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ELECTROMAGNETIC SHIELDING EFFECTIVENESS OF CARBON EPOXY PARTICULATE COMPOSITE PLATES

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ABSTRACT

An investigation was conducted on Electro Magnetic (EM) shielding effectiveness of carbon epoxy particulate composites. The specimens were tested in the X band (8 GHz to 10 GHz) and S band (2 to 4 GHz) in EM spectrum. A better shielding effectiveness material was obtained through experiments and the EM shielding effectiveness of carbon particulates of various micro structures were compared. Design of experiments with Minitab 14 was used for optimizing of the results in experiments. The various input parameters selected were the thickness of the material, distance from source, weight fraction and frequency. The output parameters selected were attenuation and shielding effectiveness. Study was carried out experimentally, graphs plotted and results were analyzed.

Key words: *EM Shielding, Carbon Particulate Composites, DOE and Minitab*

1. Introduction

In the recent years, the importance of electromagnetic interference (EMI) shielding materials has increased due to the more prevalent use of personal communications devices [1]. So a need for the development of new, renewable, cheap, conducting and eco friendly materials exists. Though metals have typically been used as the material of choice for shielding applications, they have many limitations [2]. Shields designed for portable devices must also meet demanding mechanical and electrical requirement [3]. A good shielding material is one which absorbs all EM waves and does not allow them to pass through it.

2. Literature Survey

N.C.Das et al observed that the SE of the composites is frequency dependent, especially at higher frequency range, and it increases with the increasing frequency. The SE also increases with the increase in filler loading. The short carbon fibre filled composites show higher SE compared to that of conductive carbon.[4]. Zuoyong Dou et al found that by using the fly ash particles, the shielding effectiveness properties of the matrix aluminum can be improved in the frequency ranges 30.0 kHz–600.0 MHz and the increment varied with increasing frequency [5].

3. Materials & Process

Matrix polymer used in present study is Lapox L12, epoxy resin and K-6 hardener supplied by ATUL India Ltd. with following properties as given in table 1.

Table 1: Properties of Epoxy and Hardener

Constituent	Trade name	Chemical name	Density (gm/cm^3)
Resin	LAPOX L12	Diglycidyl Ether bisphenol (DGEBA)	1120
Hardener	K-6	Tryethylel tetramine(TETA)	954
Constituent	Trade name	Chemical name	Density (gm/cm^3)

Lapox L12 resin is a thermosetting plastic and get hardened with the help of hardener K6. This hardener cures at room temperature and has low viscosity. They are commonly used for hand lay application. In present study conducting material carbon is used as reinforcement to make composites conducting so that shielding effectiveness of the material will be improved.

3.1 Carbon particles

Carbon powder used in the present study is taken in three different sizes viz 5, 20 and 36 microns and their Scanning Electron microscope (SEM) pictures are shown in fig.1-3.

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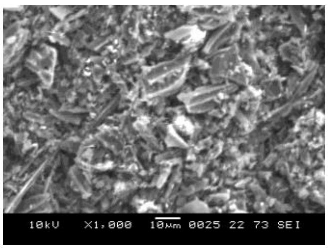

Fig. 1 Fine Size Particle (5 micron)

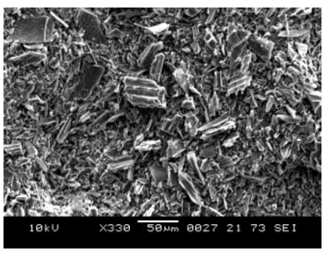

Fig. 2 Medium Size Particle (20 micron)

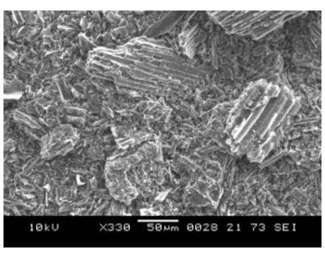

Fig. 3 Coarse Size Particle (36 micron)

Cf,Cm, Cb are used to represent fine size, medium size and coarse size particles of caron respectively.

4. Processing of Composites

Mould for round specimen is made of polyvinylchloride stops available in market. They are fixed to the base temporarily using wax. Specimens are made by mixing calculated amount of epoxy resin with 10 % of hardener. Then weighted quantity of carbon powder of specified size is poured in to the mixture till it becomes jelly state. They are mixed properly for uniform distribution of carbon particles and then poured in the mould. Silicon releasing agents are applied to mould before poring the composite mixture, then the round specimen formed is kept in mould for 24 hours for proper solidification. Once it's solidified its taken out from the mould and kept in the oven for two hours at 80 degree centigrade to remove the vapors present in the specimen. Similarly specimen for various thickness (1mm,2mm and 3mm) and different weight fractions (5%. 10% and 15 %) are made.

5. Experiment Plan

Minitab R14 is used for analysis of variance (ANOVA) calculations, for various plots and to draw decisions from it. Geometrical parameters can be varied by varying the thickness of shielding material. It was decided that parameters will be studied each in the three levels for S band and X band of microwaves.

As the Shielding effectiveness mainly depends on the frequency of the EM source, distance of the shielding material from the source and thickness, testing for shielding effectiveness is carried out by varying the three levels of these factors as per L9 orthogonal array in table 2 and 3 for X band and S band. Shielding effectiveness is measured as the attenuation of the signal passing through the composite, expressed in decibels. Nine specimens are used ,each of fine, medium and coarse grain size, so that a total of twenty seven specimens are tested in S band and X band. For each specimen three readings one at left end, second at right end and third at the centre of specimen are taken and average values in each case is taken from it.

Table 2: Experimental Plan for X Band

Sl No	Distance	Frequency	Weight Fraction	Thickness
1	220	9	5	1
2	220	9.3	10	2
3	220	9.5	15	3
4	440	9	10	3
5	440	9.3	15	1
6	440	9.5	5	2
7	660	9	15	2
8	660	9.3	5	3
9	660	9.5	10	1

Table 3: Test Plan for S Band

Sl No	Frequency	Weight Fraction	Thickness
1	2.78	5	1
2	2.78	10	2
3	2.78	15	3
4	2.85	10	3
5	2.85	15	1
6	2.85	5	2
7	2.94	15	2
8	2.94	5	3
9	2.94	10	1

6. Testing Methods

Shielding Effectiveness (SE) can be calculated based on EM wave voltage levels as follows.

If the receiver readout is in units of voltage, use the following equation:

$S.E. = 20 \log_{10} (V_2/V_1)$ (1) [6, 7]

Where:

V_1 and V_2 are voltage levels with and without shield respectively.

For the S and X band testing it was decided to test the main effect of each factor at three levels as it can be done in fewer trials.

6.1 Testing for X band

The test set up consists of an EM source and an EM sensor between which the composite plate under consideration is introduced as obstacle. The experimental set up conforms to the suggestions given by ASTM D 4953 [8].

The experiment is setup as indicated in a relatively reflection free surrounding. Power the Gunn Diode with a voltage of about 9V from the Gunn Diode Power Supply. The modulation switch is set to produce square wave. Modulation BNC output is connected to the Modulator in the setup. The Detector is connected to the Rotary Joint and the Gunn oscillator is tuned up at 9.0GHz to get a wave with maximum field intensity on the Digital Storage Oscilloscope connected to the Detector. Also the Gunn voltage is adjusted to around 9V to obtain wave of maximum amplitude in the Digital Storage Oscilloscope. Frequency Meter if used can be detuned by at least 150 MHz. The horn antenna is placed on the rotary joint and the detector is connected to the horn antenna on the stand. The antenna on the rotary joint scale is aligned to read 90 degrees.

The Parabolic Antenna is placed on the stand at a distance of at least 88 centimeters from the Horn Antenna. The Parabolic Antenna is aligned on the stand in height and direction so that it indicates maximum field intensity on the DSO when the antennas are perfectly in line with the horn antenna. The atenuator is set at 12 dB which will be taken as reference for all the readings. The digital storage oscilloscope is switched on. The readings are noted on the display in mV and are set as reference. Composites specimens of different thickness are placed at different distance from the horn antenna. Also attenuations for plain metal and epoxy are measured. The attenuation is the difference between the initial reading on the DSO and the final reading on the DSO after placing the material. Tests are conducted for three for different frequencies (9.0 GHz, 9.3GHz, and 9.5GHZ) in the manner described above and attenuations corresponding to different levels of factors are tabulated.

6.2 Testing for S band

The experiment is conducted using ASTM D4935 [8].The helical antenna is mounted on one stand. This may be chosen as the transmitting antenna. The second helical antenna from the kit is mounted on another stand and this is chosen as the receiving antenna. Switch on the power supply. Set the frequency of operation at 2.8GHz (2.75GHz and 2.95GHz) on the microwave signal source connected to the transmitting antenna. Keep the receiving antenna at a distance of about 20cms from the transmitting antenna. Align the two antennas such that they face each other. When properly aligned the digital storage oscilloscope (DSO), connected to the receiving antenna, will show maximum reading [Pk-Pk] (mV). This reading on the digital storage oscilloscope is taken as the reference. Now place the polymers and the composites in between the two antennas using the specimen holder at different frequencies. Note down the reading on the DSO. Using eq. (1) calculate the SE offered by that material. The experiment is repeated for one-side roughened polymers facing the transmitting antenna and both-side roughened polymers. Tabulate the readings. The results are plotted. The loss of energy in EM wave passing through the test material is measured as attenuation. The attenuation values are tabulated and used for analysis of EM shielding

7. Results and Discussion

7.1 EM performance of carbon particulate composites in X band

From the main effect plots in Fig 4-6, it can be inferred that for Cf composites distance and weight fraction influence SE, while in Cm composites not much influence by various parameters is found and in Cb composites distance and frequency has more influence than other factors . Graph shows that there is an increase in through-transmission of EM waves with respect to increase in thickness. This could be due to increased interaction of matter with EM wave for a thicker specimen .A maximum shielding effectiveness of 0.3Db is obtained at a weight fraction of 5, frequency 9 GHz and thickness of 3 mm for Cf composites. Similarly for Cm composites, maximum SE of 0.4 Db is obtained at weight fraction of 5, frequency 9 GHz, and thickness of 1 mm and for Cb composites, maximum value of 0.5 Db is obtained at weight fraction of 5, frequency 9.5 GHz, and thickness of 1 mm.

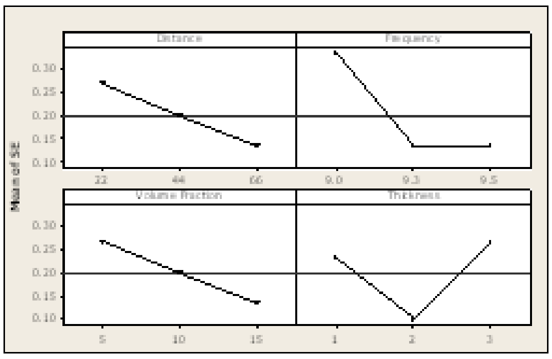

Fig. 4 Main Effects Plots of Cf Composites

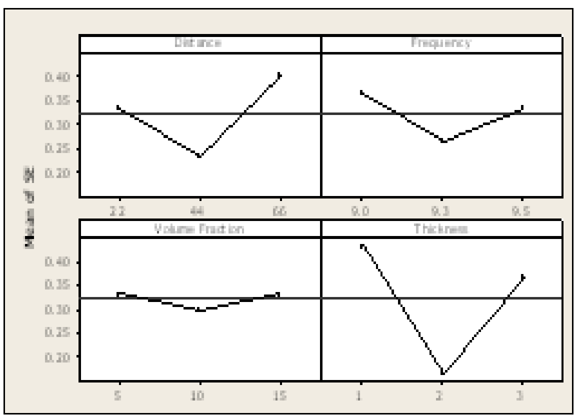

Fig. 5 Main Effects Plots of Cm Composites

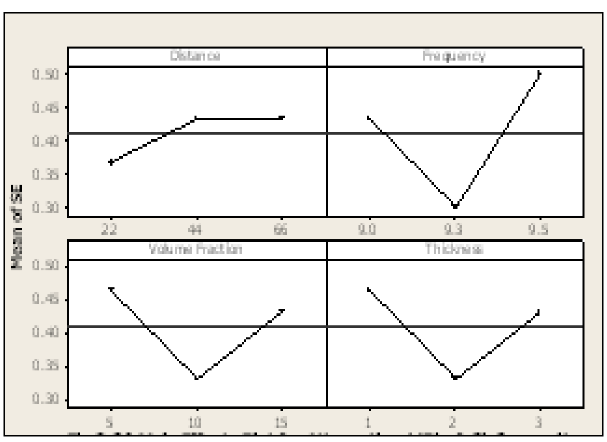

Fig. 6 Main Effects Plots of Cb Composites

From the main effects plots, frequency and thickness seemed to be more influencing than other factors of which frequency is the most contributing factor.

7.2 EM performance of carbon particulate composites in S band

Testing of particulate composites at S Band of microwave frequency range are done. The experimental data and its analysis are presented in modular fashion. In all cases the response of the experiment is related to the input changes namely frequency of the microwaves, thickness of the shield material, distance of the shield material from the transmitting antenna and weight fraction of composites. The section below illustrates the results of exposing carbon-epoxy particulate composites to radiation frequencies 2.78, 2.85 and 2.94 which fall in S band range.

From the ANOVA graph it can be observed that at S Band frequency bears significant effect on attenuation than thickness and weight fraction of the material.

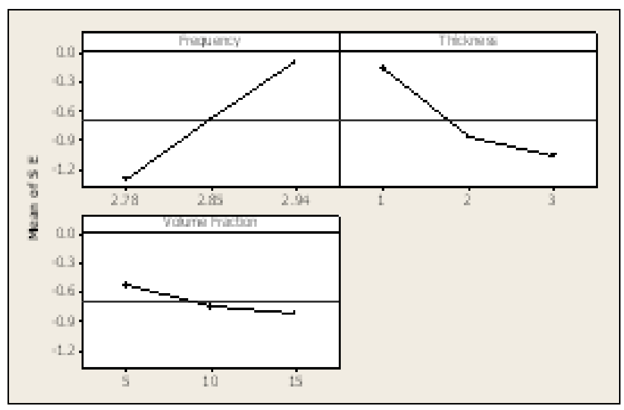

Fig. 7 Attenuation of Cf Composites

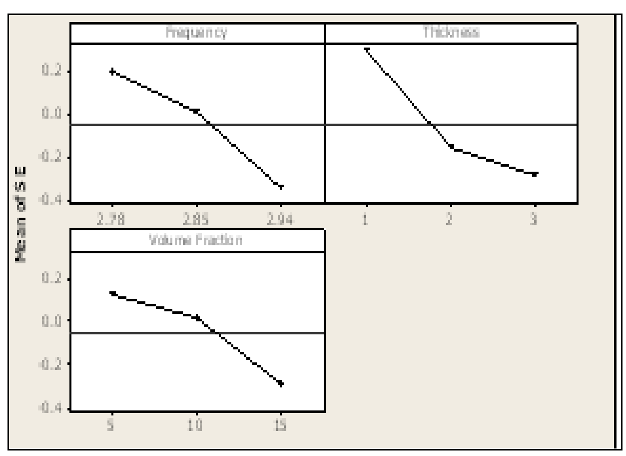

Fig. 8 Attenuation of Cm Composites

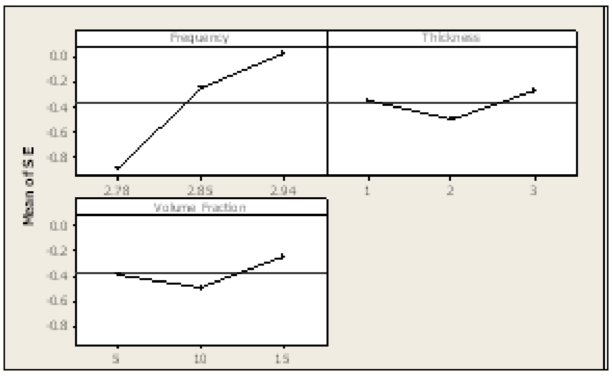

Fig. 9 Attenuation of Cb Composites

In the effect plots (Fig. 7-9) it can be observed that attenuation has increased from 2.78GHz to 2.94GHz. It is also inferred that Cf composites of 1mm thickness has contributed better attenuation. All parameters are strongly affecting the SE as they show steep curves in main effects plots.

It was found that SE is negative in carbon particulate composites. This may be due to the facts the specimen being small in diameter rather than acting as a shield, will act as focusing lens for the EM waves striking on the specimen. So as a result the beams get concentrated and have higher beam intensity at the receiving antenna than the transmission, thereby giving a negative shielding effectiveness.

8. Comparison of S band and X band Responses

From the graph in Fig.10-11, as the thickness of the composite materials varies, SE decreases with increase in thickness .This may be contributed due to the presence of voids present in the composite materials in S band but is improved in the case of X band. This shows that the thickness variation is not affecting SE in X band range.

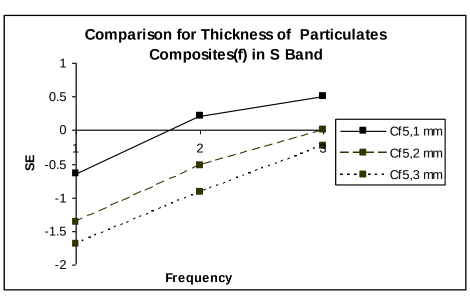

Fig. 10 Comparison Plot of Shielding Effectiveness of Carbon Particulate Composite (Cf) in band, varying thickness

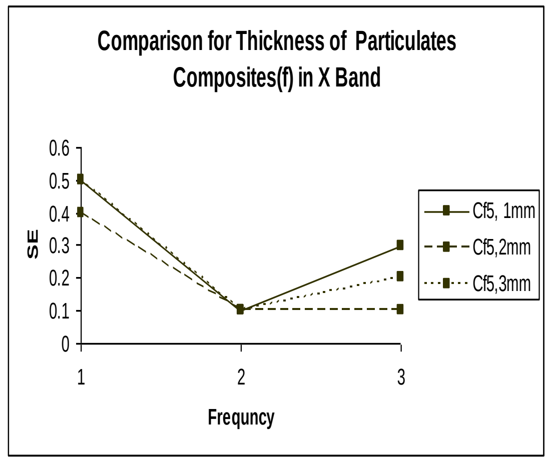

Fig. 11 Comparison Plot of Shielding Effectiveness of Carbon Particulate Composite (Cf) in X band, varying thickness

9. Conclusion

A study of the electromagnetic performance of carbon particulate composites at X Band and S Band of microwave frequency range are conducted and EM shielding effectiveness was evaluated in order to analyze the possibility of its usage in shielding elements. Testing is done on carbon epoxy particulate composite of various particle sizes. Experiments are carried out according to Taguchi's efficient experimental design methods and response data is analyzed with ANOVA technique with the help of commercial software MINITAB 14.

Polymeric specimens having different thickness and weight fractions as governing factors are tested for various responses namely attenuation (dB) and percentage of shielding. It is observed that Cb composites are showing better SE materials than fine and medium particulate composite, as conducting fillers forms a network of chain for conduction in Cb composites. Coarse grain particle composites of carbon have displayed better shielding effectiveness relative to lower particle size composites. This could be due to increased probability of a conducting network formation at low thickness (because of lower sample volume). SE of the specimen is better than that of plain polymers in X band .At higher thicknesses, network formation is not promoted; as voids get increased more for higher thickness creating air gaps which reduces the conductivity and hence these composites have displayed no effectiveness but on contrary have encouraged more transmission of the EM energy. Particulate composites are less preferred for S band range as SE value is not much of significance in S band.

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