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OPTIMIZING NOISE LEVELS IN A VEHICLE – CASE STUDY

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Abstract: This paper presents the problem of vehicle produced noise and explores ways to reduce that noise for the driver and the passengers of a common driven car on european roads, the Mazda 3 Hatchback from 2008. Using a sound level meter, it was measured acoustic levels at ear level for the driver and passengers of the car at different speeds and gears. The road type, weather conditions, tires and vehicle condition were unchanged in order not to influence the obtained results.

Key words: *vehicle restauration, noise control, acoustic comfort*

INTRODUCTION

Noise measurement focuses on studying the intensity, frequency, and direction of sound, with particular attention to environmental and traffic-related sources. In urban areas, the widespread use of vehicles is a major contributor to noise pollution, which affects both pedestrians and drivers. Prolonged exposure to high noise levels can cause discomfort, stress, and even health problems such as hypertension or cardiovascular disease.
Traffic noise is regulated by European and national legislation, which sets maximum acceptable sound levels for different zones and times of day. However, in many cities these limits are often exceeded, especially in densely populated areas.
To improve comfort inside vehicles, modern manufacturers invest heavily in soundproofing technologies, while budget cars often rely on minimal insulation. Cabin noise typically enters through the floor, doors, roof, and wheel arches [1]. This paper investigates noise measurement and reduction in a widely used vehicle, aiming to demonstrate how modern soundproofing solutions can significantly enhance comfort in older models.
Recent advances in acoustic measurement technologies have expanded the ability to monitor and analyze vehicle noise in real time. For instance, sensor-based systems allow for the detection and characterization of sound sources with high precision, enabling researchers to assess how noise propagates both inside and outside a moving vehicle. Such systems provide valuable insights into the complex interaction between vehicle mechanics, road conditions, and surrounding environments, ultimately helping engineers design more effective noise-reduction strategies [2].
Another important aspect in the study of traffic-related noise is its impact on urban mobility and the quality of life of city residents. Research on transportation systems has shown that high noise levels from vehicles not only affect drivers but also lead to social dissatisfaction among communities exposed to constant traffic noise. This has significant implications for transport planning, as policymakers are encouraged to adopt strategies that mitigate the acoustic impact of road networks through infrastructural adjustments and vehicle-level solutions [3].
In addition to traffic noise in general, interior vehicle acoustics have become an area of increasing research interest. Studies have revealed that cabin noise depends heavily on the distribution of vibration across different car components, such as the body panels, suspension, and tires. Numerical simulations and experimental tests are often combined to identify the dominant vibration sources, enabling more effective soundproofing strategies. By reducing these structural vibrations, manufacturers can significantly improve acoustic comfort and overall driving experience [4].

A related stream of research has focused on the role of materials and insulation techniques in reducing vehicle cabin noise. Investigations have shown that using advanced composites and multilayer panels can drastically minimize noise transmission from the external environment to the passenger space. Furthermore, comparative studies between traditional and modern insulation materials highlight clear benefits in terms of both acoustic efficiency and weight reduction, which is crucial for maintaining fuel efficiency in vehicles [5].
Beyond passenger comfort, traffic-generated noise also represents a broader environmental concern. Research has highlighted that road noise contributes significantly to overall urban sound pollution, influencing not only human health but also urban ecosystems. Studies in this area emphasize that effective mitigation requires a combination of technological innovation at the vehicle level and broader policy measures aimed at reducing exposure in densely populated areas [6].
Finally, experimental approaches to noise evaluation demonstrate the importance of standardized methodologies for obtaining reliable results. Measurements conducted in controlled and real-world conditions underline the necessity of considering variables such as vehicle speed, type of road surface, and traffic density. These factors are essential for ensuring accurate comparisons between vehicles and for developing practical solutions that can be applied consistently across different contexts [7].

MATERIAL AND METHODS

The car used for soundproofing and measurements is a Mazda 3 Hatchback from 2008 since it is a common, affordable transportation solution for most people looking to buy a vehicle. Mazda always meant for the model to be a good and compact solution for lower budgets, so they made the car affordable leaving room for sound comfort improving. The cars engine, exhaust and chassis have not been modified prior to our soundproofing solution.
The gearbox comes with only 5 gears for moving forward, so driven at high speeds like 130 km/h keeps your engine at around 3500 RPM. In this situation the engine and exhaust produce a lot of noise that can't be avoided in the standard configuration.
Being a budget car also means that besides having too much noise in the cabin at higher speeds, comfort was not a priority, so unnecessary noise gets in the cabin even at lower speeds or even while idling.
The car is equipped with a 1.6 liter naturally aspirated engine making 105 hp at 6000 rpm. The chassis is built out of steel, having the following panel thicknesses:

- Side panels (doors), 0.7 mm – 1 mm,
- Floor, 1 mm – 1.5 mm,
- Structural components 1.2 mm – 2 mm +.

Fig. 1. *Mazda 3 HatchBack 2008 [8]*

The decibel meter used in this work is DT-8852 made by CEM. This device was used to measure sound level inside the car for the driver and passengers. By recording the sound level in the car before and after our soundproofing procedure, an exact result of decibel reduction can be defined. The measurements are all taken at ear level for the driver, front passenger and rear passengers, all at different travel speeds and engine RPM according to speciffic gears.

Fig. 2. *DT-8852 made by CEM [9]*

The CEM DT-8852 is a high accuracy digital sound level meter used for environmental and quality control use, measuring from 30 dB up to 130dB with type 2 accuracy ± 1.4 dB.

Soundproofing the vehicle

For the procedure of soundproofing the main focus was on the doors and the floor of the car, since that is where most of the road noise comes through in the cabin.
The materials used are from STP and they have the role of absorbing vibration, improving thermal insulation, reducing noise and resonance in vehicles, while improving acoustic comfort and enhancing the performance of the car’s audio system.

STP Bimast Bomb Premium is the vibration absorbing layer that needs to have first contact with the metal sheets. It is applied on a clean surface and needs to be heated up and rolled down with a special roller that makes sure the bond between this layer and the metal sheet is as good as possible.
It is made from butyl rubber, aluminum layers and adhesive backing, making a very efficient vibration absorbing and reducing resonance in metal panels while also adding about 2.38 kg with each sheet.

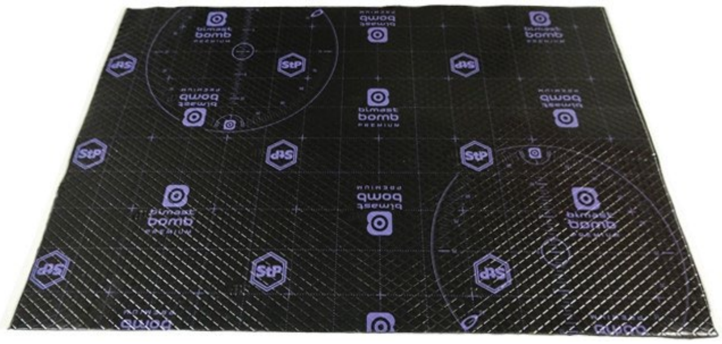

Fig. 3. *STP Bimast Bomb Premium [10]*

STP Accent 6 was designed to be used as layer you lay on top of vibration absorbing materials. It reduces noise and it also helps with the vibration damping of the first soundproofing layer.

Fig. 4. *STP ACCENT 6 [11]*

This material must be laid down as tight as possible, trying to not leave any gaps at all between the pieces. It is made from evenly foamed polyethylene with a partly ruptured closed cell structure.

STP Biplast 15 is made from open-cell polyurethane foam and is meant to be used for total coverage of parts by being very flexible. This layer is applied on the inside of door panels for noise reduction. In the front doors of the car, there were found materials similar to Biplast 15 that has the intent to reduce noise. The difference in technology and the fact the present solution will actually stick to each part of the door panel, will serve to reduce noise even further.

Fig. 5. *STP Biplast 15 [12]*

All the interior trim were removed, and also door pannels, floor carpet, accessories so there can exist good access to the sheets that were applied on. While soundproofing the car, the interest was to assure that there is no dust or oil on the surfaces where the materials were applied. The vibration absorbing sheets having a good bond with the metal sheet is crucial. Air bubbles can lead to corrosion in time and negatively influence the performance of all following materials.

Fig. 6. *Front door plastic cover with STP Biplast 15*

Through the installation there was found foam in the front door panels for noise reduction and a bit of vibration absorbing material on the floor of the car. Mazda focused on the most important spots in the car to apply their solutions to keep production and sale prices low.
With the materials applied to the car on the floor and on the interior of the doors, the next step was to record new sound levels and to test for improvements.

RESULTS AND DISCUSSION

The used sound level meter connects through a USB cable to a laptop that has installed the specific software application. Through the software, one can record live sound level data and have a live graph of dB / seconds generated. In figure 7 the recorded data can be observed for 0 km/h.

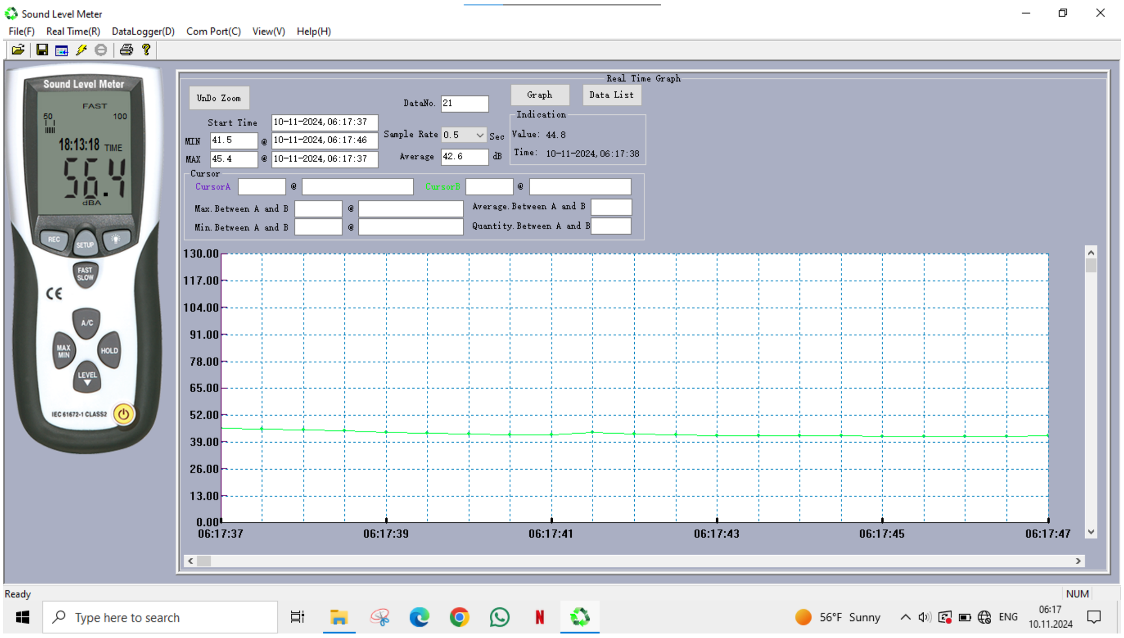

Fig. 7. *Sound Level Meter Windows application*

The measured sound levels were determined before and after soundproofing the car, in order to reduce the sound level medium measured in a 10 second period at different speeds. The speeds and gears chosen for measurements are the most common used in the city or outside the city:

- 0 km/h – neutral,
- 30 km/h – second gear,
- 50 km/h – third gear,
- 90 km/h – fourth gear,
- 110 km/h – fifth gear,
- 130 km/h – fifth gear.

From all the measurements one of the most representative for this car is the 130 km/h in fifth gear.

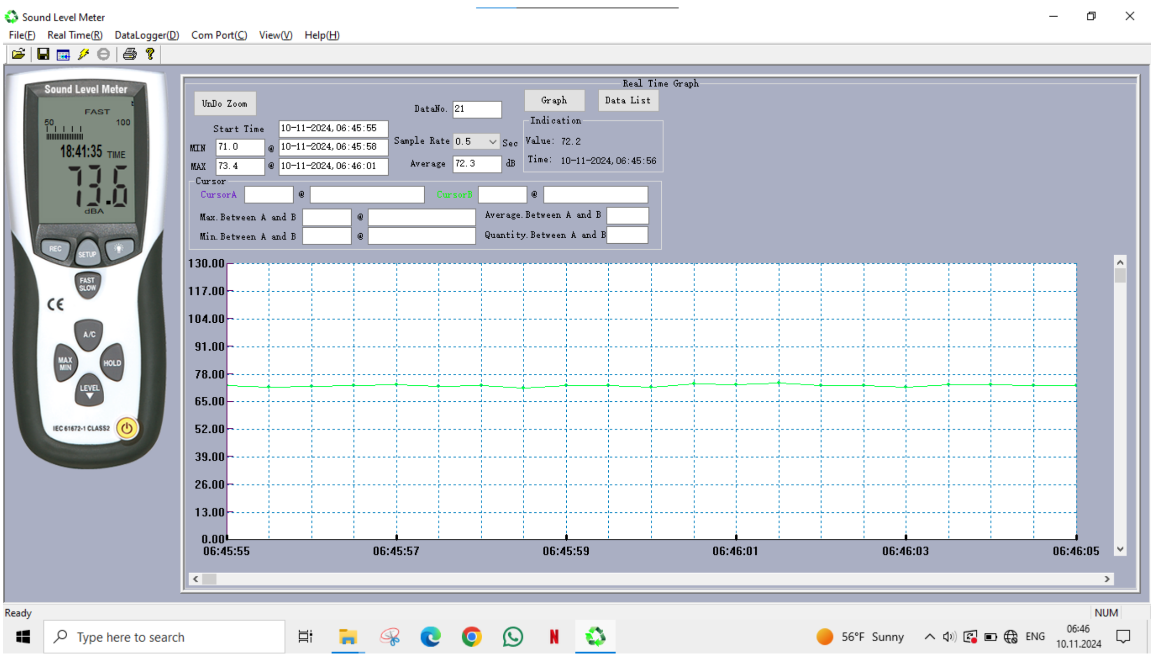

Fig. 8. *Sound Level Meter measurement at 130 km/h in fifth gear before soundproofing*

In figure 8 from above it can be observed a medium measurement of **72.3 dB** before soundproofing the car. This measurement was taken for the front passenger of the vehicle. The minimum recorded value in the 10 second period was **71 dB**.

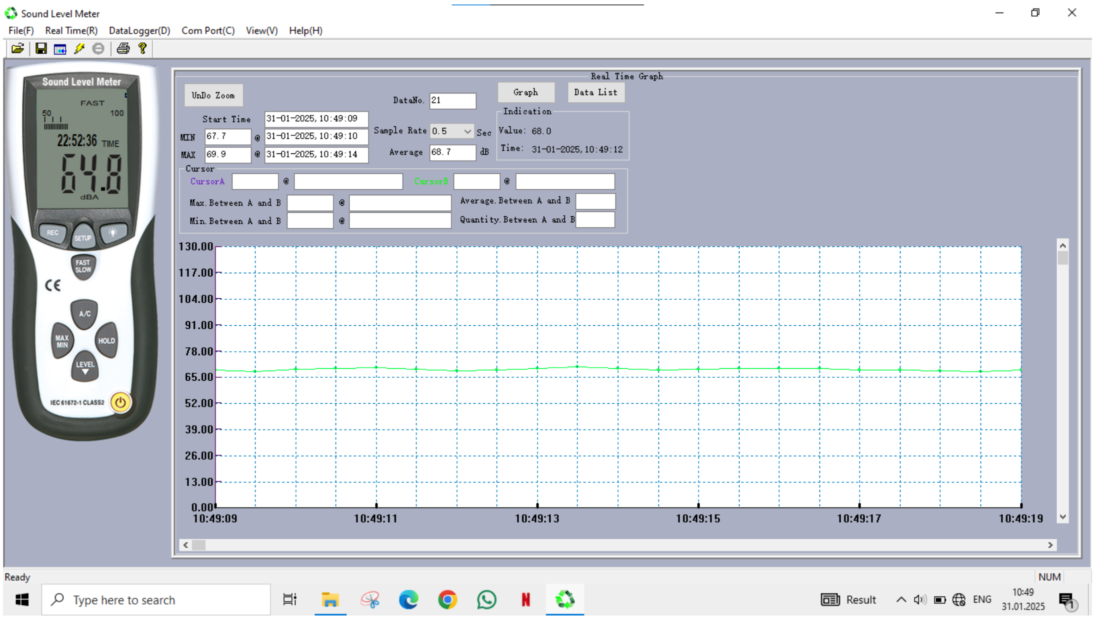

Fig. 9. Sound Level Meter measurement at 130 km/h in fifth gear after soundproofing

The results from figure 9, after soundproofing, show a medium decibel level decrease of **3.6 dB** with a minimum decrease in the recorded 10 second period of time of **3.3 dB**.
A decrease of 3.6 dB can be calculated to a percentual decrease of 56% of acoustic power [13]. To the human ear this decrease can be calculated to about 23% reduction of previous sound pressure. Only starting at 3 dB can the human ear percept sound pressure difference and at 10 dB difference the sound pressure sensation is doubled [14].

The decibel reduction results we got for all cases are the following:
Driver: **2.48 db** (medium), **3.6 db** max and **1.2 db** min.
Front passenger: **3.13 db** (medium), **4.7 db** max and **1.6 db** min.
Back passengers: **2.25 db** (medium), **4.9 db** max and **0.8 db** min.
Total medium reduction = **2.6 db**

CONCLUSION

For further reduction of noise level from inside the cars cabin, soundproofing operations can be done on the firewall, wheel arches, hood and rear floor of the spare tire. Besides using soundproofing material we can buy new tires with a better decibel rating, or it can be installed a suspension that lifts the car from the ground a bit more, so road noise made by tires is further away from the driver or the passengers.
The transmission can be modified from 5 gears to one with 6 gears, so lower RPM can be achieved at higher speeds. The exhaust could be replaced with a new one with even better mufflers and more resonating components.
The windows of the car let through a lot of noise, but they are very tough to improve. Having new windows with more layers of glass for better soundproofing would drastically change the comfort.
All these solutions for further improvement can be very expensive and hard to obtain. There is also the issue of the balance between the acoustic comfort reached with how much the work would be worth it. Continuing to soundproof the roof, wheel arches, hood, firewall and rear

floor would be enough for most people, and it would potentially reduce another estimated 3 dB in noise levels

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