Measurement of SPL inside the Truck Cabin for Acoustic Materials: An Experimental Approach

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ABSTRACT: Noise is defined as any unwanted signal that affects with the communication, measurement or processing of an information-bearing signal. A noise itself is a signal which conveys information about the source of the noise. Noise is present in many degrees in almost all environments. The reduction of noise because of vibration of parts of the body of a vehicle is a challenging task. In this paper the experimental work is elaborated for the reduction of sound pressure level inside the truck cabin under different working conditions by using variety of acoustic materials.

Index Terms: **Frequency, Noise, Vibration, Harshness, acoustic materials, truck cabin, damping etc..**

I. INTRODUCTION

Noise is defined as any unwanted signal that affects with the communication, measurement or processing of an information-bearing signal. Noise is present in many degrees in almost all environments. For example, the noise from a vehicle engine be classified into a many categories, indicating the broad physical nature of the noise, as follows:

(a) Acoustic noise
(b) Electromagnetic noise
(c) Electrostatic
(d) Channel distortions, echo, and fading
(e) Processing noise

Driving condition in India such as roads are not good. Driving all over the day in such conditions lead to accidents. So it is very important to design cabin interiors and inside things considering, comfort, aesthetics and lesser noise for drivers in Indian driving situations. Low noise level in the vehicle cabins is a comfort parameter of high significance. Since most of the working places are subjected to guidelines in the noise area, defining the maximum noise level for which a worker is allowed to expose.

II. SOURCES OF NOISE

There are many sources of noise on a vehicle, all resulting either from the application of power to propel the vehicle or from the motion of the vehicle itself. Generally, the predominant sources of noise are diesel engine block noise, intake and exhaust noise, although occasionally gear whine and fan noise can make a significant contribution to the overall noise emitted by the vehicle, and such secondary sources as brake squeal, body noise and load noise can make significant contributions to the annoyance of pedestrians.

Road noise is usually associated with noise inside the vehicle, especially in cars, but external coasting noise mainly arising from the tyre and vehicle being excited by road surface roughness gives levels of 75-80 dB.

III. THE EFFECT OF NOISE

The effects of noise on human beings are illustrated in figure 1. This summarizes how noise complaints and annoyance are caused through various effects. When considering a permit level, the potential for complaints should be considered.

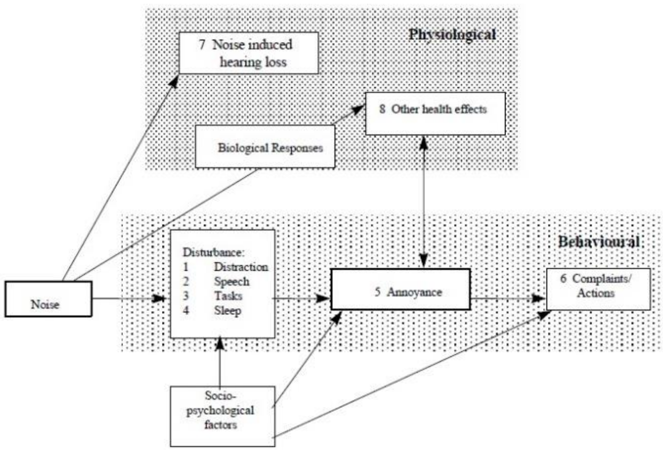


Fig 1. Cause and Effect Relationship with Noise

Noise that induces hearing loss is not a concern at the levels of noise felt by neighbours of noise producing facilities. It is only a potential hazard that happens above noise levels of 80 dB (A) and where exposure is for long periods of time.

A difference is made between disturbance and irritation. Someone is disturbed because of noise when it prevents or inhibits them from doing an everyday activity such as concentrating while reading (distraction), hearing spoken conversation, listening to the radio or sleeping. The feeling of displeasure or annoyance caused by noise is irritation. Irritation is often a result of disturbance and it can be influenced by socio-psychological factors, such as a partiality for or against the facility or person making the noise, of the environmental potentials of an individual. Other effects may occur due to the result of vibration. These include: noticeable vibration, fast-moving of windows, items on shelves and photo frames hanging on walls. In addition, the sound emitted from vibrating walls may leads to indirect effects. These effects may contribute to irritation or annoyance.

IV. VEHICLE NOISE PATHS

Internal vehicle noise does not depend only on the acoustic and vibration sources; very important roles are also played by the different transmission paths between the sources and the receivers (i.e. the drivers and passengers 'ears). In a vehicle there are two different categories of transmission paths: structure-borne and airborne paths. They are related to completely different mechanisms of energy transmission. In a common vehicle (like a car) experience shows that very often the structure-borne noise transmission path dominates at low frequency (<200 Hz) while the airborne noise transmission path dominates above 500 Hz. In the mid-frequency range, both transmission paths have commonly the same level of importance.

Structure-borne noise transmission paths:

The structure-borne path is a vibration transmission path, in which noise is emitted by the panels surrounding the internal cabin. A simple example is the case of the engine of a vehicle: if we consider the engine when running as a source of vibrations (Fig. 2), the energy associated with this vibration will be transferred to the vehicle structure through the engine mounts, then the vibration will propagate over the whole vehicle structure onto the panels facing the passenger compartment. The vibration of these panels will transfer the energy to the air cavity inside the cabin, generating the noise perceived by the occupants. The reduction of structure-borne noise is therefore focused mainly on the structure and the isolation of the vibrations: Here the engine mounts play an important role in the attenuation of the level of vibration, the vehicle structure should have a low sensitivity to the forces coming from the mounts, and the panels should have a low radiation efficiency and possibly be damped to reduce their levels of vibration.

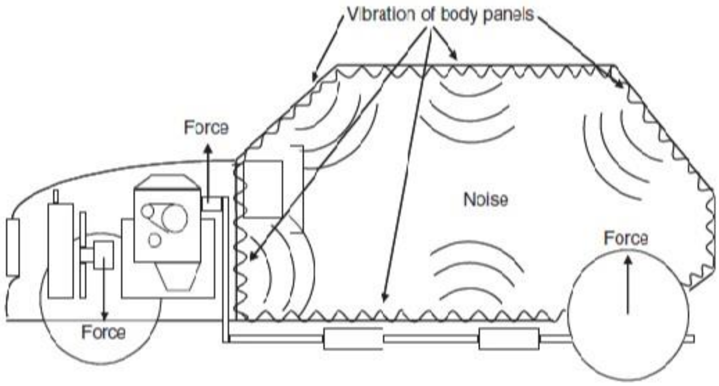


Fig. 2 Structure - borne paths

Airborne noise transmission paths:

The airborne path is a completely different transmission mechanism, as it is an acoustic transmission path. A simple example is still the engine in running conditions (Fig. 3): if we consider the engine as an acoustic source (i.e. the noise generated by the vibrating panels of the engine body), in this case the noise propagates through the air, through holes and across the surfaces of the structure. In the latter case the acoustic propagation will involve also the vibration of the panels of the structure but we are still dealing with an airborne path (the noise outside the panel makes it vibrate, and the panel will generate noise inside the passenger compartment). For these reasons the reduction of airborne noise is more focused on the acoustic path (particular attention should be paid to avoid holes and leakages), on the structure (which should work in acoustic isolation) and on acoustic absorption inside the cabin (this could be done also for structure-borne noise, but the common acoustic materials show better performance in the high-frequency range, where the noise is dominated by the airborne path).

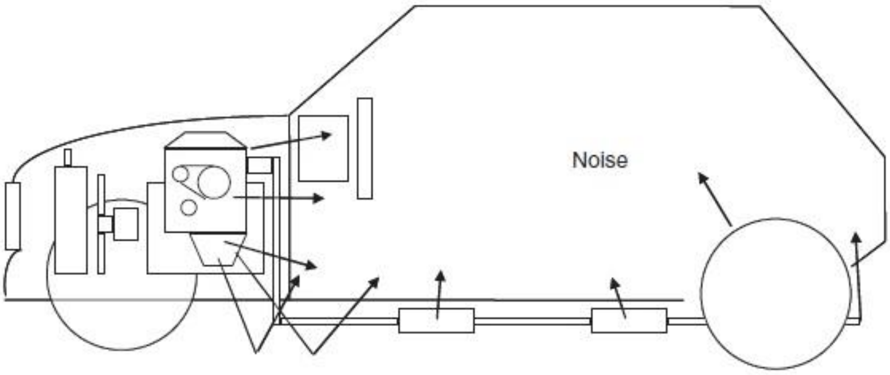


Fig. 3 Airborne paths

V. ACOUSTIC MATERIALS

The most common materials used on vehicle applications are Porous materials, Fibrous materials and Damping materials

Following are the acoustic materials used for reducing SPL inside the cabin.

1. Water based Sound Deadening Coating

2. Vinyl Noise Barrier
3. Polyester Wadding
4. Polyethylene Foam
5. Wool Foam
6. I-Copper Noise Barrier
7. Cell Foam Cotton

VI. EXPERIMENT ON NVH

In the present experiment work TATA ace HT mini truck vehicle is used for the measurement of sound pressure level (SPL) inside the cabin. The Specifications of the Tata ace vehicle is as mentioned in table number 1 below.

Table 1 Technical specifications of Tata Ace HT Mini Truck

Particulars	Details
Engine	4 Stroke, naturally aspirated, indirect injection
Model	TATA 275 IDI Diesel
Displacement	Two cylinder, 702cc
Max Power	11.3kW (16 hp) @ 3200 rpm
Max Torque	37.5 Nm @1500rpm
Rear axle	Live with differential gearbox

Experimental tests are conducted on measuring sound pressure level of TATA Ace HT Truck cabin to study the noise and vibration characteristics of the cabin material under following four different cases. In each case the SPL vs Frequency and SPL vs Time plots are noted. Correspondingly the data is logged to record the noise level inside the cabin.

a) Stationery vehicle with the engine idling.
b) Stationery vehicle with Full throttle acceleration.
c) Moving with 30 kmph Steady speed at each of the gearbox speeds.
d) Moving with 50 kmph Steady speed at each of the gearbox speeds.

The frequency of generated is in the range of 0 to 8000 Hz. In each of the above cases the SPL (dB) is measured in the following categories.

1. SPL without any treatment.
2. SPL with water based sound deadening coating (applied on outside cabin floor).
3. SPL with Vinyl noise barrier (applied on inside panels of the cabin).
4. SPL with Copper noise barrier (applied on inside panels of the cabin).
5. SPL with Polyester Wadding (applied on inside panels of the cabin).
6. SPL with Polyethylene Foam (applied on inside panels of the cabin).
7. SPL with Wool Foam (applied on inside panels of the cabin).
8. SPL with Cell foam Cotton (applied on inside panels of the cabin).
9. SPL for Combination of Coating and Vinyl noise barrier (Base Material 1 i.e. B1)
10. SPL for Combination of Coating and Copper noise barrier (Base Material 1 i.e. B2)
11. SPL for Combination of B1 and Polyester Wadding (applied on inside panels of the cabin).
12. SPL for Combination of B1 and Polyethylene Foam (applied on inside panels of the cabin).
13. SPL for Combination of B1 and Wool Foam (applied on inside panels of the cabin).
14. SPL for Combination of B1 and Cell foam Cotton (applied on inside panels of the cabin).
15. SPL for Combination of B2 and Polyester Wadding (applied on inside panels of the cabin).
16. SPL for Combination of B2 and Polyethylene Foam (applied on inside panels of the cabin).
17. SPL for Combination of B2 and Wool Foam (applied on inside panels of the cabin).
18. SPL for Combination of B2 and Cell foam Cotton (applied on inside panels of the cabin).

In each case the equivalent sound pressure level (SPL), Maximum SPL (MSPL) and the corresponding frequency for maximum SPL are noted.

1. **SPL (dB) without any treatment:**

The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 5 to 8.

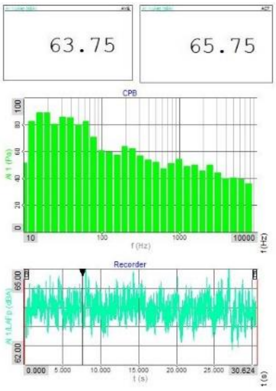


Fig 4. Engine idling

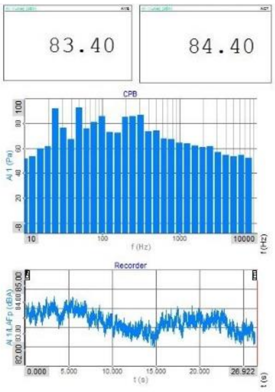


Fig 5. Full throttle acceleration

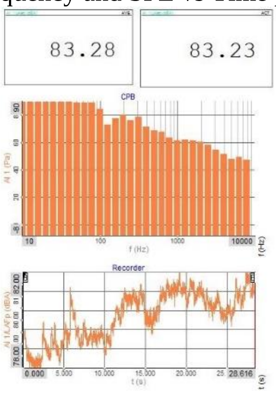


Fig 6. At 30 kmph speed

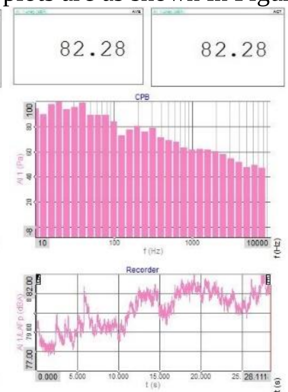
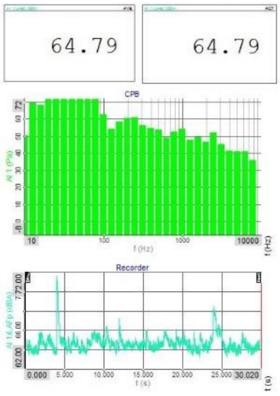
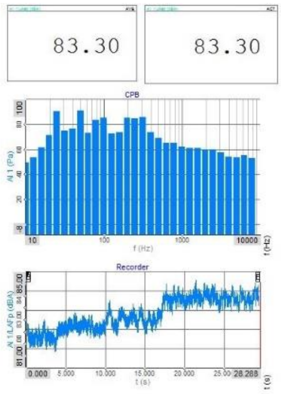


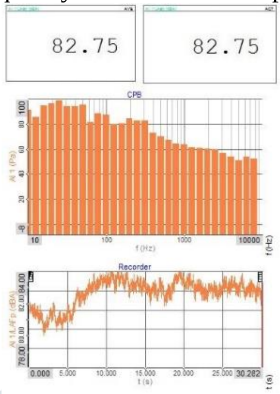
Fig 7. At 50 kmph speed

From the Figure 4 to 7 it is observed that minimum equivalent SPL of 63.75 dB is found in engine idling condition and maximum equivalent SPL of 83.23 dB is identified at 30 kmph steady speed condition under no treatment inside the cabin.
The maximum SPL of 88.65 dB at 16 Hz in engine idling condition, 92.37 dB at 50 Hz in full acceleration condition, 105.3 dB at 25 Hz in 30 kmph speed and 102.7 Hz at 20 Hz was identified.

2. SPL (dB) with sound deadening coating:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 8 to 11.







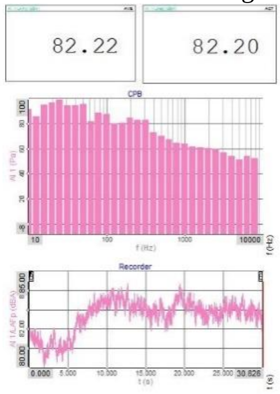
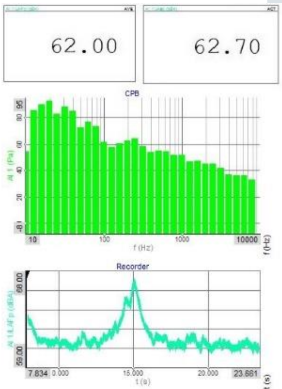
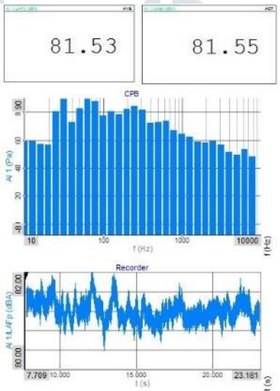


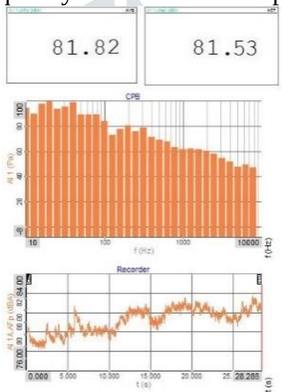
Fig 8 Engine idling Fig 9 Full throttle acceleration Fig 10.At 30 kmph speed Fig 11. At 50 kmph speed

From the Figure 8 to 11 it is observed that minimum equivalent SPL of 64.79 dB is found in engine idling condition and maximum equivalent SPL of 82.75 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 95.82 dB at 20 Hz in engine idling condition, 91.04 dB at 50 Hz in full acceleration condition, 100.4 dB at 25 Hz in 30 kmph speed and 99.13 Hz at 25 Hz was identified.

3 SPL (dB) with Vinyl Noise Barrier:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 12 to. 15.







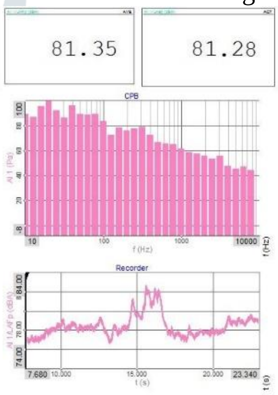
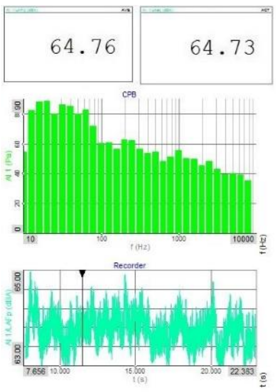
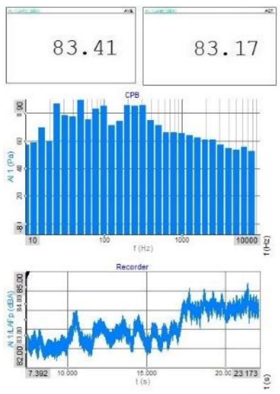


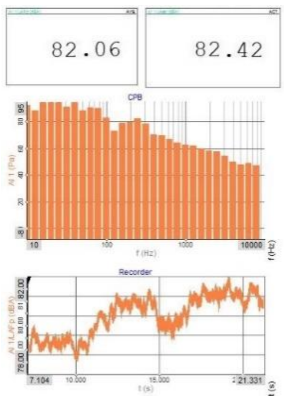
Fig 12. Engine idling Fig 13 full throttle Acceleration Fig 14. At 30 kmph speed Fig 15. At 50 kmph speed

From the Figure 12 to 15 it is observed that minimum equivalent SPL of 62.70 dB is found in engine idling condition and maximum equivalent SPL of 81.53 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 92.9 dB at 20 Hz in engine idling condition, 97.4 dB at 65 Hz in full acceleration condition, 99.7 dB at 20 Hz in 30 kmph speed and 98.6 Hz at 20 Hz was identified.

4 SPL (dB) with Polyester Wadding:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 16. to 19.







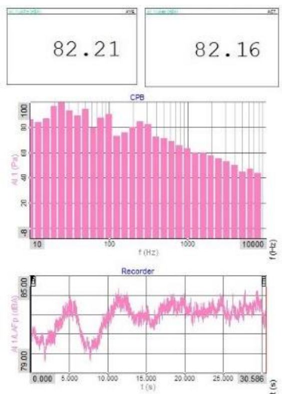


Fig 16. Engine idling Fig 17. Full throttle acceln. Fig 18. At 30 kmph speed Fig 19. At 50 kmph speed

From the Figure 16 to 19 it is observed that minimum equivalent SPL of 64.73 dB is found in engine idling condition and maximum equivalent SPL of 82.42 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 93 dB at 20 Hz in engine idling condition, 98 dB at 60 Hz in full acceleration condition, 101 dB at 25 Hz in 30 kmph speed and 100.5 Hz at 20 Hz was identified.

5 SPL (dB) with Polyethylene Foam:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 20 to 23.

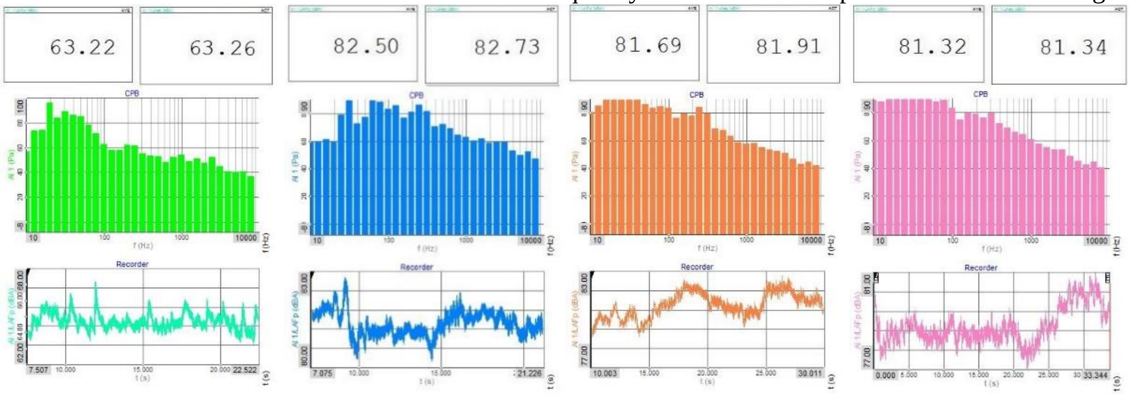


Fig 20. Engine idling Fig 21. Full throttle Acceleration Fig 22.At 30 kmph speed Fig 23. At 50 kmph speed

From the Figure 20 to 23 it is observed that minimum equivalent SPL of 63.26 dB is found in engine idling condition and maximum equivalent SPL of 81.91 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 94.02 dB at 20 Hz in engine idling condition, 98.61 dB at 240 Hz in full acceleration condition, 106 dB at 25 Hz in 30 kmph speed and 104.43 Hz at 25 Hz was identified.

6 SPL (dB) with Wool Foam:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 24 to 27.

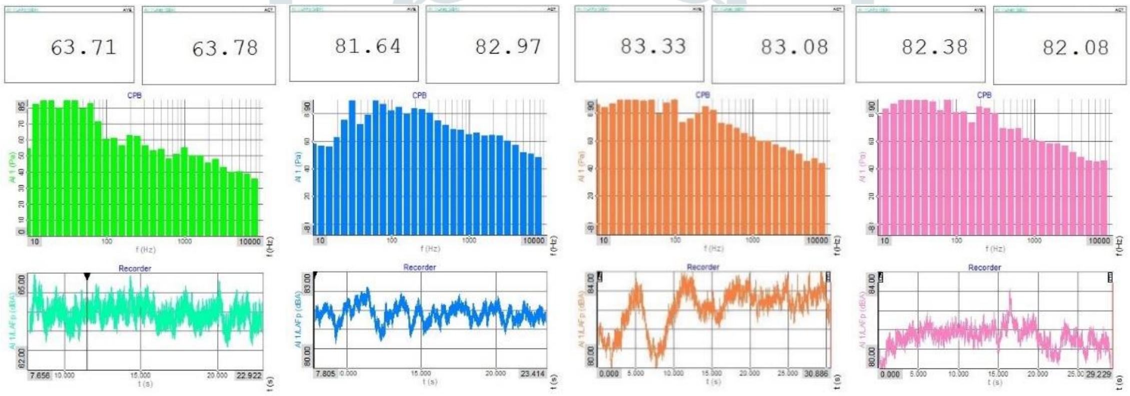


Fig 24. Engine idling Fig 25. Full throttle Acceleration Fig 26 At 30 kmph speed Fig 27. At 50 kmph speed

From the Figure 24 to 27 it is observed that minimum equivalent SPL of 63.78 dB is found in engine idling condition and maximum equivalent SPL of 83.08 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 90.48 dB at 20 Hz in engine idling condition, 94.5 dB at 66 Hz in full acceleration condition, 105 dB at 25 Hz in 30 kmph speed and 101 Hz at 25 Hz was identified.

7 SPL (dB) with Copper Barrier:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 28 to 31.

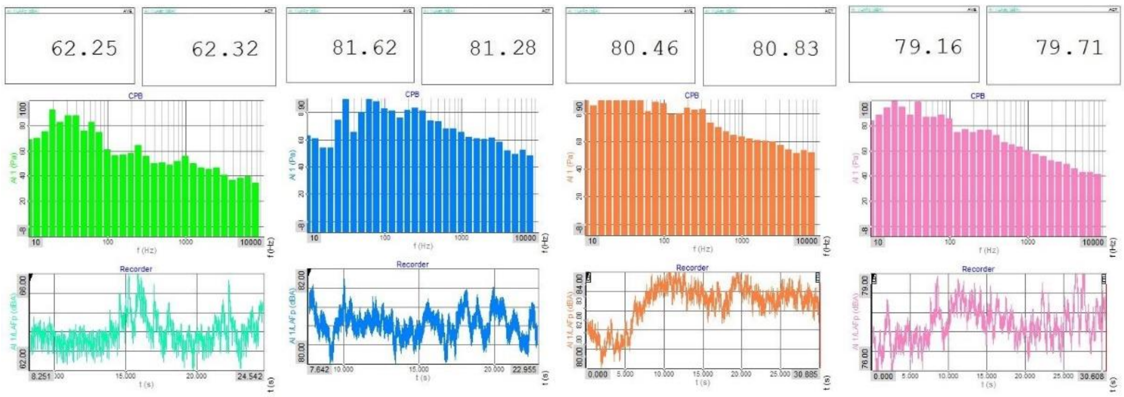
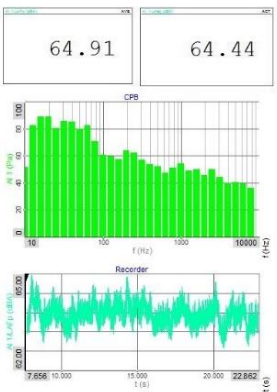
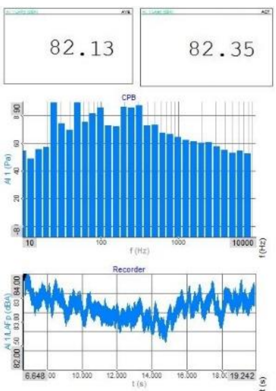


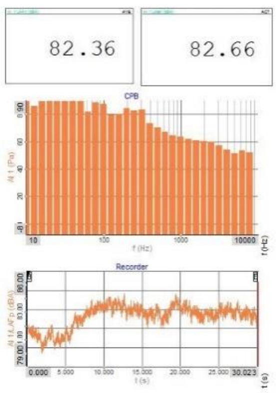
Fig 28 Engine idling Fig 29. Full throttle Acceleration. Fig 30 at 30 kmph speed Fig 31. At 50 kmph speed

From the Figure 28 to 31 it is observed that minimum equivalent SPL of 62.32 dB is found in engine idling condition and maximum equivalent SPL of 80.83 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 90 dB at 20 Hz in engine idling condition, 100.3 dB at 25 Hz in full acceleration condition, 98.6 dB at 20 Hz in 30 kmph speed and 97.85 Hz at 20 Hz was identified.

8 SPL (dB) with Cell Foam Cotton:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 32 to 35.







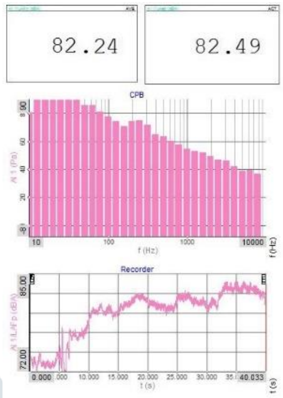


Fig 32. Engine idling Fig 33. Full throttle Acceleration. Fig 34 At 30 kmph speed Fig 35. At 50 kmph speed

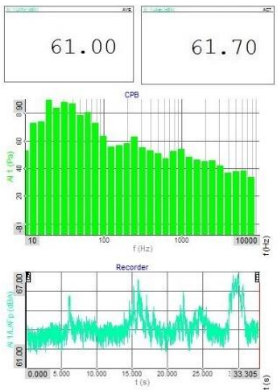
From the Figure 32 to 35 it is observed that minimum equivalent SPL of 64.44 dB is found in engine idling condition and maximum equivalent SPL of 82.66 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 92.5 dB at 20 Hz in engine idling condition, 95.35 dB at 63 Hz in full acceleration condition, 103.9 dB at 20 Hz in 30 kmph speed and 102 Hz at 20 Hz was identified.

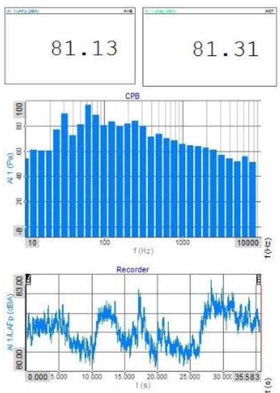
The individual acoustic material testing results are tabulated in table no 2 below.

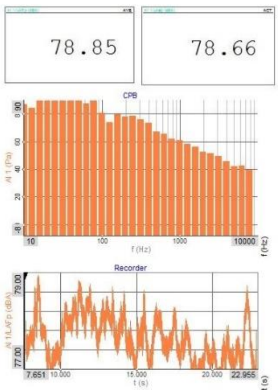
Table No 2 Experimental testing results of Individual acoustic materials used.

Sl.No	Material	Engine Idle			Full Acceleration			30 Kmph			50 Kmph		
		MSPL (dB)	Frequency (Hz)	SPL (dB)	MSPL (dB)	Frequency (Hz)	SPL (dB)	MSPL (dB)	Frequency (Hz)	SPL (dB)	MSPL (dB)	Frequency (Hz)	SPL (dB)
1.	Plain Cabin	88.65	16	65.75	92.37	50	84.4	105.3	25	83.23	102.7	20	82.28
2.	Sound Deadening Coating	95.82	20	64.75	91.04	50	83.3	100.4	25	82.75	99.13	25	82.75
3.	Vinyl Barrier	92.9	20	62.70	97.4	65	81.55	99.7	20	81.28	98.6	20	81.53
4.	Polyester Wadding	93	20	64.73	98	60	83.17	101	25	82.42	100.5	20	82.16
5.	Polyethylene Foam	94.02	20	63.26	98.61	240	82.73	106	25	81.91	104.43	25	81.34
6.	Wool Foam	90.48	20	63.78	94.5	66	82.97	105	25	83.08	101	25	82.08
7.	Copper Barrier	90	20	62.32	100.3	25	81.28	98.6	20	80.83	97.85	20	79.71
8.	Cell Foam Cotton	92.5	20	64.44	95.35	63	82.35	103.9	20	82.66	102	20	82.49

9 SPL (dB) for Combination of Coating and Vinyl Barrier:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 36 to 39.







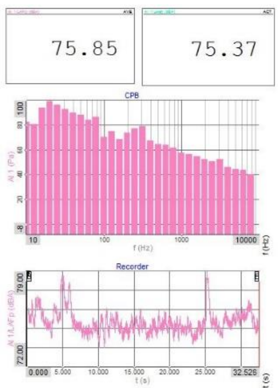
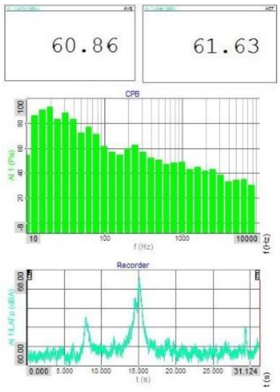
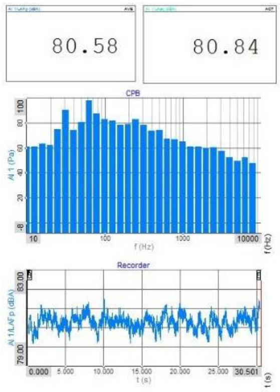


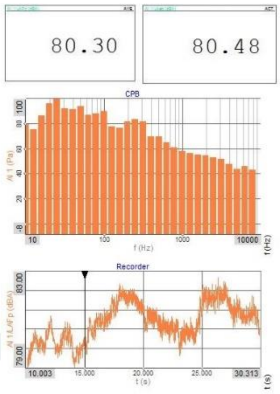
Fig 36. Engine idling Fig 37. Full throttle Acceleration. Fig 38 At 30 kmph speed Fig 39. At 50 kmph speed

From the Figure 36 to 39 it is observed that minimum equivalent SPL of 61.70 dB is found in engine idling condition and maximum equivalent SPL of 78.66 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 92.7 dB at 20 Hz in engine idling condition, 96.37 dB at 63 Hz in full acceleration condition, 99.81 dB at 20Hz in 30 kmph speed and 98.69 Hz at 20 Hz was identified.

10 SPL (dB) for Combination of Coating, Vinyl Barrier and Polyester Wadding:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 40 to 43.







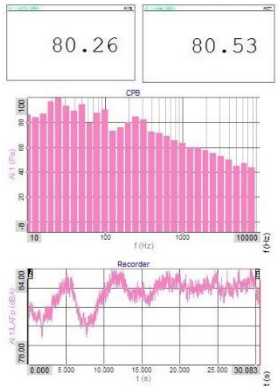
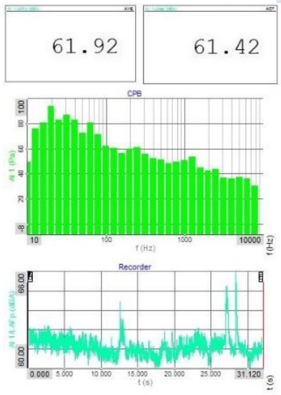
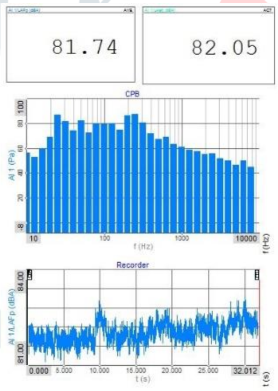


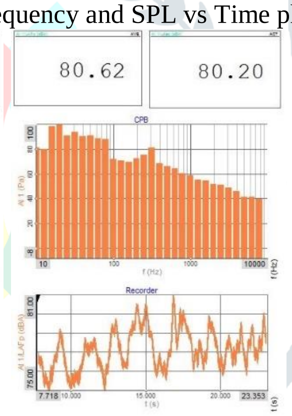
Fig 40. Engine idling Fig 41. Full throttle Acceleration. Fig 42 At 30 kmph speed Fig 43. At 50 kmph speed

From the Figure 40 to 43 it is observed that minimum equivalent SPL of 61.63 dB is found in engine idling condition and maximum equivalent SPL of 80.48 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 92.85 dB at 20 Hz in engine idling condition, 97.78 dB at 62 Hz in full acceleration condition, 100.68 dB at 25Hz in 30 kmph speed and 99.57 Hz at 25 Hz was identified.

11 SPL (dB) for Combination of Coating, Vinyl Barrier and Polyethylene Foam:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 44 to 47.







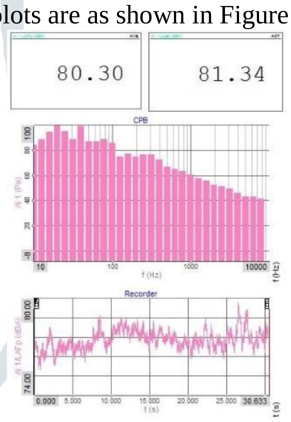
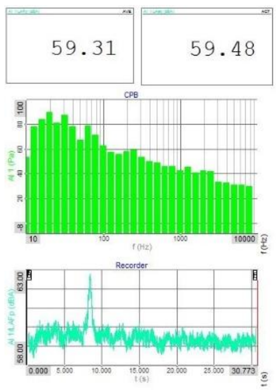
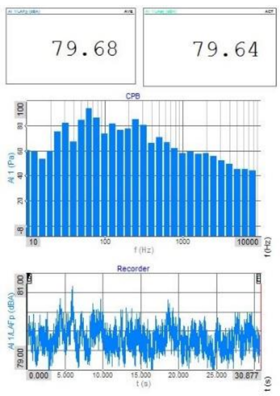


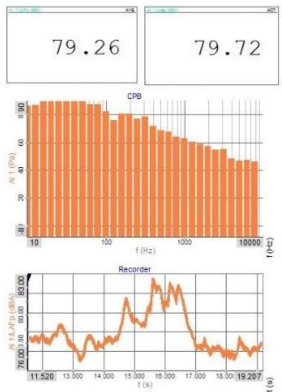
Fig 44. Engine idling Fig 45. Full throttle Acceleration. Fig 46 At 30 kmph speed Fig 47. At 50 kmph speed

From the Figure 44 to 47 it is observed that minimum equivalent SPL of 61.42 dB is found in engine idling condition and maximum equivalent SPL of 80.20 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 93.95 dB at 20 Hz in engine idling condition, 97.39 dB at 250 Hz in full acceleration condition, 105.9 dB at 20Hz in 30 kmph speed and 103.2 Hz at 20 Hz was identified.

12 SPL (dB) for Combination of Coating, Vinyl Barrier and Wool Foam:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 48 to 51.







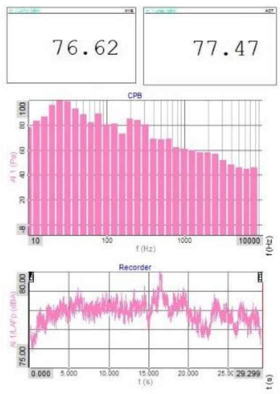
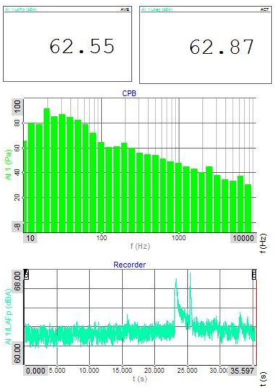
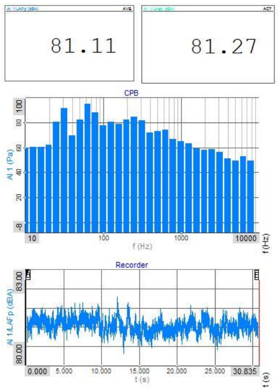


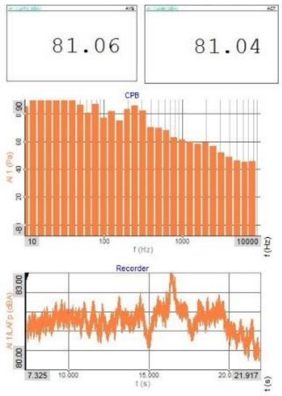
Fig 48. Engine idling Fig 49. Full throttle Acceleration. Fig 50. At 30 kmph speed Fig 51. At 50 kmph speed

From the Figure 48 to 51 it is observed that minimum equivalent SPL of 59.48 dB is found in engine idling condition and maximum equivalent SPL of 79.72 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 89.69 dB at 20 Hz in engine idling condition, 93.64 dB at 63 Hz in full acceleration condition, 103.4 dB at 25Hz in 30 kmph speed and 100.9 Hz at 25 Hz was identified.

13 SPL (dB) for Combination of Coating, Vinyl Barrier and Cell Foam Cotton:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 52 to 55.







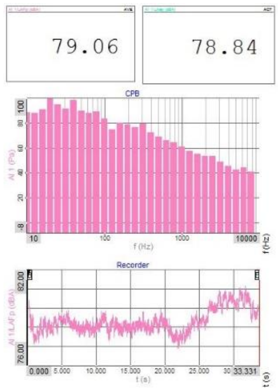
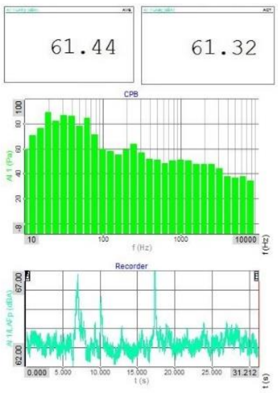
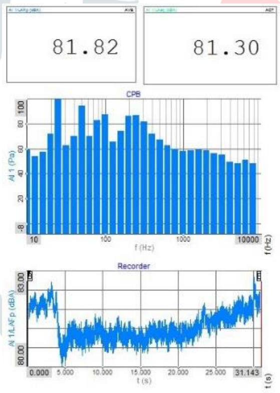


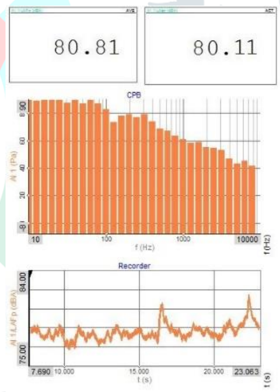
Fig 52. Engine idling Fig 53. Full throttle Acceleration. Fig 54. At 30 kmph speed Fig 55. At 50 kmph speed

From the Figure 52 to 55 it is observed that minimum equivalent SPL of 62.87 dB is found in engine idling condition and maximum equivalent SPL of 81.04 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 91.66 dB at 20 Hz in engine idling condition, 94.99 dB at 63 Hz in full acceleration condition, 103.7 dB at 20Hz in 30 kmph speed and 101.9 Hz at 20 Hz was identified.

14 SPL (dB) for Combination of Coating, Copper Barrier:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 56 to 59.







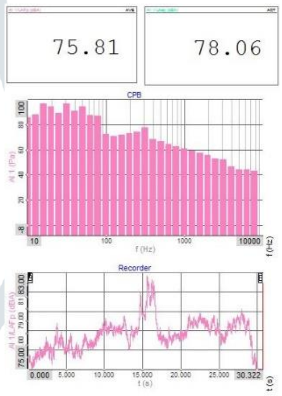
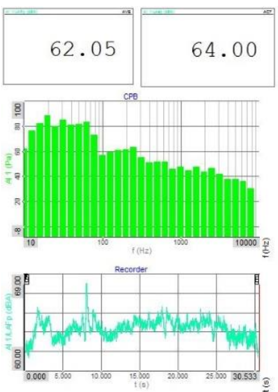
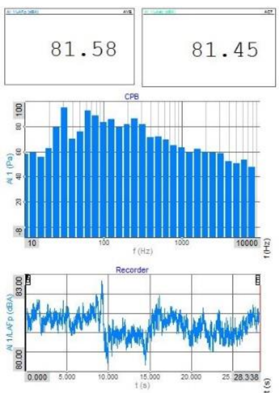


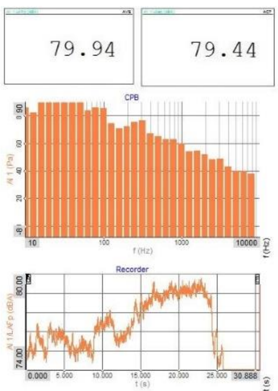
Fig 56. Engine idling Fig 57. Full throttle Acceleration. Fig 58 At 30 kmph speed Fig 59. At 50 kmph speed

From the Figure 56 to 59 it is observed that minimum equivalent SPL of 61.32 dB is found in engine idling condition and maximum equivalent SPL of 80.11 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 88.87 dB at 20 Hz in engine idling condition, 99.62 dB at 25 Hz in full acceleration condition, 97.31 dB at 20Hz in 30 kmph speed and 96.45 Hz at 16 Hz was identified.

15 SPL (dB) for Combination of Coating, Copper Barrier and Polyester Wadding:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 60 to 63.







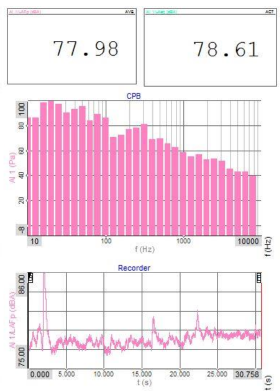


Fig 60. Engine idling Fig 61. Full throttle Acceleration. Fig 62. At 30 kmph speed Fig 63. At 50 kmph speed

From the Figure 60 to 63 it is observed that minimum equivalent SPL of 64 dB is found in engine idling condition and maximum equivalent SPL of 79.44 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 88.62 dB at 20 Hz in engine idling condition, 94.92 dB at 31.5 Hz in full acceleration condition, 104.5 dB at 25Hz in 30 kmph speed and 103.3 Hz at 20 Hz was identified.

16 SPL (dB) for Combination of Coating, Copper Barrier and Polyethylene Foam:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 64 to 67.

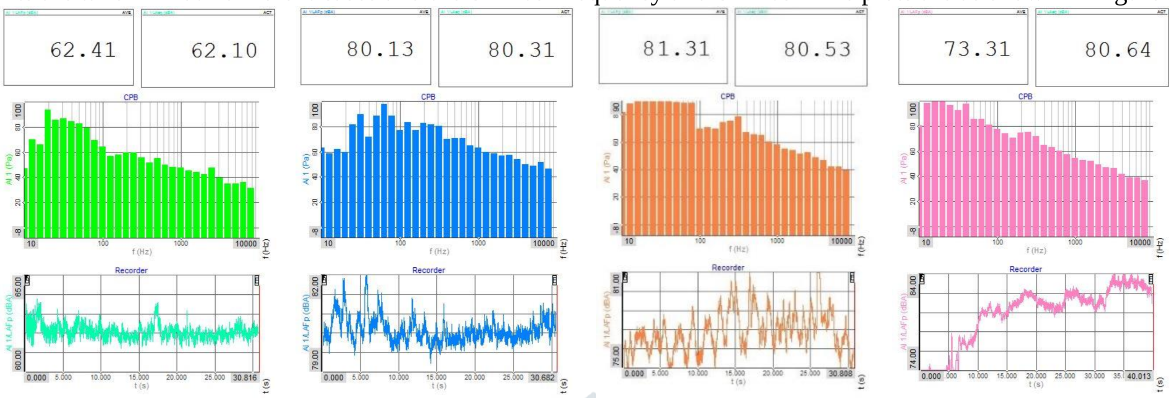


Fig 64. Engine idling Fig 65. Full throttle Acceleration. Fig 66 At 30 kmph speed Fig 67. At 50 kmph speed

From the Figure 64 to 67 it is observed that minimum equivalent SPL of 61.70 dB is found in engine idling condition and maximum equivalent SPL of 78.66 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 92.7 dB at 20 Hz in engine idling condition, 96.37 dB at 63 Hz in full acceleration condition, 99.81 dB at 20Hz in 30 kmph speed and 98.69 Hz at 20 Hz was identified.

17 SPL (dB) for Combination of Coating, Copper Barrier and Wool Foam:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 68 to 71.

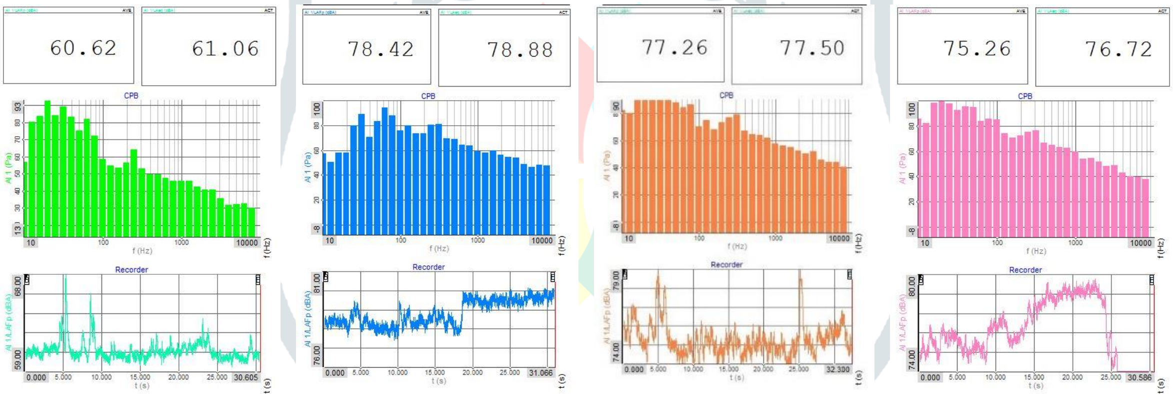


Fig 68 Engine idling Fig 69. Full throttle Acceleration. Fig 70 At 30 kmph speed Fig 71. At 50 kmph speed

From the Figure 68 to 71 it is observed that minimum equivalent SPL of 61.06 dB is found in engine idling condition and maximum equivalent SPL of 77.50 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 92.39 dB at 20 Hz in engine idling condition, 94.1 dB at 63 Hz in full acceleration condition, 102 dB at 25Hz in 30 kmph speed and 101.9 Hz at 20 Hz was identified.

18 SPL (dB) for Combination of Coating, Copper Barrier and Cell Foam Cotton:
The measurements are taken in four different cases and the SPL vs Frequency and SPL vs Time plots are as shown in Figure 72 to 75.

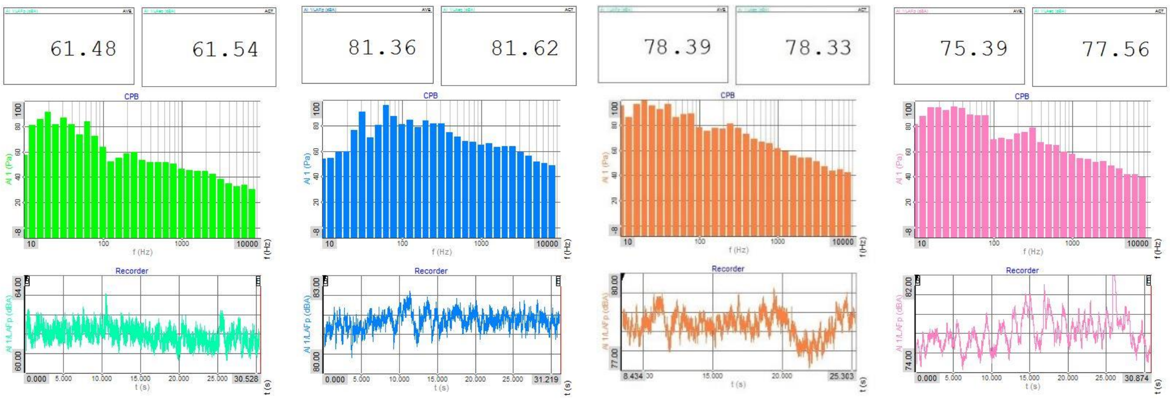


Fig 72 Engine idling Fig 73. Full throttle Acceleration. Fig 74 At 30 kmph speed Fig 75. At 50 kmph speed

From the Figure 72 to 75 it is observed that minimum equivalent SPL of 61.54 dB is found in engine idling condition and maximum equivalent SPL of 78.33 dB is identified at 30 kmph steady speed condition under sound deadening coating outside the cabin.
The maximum SPL of 91.54 dB at 20 Hz in engine idling condition, 96.23 dB at 63 Hz in full acceleration condition, 98.24 dB at 33Hz in 30 kmph speed and 95.66 Hz at 31.5 Hz was identified.

The combination of acoustic material testing results are tabulated in table no 2 below.

Table No 3 Experimental testing results of combination of acoustic materials used.

Sl.No	Material	Engine Idle			Full Acceleration			30 Kmph			50 Kmph		
		MSPL (dB)	Frequency (Hz)	SPL (dB)	MSPL (dB)	Frequency (Hz)	SPL (dB)	MSPL (dB)	Frequency (Hz)	SPL (dB)	MSPL (dB)	Frequency (Hz)	SPL (dB)
1.	Sound Deadening Coating and Vinyl Barrier	92.7	20	61.70	96.37	63	81.31	99.81	20	78.66	98.69	20	75.33
2.	Sound Deadening Coating, Vinyl Barrier and Polyester Wadding	92.85	20	61.63	97.78	62	80.84	100.68	25	80.48	99.57	25	80.53
3.	Sound Deadening Coating, Vinyl Barrier and Polyethylene Foam	93.95	20	61.42	97.39	250	82.05	105.9	20	80.20	103.2	20	81.34
4.	Sound Deadening Coating, Vinyl Barrier and Wool Foam	89.69	20	59.48	93.74	63	79.64	103.4	25	79.72	100.9	25	77.47
5.	Sound Deadening Coating, Vinyl Barrier and Cell Foam Cotton	91.66	20	62.87	94.99	63	81.27	103.7	20	81.04	101.9	20	78.84
6.	Sound Deadening Coating and Copper Barrier	88.87	20	61.32	99.62	25	81.30	97.31	20	80.11	96.45	16	78.06
7.	Sound Deadening Coating, Copper Barrier and Polyester Wadding	88.62	20	64.00	94.92	31.5	81.45	104.5	25	79.44	103.3	20	78.61
8.	Sound Deadening Coating, Copper Barrier and Polyethylene Foam	93.94	20	62.10	97.47	63	80.31	103.85	20	80.53	103	16	80.64
9.	Sound Deadening Coating, Copper Barrier and Wool Foam	92.39	20	61.06	94.1	63	78.88	102	25	77.50	101.9	20	76.72
10.	Sound Deadening Coating, Copper Barrier and Cell Foam Cotton	91.54	20	61.54	96.23	63	81.62	98.24	33	78.33	95.66	31.5	77.56

VII. CONCLUSIONS

- From the experimental testing of NVH of the cabin, it is found that the structural vibration is more due to engine power which is mounted just below the cabin.
- The SPL noted in all the 4 cases was more in cabin under no treatment condition.
- The SPL got attenuated to maximum extent in vinyl barrier and copper barrier materials when used as individual material.
- The SPL got attenuated to maximum extent in combination of Sound Deadening Coating, Vinyl Barrier and Polyester Wadding materials.
- The SPL got attenuated to maximum extent in combination of Sound Deadening Coating, Copper Barrier and Polyethylene Foam materials.

VIII. SCOPE FOR FUTURE WORK

- The knowledge of this individual and combination of material on NVH testing can be extended to other acoustic materials and other vehicles.
- The attenuation of SPL can be observed in different combinations of acoustic materials.
- FEM simulation can be performed similar to experimental testing and the results can be compared.

IX. ACKNOLODGMENT

This paper is the result of experimental work performed by the authors with the support of engineering college staff and students. Authors thank each and every individual, who directly or indirectly involved in successful completion of experimental work and formation into the paper.

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