



In-situ Noise Measurement and Analysis for the Motorcycle Muffler

Wei-Hong Tan^{1*}, Hun-Guan Chuah², Ee-Meng Cheng¹, Eng-Aik Lim³, Chip-Hao Lok¹

¹School of Mechatronic Engineering,
Universiti Malaysia Perlis (UniMAP), Pauh Putra Campus, 02600 Arau, Perlis, MALAYSIA

²School of Engineering, Computing & Built Environment,
KDU Penang University College, 10400 Georgetown, Penang, MALAYSIA

³Institute of Engineering Mathematics,
Universiti Malaysia Perlis (UniMAP), Pauh Putra Campus, 02600 Arau, Perlis, MALAYSIA

*Corresponding Author

DOI: <https://doi.org/10.30880/ijie.2020.12.08.005>

Received 7 January 2020; Accepted 25 March 2020; Available online 30 August 2020

Abstract: Noise from the vehicles is one of the noise pollutions to the environment. The noises emitted by the vehicles have to obey the requirement of regulation of maximum sound pressure level permitted for respective vehicles. In this study, the aim is to reduce the noise emitted from the motorcycle muffler. The noise emitted from the motorcycle muffler is analyzed and measured using a sound level meter. The average sound pressure level of the motorcycle muffler is determined in certain conditions. The sound pressure levels for original installed muffler are recorded as 76.4dB, 79.5dB and 82.3dB under the constant speed of 10km/hr, 20km/hr and 30km/hr respectively by engaging 2nd gear. For the acceleration with the scope of 0 km/hr to 30 km/hr, the difference of sound pressure level between 2nd and 4th gear engaged is 5.4dB. The study is continued by using a modified muffler which contains sound absorptive materials. The absorptive materials chosen are glass wool, cotton and Styrofoam and they are taking turn to be placed into the modified muffler to reduce the sound pressure level. Then the experiment is repeated. By applying 100g absorptive materials in the modified muffler, the reduction of sound pressure level are recorded as 12.6% (glass wool), 7.5% (cotton) and 4.4% (Styrofoam) compared with original installed muffler while 2nd gear engaged. Styrofoam is observed does not perform significantly in absorbing sound or noise in this study. Glass wool demonstrates relatively better sound energy absorption compared with cotton. In general, soft and porous materials are considered good performance in sound absorption. Denser materials are better at soundproofing or sound blocking. Therefore, glass wool with relatively higher density among the investigated absorptive materials in this study has the greatest sound absorption performance.

1. Introduction

Noise from the vehicles is one of the major noise pollutions to the environment especially in the urban area [1,2]. Noises emitted by the vehicles have to obey the requirement of regulation of maximum sound pressure level permitted for respective vehicles. Therefore, muffler is one of the important vehicle parts which acts as a silencer to decrease the amount of noise emitted from the combustion of engine. An exhaust system is a combination of metallic pipes with the purpose of re-route the toxic emission from the combustion of gases of the automobile engines [3,4]. If the flow of toxic gases is not handled properly, the gases may get trapped in the system and the performance of engine may be declined.

Exhaust systems are basically made from aluminum, steel, titanium, carbon fiber and alloy [5,6]. A well- maintained muffler can actually increase the engine performance and prolong an engine’s life beside reduce the noise emitted [7,8]. In this study, a standard motorcycle with its engine capacity below 150cc is chosen. It is the most common type of motorcycle that is being used by Malaysian. It is a regular bike with great power as well as fuel efficiency. Motorcycle with engine capacity below 150cc has the lowest fuel consumption among other motorcycles. The original installed motorcycle muffler is tested in normal condition and then it is modified by adding absorptive materials to reduce the noise level emitted by combustion engine of motorcycle.

2. Methodology

This study is conducted by measuring the sound pressure level of motorcycle muffler under a few situations by using a sound level meter. An original installed muffler is tested while idle engine, constant speed (10km/hr, 20km/hr and 30km/hr) and acceleration (in the scope of 0km/hr to 30km/hr). After that, a modified muffler was tested under similar testing criteria with original installed muffler, which included idle engine, constant speed (20km/hr) and acceleration (in the scope of 0km/hr to 30km/hr). It is then continued by the comparison of results and discussions.

2.1 Sound Level Meter

Sound level meter as shown in Fig. 1 is calibrated to the normal level range for calibration which is 30dB to 120dB before conducting the measurement. The sound level meter used in this study is model NL-21, manufactured by Rion Co, Japan. The sound level meter is set as fast time-weighting. A tripod is prepared to hold the sound level meter during the measurement.



Fig. 1 - Sound level meter used in the measurement

2.2 Motorcycle Technical Specification

Honda EX5 as shown in Fig. 2 is chosen as the model of this study since it is the most common motorcycle that can be easily seen on the streets in Malaysia. The technical specification of the motorcycle is tabulated in Table 1.



Fig. 2 - Motorcycle Honda EX5

Table 1 - Technical specification of Honda EX5 [9]

Type	Air-cooler, 4 cycle engine
Engine displacement	97.1 cc
Overall length	1,833mm
Overall width	672mm
Overall height	1,033mm
Wheel base	1,183mm

2.3 Test Site and Environment for Muffler Sound Pressure Level Measurement

According to the standard of SAE J1287 JUL98 stationary sound test procedure, the site of measurement must be in an open space of outdoor to prevent any echoes created which may affect the accuracy of results obtained. The motorcycle should be located at least 2.5m away from any obstacles. Test site ambient sound level (including wind effects) at the site shall be at least 10dB lower than the sound level of the motorcycle tested and wind speed must not exceed 10m/s during the measurement [10,11]. Temperature of the test site should not exceed 40°C, therefore the measurement is preferable conducted in the morning or evening [12]. In this study, the motorcycle was located a distance of 3m away from any obstacles as shown in Fig. 3. The measurement was conducted in the morning at 9am on 3 Mac 2018. The ambient sound level was recorded as 40.7dB for the test site, wind speed is 2.22m/s and ambient temperature is 29°C according to the World Weather Online website [13].

The operator or assistant of measurement was suggested to keep a fair distance from the sound level meter to prevent any noises created. The motorcycle was kept stationary in full stand mode with the engine in the condition of normal running temperature. The sound level meter was placed 50cm away from the motorcycle muffler, on an imaginary line of 45° with respect to the longitudinal axis of the motorcycle, pointing to the motorcycle muffler, which is shown in Fig. 4. It is also placed at least 20cm from the ground where it is aligned to the motorcycle muffler [12] as shown in Fig. 5. The speed of motorcycle was then increased to 10km/hr, 20km/hr and 30km/hr and the sound pressure level was measured for each of the speeds and when the motorcycle was in constant acceleration. The motorcycle was travelled with the specific speed limits (10km/hr, 20km/hr and 20km/hr) before the stationary noise measurement and the throttle was marked in order to make sure the rpm engine was in the desired speed when the motorcycle is undergone stationary noise measurement. All the measures above were repeated at second gear and fourth gear [14].

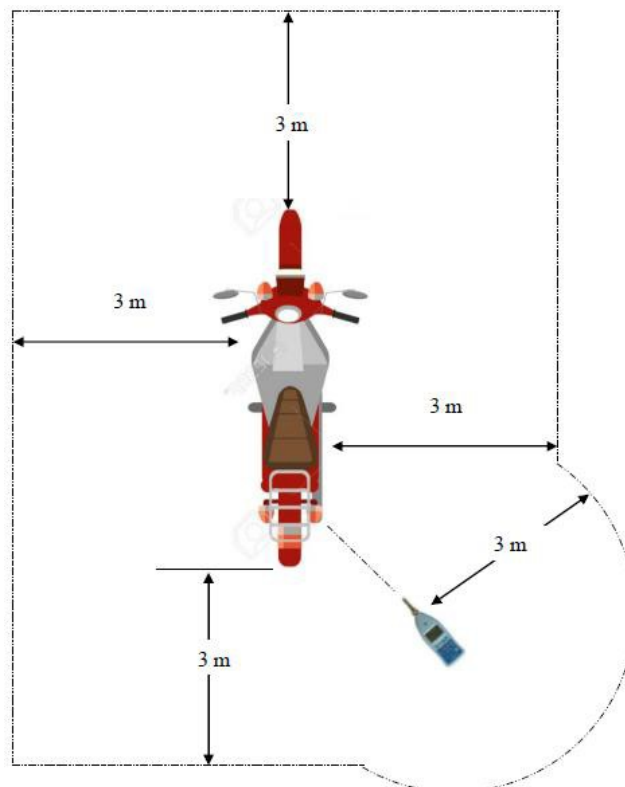


Fig. 3 - The clearance to leave around the motorcycle and sound level meter [10, 11, 14]

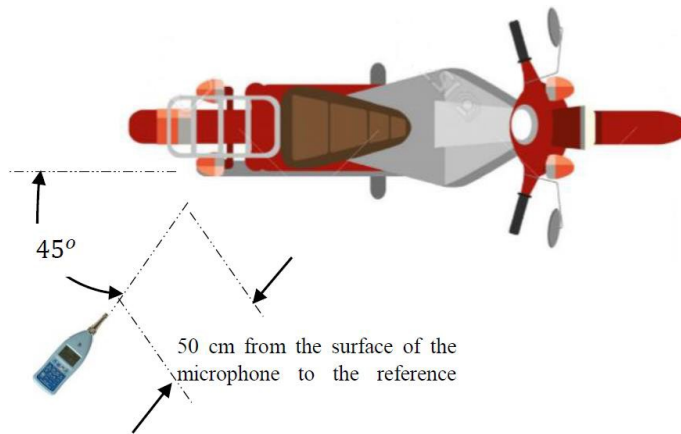


Fig. 4 - 50cm distance and 45° angle of sound level meter [10, 11, 14]



Fig. 5 - 20cm height of sound level meter to the reference point [10, 11, 14]

3. Materials

The absorptive materials used in this study are glass wool, cotton and Styrofoam as shown in Fig. 6 (a), (b) and (c) respectively. The suggestion of using glass wool and Styrofoam as absorptive material in the motorcycle muffler is due to the characteristics of recyclable, high thermal insulation, excellent sound insulation and lightweight [15]. Cotton is considered a biodegradability, safe, lightweight, and low-cost absorptive material. At the same time, it is also widely used as sound absorber for the cost-effective acoustical materials in building [16,17]. Thus, it is believed the noise level come from motorcycle muffler will be reduced by applying glass wool, Styrofoam and cotton in the original installed muffler [18]. Fig. 7 shows the motorcycle muffler is used to be dissected. The casing of muffler is cut for inserting absorptive materials in the muffler as depicted in Fig. 8. Fig. 9 shows the cross section of motorcycle muffler where the absorptive materials applied in the void space between casing and inner wall. Glass wool, cotton and foam are attached inside the void space between casing and inner wall of muffler will will enhance the sound absorption. All the measurement results are recorded and the abilities of sound absorption between these sound absorption materials are compared and discussed.

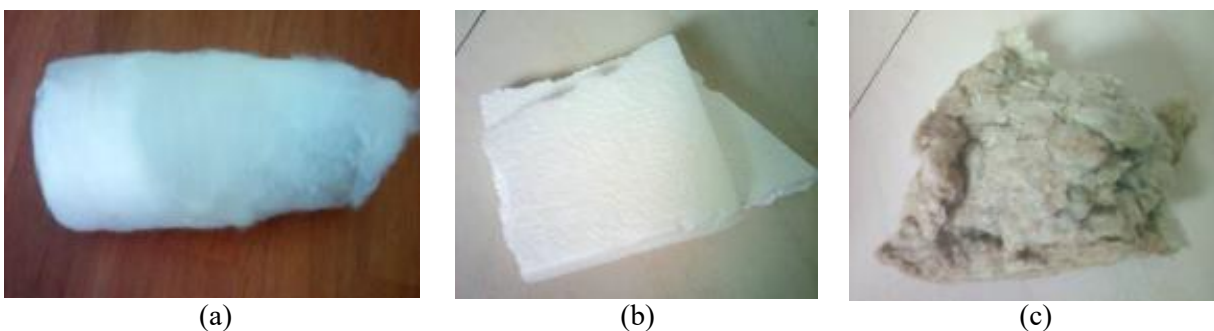


Fig. 6 - (a) cotton, (b) styrofoam and (c) glass wool



Fig. 7 - Motorcycle muffler to be modified



The casing of motorcycle muffler is cut in to half but the perforated tube is remained uncut.

Fig. 8 - The modified motorcycle muffler



Fig. 9 - Cross section of motorcycle muffler where the sound absorption materials applied

4. Result and Discussion

In this section, the measurement results of the original installed muffler and modified muffler with absorptive materials (cotton, glass wool and Styrofoam) are obtained. The significant outputs from the measurements will be explained and discussed.

4.1 Original Installed Muffler

The experiment is first tested on an idle engine to obtain the sound pressure level of original installed muffler. The test is conducted for 1 minute and about 60 data are collected. The average sound pressure level is determined by the logarithmic average theory. The average sound pressure level is calculated from a set of data which is 68.9dB. Fig. 10 shows the differences of sound pressure levels between 2nd and 4th gears are 2.6dB, 3.7dB and 3.1dB in 10km/hr, 20km/hr and 30km/hr respectively. The measures are conducted in different gears but in the same speed. The results show a significant influence of using the same speed of gear but different transmission and rotating speed of engine or rpm of engine. When the motorcycle is in 2nd gear, the engine is at greater rpm while a greater torque is supplied to the output shaft of the gearbox. Since the 2nd gear is larger than the 4th gear according the gear ratio, larger gear supplies higher torque in the same speed. Therefore, greater noise produced by the motorcycle muffler.

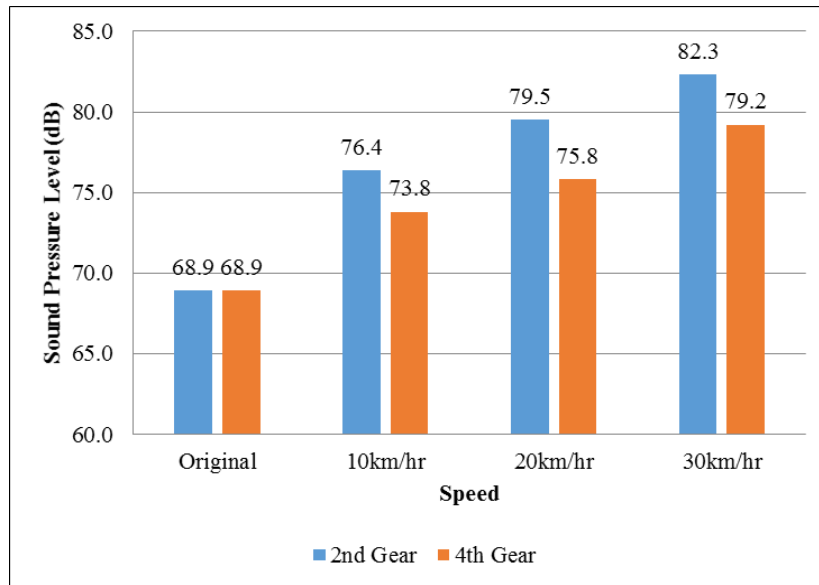


Fig. 10 - Comparison of sound pressure level between 2nd and 4th gear in different speed

In this study, the sound pressure level of original installed muffler in 2nd gear is recorded for seconds and the test is repeated 5 times to achieve better and more accurate average value of sound pressure level. There are 7 readings are recorded each time and a total of 35 readings are being used to be analyzed. The acceleration of the motorcycle from stationary to 30km/hr only happen in about 5-7 seconds therefore only 7 readings can be collected in a test. While in 4th gear, the time taken is slightly longer than using 2nd gear. 12 data collected per test and 5 tests are conducted to increase the sample size of readings. Total 60 readings obtained for the sound pressure level of the motorcycle acceleration in 4th gear. The sound pressure levels during acceleration as shown in Fig. 11, having a fair amount of difference between both gears which is 5.4dB. In this case, the motorcycle is accelerated in the scope of 0km/hr to 30km/hr. The 2nd gear has a higher gear ratio, the higher of gear ratio, and the greater of acceleration. By using 2nd gear, it takes less time to achieve 30km/hr compared with 4th gear. Thus, louder noise is induced due to higher torque produced by the 2nd gear.

Table 2 includes all the sound pressure levels recorded in different categories. The results are based on the average sound pressure levels calculated when the motorcycle is in constant speed (10km/hr, 20km/hr and 30km/hr) and acceleration (in the scope of 0km/hr to 30km/hr). The differences of sound pressure level between both gears are also displayed in Table2.

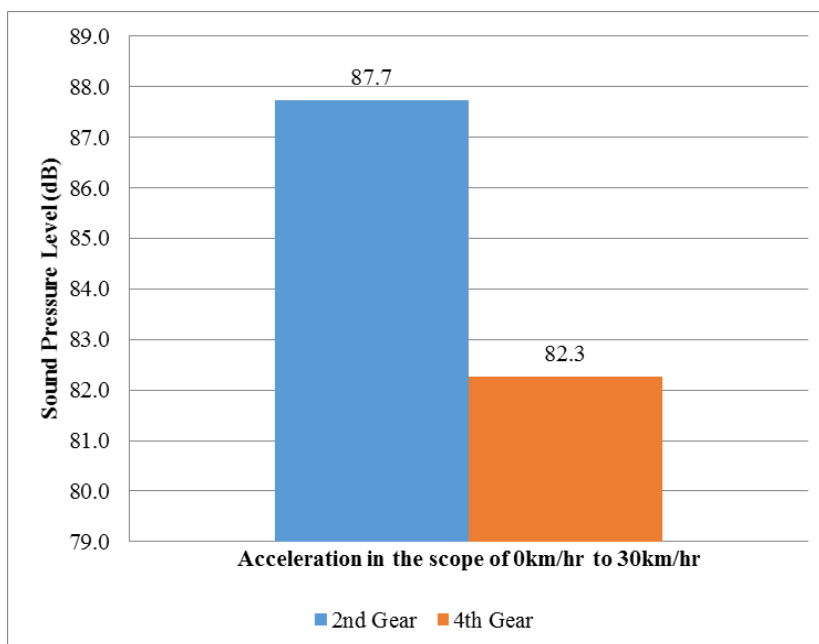


Fig. 11 - Comparison of sound pressure level between 2nd and 4th gear in acceleration

Table 2 - Sound pressure level of the original installed muffler

Category	Type of Gear	Sound Pressure Level (dB)	Difference (dB)
	Idle Engine	68.9	
Constant Speed (10km/hr)	2nd	76.4	2.6
	4th	73.8	
Constant Speed (20km/hr)	2nd	79.5	3.7
	4th	75.8	
Constant Speed (30km/hr)	2nd	82.3	3.1
	4th	79.2	
Acceleration (0-30km/hr)	2nd	87.7	5.4
	4th	82.3	

4.2 Modified Muffler

Table 3 lists the sound pressure levels of absorptive materials in different mass to ease the comparison process. The sound pressure level of the original installed muffler decreases from 68.9dB in idle engine to 51.9dB after attaching with 150g of glass wool. By using cotton, the sound pressure level drops to 62.5dB, less effective compared with glass wool. Lastly, 150g of Styrofoam reduces the sound pressure level to 66.1dB only. Styrofoam is considered less effective sound absorptive material among these three materials used in this study.

Based on Fig. 12, glass wool has the greatest sound absorption ability among three absorptive materials chosen for this study. There are lowest sound pressure levels observed by the modified muffler attached with glass wool, followed by the modified muffler attached with cotton. It is found that sound absorption ability of Styrofoam is insignificant as the sound pressure levels are scored the highest among three chosen absorptive materials. It is observed that three absorptive materials are sharing the same trend where sound pressure level decreases as the mass of absorptive materials increases. According to this study, glass wool is considered more suitable absorption material in constructing a hybrid-type muffler.

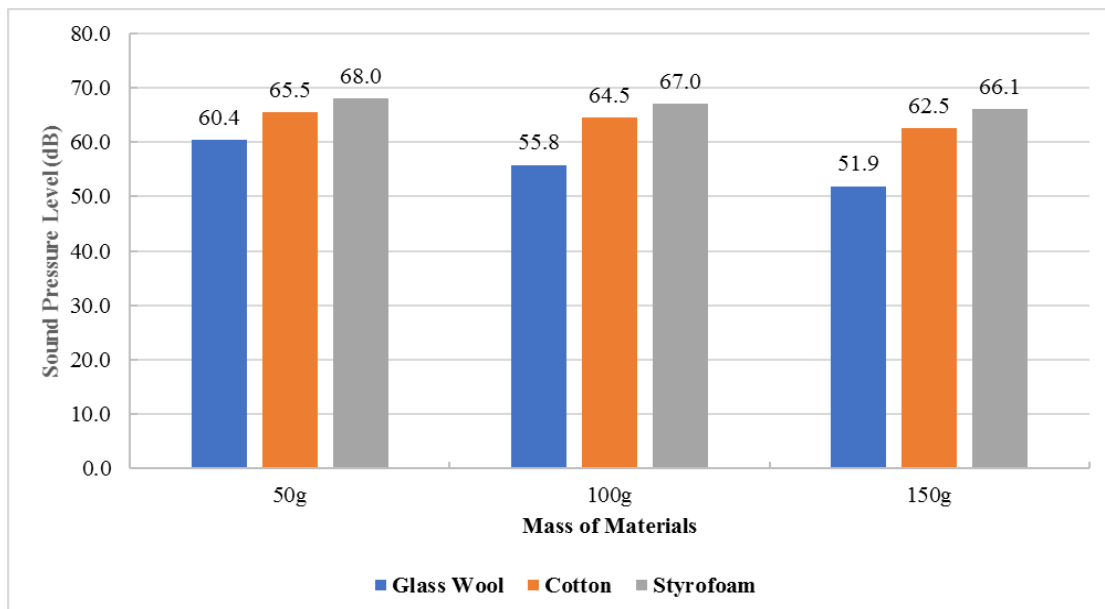


Fig. 12 - Comparison of sound pressure level between 3 absorptive materials in the modified muffler

Table 3 - Sound pressure level of modified muffler

Material	Mass (g)	Sound Pressure Level (dB)
Glass wool	50	60.4
	100	55.8
	150	51.9
Cotton	50	65.5
	100	64.5
	150	62.5
Styrofoam	50	68.0
	100	67.0
	150	66.1

The sound pressure level of 4th gear is lower compared with 2nd gear as shown in Fig. 13 and Table 4. The differences between both gears are 2.0dB, 1.1dB and 2.5dB when glass wool, cotton and Styrofoam are applied in the motorcycle muffler respectively. By attaching absorption materials, the trend or pattern of graph does not experience any crucial changes.

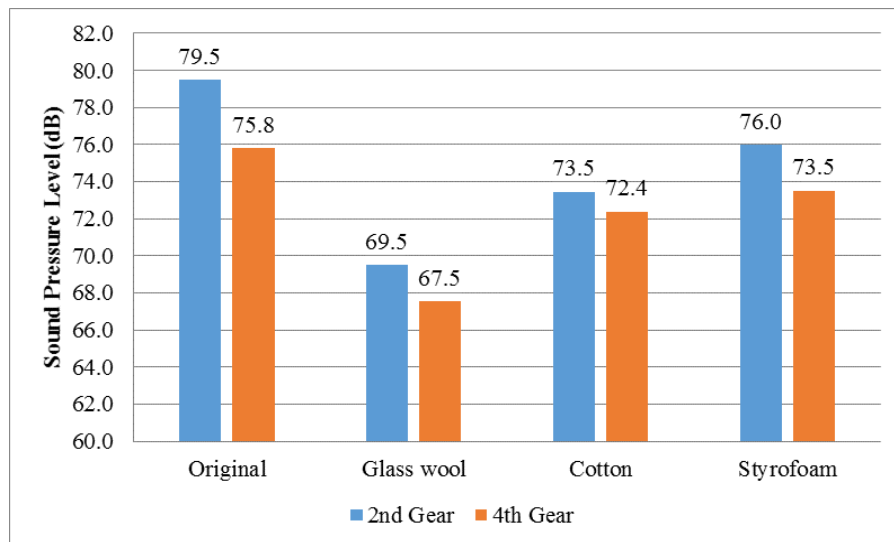


Fig. 13 - Comparison of sound pressure level between 2nd and 4th gear in constant speed (20km/hr) using 100g of absorptive materials

Table 4 - Sound pressure level of modified muffler in constant speed (20km/hr) using 100g of absorptive materials

Material	Type of Gear	Sound Pressure Level (dB)	Difference (dB)
Original	2nd	79.5	3.7
	4th	75.8	
Glass wool	2nd	69.5	2.0
	4th	67.5	
Cotton	2nd	73.5	1.1
	4th	72.4	
Styrofoam	2nd	76.0	2.5
	4th	73.5	

Fig. 14 and Table 5 shows that glass wool is still remained the best sound absorber among the selected materials. The mass of the absorptive materials used is 100g. By attaching glass wool in the modified muffler, the sound pressure level reduced from 87.7dB to 74.6dB (14.93%) in 2nd gear and 82.3dB to 71.7dB (12.88%) in 4th gear. When engaging to 2nd gear, the sound pressure levels are recorded as 74.6dB, 80.8dB and 82.2dB for glass wool, cotton and Styrofoam respectively. Sound pressure levels are dropped to 71.7dB, 76.4dB and 78.4dB for glass wool, cotton and Styrofoam respectively when 4th gear is engaged.

It is found that the differences between 2nd and 4th gear are 2.9dB, 4.4dB and 3.8dB for glass wool, cotton and Styrofoam respectively. It can be observed that the pattern of graph (Fig. 14) is not much difference by switching from 2nd to 4th gear even attaching with absorptive materials in the motorcycle muffler. In general, sound pressure level of modified muffler in 2nd gear is higher than in 4th gear.

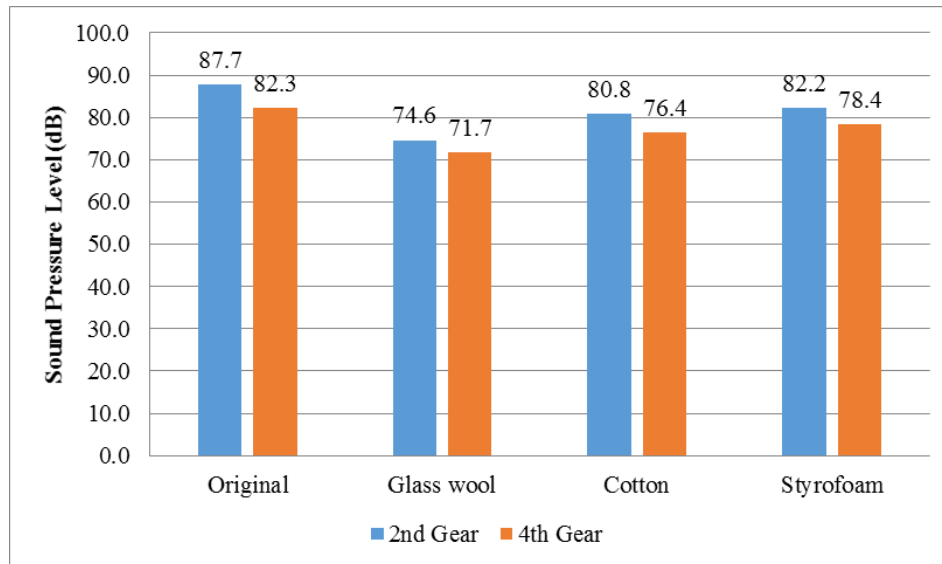


Fig. 14 - Comparison of sound pressure level between 2nd and 4th gear in acceleration using 100g of absorptive materials

Table 5 - Sound pressure level of modified muffler in acceleration using 100g of absorptive materials

Material	Type of Gear	Sound Pressure Level (dB)	Difference (dB)
Original	2nd	87.7	5.4
	4th	82.3	
Glass wool	2nd	74.6	2.9
	4th	71.7	
Cotton	2nd	80.8	4.4
	4th	76.4	
Styrofoam	2nd	82.2	3.8
	4th	78.4	

5. Conclusion

Most of the motorcycle mufflers in the market are reflective type of muffler. In this study, original installed muffler has a higher sound pressure level as recorded 68.9dB due to its simple design of reflective type muffler. The addition of absorptive materials in the muffler can decrease the sound pressure level of motorcycle muffler and transform the motorcycle muffler into hybrid-type muffler. The percentage of sound pressure level decreased from the original sound pressure level of idle engine are 12.33%, 19.01% and 24.67% when the masses of glass wool are 50g, 100g and 150g respectively. Styrofoam does not perform well in absorbing sound or noise in this study. Glass wool and cotton are decent sound absorber in sound absorbing where glass wool is slightly better. Generally, soft and porous materials are good sound absorber. Denser materials are considered better for soundproofing or sound blocking. Glass wool with the highest density among the absorptive materials in this study has the greatest performance.

Acknowledgement

The authors would like to thank School of Mechatronics University Malaysia Perlis (UniMAP) for providing the equipment and environment to success the study.

References

- [1] Segaran, V. C. (2019). Assessment of traffic noise pollutions outside school, residential, hospital and commercial areas along Jalan Kluang, Batu Pahat, Johor. *International Journal of Integrated Engineering*, 11(9), 123-131.
- [2] Halim, H. (2019). Road traffic noise levels at different types of residential areas in Nibong Tebal, Penang. *International Journal of Integrated Engineering*, 11(1), 101-112.
- [3] Tan, W. H., & Mohd Ripin, Z. (2013). Analysis of exhaust muffler with micro-perforated panel. *Journal of Vibroengineering*, 15(2), 558-573.
- [4] Lee, S., Bolton, J. S., & Martinson, P. A. (2016). Design of multi-chamber cylindrical silencers with microperforated elements. *Noise Control Engineering Journal*, 64(4), 532-543.
- [5] Kimbrough, B. (2014). Understanding muffler design and sound absorption strategies. Available: <https://www.fordmuscle.com/tech-stories/exhaust/understanding-muffler-design-and-sound-absorption-strategies/>.
- [6] Arenas, J. P. & Crocker, M. J. J. S. (2010). Recent trends in porous sound-absorbing materials. *Sound & Vibration*, 44(7), pp. 12-18.
- [7] Anami, B. S., & Pagi, V. B. (2013). Acoustic signal based detection and localisation of faults in motorcycles. *IET Intelligent Transport Systems*, 8(4), 345-351.
- [8] Jia, B., Smallbone, A., Zuo, Z., Feng, H., & Roskilly, A. P. (2016). Design and simulation of a two-or four-stroke free-piston engine generator for range extender applications. *Energy conversion and management*, 111, 289-298.
- [9] Siew, B. (2017). Boon Siew Honda - Passion Towards Dreams - EX5_FI specification. Available: <https://www.boonsiewhonda.com.my/english/product-ex5-fi-spec.html>.
- [10] SAE International: J1287: Measurement of Exhaust Sound Levels of Stationary Motorcycles—SAE International (2017)
- [11] United States Department of Agriculture (2012). Spark Arrester Guide Off – Highway Vehicle (OHV) Volume 3. Available: https://www.fs.fed.us/t-d/programs/fire/spark_arrester_guides/_assets/2012_OHV.pdf.
- [12] Lévesque, B. Measurement of exhaust pipe sound pressure levels of stationary motorcycles. Department of Mechanical Engineering, Université Laval, 1-24.
- [13] World Weather Online- Kampung Ulu Pauh, Perlis Malaysia Historical Weather. Available: <https://www.worldweatheronline.com/kampung-ulu-pauh-weather-history/perlis/my.aspx>
- [14] Figlus, T., Wilk, A., Liscák, S. & Kalafarski, M. (2013). The influence of muffler type of the exhaust system in the sports motorcycle on the level of the emitted noise. *Acta Technica Corviniensis-Bulletin of Engineering*, 6(4), 59.
- [15] Jeon, C. K., Lee, J. S., Chung, H., Kim, J. H., & Park, J. P. (2017). A study on insulation characteristics of glass wool and mineral wool coated with a polysiloxane agent. *Advances in Materials Science and Engineering*, 1-6.
- [16] Collings, S., & Stewart, K. (2011). Building material panel transmission loss evaluation using an impedance tube, *Proceedings of the ACOUSTICS 2011*. Gold Coast, Australia, paper 113.
- [17] Callister, W. D., & Rethwisch, D. G. (2011). *Materials science and engineering* (9th ed.). New York: John Wiley & Sons.
- [18] Nasri, S. M., & Shofwati, I. (2018). Utilization of Styrofoam as Soundproofing Material with Auditory Frequency Range. *Kesmas: National Public Health Journal*, 13(2), 99-104.