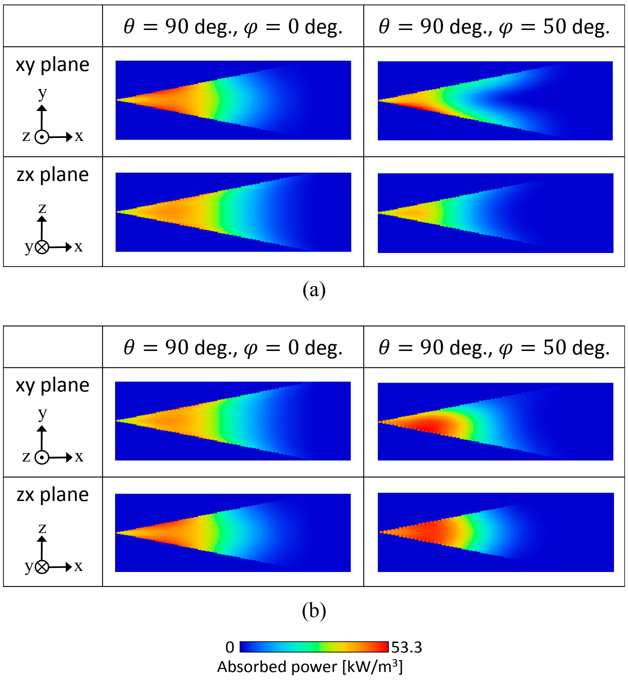

Fig. 2. Distribution of absorbed power, (a) TE wave, (b) TM wave.

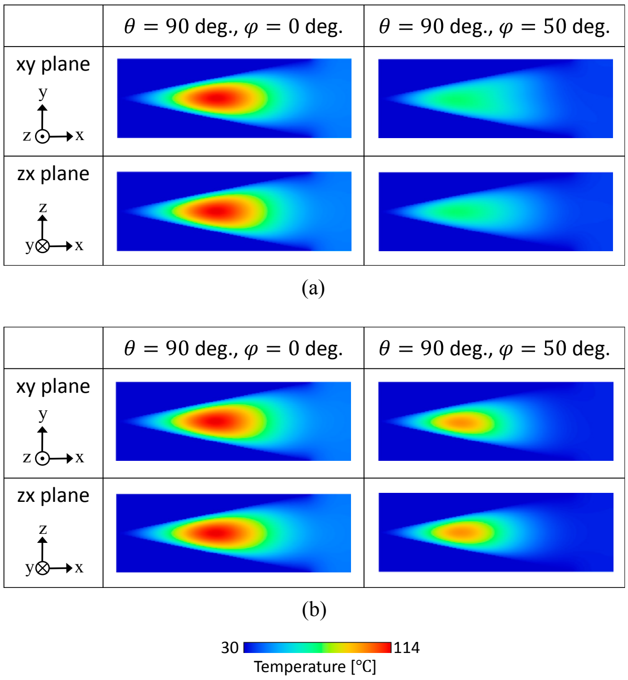

Fig. 3. Temperature distribution, (a) TE wave, (b) TM wave.

angle φ is set to 0 and 50 degrees as an example due to limitations of space. It is shown that an absorbed power is strong in the part of which a plane wave is incident directly for both TE and TM waves as shown in Fig. 2. On the other hand, it seems that the max temperature is observed in near the center of absorber as shown in Fig. 3. As a result, it is indicated that a distribution of absorbed power is not corresponding to a temperature distribution.

Fig. 4 shows the effect of incident angle on reflection coefficient of pyramidal radiowave absorber for θ = 90 deg. It is shown that a reflection coefficient is minimum when φ is 0 degree. It is seen that reflection coefficient increases with the increasing φ. It is indicated that the reflection coefficient for TE wave is large compared with one for TM wave when φ is from 10 to 40 deg. in this simulation.

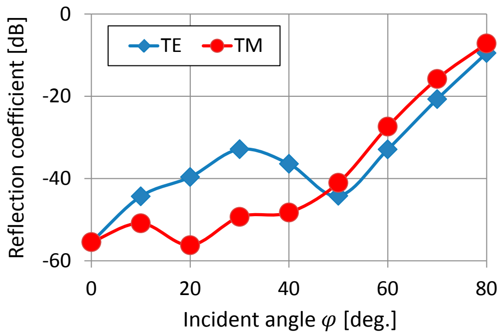

Fig. 4. Effect of incident angle on reflection coefficient of pyramidal radiowave absorber for θ = 90 deg.

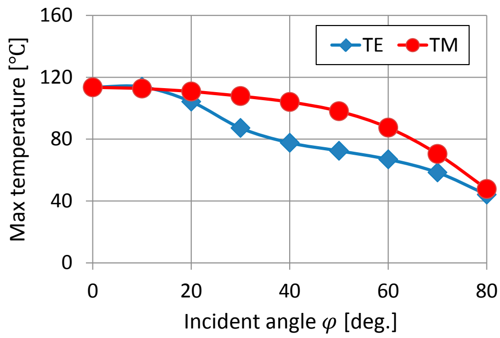

Fig. 5. Effect of incident angle on max temperature in pyramidal radiowave absorber for θ = 90 deg.

Fig. 5 shows the effect of incident angle on max temperature in pyramidal absorber for θ = 90 deg. It is shown that max temperatures are about 114 °C when φ is 0 degree. If incident angle is increased, it seems that the max temperature of absorber is decreased. The reason why is that the reflection coefficient is increased. It is seen that the max temperature for TE wave is below compared with one for TM wave when φ is from 30 to 70 deg. in this simulation.

IV. CONCLUSION

In this paper, effects of incident angle on electromagnetic absorption and temperature characteristics of a pyramidal radiowave absorber were investigated by using the FDTD method and the heat-transfer analysis. As a result, it was shown that the reflection coefficient increases when incident angle increases. And it was seen that the max temperature of the absorber decreases if incident angle increases.

In the near future, we will investigate both electromagnetic absorption and temperature characteristics for other combinations of θ and φ. Additionally, we have a plan to investigate the change of characteristics by input frequency. Moreover, the effect by incident power will be analyzed, because temperature characteristics are the non-linear problem that the electric constant of absorber changes due to a temperature.

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