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Estimation of Damping Loss Factor (DLF) for Automotive Glass

Aditya A. Jadhav[1] and S.R. Desai[2]

[1]S.Y.M. Tech. Student, Automobile Engineering Department, Rajarambapu Institute of Technology, Sakharale, Dist. Sangli, Maharashtra, India
[2]Automobile Engineering Department, Rajarambapu Institute of Technology, Sakharale, Dist. Sangli, Maharashtra, India
E-mail: adityajadhav49@gmail.com, sandeep.desai@ritindia.edu

Abstract—*Vibration study is an important aspect to identify the amount of vibration present in the system. Across several components and modules of the automotive such as Driver and Passenger compartment, Drive train, Engine, Braking system and Suspension are systems wherein vibration must be damped for better performance. Vibration analysis of automotive systems require determination of parameters such as Damping loss factor, Modal densities, Mode shape, Coupling loss factor and Natural frequency. Various analysis methods are used for predicting the damping in systems. Damping is one of the important characteristics that give an idea about an extent to which the structure can resist to vibrations .Damping is generally characterized by the amount of energy dissipated and common measure of dissipation is damping loss factor. This paper presents experimental and software analysis of automotive window glass to determine its damping effect of different boundary conditions and materials on damping characteristics of automotive window glass. Half-power bandwidth method is used for experimental determination of automotive window glass. Results of experimental analysis are validated by comparison with those obtained by an analysis done using ANSYS.*

1. INTRODUCTION

The damping loss factor (DLF) is important parameter in all types of dynamical analysis. For many subsystems the overall response level is inversely proportional to the damping level. Energy of vibration gets accumulated in the vibrating structures in the form of kinematical energy and Potential energy. The vibrating structures dissipate and radiate the energy. The conversion of mechanical energy to thermal energy takes place as a result of internal dissipation. Damping loss factor talks about amount of energy dissipated into the system [10]. It can be defined as ratio of amount of energy dissipated per radian to the total energy of the system. DLF can be determined by three methods; those are decay rate method, half power bandwidth method and power injection method.

2. HALF-POWER BANDWIDTH METHOD

The most common method of determining damping is to measure frequency bandwidth between points on the response curve, for which the response is some fraction of the resonance of the system. The usual convention is to consider points Z1 and Z2 as in the Fig.1 below, to be located at frequencies on the response curve where the amplitude of response of these points is $\frac{1}{\sqrt{2}}$ times the maximum amplitude [6].

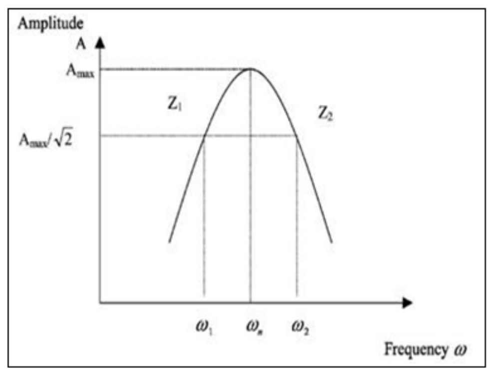

Fig. 1: Half power bandwidth method.

The bandwidth at these points is frequently referred as 'half-power bandwidth'. The frequency interval between these two half-power points is $\Delta\omega = \omega_2 - \omega_1$. Loss factor of this method is defined as, $n = \frac{\Delta\omega}{\omega n}$

3. SELECTION OF GLASS MATERIAL

For experimental investigation of damping loss factor, laminated and tempered glass with IS 2553 standards were taken into consideration.[9] Table 1 shows the dimensions of glass specimen that is to be used for experimental estimation of DLF.

Table 1: Dimensions of glass specimen

Specimen size	300 x 300 mm
Thickness	2mm to 6 mm
Tolerance	± 0.3 mm

4. FIXTURE DESIGN FOR EXPERIMENTATION

So as to hold the glass plate firm during testing there must be a fixture to clamp the glass properly, A much lighter, more convenient, more compact and considerably less expensive fixture is realized without loss of dimensional precision and stability in the most vital components of the fixture. Fixture modeling is designed by using CATIA V5 R20 considering the dimensions of glass and referring the IS 2553 standard .Below fig.2 gives the idea about the test fixture wherein the fixture is blue in color, nut and bolt green in color, cushioning plates yellow color, rubber bushing black and test specimen of glass is shown in red color. Further for experimentation this model is fabricated [11].

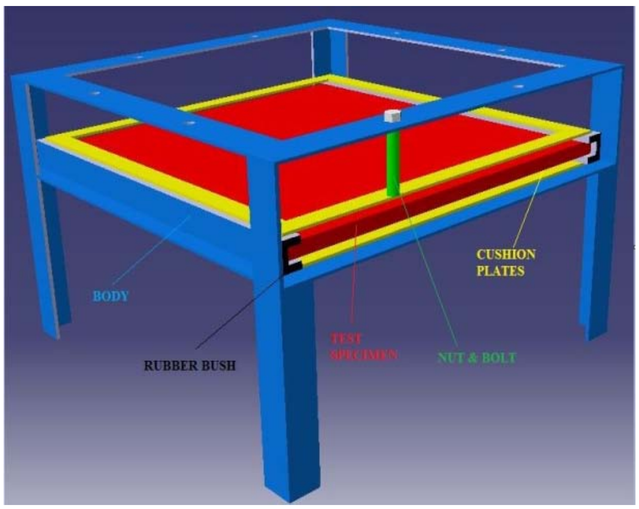

Fig. 2: Model of Fixture as per standard.

5. EXPERIMENTAL SETUP

Fig. 3 shows experimental set up for measurement of damping loss factor of automotive glass. Here the test specimens are glasses used in automotive, like laminated and tempered. For free-free condition the plates were hanged to the frame with the help of threads. The plates were excited with hammer impact. The accelerometer was mounted at the center of plate. The hammer input and accelerometer output signal were given to the FFT analyzer. After hammer excitation, the different spectrums were recorded by the software, out of them Amplitude Vs. Frequency spectrum was used to evaluate damping loss factor. The elements of experimental setup are a follows.[1]

1) Impact Hammer 2) Glass specimen

3) Fixture 4) Accelerometer

5) Signal Conditioner 6) DEWE-Rack

7) CPU 8) Display

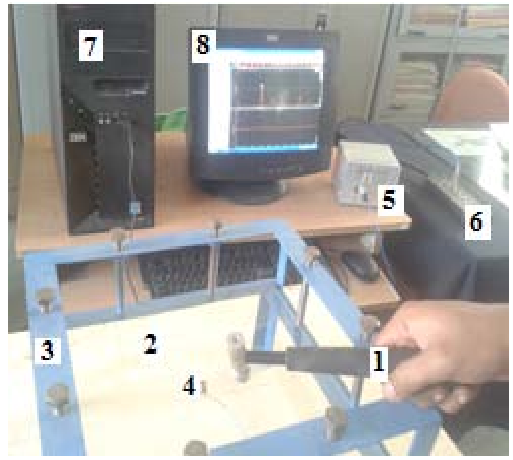

Fig. 3: Photograph of Experimental setup.

Fix-Fix condition of plate was achieved by using the special arrangement made up of metal fixture having bolts for tightening purpose as shown in Fig. 2. The specimen was placed in that fixture and accelerometer was mounted at the center of specimen. The excitation to that plate was given by hammer and by using the FFT analyzer the data were recorded. Specimen of same material and same dimensions were taken for this condition. Three sides fix condition of plate was achieved by using the same arrangement which was used for fix-fix condition. Only three edges of the plate were fixed with the help of bolts.

5.1 Results (Experimentation)

ussing DEWEsoft software.

Table 2: Laminated glass

Boundary Condition	**Freq. (Hz)**	**DLF**
Fix-Fix with rubber busing	78.13	0.129
3-Sides fix with rubber bushing	78.13	0.117
Free-Free	332.03	0.046
Fix-Fix	75.684	0.107
3-Sides fix	78.13	0.094

Table 3. Tempered glass

Boundary Condition	**Freq. (Hz)**	**DLF**
Fix with rubber bushing	75.68	0.11
3-Sides fix with rubber bushing	73.24	0.095
Free-Free	242.31	0.029
Fix-Fix	70.68	0.088
3-Sides fix	68.36	0.07

6. SOFTWARE ANALYSIS USING ANSYS

Damping Loss factor for the same glass specimen has been evaluated by ANSYS software. Specimen structure is modeled using ANSYS. The structure is meshed with shell elements of the type SHELL, which is 8-node element.

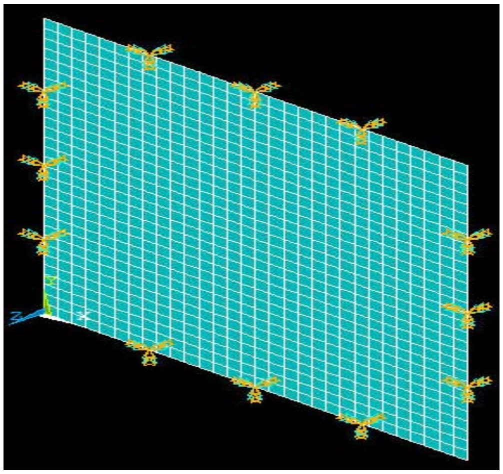

Fig. 4: Meshing of glass plate

Shell elements are typically used for structure where the thickness is negligible compared to its length and width. After preparing model material properties like modulus of elasticity (N/m^2), Poisson's ratio and density (Kg/m^3) etc. have been defined.[7,8]. After defining properties Meshing of specimen is done, different boundary conditions were applied and solution is obtained. In general post processor the list of frequency and corresponding Amplitude is noted down and exported to Mat-lab. Graphs were drawn in Mat-lab and applying Half Power Bandwidth Method the Damping Loss Factor is evaluated..

6.1 Results using ANSYS software.

Table 4: Laminated glass

Boundary Condition	Freq. (Hz)	DLF
Fix with rubber busing	76.24	0.118
3-Sides fix with rubber bushing	75.35	0.108
Free-Free	330.32	0.0404
Fix-Fix	74.26	0.099
3-Sides fix	73.27	0.0878

Table 5: Tempered glass

Boundary Condition	Freq. (Hz)	DLF
Fix-Fix with rubber busing	73.27	0.101
3-Sides fix with rubber bushing	71.29	0.0925
Free-Free	235.30	0.0196
Fix-Fix	69.31	0.088
3-Sides fix	66.34	0.0675

7. RESULT AND DISCUSSION

It has been observed that, for every boundary condition there is a variation in damping loss factor

- For fix-fix condition with rubber bushing the damping loss factor for laminated and tempered glass is highest. This is because all boundary conditions are fixed and the amplitude of vibration is less. Resistance provided by glass specimen is high , energy dissipation in this condition is high and there is additional damping because of rubber bushing.
- For 3-sides fix condition with rubber bushing the damping loss factor is dropped as compared to the above case, this is because one end is not fix and amplitude of vibration has raised as compared to above case.
- For free-free condition the damping loss factor has drastically fallen, because rubber bushing is not present in this case and amplitude of vibration is highest in this case.
- For fix-fix and 3-sides fix condition without rubber bushing the damping loss factor decreases by some value cause the damping of rubber is absent in this case.
- Laminated glass for all conditions shows the highest damping loss factor with and without rubber bushing.

8. CONCLUSION

This paper describes estimation of damping loss factor (DLF) of automotive glass by half power bandwidth method. As damping cannot be measured directly, it is usually estimated from the response curves of the vibrating system. DLF was calculated for different glass specimens to understand the effect of materials and various boundary conditions on its value. Material and boundary condition which shows higher DLF value states that more vibration energy is dissipated by that system. This study shows that proper materials with proper boundary conditions should be selected to minimize the vibrations of the system.

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