ABSTRACT

Natural fibre is a well-known material that is abundant in the world and environmentally friendly. It is combined with other materials to enhance the mechanical, acoustical, and physiological properties. Additionally, the strength of the composite is increased by combining it with other materials, resulting in a hybrid composite. In this work, Natural Fibre Reinforced Hybrid Composite (NFRHC) is taken for the analysis, particularly to study the acoustical property, by including the particulate tea fibre. This work possesses three phases of work are involved: experimental, image analysis, and numerical modelling. The composite material is prepared with the combination of 60% epoxy resin, 10% glass fibre as a constant proportionate, wherein, by varying the tea particulate fibre along with pineapple long fibre to occupy the remaining proportionate of 30% by weight. The specimen is prepared using compression moulding process wherein, delivers superior surface finish along with significantly reduced wastage. Additionally, mercerization (alkaline chemical pre-treatment) is used to remove foreign substrates such as hemicellulose, waxes, lignin, pectin, and ash content from the cellulosic fibre wall, which interferes with the fibre’s bonding to the matrix.

In the first module, five different compositions of composite material specimens are being subjected to acoustical testing. The sequential arrangement while preparing the specimen is glass fibre, pineapple, and particulate tea fibre correspondingly, thereby to provide the identity of

symmetry along with the outer layers as glass fibre to act as an insulating layer to provide the conducive way for the electrical application. The immediate pineapple layer is used to monitor the sound and shield the glass fibre from particle tea fibre infiltration. In general, the specimen size is made of 5 mm thickness wherein, which is ideally selected for versatile glazing applications. Thus, the constructed specimens demonstrate superior acoustical qualities for the ratio of 25% by weight of treated wasted tea leaf fibre (T-WTLF), 5% by weight of treated pineapple leaf fibre (T-PALF), 10% by weight of glass fibre and 60% by weight of the epoxy resin. In addition to that, the relation between the porosity and noise reduction coefficient is analysed for all the compositions of the developed composites. This specimen testing is then extended to mechanical property analysis, in which properties such as tensile, flexural, impact, hardness, and interlaminar shear stress are determined in order to know about the feasible strength of the composite. Additionally, for finding the best composition that has both acoustical and mechanical qualities of developed NFRHC, MADM – TOPSIS methodology is equipped. As a result, the compositions containing 25% by weight of Treated Wasted Tea Leaf Fibre (T-WTLF), 5% by weight of Treated Pineapple Leaf Fibre (T-PALF), 10% by weight of glass fibre and 60% by weight of the epoxy resin is obtained as a best composition of the developed composites.

The second module of this work aims to develop a fitting relationship between the weight fraction of T-WTLF and the fractal dimension. Using the fitting relation, the sound absorption properties can be able to determine without experimentation. This is made through the image processing technique using MATLAB to calculate the fractal dimension via the box-counting method. Additionally, the fitting relation is established to estimate the developed composite's SAC. Also, this method obviates the requirement for sound testing via the impedance test tube method.

The third module of the study is mainly focused on the development of a numerical model for the newly developed NFRHC. After acquiring essential knowledge about the sound absorbing capabilities of the developed composites, it will be assessed whether it is possible to model sound absorption using impedance models. Numerous models capable of predicting the acoustic impedance of rigid-frame porous materials have been evaluated. Phenomenological models are believed to be more accurate for a considerable amount of experimental data for various fibrous and porous absorbers. Unlike empirical models, phenomenological models analyse wave propagation microscopically within the pores and cavities of materials. These methods predict more accurate results for samples having pores that seem to be randomly and irregularly developed. The focus of this chapter will be on describing the various models available and their suitability. As a result. the Zwikker-Kosten (ZK) and Johnson-Champoux-Allard (JCA) models are found to be the best acceptable for fitting the values of normal incidence sound absorption of synthetic fibre (glass fibre) and natural fibre (T-WTLF and T-PALF) individually obtained in an impedance tube. For multilayer structure, NFRHC with the combination of both the synthetic and natural fibre, the single model will not give reliable output. Therefore, by developing the hybrid phenomenological model based on the fibre and pores type, the reliable Sound Absorption Coefficient (SAC) can be determined. To develop those models, the Electrical Equivalent Circuit Approach (EECA) is equipped in this study. This approach helped to develop a hybrid phenomenological model for multi-layered structures with any number of plies and thicknesses. To validate the developed model, the SAC of the developed composites is

numerically derived using the same model. The five different input parameters for this impedance model, including airflow resistivity, open porosity, tortuosity, viscous and thermal characteristic lengths, were obtained using an inverse calculation method. The result showed that this model is found to be closer to the impedance test results. As a recommendation, by making use of the developed hybrid phenomenological model with help of the Electrical Equivalent Circuit Approach (EECA), it is concluded to be possible to predict the normal incidence of sound absorption of any multi-layered structure.