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Determining the Electromagnetic Shielding Properties of Non-Woven Materials

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Abstract

The issues of measuring, and predicting, the anisotropic electromagnetic shielding properties of electrically conductive, non-woven materials are considered. An efficient method for measuring the shielding properties is along with a stochastic model which can predict the sheet conductance is described.

Non-Woven Materials

Non-woven materials are used throughout the aerospace, defence and medical industries, usually to provide lightweight, functional enhancement to existing composite structures. Applications include electromagnetic shielding, collapsible antenna reflectors and defibrillator electrodes.

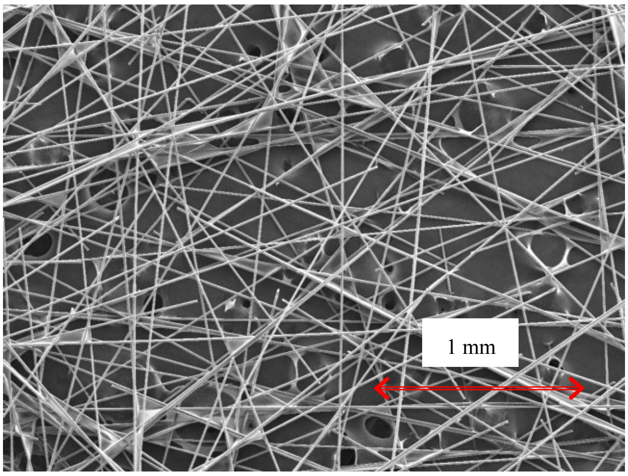

Fig 1. An SEM image of a carbon fibre non-woven material.

A non-woven fabric is an array of discontinuous fibres that are formed into a sheet using a wet-laid process like that used for paper manufacture. Non-woven materials possess a complicated structure with varying local parameters such as thickness, areal density, and fibre angle. Fig 1. shows a scanning electron microscope (SEM) image of a non-woven fabric veil, constructed from 12mm long polyacrylonitrile carbon fibres stabilised using a polyester binder.

Shielding Measurement

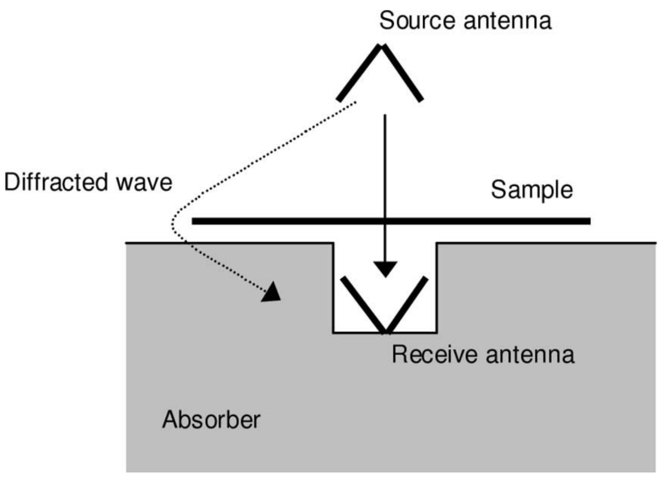

Fig 2. A cross section through the absorber box measurement system.

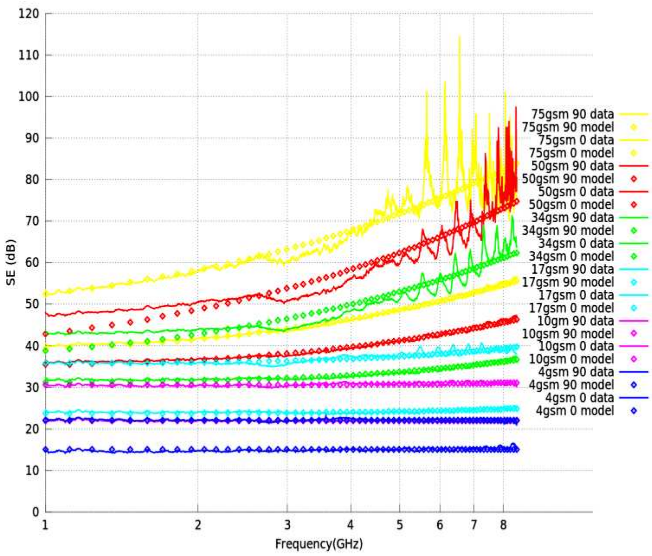

Fig 3. Shielding effectiveness for a range of material weights.

To measure the plane-wave shielding effectiveness of planar materials we have developed a fast "Absorber Box" method which minimises the requirements for sample preparation [1]. The test cell is linearly polarised and can therefore be used to measure anisotropic materials. The test cell consists of a cavity surrounded by radio absorptive material (RAM) on which a planar sample can be placed (Fig 2.). A broadband linearly polarised horn antenna in the cavity illuminates the sample and a second horn antenna above the sample is used as a receiver. The current cell design works well from 1 to 8 GHz. The RAM gives a good isolation of the diffracted wave and is comparable with the gasket and clamp techniques used by more conventional measurement systems.

Initially the shielding properties of a number of different non-woven veils were measured using the Absorber box method. Fig 3. Shows the measured shielding effectiveness for zero and 90 degree orientations relative to the direction of the manufacturing process (lines). A Schelkunoff [2] homogenous sheet model was fitted to each measurement (points). It can be seen that at the low frequency end for most of the materials the shielding effectiveness is constant with frequency, beginning to rise at higher frequencies. The low frequency flat region corresponds to the case where the skin depth in a homogenous material is larger than the material thickness and the shielding effectiveness depends only on the sheet conductance of the material. At higher frequencies as the skin depth becomes smaller than the material thickness the shielding effectiveness of a homogenous material increases rapidly, this effect can also be seen in the non-woven veils, although aperture coupling is also likely to become significant as frequency increases.

Predicting shielding effectiveness

In order to understand better the non-woven material properties we decided to construct models by randomly generating fibres with the same distribution of orientations as found in the real materials, an example of part of a

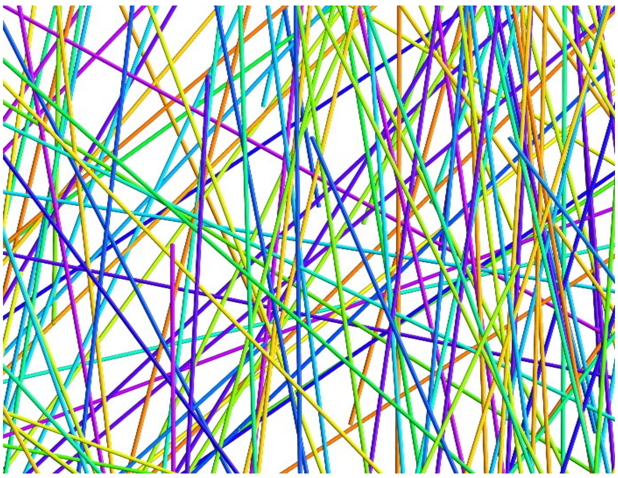

Fig 4. 3D CAD model non-woven material..

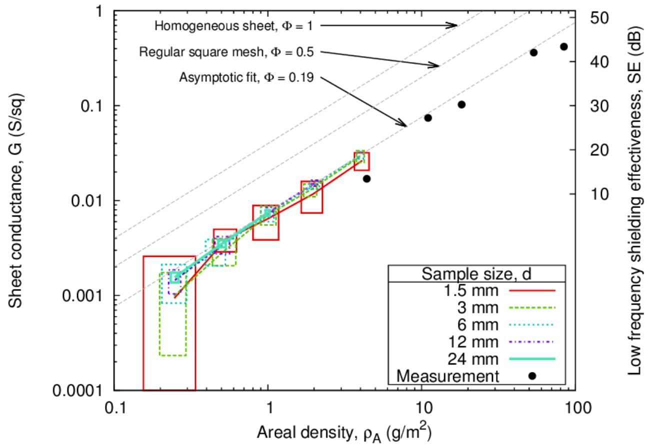

Fig 5. Mean conductance Gs^{90} versus areal density

veil is shown in Fig 4. In practice, a large veil was constructed and a number of small square samples were cut from the veil and modelled as resistive elements to determine the sheet conductance and its variability. Fig 5. shows the sheet conductance against areal weight for a number of different material weights (areal density) . The conductance is measured at 90 degrees from the manufacturing direction and is somewhat lower than is seen in-line with the direction of manufacture. Fig 5. also shows the shielding effectiveness of such a sheet. The boxes show the variation of areal density and conductance for different sample sizes. It can be seen that sample sizes of the order of 6mm square are required to model the behaviour with reasonable accuracy and that there is considerable statistical variation across the veil. Some actual material measurements are also shown, however at the moment, due to model run-time we have not yet simulated the more dense veils.

Conclusions and further work

Shielding measurements using a novel absorber box jig have been presented which show that the performance of a range of non-woven veils have a shielding effectiveness that is constant for a range of frequencies. The Schelkunoff theory suggests that the constant shielding region depends only on sheet conductance so a means of predicting sheet conductance has been presented. Stochastically generated CAD model of the fibre geometry of a non-woven veil has been used to predict the sheet resistance for a range of weights. The CAD model is also suitable to allow full wave- modelling of the higher frequency performance which we hope to consider in future work. We are also working on analytic models to describe the electromagnetic shielding performance of non-woven materials.

References

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[2] S. A. Schelkunoff, “The impedance concept and its application to problems of reflection, refraction, shielding, and power absorption,” *Bell System Tech. J.*, vol. 17, pp. 17–48, 1938.