Research Article

Noise Absorption and Mechanical Properties of Hybrid Waste Rubber Tyre-Based Polypropylene Composites for Car Door Panel Applications

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Abstract: *Engine and transmission vibration-tired drivers and passengers. Traffic, weather, etc. Some passenger compartment materials don't absorb noise or vibration. Finally, new noise-absorbing materials are expensive. Hybrid waste rubber tyre-based polymer composites for car door panels reduce noise and vibration. Next, improve strength and stiffness by studying recycled composites like waste rubber tyres. Finally, analyse hybrid composite noise to reduce passenger compartment noise. Mixers were used. Hot compress/tensile testing. Impendence tube sound transmission loss testing followed. Tensile test. Pp/Wt/Cf ratio 70/30/5 had the highest tensile strength (5.25Mpa) and was chosen to test sound transmission loss and compare to market materials. Pp/Wt/Cf (70/30/5) has 14.71% more sound transmission loss than current material. Hybrid waste rubber tyre-polymer composites for car doors achieved the first goal. Tensile and noise/vibration samples are equal thickness. Second goal accomplished. Tensile testing determines composites' mechanical properties. Fillers affect tensile strength. Minimum 1.83 MPa pp/wt/cf (70/30/20). Filler loading raised composite modulus. Composite stiffness is Young's Modulus. Filler loading stiffens composites, reducing break elongation. Last, the composites' noise and vibration resistance were tested. The impendence tube tested hybrid composite noise. Pp/Wt/Cf (70/30/5) was compared to market-available material. Pp/Wt/Cf (70/30/5) transmits sound better than current material.*

Keywords: Noise; sound absorber; waste tyre; polypropylene; fiber; impendence tube

1. INTRODUCTION

Noise causes stress, insomnia, social problems, and economic losses. 250 million people worldwide have clinically severe noise-induced hearing loss (NIHL) above 25 dB, including 10 million US adults and 5.2 million children. Widespread noise-induced hearing loss (Seidman et al., 2010). Road excitation through the wheel and suspension system causes this (Jha et al., 1976). Vibrational (tread impact and adhesion) and aerodynamic (tyre-road interaction) mechanisms cause noise when a vehicle moves (Arenas et al., 2016).

Giulio Natta and Karl Rehn created the first polypropylene crystalline isotactic polymer in March 1954. Polypropylene outperforms polyethylene in strength, stiffness, and temperature resistance. Polypropylene's main use is fibres. Car bumpers, chemical storage tanks, wire and cable insulation, battery boxes, gasoline bottles and cans, indoor and outdoor carpeting, and carpet fibres use this material. (Ghorbani et al., 2017).

Stockpiled tyres pollute air, water, and soil, posing health, environmental, and economic risks. Waterproof tyres attract mosquitoes (Eldin et al., 1994; Mohammed et al., 2012; Thomas et al., 2015). Lingo-cellulosic natural fibres have helical cellulose microfibrils in lignin and hemicelluloses (Amar et al. 2005). Biodegradable polymers are recyclable and less abrasive than synthetic fibres. Fibres release and absorb the same CO2 during growth and disposal (Wambua et al., 2003). Natural fibres improve thermosetting and thermoplastic matrices. Strong and affordable natural fibres

Mechanical tensile tests. This test measures tensile, ultimate, elongation, modulus of elasticity, yield strength, Poisson's ratio, and strain hardening. Tensile test. The test machine measures load and long-range strain twist extensometers strain. 20 m/s servo-hydraulic tensile tests. Material strain dependence was tested. 0.1 mm/s–10 m/s was measured. (Hufenbach, 2011)

This paper conducts two experiments which are tensile test and noise test. Then, show the comparison of new material sound to market material.

2. METHOD & MATERIAL

This section includes details on the many pieces of apparatus that were utilised in the research. The required procedure and analysis for the polypropylene. This section is organised in a step-by-step method in the following order: materials, and raw materials; fabrication and characterization of polypropylene; preparation of materials; process of mixing; experiment, equipment, and facilities.

2.1 Project Flowchart

This project starts with project planning. The project planning is collecting the data and researching the sound absorption material. Then, prepare the material with Polypropylene, Waste tyre, and Coco peat. The cutting process and blend process are on in this flow. After that, the preparation of the sample needs to be done by using a mixer machine and a hot press machine. The sample preparation has been made for the tensile test and noise test. Next, run the experiment of the tensile test and noise test to collect data. After collecting data, do a data analysis of the result and conclusion.

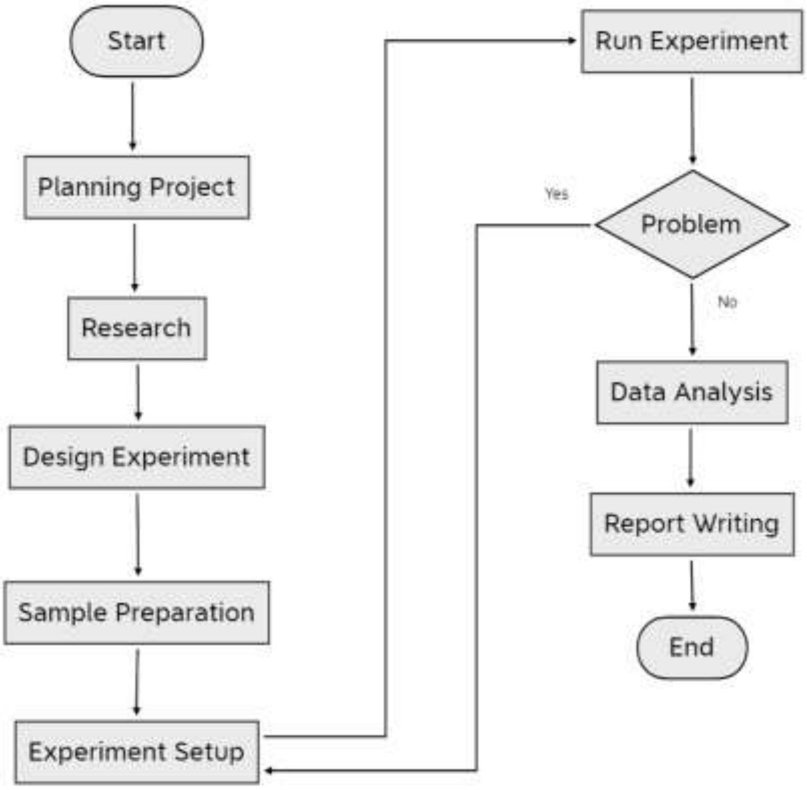

Figure 1. Project Flowchart

2.2 Material

2.2.1 Polypropylene

Polypropylene will be used as the matrix phase. Polypropylene (PP) is a linear hydrocarbon polymer. Polypropylene was used in this project as an adhesive between the tyre and coco peat fibre. The properties of Polypropylene include:

- Semi-rigid
- Good resistance to chemicals
- Tough
- Good ability to not get fatigued
- Property of the integral hinge
- Good ability to handle the heat.

Figure 2. Structure of Polypropylene

2.2.2 Rubber from the Waste Tyre

The disposal of used tyre rubber has emerged as a significant environmental problem in every region of the world, representing a very significant ecological risk. This problem is a global phenomenon. The process of getting rubber from the waste tyre is shown in Figure 3.

Figure 2. Rubber waste tyre preparation

2.2.3 Cocopeat Fibre

Before extracting peat fibre, coconuts must be husked. First, scissors cut the coco peat into smaller pieces. After cutting, coco peat was filtered to get smaller fibre particles. Mix the coco peat fibre to get well-mixed pieces. The specimen will be combined with well-mixed coco peat. Shredded coco peat mixes better with rubber and polypropylene. The figure below shows the flow technique.

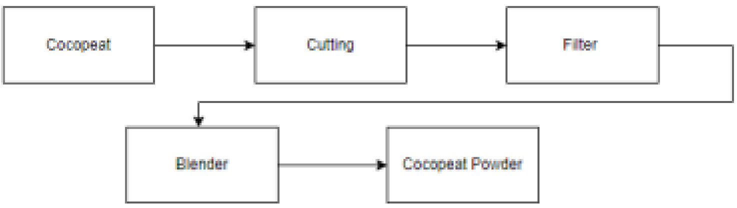

Figure 3. Cut and Blend Process Coco Peat

2.3 Sample Preparation

Step-by-step specimen preparation. First, High Precision Electric Mass Balance tested rubber, polypropylene, and cocopeat fibre. Table 1 shows the measurement composition. Mix everything in the Haake PolyLab Mixing Machine after measuring. This machine combined all three materials at 180°C and 60n/min. For tensile and noise tests, the combined material was moulded.

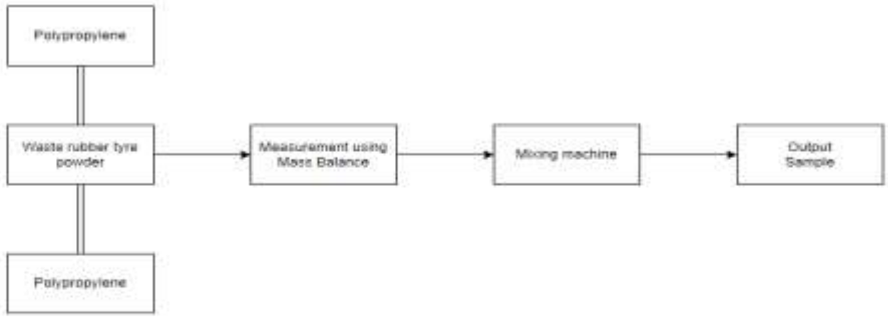

Figure 4. Specimen Preparation Flow

Table 1. Composition of PP/WT/CF

	Material	PP/WT/CF	PP/WT/CF	PP/WT/CF	PP/WT/CF	PP/WT/CF
	Polypropylene	70	70	70	70	70
Percentage (%)	Rubber	30	30	30	30	30
	Coco peat fibre	0	5	10	15	20

2.3.1 Mixing Process

A HAAKE PolyLab QC Mixer Machine was used for an hour at 180 degrees Celsius and 60 revolutions per minute to prepare for composite mixing. The scrap rubber tyre was then poured into the mixing chamber to melt for 20 minutes. The polypropylene is dumped into the mixer chamber after twenty minutes, following the waste rubber tyre. Mixing took 20 minutes. After that, the coco peat fibre is discharged into the mixer chamber for 20 more minutes. Each mix was finished after an hour. Table 1 shows how different coco peat fibre loadings form composite combinations.

2.3.2 Hot-press Process

After compressing the composite mixes in a Hot-Press Machine (GT 7014), the moulding process produces a 2-millimetre-thick dumbbell-shaped composite sheet. At 180 degrees Celsius, the material is preheated for 15 minutes and compacted for 5 minutes. Hot press procedures are these. Each composite mixture is squeezed in its mould to generate a minimum of five specimens, totalling twenty-five. This method creates a dumbbell model. To assess tensile strength.

2.3.3 Tensile Testing

A tensile test measures a material's ability to endure pulling pressures and how far it stretches before breaking. A material's tensile modulus can be determined by the stress-strain curve.

The cross-head speed was 10 mm/min on a Galdabini Quasar 100 tensile machine. The testing apparatus's grip was changed to hold specimens vertically. To reduce slippage and keep the gauge at 50 millimetres, the grips were adjusted consistently and securely.

Five composites' combinations are evaluated. The results were narrowed down to the top three. The test results, which were:

- Tensile Strength
- Young Modulus
- Maximum elongation (%)

2.3.4 Impendence Tube Testing

This Impendence Tube Sound measures frequency, vibration, absorption, and transmission loss. Sample measurements must match tube space. The sample must have a 9-millimetre diameter and 3-millimetre thickness. The hot press then made the sample. Figure 6 shows the sample.

Figure 6. Sample for testing

Figure 7. Impendence Tube Setup

Setup must be completed before production. The sample was in the tube's centre. After that, the tube is joined to another tube and the screw is secured. The frequency was 500–700 hertz. According to (Gladwell et al., 1964), a car's frequency is 500–100 hertz. The innovative and market-available materials were tested together.

3. RESULT AND DISCUSSION

This section presents the experiment results. The parameters highlighted the noise and mechanical properties of these new composites. New composites passed impedance tube tensile tests. This project's maximum tensile strength, young modulus, and elongation at break are affected by its filler loading. The procedure also measured the new material's tensile properties. Impedance tube tests use the model with the highest tensile strength. To evaluate the materials and processes, all results will be compared.

3.1 Mechanical Testing

Stress-strain graphs show the stress-strain relationship. Each material has a unique graph that shows yield strength, tensile strength, and modulus of elasticity. The formula for engineering stress:

$$\boxed{\sigma = \frac{F}{A}}$$

where: σ = Stress (average)
F = the applied tensile force
A_o = the area of the original cross-sectional

$$\boxed{\varepsilon = \frac{\Delta L}{L_0}}$$

Where: ε = Strain (average)
ΔL = the change in the length
L_o = the original length

3.2 Tensile Strength

Figure 8 plots tensile test data. The graph shows tensile strength increasing at PP/WT/CF (70/30/5) by about 1.45. The graph shows that filler loading decreases strength by 1.26 MPa at PP/WT/CF (70/30/10). The graph shows that tensile strength decreases uniformly from PP/WT/CF (70/30/10) to 70/30/20 filler loading. Poor interfacial and weak bonding between hydrophilic filler and hydrophobic matrix polymer causes decreases (Yang et al., 2005). Tensile strength is highest at PP/WT/CF (70/30/5) and lowest at (70/30/20).

Table 2. Tensile Strength of PP/WT/CF

Filler Loading	Tensile Strength (MPa)			Average (MPa)	Standard deviation
	Test 1	Test 2	Test 3		
PP/WT 70/30	3.5	3.96	3.96	3.80	0.27
PP/WT/CF 70/30/5	5.71	6.13	3.92	5.25	1.17
PP/WT/CF 70/30/10	3.42	4.83	3.71	3.99	0.74
PP/WT/CF 70/30/15	4.42	3.54	4.21	4.06	0.46
PP/WT/CF 70/30/20	3.33	2.88	1.83	2.68	0.77

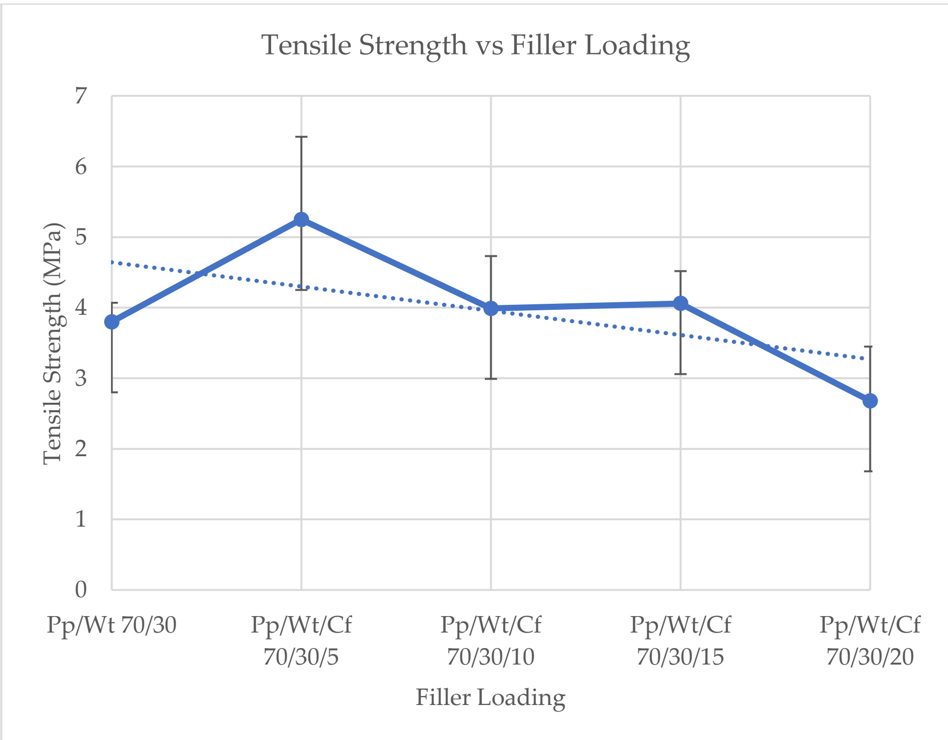

Figure 5. Tensile Strength vs Filler Loading graph

3.3 Young's Modulus

Figure 9 shows that the Young Modulus graph trendline increases slightly from PP/WT (70/30) to PP/WT/CF (70/30/20) filler loading. Graphs show this. PP/WT/CF (70/30/20) corresponds to the highest modulus of elasticity, 102.26 MPa. Increased filler loading increased PP/WT composite ductility. CF was intended to reduce composite ductility and increase stiffness. Graphs show initial curvature. Coco peat fibre increases young modulus. Fibres increase elastic modulus significantly. Gloria et al. (2017).

Table 3. Young's Modulus of PP/WT/CF

Filler Loading	Young Modulus, E (Mpa)			Average (MPa)	Standard deviation
	Test 1	Test 2	Test 3		
PP/WT 70/30	69	49	55	57.67	10.263
PP/WT/CF 70/30/5	118.82	59.18	38.43	72.14	41.73
PP/WT/CF 70/30/10	59.60	55.45	50.81	55.28	4.40
PP/WT/CF 70/30/15	71.88	69.39	72.21	71.16	1.54
PP/WT/CF 70/30/20	54.5	141.94	110.35	102.26	44.28

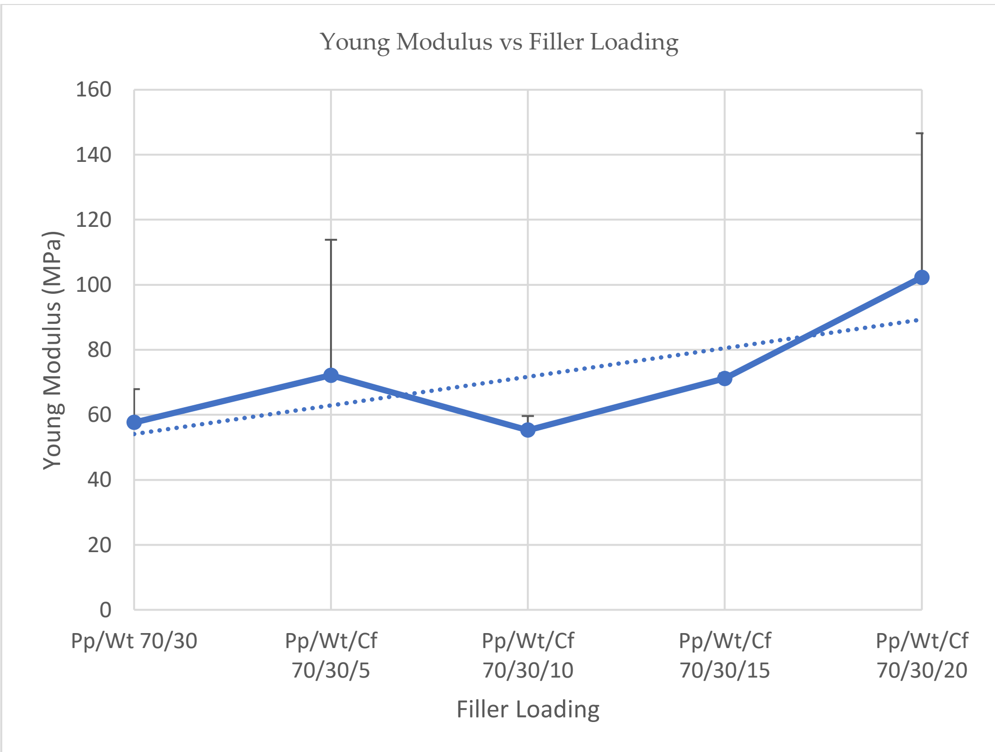

Figure 6. Young Modulus vs Filler Loading graph

3.4 Elongation Percentage

Figure 10 shows the graph's elongation trendline decreasing from filler loading of PP/WT (70/30) to PP/WT/CF 70/30/20. PP/WT (70/30) has the highest break elongation at 22%. Figure 10 shows how CF loading affected break elongation. Increased CF decreases break elongation. PP/WT/CF (70/30/20) is the lowest percentage point on the graph. Palomba, Vazquez, & Diaz (2014) When filler loading increased, composite ductility decreased significantly. Fillers made composites brittle and less stretchable.

Table 4. Elongation at Break of PP/WT/CF

Filler Loading	Elongation (%)			Average (%)	Standard deviation
	Test 1	Test 2	Test 3		
PP/WT 70/30	21.18	23.40	23.88	22	14
PP/WT/CF 70/30/5	14	6	5.54	8.51	4.76
PP/WT/CF 70/30/10	15.01	12.77	14.13	13.97	1.13
PP/WT/CF 70/30/15	13.09	10.47	11.07	11.54	1.37
PP/WT/CF 70/30/20	15.8	5.01	4.06	8.29	6.5

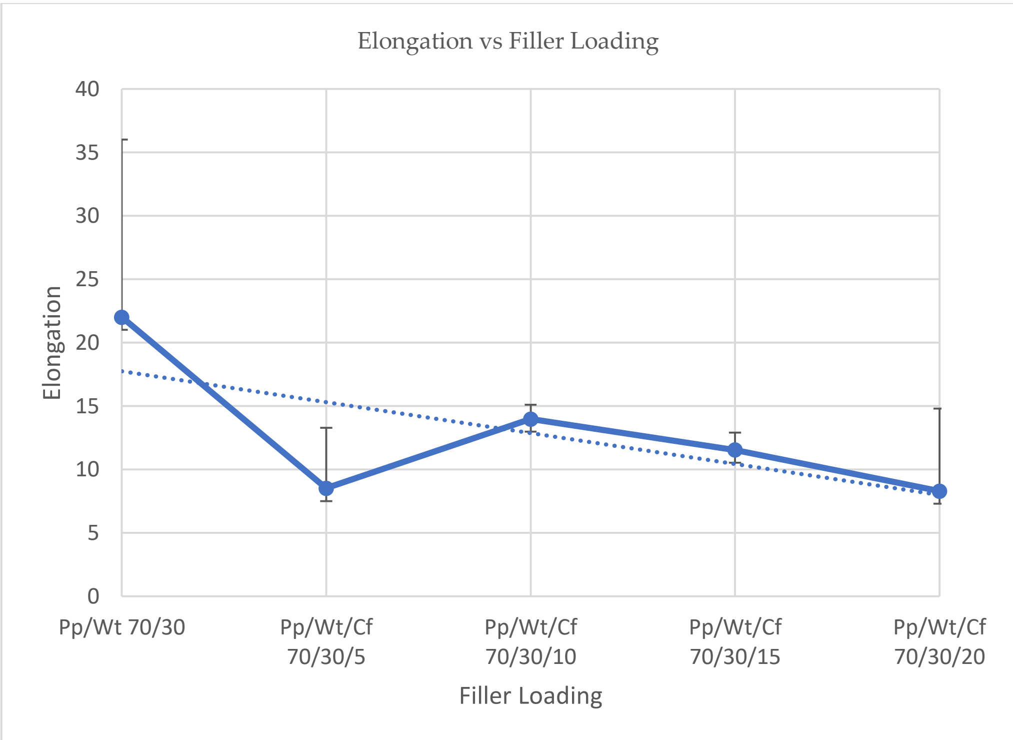

Figure 7. Elongation vs Filler Loading graph

3.5 Sound Transmission Loss Testing

The Impendence Tube Test measured amplitude and frequency. Then, the sound transmission loss coefficient was calculated. Formula used is

$$\boxed{\begin{gathered} \mathrm{TL} = 20\log(\mathrm{Pa\ in}/\mathrm{Pa\ out}) \\ TL = 10\,log\,(\tau) \end{gathered}}$$

Where: TL = Transmission Loss

τ = Coefficient of Sound Transmission Loss

Figure 11 shows the sound transmission loss curve of new versus old material. New material with PP/WT/CF (70/30/5) was chosen. Each frequency and material had five measurements. Reading the coefficient of sound transmission loss from the graphs at each frequency was necessary. A graph was created from a table. The findings show that these two materials have identical trendlines. The graph shows that the new material has much higher data. It shows that the current material has a lower coefficient of sound transmission loss than the new material.

Table 5. Sound Transmission Loss

Frequency	**Model**	**Sound Transmission Loss/ dB**					
		Test 1	Test 2	Test 3	Test 4	Test 5	Average
500Hz	New material	0.32	0.36	0.31	0.31	0.36	0.34
	Current Material	0.44	0.23	0.60	0.07	0.23	0.311
600Hz	New material	11.42	11.42	11.46	9.26	11.46	11.01
	Current Material	10.67	10.45	9.66	9.34	6.67	9.39
	Current Material	4.61	4.62	4.61	4.42	4.69	4.59

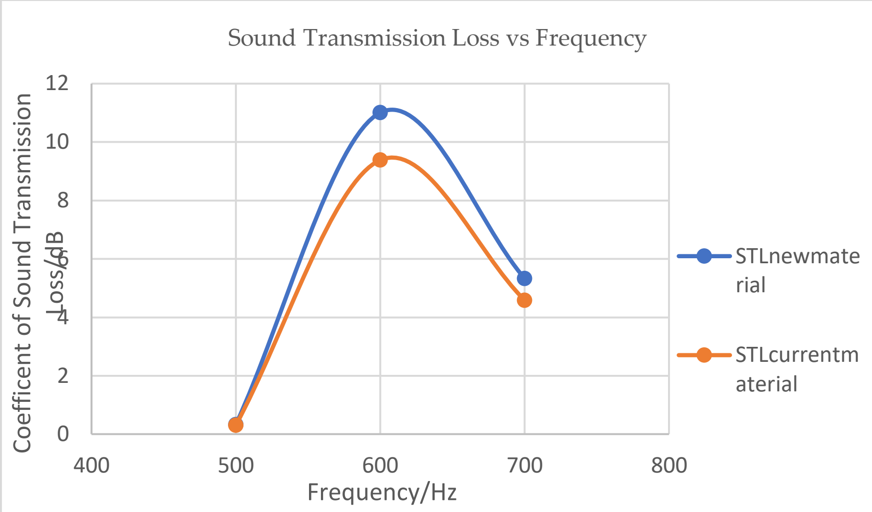

Figure 8. Sound Transmission Loss vs Frequency graph

4. CONCLUSIONS

The first goal has been done. Experiment samples are ready. The first goal was achieved by preparing hybrid waste rubber tyre-polymer composites for car doors. The mixer mixed Polypropylene (PP), Waste Rubber Tyre (WT), and Cocopeat Fibre (CF). Tensile test specimens were dumbbells. Dumbbell-shaped mechanical properties were analysed. Noise and vibration samples are 3 millimetres thick like the sound material.

The second goal was accomplished afterwards. Tensile testing determines the composites' mechanical properties. Maximum tensile strength is 5.25 MPa at PP/WT/CF (70/30/5). The graph shows a decrease in tensile strength. Filler loading affects tensile strength. 1.83 MPa (PP/WT/CF (70/30/20/)) is the minimum.

After that, filler loading increased the composite modulus of elasticity. Young's Modulus indicates the composite material's stiffness. Filler loading increases stiffness, which reduces elongation at break.

Elongation at break decreases with filler loading. Composite elongation at break decreased with stiffness.

Testing the composites' noise and vibration resistance completed this last objective. The impendence tube test assessed hybrid composite noise. The PP/WT/CF (70/30/5) was tested and compared to market-available material. The graph shows that PP/WT/CF (70/30/5) has a lower sound transmission loss than the current material.

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