Sound Transmission Loss Analysis for Laminated Glass and Perspex

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Abstract. The aim of this study is to analysis the sound transmission loss (STL) for the laminated glass and Perspex. In this study, the STL of laminated glass and Perspex are determined using the two-load transfer function method (TFM) impedance tube measurement setup. There are 5 mm and 8 mm thickness of glass and Perspex were used. Glass and Perspex will be laminated into double and triple layer in order to investigate its STL due to interlayer effect. All the specimens are prepared into round shape with the diameter of 33 mm that fit with the inner diameter of impedance tube. From the measurement, it is concluded that the STL almost similar for the Perspex and glass without the layer lamination at the frequency range below 3500Hz. Number of interlayer for the glass or Perspex lamination plays the major role as main parameters that affect the overall STL.

1. Introduction

Nowadays, there are many noise problems happened in our workplace and surrounding, such as noises come from busy traffic of transportation, industries machining, construction site and etc. that affecting our daily life. To solve these problems, it is crucial to understand the knowledge of acoustic, noise control and its prevention. Usually, to reduce noise level, it is compulsory to deal with frequency, amplitude and wavelength of the sound. The sensitivity of human being on the sound frequency is limited from 20 Hz to 20 KHz [1].

A laminated glass is the glass that consists of two or more layer of glasses with an interlayer that typically made using ethylene-vinyl acetate (EVA) or polyvinyl butyral (PVB) in the middle of the glasses [2]. Usually, laminated glass was used for automobile windshield, exterior store front, window and wall for the building. Laminated glass is considered one type of safety glass in protecting human from injuries as it can hold together when shattered. Thus, vehicle front windshield normally installed with laminated glass. The stress applies on the laminated glass could cause it to deform elastically and demonstrate no plastic deformation before it fractures [3]. On the contrary, Perspex
flexibility is higher than the glass and therefore, it is able to withstand high speed wind and pressures as it is used as building windows [4]. In general, Perspex was made using heating method, bending and pressure forming [5].

In this study, the acoustic property of laminated glass and Perspex were analysed. The sound transmission loss (STL) of the laminated glass and Perspex are measured using the two-load transfer function method (TFM) impedance tube [6] [7].

2. Methodology
In this study, the impedance tube was fabricated using acrylic tube. The inner diameter of the tube is 33 mm with length of 1.25 m [8]. The detectable frequency range for the impedance tube is in between 60 Hz to 6000 Hz. The schematic drawing of the impedance tube is shown in Figure 1, and Figure 2 shows the fabricate impedance tube for this study.

![Figure 1. Design for impedance tube CATIA V5.](image1.png)

![Figure 2. Fabricated impedance tube.](image2.png)

2.1. Specimen preparation
Table 1 listed the specimens that were used for the sound transmission loss (STL) measurement. There are 5 mm and 8 mm thickness of glasses and Perspex were used. Glass and Perspex are laminated into double and triple layer to investigate its STL via interlayer effect. All the specimens are prepared into round shape with the diameter of 33 mm that fit tightly with the inner diameter of impedance tube. For the laminated glass and Perspex specimen, the interlayer is seals using silicone SN 503 Silicon Sealant. The veneer clipper tool is the jig that is used to control the thickness of interlayer for the laminated glass and Perspex [10]. Figure 3–4 shows the prepared specimens that are used for the measurement. The cross section layouts of specimens are showed in Figure 5–6.

| Material         | Thickness         | Thickness         |
|------------------|-------------------|-------------------|
|                  | 5mm (single interlayer) | 8mm (double interlayer) |
| Glass            | Single            | Single            |
| Perspex          | Single            | Single            |
| Laminated Glass  | Double            | Triple            |
| Laminated Perspex| Double            | Triple            |
Figure 3. Perspex and laminated Perspex specimens. Figure 4. Glass and laminated glass specimens.

Figure 5. Double laminated layer with single interlayer (5mm thickness). Figure 6. Triple laminated layer with double interlayers (8mm thickness).

2.2. Measurement setup
In this study, two-load transfer function method (TFM) impedance tube is used for the sound transmission loss (STL) measurement. Figure 7 showed STL measurement setup in the laboratory. For the measurement setup, the impedance tube required four microphones with each connected to the Data Acquisition (DAQ), where the sensor signals are synchronised in post-processing and stored in a computer where the measurement is done with two sensors simultaneously instead of one sensor in two-times [11]. The speaker was connected to the output port of DAQ, that provides random sinusoidal noise signal generated by the DAQ using an analysis software known as LMS Test Lab 14A [12]. The rigid cap is used as the rigid termination, while the sponge works as the anechoic termination for the two-load TFM. All microphones were calibrated using microphone calibrator before the measurement. The measurement data is collected and analysed via DAQ coupled with the installation of analysis software in the computer. The STL measurement graph against frequency is then plotted [13].
3. Result and discussion

In this section, the sound transmission loss (STL) measurement results are compared and discussed, in term of specimen thickness, materials, and interlayer thickness.

3.1. Effect of specimen thickness on STL

The sound transmission loss (STL) for the glass with the thickness of 5mm and 8mm is shown in Figure 8. The blue line indicates the STL of 5mm thick glass while the red line is 8mm thick glass. From the result, it is discovered that STL of 5mm thick glass is always higher than 8mm thick glass for the frequency range of 0Hz to 4500Hz. Overall, the STL of 5mm and 8mm thick glass are relatively low, typically below 10dB for the frequency range below 3500Hz. Meanwhile, for the frequency range 3500Hz and above, the STL shows much higher value for 5mm and 8mm glasses. Similar observation is found for the Perspex with the thickness of 5mm and 8mm as shown in Figure 9.

![Figure 7. Setup of two-load transfer function method (TFM) impedance tube.]

![Figure 8. Sound transmission loss for 5mm and 8mm thick glasses.]

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Figure 7. Setup of two-load transfer function method (TFM) impedance tube.

Figure 8. Sound transmission loss for 5mm and 8mm thick glasses.
3.2. STL comparison between glass and Perspex

Figure 10 and 11 show the sound transmission loss (STL) comparison results for glass and Perspex with thickness of 5mm and 8mm. Based on Figure 10, it is observed that STL of Perspex always higher than glass with similar thickness of 5mm throughout the whole investigated frequency domain. Similar trend is observed for the 8mm thick Perspex with frequency below 3500Hz as illustrated in Figure 11. Hence, it is concluded that Perspex gives higher insulation than glass for same thickness based on the obtained STL results in this study.

Figure 9. Sound transmission loss for 5mm and 8mm thick Perspex.

Figure 10. Sound transmission loss for Perspex and glass with thickness of 5mm.

Figure 11. Sound transmission loss for Perspex and glass with thickness of 8mm.
3.3. Comparison of laminated layer with single and double interlayer on STL

Figure 12 and 13 shows the comparison sound transmission loss (STL) graph for laminated glass and Perspex with single and double layers respectively. According to Figure 12, it is observed that STL for laminated Perspex and glass is almost similar with small differences of STL for the frequency range from 0Hz to 3500Hz. In contrary, when the interlayer increases to double layers, the STL is also improved significantly compared with single interlayer. This phenomenon is proven in Figure 13 with double interlayers. Simultaneously, it is also observed that laminated Perspex with double interlayers obtained better STL throughout the investigated frequency domain in comparses to laminated glass with double interlayers. Therefore, it can be concluded that laminated Perspex with double interlayers delivers higher STL as the interlayer is considered as an insulation material where it can absorb more noise when the interlayer increases [14]. This phenomenon is proven in Figure 14 and 15, where the comparison is done using similar thickness for laminated glass or Perspex, and the results shown the laminated glass or Perspex is able to provide higher STL compared to non-laminated glass or Perspex.

Figure 12. Sound transmission loss for laminated Perspex and glass with single interlayer (5mm thickness).

Figure 13. Sound transmission loss for laminated Perspex and glass with double interlayers (8mm thickness).
4. Conclusion
This study involves exploring, observing, and understanding the sound transmission loss (STL) for the laminated glass and Perspex. From the STL results, it is concluded that the STL almost similar for the Perspex and glass without the layer lamination. Simultaneously, one of the significant findings observed in this study is when the interlayer increases for laminated Perspex or glass; the STL is also increasing respectively. Thus, the number of interlayer for the glass or Perspex lamination plays the major role in parameters that affect the overall STL.

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