TRANSMISSION LOSS OF A SOUND INSULATING PANEL MADE FROM CHARGED RECYCLABLE THERMOPLASTIC

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1. INTRODUCTION

Nowadays, the design and fabrication of acoustic materials must integrate environmental regulations and sustainable development policies. Therefore it is not surprising that the use of recycled and/or recyclable materials is regarded as an effective way to comply with those rules [1-2]. Among available materials, thermoplastic polymers seem to be potential candidates for sound barrier applications due to their recyclability.

In the literature, many works deal with recycled thermoplastic-based sound absorbing materials but, in contrast, few works are really devoted to sound insulation materials [3].

This paper aimed at investigating the sound insulation property of composites made of recyclable thermoplastic charged with heavy particles. Then, their simulated transmission loss, in the frequency range of 10 to 10 kHz, is compared to those of commercial materials.

1.1 Theoretical Background

Figure 1 presents the theoretical evolution of transmission loss (TL) of an infinite panel as a function of frequency excited by an oblique incidence acoustic wave. Generally, the curve is characterized by the presence of three regions: (1) a mass-controlled region, (2) a critical frequency region, and (3) a stiffness-controlled region. The drop in the TL curve is limited by the structural damping of the panel. The frequency at which TL drops is termed critical frequency (f_c). It corresponds to the frequency where the natural bending wave speed of the panel equals the trace speed of the excitation acoustic wave.

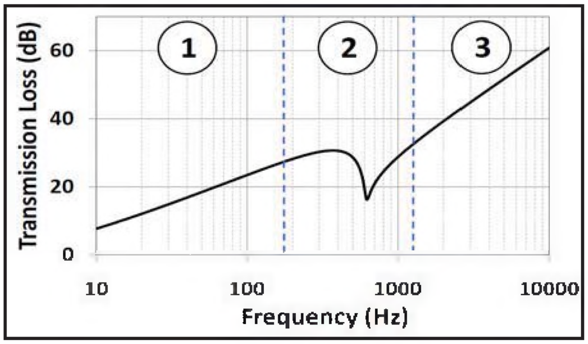

Figure 1. Transmission loss of an infinite panel vs. frequency

The critical frequency is given by:

$$f_c = \frac{c_0^2}{2\pi \sin^2\theta}\sqrt{\frac{\rho 12(1-\nu^2)}{Eh^2}}$$

where ρ is the density of the material, h the thickness of the wall, E is Young modulus of the material, ω the angular frequency, θ the incidence angle of the acoustic wave, ν is the Poisson ratio, and c_0 the sound speed in air.

It is important to mention that f_c is mainly dependent on Young modulus and shifted toward higher frequency as E decreases. In addition and for better acoustic performances, it is preferable that f_c is out of the frequency range of interest (*i.e.* > 10kHz). In other words, for large panels, TL vs. frequency of an optimal acoustic panel should exhibit only region 1, where TL is essentially governed by mass law. This latter is density-dependent primarily and increases with density. Accordingly, lowering E and increasing ρ or, in other words, decreasing (E/ρ) ratio is a good manner to enhance noise insulating properties of a given material. Consequently, in this work (E/ρ) ratio was taken as the criterion to evaluate the sound insulation performance of various composites.

2. MATERIALS AND EXPERIMENTAL PROCEDURE

2.1 Materials

Polyethylene (PE) is the most used thermoplastic polymer worldwide. Behind this generic name lies several types of PE, where linear low density polyethylene (LLDPE) is the most common one. It is characterized by a Young modulus and density of 700 MPa and 930 kg/m^3, respectively. In this work, the LLDPE Sclair FP-120A, purchased from Nova Chemicals, was used.

It is important to point out that the density of LLDPE is lower than those of the conventional materials used in construction (*e.g.* 2200 kg/m^3 for concrete). Consequently, it's necessary to increase LLDPE density by, for instance, adding heavier particles.

Metal particles are often used to improve the electrical properties of materials; however Young modulus increases too [4]. Nonetheless, it has been shown that the use of large spherical particles can limit this increase [5]. Consequently to increase significantly the density of LLDPE, 3.175 mm radius metal beads were added to LLDPE matrix.

2.2 Sample preparation

LLDPE/metal beads composites having a volume fraction ϕ of 0, 12.5 and 23%, respectively, were elaborated by compression melt molding at 250°C using a hydraulic press. All samples were held at 250°C for 15 minutes and then air cooled to room temperature. Three samples were made for 0 and 12.5% concentrations while 2 were elaborated for the 23% composition.

During samples fabrication, a particular attention was paid to samples preparation in order to have a random beads distribution and an average distance between beads lower than the lower wavelength λ corresponding to the highest frequency in frequency range of interest (i.e. 10 kHz or λ ≈ 3.4 mm).

2.3 Characterization

To analyze acoustic property of elaborated composites (*E/ρ*) ratio is required. Therefore, tensile mechanical tests, following ASTM E 756-04 standard, were carried out to determine Young modulus of all composites. Subsequently, and in order to reduce composites rigidity, samples microstructure was modified by subjected all composites to a special procedure. Then, Young modulus was again re-evaluated. Buoyancy method was used to assess the composites density.

3. RESULTS

Table 1 depicts (*E*/ρ) ratios for unmodified and modified composites. As can be seen (*E*/ρ) ratio decreases as ϕ increases and, as expected, the induced micro-structural modification decreases more significantly the ratio.

Table 1. (*E/ρ*) **for unmodified and modified composites**

ϕ (%)	$(E/\rho)_{\text{unmodified composite}}$	$(E/\rho)_{\text{modified composite}}$
10.9	0.67_1	0.51_9
12.4	0.62_6	0.41_8
13.8	0.61_8	0.43_2
23.2	0.50_7	0.32_6
23.4	0.53_4	0.31_8

Simulated TL for infinite panels was obtained, by means of NOVA vibro-acoustic software. Figure 4 shows the simulated TL of the 23% LLDPE/beads composite and the TL of 4 mm thickness conventional materials such as concrete, glass and gypsum.

As it can clearly be seen, the composite with ϕ=23% appears to be better than conventional materials. Indeed, the TL vs. frequency curve of this composite shows either higher or equal TL than gypsum, concrete or glass but, in contrast, the coincidence frequency, f_c, is no longer present.

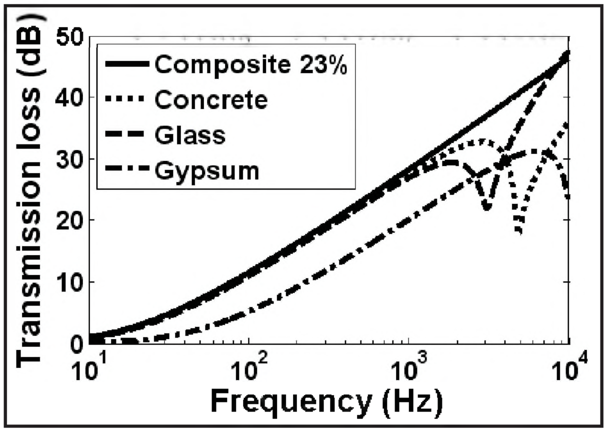

Figure. 3. Transmission loss vs. frequency of an LLDPE/beads composite and conventional materials

4. CONCLUSION

In this work, it was shown that the sound insulation properties of a material made of recyclable thermoplastic can be assessed by the rigidity to density ratio, (*E*/*ρ*) and, enhanced by reducing this ratio. Consequently, this ratio was used to evaluate the acoustic performances of composites, elaborated by compression melt molding and consisting of linear low density polyethylene, a thermoplastic polymer, and metal beads. Furthermore, all composites were subjected to a particular procedure to induce micro-structural changes in order to lower more (*E/ρ*) ratio. Finally it was clearly demonstrated that modified composites exhibits no coincidence frequency in the frequency range of interest, and have higher or similar transmission loss as compared to conventional materials such as concrete, glass or gypsum.

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