Electro Magnetic Shielding Effectiveness of High Density Polyethylene Based Composite Materials

Abin Paul[1], Clint K S[2]

Department of Mechanical Engineering, IES College of Engineering, Chittilapilly,Thrissur, Kerala, India

Abstract: ***Our project is on Electromagnetic shielding effect of High density polyethylene based composite material and also try to analysis the mechanical properties of the materials. Composite making aims on light weight materials having the same strength of metals and at low expense. In this project we are making mainly three type of composite materials, carbon ISAF 220 (Intermediate super abrasion furnace black) with high density polyethylene, fly ash with high density polyethylene and copper with high density polyethylene at 1mm at 5%, 10%, 15% weight fraction. After making the specimens, we conducted non destructive test of shielding effectiveness in the materials using microwave testing apparatus and using the observed values we plotted graphs to get result. Mechanical properties of composite have also been studied.***

Keywords: composite, polyethylene, carbon, electromagnetic shielding

1. Introduction

There is a great need for materials with special properties with emergence of new technologies. However, conventional engineering materials are unable to meet this requirement of special properties like high strength, ductility and low density materials for the special purpose applications in the fields of aerospace, automobile, electromagnetic shielding etc. Thus, emerged new class of engineering materials the composites. Composite material is defined as any multiphase material that is artificially made and exhibits a significant proportion of the properties of the constituent phases. The constituent phases of a composite are usually of macro sized portions, differ in form and chemical composition and essentially insoluble in each other. In our project we are making polymer composite to study its shielding effect. Ability of a material to shield Electro Magnetic (EM) radiation depends attributes like volume fraction and conductivity of the materials. There are mainly two types of composite materials. Fiber based and particulate based composites. First one consists of fibers and second one consists of particles mainly in the matrix material.

In this work the matrix is High Density Polyethylene. High-density polyethylene (HDPE) or polyethylene high-density (PEHD) is a polyethylene thermoplastic made from petroleum. HDPE is defined by a density of greater or equal to 0.941 g/cm^3. HDPE has a low degree of branching and thus stronger intermolecular forces and tensile strength. . HDPE is used in products and packaging such as milk jugs, detergent bottles etc. HDPE has little branching giving it stronger intermolecular forces and tensile strength than lower-density polyethylene. The difference in strength exceeds the difference in density, giving HDPE a higher specific strength. It is also harder and more opaque and can withstand somewhat higher temperatures.

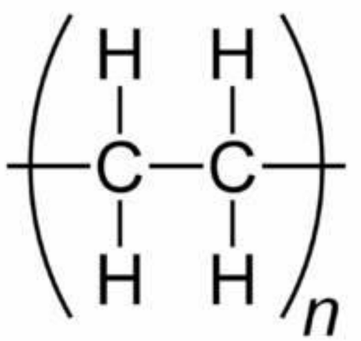

Figure 1: structure of high density polyethylene

The reinforcement materials are fly ash, carbon ISAF and copper powder. Fly ash is one of the residues generated in the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants, and is one of two types of ash that jointly are known as coal ash; the other, bottom ash, is removed from the bottom of coal furnaces. Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Since the particles solidify while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5 µm to 100 µm. They consist mostly of silicon dioxide (SiO_2), which is present in two forms: amorphous, which is rounded and smooth, and crystalline, which is sharp, pointed and hazardous; aluminum oxide (Al_2O_3) and iron oxide (Fe_2O_3). Carbon black is a material produced by the incomplete combustion of heavy petroleum products such as FCC tar, coal tar, ethylene cracking tar, and a small amount from vegetable. Carbon black is a form of amorphous carbon that has a high surface area to volume ratio, although its surface area to volume ratio is low compared to activated carbon. Copper is a chemical element with the symbol Cu and atomic number 29. It is a ductile metal with very high thermal and electrical conductivity. Pure copper is rather soft and malleable, and a freshly-exposed surface has a pinkish or peachy color. It is used as a thermal conductor, an electrical conductor, a building material, and a constituent of various metal alloys. Copper is easily worked, being both ductile and malleable. Microwaves are super high frequency (SHF) and extremely high frequency (EHF) of microwaves come next up the frequency scale.

Microwaves are waves which are typically short enough to employ tubular metal waveguides of reasonable diameter. Microwave energy is produced with klystron and magnetron tubes, and with solid state diodes such as Gunn and IMPACT devices.

Literature survey has shown the effectives of metal casings and polymer casings for various components. But they have their own limitation as far as electromagnetic shielding is concerned. So there is lot of scope doing electromagnetic testing on composite materials which can combine the benefits of both metals and polymers. Based on the available resources we have selected high density polyethylene which is a thermoplastic, as matrix material. Then we use carbon powders, copper powders, fly ash which posses conducting properties as the reinforcement.

2. Methodologies

The matrix and reinforcement are mixed in different weight fractions of 5%, 10% and 15%. Weights of matrix and reinforcement are calculated using inverse rule. Two different sections circular and I section has been created. Thickness of the specimen is kept as 1mm. circular section 9 Nos and I section 45 Nos has been created. Manual injection molding has been used for creating specimens. In this work commercial statistical software Minitab R14 is used for ANOVA calculations, to various plots and to draw decisions from it. Design of experiments (DOE) is as shown in Figure. Various mechanical properties such as tensile strength and hardness are studied. Universal testing machine and shore durometer are used for this purpose. Shielding effectiveness is studied by keeping the specimen at different distances of 0, 2, and 4mm from the transmitter. Microwave energy in the X Band has been generated. Frequencies adopted are 9.11GHz; 9.44GHz and 9.645GHz.The experiments are designed according to Taguchi's L9 orthogonal array to determine significance of each of the input parameters and their interactions in least possible trials. Responses observed were analyzed using analysis of variance technique. Specimens made for testing includes plain high density polyethylene, carbon particulate high density polyethylene, fly ash particulate high density polyethylene, copper particulate high density polyethylene.

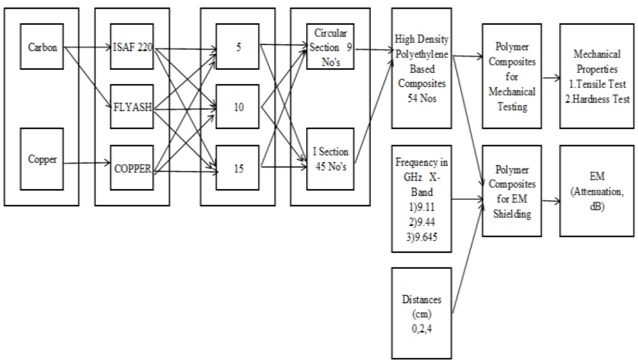

Figure 2: Methodology

3. Results and Discussions

3.1 EM Performance on Carbon Particulate Composites

3.1.1 Main effect plots for HDCI Composites

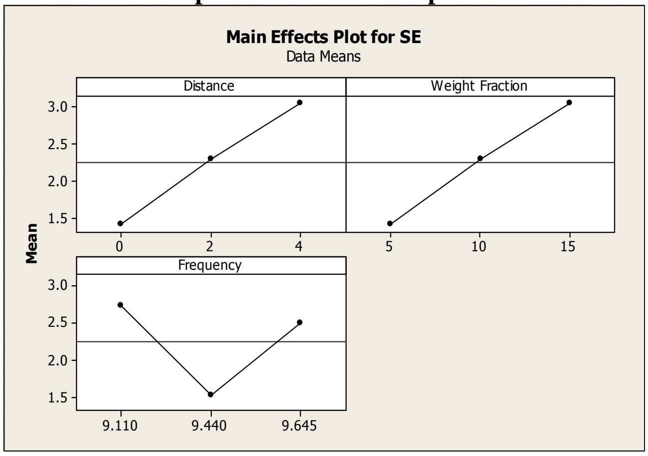

Figure 3: Plot of SE HDCI Composites

From the main effect plots, it can be seen that weight fraction and distance are strongly affecting the SE of HDCI and frequency is not very much affecting the SE. Maximum shielding effectiveness is obtained when weight fraction is 15%. This is because of carbon forming a network inside HD Matrix. The network helps the conduction of EM waves through HDCI particulate composites. Hence it behaves as a better shielding material than plain HD, HDCU and HDFC.

3.1.2 Main Effects Plot for HDFC Composites

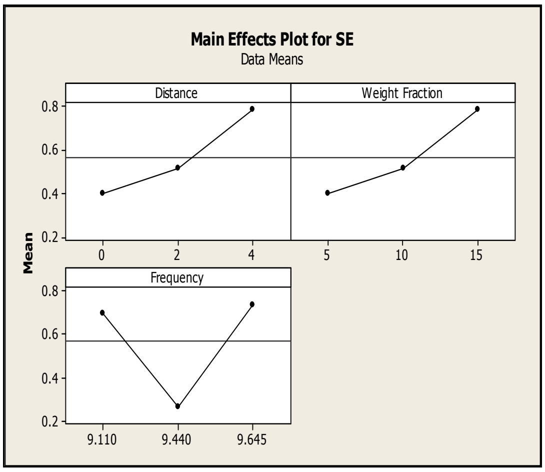

Figure 4: Plot for SE HDFC Composite

From the plot it is observed that shielding effectiveness is less compared to HDCI and HDCU composites. This is due to the low carbon content in fly ash and also carbon in fly ash having spherical shape unable to form good network within the composite. Fly ash is not able to interface properly with HD.

3.1.3 Main effect plots for HDCU Composites

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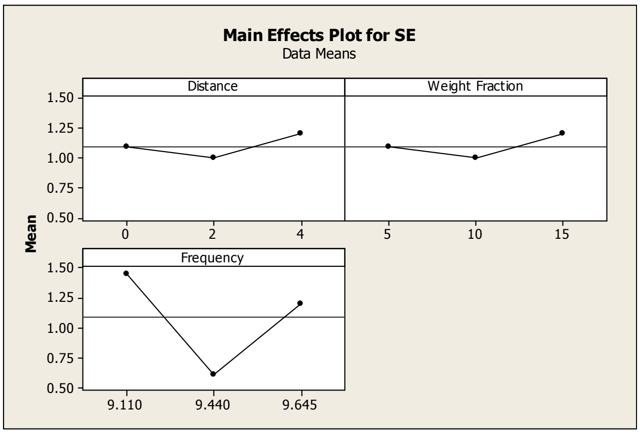

Figure 5: Plot for SE SDCU Composite

From the main effect plot it can be seen that distance and weight fraction is affecting the SE. The value obtained for SE is in between HDCI and HDFC. That is SE is moderate. From the SEM photograph, Copper gets precipitated as a network in HD matrix. The presence copper network contributes for the SE of copper particulate composite.

3.2 Mechanical Results

We have done two types of mechanical tests such as tensile test and hardness test in order to Study the behavior of various particulate composites. The tensile test has done on a Universal Testing Machine (UTM) and hardness test is done by using Shore D Hardness tester. The tests are conducted on standard shape such as I section (dumb bell).

3.2.1 Excel plot for HDCI Composites

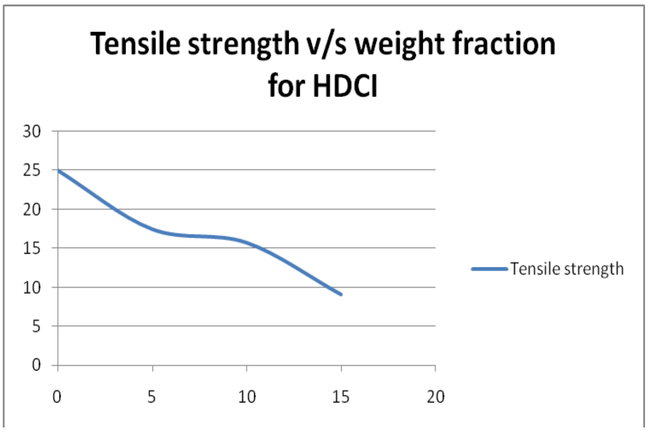

Figure 6: Tensile strength vs weight fraction HDCI

As the weight fraction increases the tensile strength decreases. This is due to the low bonding between HD and Carbon powder. So the maximum tensile strength is obtained using plane HD. The hardness v/s weight fraction graph shows that after a particular weight fraction, the hardness increases linearly with weight fraction.

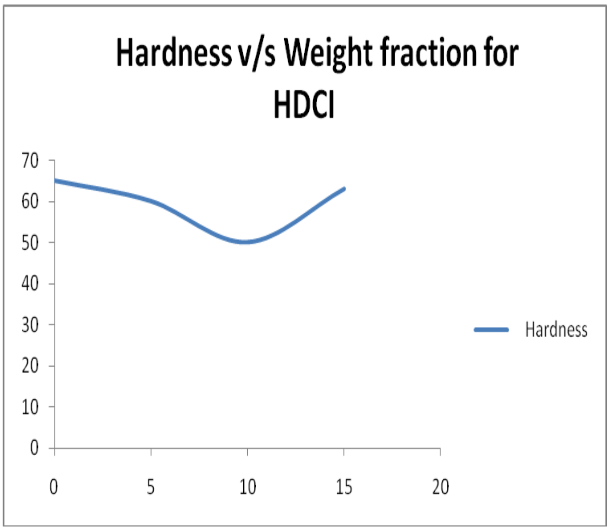

Figure 7: Hardness vs Weight fraction HDCI

3.2.2 Excel Plots for HDCU Composites

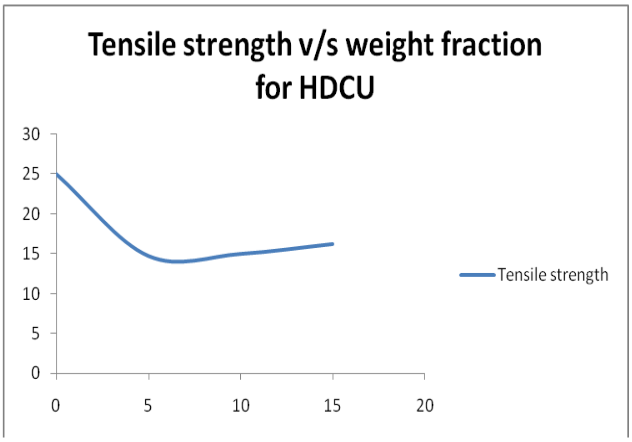

Figure 8: Tensile strength vs Weight fraction HDCU

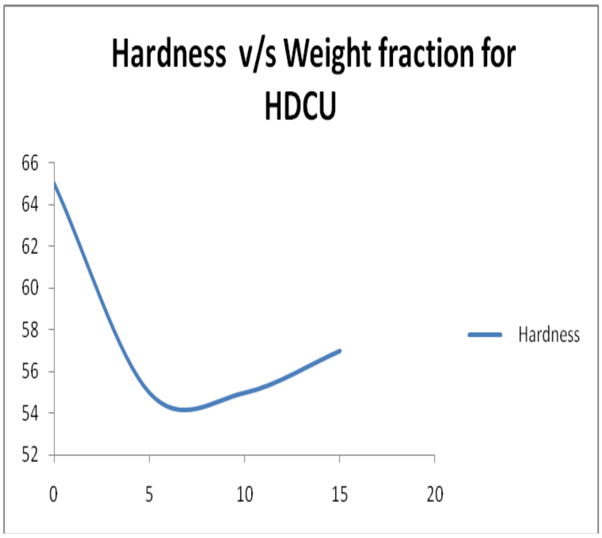

Figure 9: Hardness vs Weight fraction HDCU

As the weight fraction increases, tensile strength increases. But pure HD has maximum tensile strength. The hardness v/s weight fraction graph shows that hardness increases with weight fraction. But pure HD has maximum hardness.

3.2.3 Excel plots for HDFC Composites

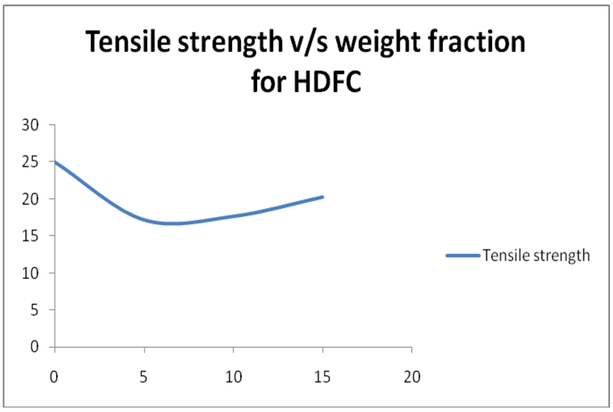

Figure 10: Tensile strength vs weight fraction HDFC

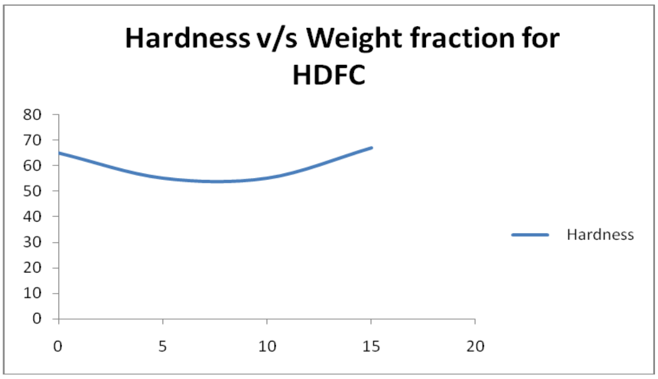

Figure 11: Hardness vs Weight fraction HDFC

As the weight fraction increases,tensile strength increases. The hardness v/s weight fraction graph for HDFC shows that hardness increases with weight fraction. The maximum value obtained at 15% weight fraction of fly ash.

4. Conclusion

From this work we can conclude that Carbon ISAF has more electromagnetic shielding effectiveness than Fly ash and Copper because of its better reinforcement , better conductivity etc. Also Carbon ISAF 220 shows a higher shielding effectiveness at 1mm thickness 15% wt.fraction. The shielding effectiveness of copper is more than that of fly ash because fly ash has large particle size, impurity content, less conductivity etc. The mechanical properties are strongly affected by the addition of reinforcements like Carbon, copper and fly ash. In most of the composites tensile strength and hardness is less compared to plain HD. But HDFC has better hardness and tensile strength at 15% wt. fraction compared to other composites and plain HD. Carbon has lower tensile strength and hardness. It may be due to the difference in particle alignment direction and direction of loading. In other words carbon particulate composites have higher brittleness. Fly ash particulate composites are more ductile than carbon particulate and copper particulate composites.

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