PYRAMIDAL MICROWAVE ABSORBER DESIGN FROM WASTE MATERIAL USING RICE HUSK AND RUBBER TIRE DUST

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Abstract

Waste material has potential to be used as an alternative material for the microwave absorber that used in the RF anechoic chamber. New material had been research to reduce the cost of designing pyramidal microwave absorber. In this research, rice husk from paddy are mixed with recycled rubber tire dust to give the better reflection loss performance to the pyramidal microwave absorber design. The pyramidal microwave absorber is operating in the microwave frequency range from 7 GHz to 12 GHz. There are three main stage of this work. Firstly, fabricate the waste material pyramidal microwave absorber had been done by using the pyramidal shaped mould. The second work is to determine the dielectric properties of the pyramidal microwave absorber and the last stage is to measure the reflection loss of the waste material using the radar cross section (RCS) technique.

Keywords: *Pyramidal Microwave Absorber, Rice Husk, Rubber Tire Dust, Waste Material.*

I. INTRODUCTION

Microwave absorbers are the main components in an anechoic chamber. This component used to eliminate the reflected microwave signals. The microwave absorbers in this frequency range are used for many applications, including in telecommunications, the military, high-speed electronics, and the automotive industry.

In reality, the waste material is considered as not useful to the community. By using this waste material the cost for designing the pyramidal microwave absorber can be reducing significantly. The example of the waste material is rice husk, shown in Figure 1.

The mixed material of rice husk and rubber tire dust is an innovation in improving the design of pyramidal microwave absorbers to be used in radio frequency anechoic chambers. Rice husks are the natural sheaths that form on rice grains during their growth and removed as waste during the processing of rice in the mills [1]. Rice husks from paddy are the by-product of rice cultivation, and are normally burnt in the field causing environmental problems. Its absorbent and insulating properties are useful to many industrial applications, such as acting as a strengthening agent in building material [2]. The rubber tire dust material is lightweight, elastic, energy absorption, and sound- and heat-insulating properties [3]. The rubber tire dust material is lightweight, elastic, energy absorption, and sound- and heat-insulating properties [4].

Figure 1: Grinded rice husk

Carbon is the most important element that must be in the absorber in order to help the absorption of unwanted microwave signals. In the current market, polyurethane and polystyrene are the most popular foam-based material that has been used in pyramidal microwave absorber fabrication. A combination of rubber tire dust and rice husks may improve the design of pyramidal microwave absorbers to be used in radio frequency (RF) anechoic chambers.

Shielded anechoic chambers are widely used to facilitate RF-isolated test regions to simulate free-space test environments for antenna measurement. Currently, there are two types of anechoic chambers in the market: the acoustic anechoic chamber and the Radio Frequency (RF) anechoic chamber. The interior surfaces (walls, ceiling, and floor) of the RF anechoic chamber are covered with radar-absorbent material (RAM) to create an electromagnetically quiet environment [5].

Figure 2 shows the schematic diagram of the pyramidal microwave absorber that had been design in CST Microwave Studio simulation software. It is consist of 9 tips of pyramidal shape of microwave absorber and a square shape of particle board on the bottom of the pyramidal shape. Table 1 shows the dimension of the simulated rice husk pyramidal microwave absorber. The dielectric constant of rice husk = 2.9. Table 1 shows the dimension of the pyramidal microwave absorber.

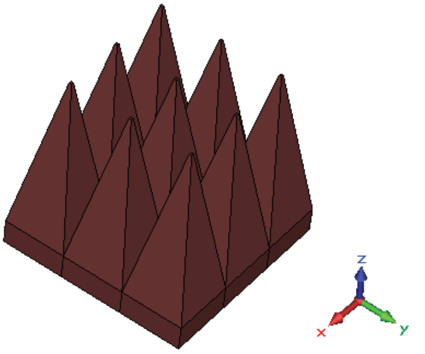

Figure 2: Rice husk pyramidal microwave absorber in CST Microwave Studio simulation software.

Table 1: The dimension of rice husk pyramidal microwave absorber.

Part	Symbol	Dimension (cm)
Pyramidal width	P_W	5
Pyramidal length	P_L	5
Pyramidal height	P_H	13
Base width	B_W	5
Based length	B_L	5
Based height	B_H	2

II. FABRICATION OF ABSORBER

There are many researches on designing microwave absorber, mostly on pyramidal shape [6-14]. In this work, the fabricated absorber has two main parts – pyramid shape part and base part (square particle board shape). The dimension of the base part is 15cm width x 15 cm length x 2 cm thickness and the dimension of the pyramidal part is 5 cm width x 15 cm length x 13 cm height. This design is based on these papers [15-28]. In this work, the mixture of waste material is rice husk and rubber tire dust with combination percentage of 50:50.

Figure 3: Rice husks-rubber tire dust particle board

To make this particle board, polyester resin and methyl ethyl ketone peroxide (MEKP) as hardener agent is necessary to mixed together with rice husk and rubber tire dust. These resins basically are used in adhesives, finishes and molded objects. Its attributes include high tensile strength, flexural modulus and heat distortion temperature, low water absorption, high surface hardness, elongation at break and volume resistance [29]. MEKP as hardener agent are used to glue any adjacent material layer for bonding the mixed material. Figure 3 shows the rice husk-rubber tire dust particle board.

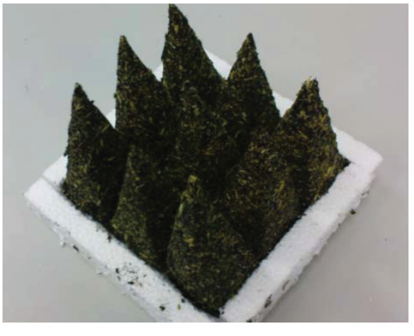

Figure 4: Fabricated rice husks-rubber tire dust pyramidal microwave absorber

The equipment needed for the microwave absorber fabrication is a hand press machine, a plastic cup, a stick, a digital scale, special transparent plastic, and a pyramidal shaped absorber mould. For 50:50 rice husk-rubber tire dust mixture, 75 g of the rubber tire dust, 75 g of rice husk, 15g of polyester resin, and 0.2 g of MEKP hardener are mixed into the basin. To make the pyramidal shape, the mixture is transfer into the pyramidal shape absorber mould. Figure 4 shows the fabricated rice husk-rubber tire dust pyramidal microwave absorber.

III. MEASUREMENT OF DIELECTRIC CONSTANT

The dielectric constant is equivalent to relative permittivity (εr), or the absolute permittivity (ε) is relative to the permittivity of free space ($\varepsilon 0$) [30]. Dielectric properties measurement is an important factor in defining the physical and chemical properties that are related to storage and loss energy in respect to different kinds of materials. At microwave frequencies, different measurement techniques can be used, including the free space measurement technique, the resonant cavity technique, the transmission line technique, and the dielectric probe technique [31]. This work uses the Agilent dielectric probe technique with Agilent Technologies 85070 measurement software to define the dielectric constant and tangent loss. Figure 5 shows the dielectric properties measurement using dielectric probe. The dielectric constant and tangent loss value had been appearing in network analyzer.

Figure 5: Dielectric properties of measurement of the pure tire rubber dust using dielectric probe technique

IV. MEASUREMENT OF REFLECTION LOSS

The reflection loss performances for twenty-one frequencies are measured from 7 GHz – 13 GHz at increments of 0.25 GHz. The requirement for a good microwave absorber performance is that it has reflection loss results better than -10 dB, which indicates that the efficiency of the absorbing performance is 90 percent. In general, the absorber reflection loss required to achieve a specific chamber performance varies with the size and shape of the shielded enclosure. Figure 6 shows the spectrum analyzer and network analyzer that used in this reflection loss measurement. Figure 7 show the loss measurement of rice husk-rubber tire dust pyramidal microwave absorber while

Figure 6: Reflection loss measurement of rice husk-rubber tire dust pyramidal microwave absorber

Radar Cross Section is defined as the area that can be perfectly reflected back when an electromagnetic wave is transmitted from its source to its target position. Radar is a method of determining the presence, location, velocity, and other characteristics of a target through the use of equipment that operates at microwave frequencies by radar and is reflected from the target/object back to the radar [32]. The equipment used was an Agilent E8362B PNA network Analyzer; two 10 m coaxial cables, a pair of horn antennas for transmitting and receiving, reference metal (reference RCS target), and a tripod/metal stick for holding the horn antennas and reference metal.

Figure 7: Spectrum analyzer, network analyzer and coaxial cables used in reflection loss measurement

V. RESULT

This section represents the dielectric constant, tangent loss, and reflection loss performance of the rice husk-rubber tire dust. The dielectric constant and tangent loss value are taken from dielectric probe measurement technique. The reflection loss results are obtained from experiments using the radar cross section measurement method.

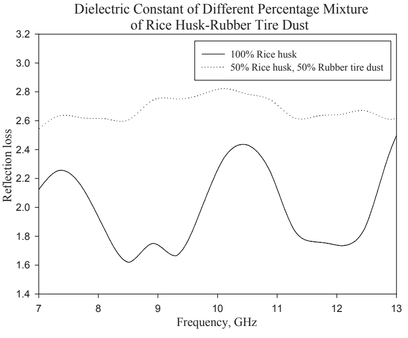

Figure 8: Dielectric constant of different percentage mixture of rice husk-rubber tire dust

Figure 8 and Table 2 shows the dielectric constant of different percentage mixture of rice husk-rubber tire dust. It shows that 100% rice husk have lower dielectric constant compare to the 50%:50% rice husk-rubber tire dust mixture. The average dielectric constant of pure rice husk in the range from 7 GHz to 13 GHz is εr = 2.03 while another mixture is εr = 2.67.

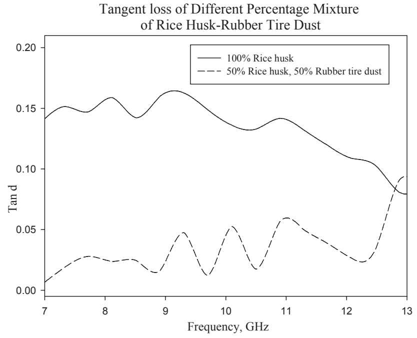

Figure 9: Tangent loss of different percentage mixture of rice husk-rubber tire dust

Figure 9 shows the tangent loss of different percentage mixture of rice husk-rubber tire dust. The first mixture is 100 % of rice husk and the second mixture is 50 % of rice husk – 50 % of rubber tire dust. The average tangent loss for pure rice husk is 0.132 while rice husk-rubber tire dust mixture is 0.037.

Table 2: Dielectric properties for different ratios of rice husk-rubber tire dust

Percentage of mixture (%)		**Average Dielectric constant**	**Average Tangent Loss**
Rice husk	Rubber tire dust		
100	0	2.03	0.132
50	50	2.67	0.037

Figure 10 shows the reflection loss performance of the fabricated rice husk-rubber tire dust pyramidal microwave absorber. The average reflection loss (from 7 GHz to 13 GHz) for this absorber is - 27.40 dB. The best performance is shown at frequency of 11 GHz with - 34.96 dB while the worst point among 7 GHz to 13 GHz is at 7 GHz with only - 20.18 GHz.

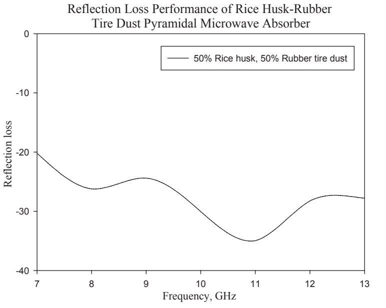

Figure 10: Reflection loss performance of rice husk-rubber tire dust pyramidal microwave absorber

VI. CONCLUSION

The cost of the rice husk-rubber tire dust-polyester-MEKP absorber is cheaper compare to the commercial market microwave absorber. The raw material of rice husks are available for free, the rubber tire dust can be get by recycle the old vehicle tires. The cost for the polyester is only USD 0.0103 / gram and the cost for the methyl ethyl ketone peroxide (MEKP) is USD 0.0035/gram. Therefore, the cost for making a single rice husks pyramidal microwave absorber is USD 0.0423 and the cost for making an array of 8 x 8 rice husk pyramidal microwave absorber is only USD 2.71. This is significant reduction in fabrication costs. As the comparison, the price of 8 x 8 Emerson Cumming VHP-8-NRL Pyramidal microwave absorber is USD 74.91 [33].

The base materials for commercial microwave absorber are not environmental friendly. This is due to the usage of 100% base chemical materials. Both materials like polystyrene and polyurethane can increase the pollution into the environment. The rice husk–rubber tire dust-polyester-MEKP absorbers can reduce the chemical based material by using only 9.3 % of chemical base material. The environment benefit can be increased if this rice husk and rubber tire dust can be reused and re-cycled by avoiding the rice husk burning activity and abundant in the nature.

The investigation showed that different mixture will give the different dielectric constant and also different reflectivity or reflection loss of pyramidal microwave absorber. Lastly, it also proofs that the agriculture waste and industrial waste such as rice husk and rubber tire dust have a huge potential in serving as an alternative material in fabricating microwave absorbers.

For the future works, the several researchers can define the best new material (agricultural waste or industrial waste) to use as base material for pyramidal microwave absorber. Beside that, the other parameter that can be research on the microwave absorber is the shape of the absorber especially the microwave absorber that has the acceptable reflection loss performance result.

Another way to improve the pyramidal microwave absorber is to add the metamaterial structure into the pyramidal microwave absorber design. The examples of the metamaterial structures are split ring resonator (SRR), electromagnetic band gap (EBG), artificial magnetic conductor (AMC), photonic band gap (PBG) and others.

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