An experiment on different type of muffler on spark Ignition engine 110 cc performance

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Abstract. The design of the exhaust system affects many parameters such as reducing the noise level, control velocity, temperature, back-pressure of exhaust gas and reduce pollution production. The exhaust system has many parts which consist of an exhaust manifold, resonator, catalytic converter, muffler, and connecting pipes. Muffler has the main function as a noise absorber. Furthermore, the temperature distribution on mufflers is also affected by fuel consumption by reducing back-pressure effect. This study has conducted an experiment to determine the effect of modified muffler shape in a motorcycle which consists of standard, scorpion, and 3v3 type. The effects of mufflers' performance on the motorcycle are described on torque and power graphics. Furthermore, this study explains the muffler geometry effect on noise reduction from the combustion process. The installation of 3v3 muffler decreases torque and power in a motorcycle. Moreover, the installation of 3v3 muffler type raises noise pollution level which generates by the engine combustion process.

1. Introduction

1.1. Exhaust system on reducing pollution particle

The automotive vehicle uses is very effective to transport goods and passengers immediately. However the use of automotive vehicle enhancement pollution to our environment such as noise, emission gas, and increase the global warming effect. Emission gas flows through the exhaust system which consists of piping lines from the combustion chamber to the surrounding air. The amount of pollution product can be reduce by using biofuel, ethanol, catalyst pollution control, and modified exhaust design. Ethanol (C₂H₅OH) is a low price renewable energy which can be regenerated by fermentation process. Ethanol-gasoline is a suitable candidate as an alternative engine fuel with 25-45% efficiency range [1]. Biofuel reduce air pollution such as smoke, carbon monoxide (CO) and hydrocarbon (HC). Meanwhile using biofuel in combustion process resulted cold flow properties, high viscosity, poor oxidation stability and high nitrogen oxides (NOₓ) emissions[2]. Emission production in combustion process can be control by using catalyst pollution control. The commercial vehicles reduce the amount of particles production, but produce very fine and reactive fullerene-like soot. The fine particles size potentially absorb to human lung membranes. A particulate matter catalyst system (PMKAT) consisting of a platinum oxidation catalyst and metallic substrates with open cells for storage and oxidation of soot. This system can be reducing the amount of soot particle spreading through the environment[3]. Exhaust system is modified to reduce noise and air pollution for example by using asbestos fibre material[4]. Combustion engine modifying can be done in order to reduce emission product in combustion process for example by modifying the material that used in spark plug. Iridium spark plug reduce HC and CO emission on high
speed motor cycle effectively[5]. Moreover, the use of spark plugs from iridium material can also improve engine performance which is indicated by an increase in engine power output[6].

The design of exhaust system affects many parameters such as reducing the noise level, control velocity, temperature, back pressure of exhaust gas and reduce pollution production[7][8]. Back pressure is defined as gas emission which is flowing back to the combustion chamber and causes nonstoichiometric combustion[9]. This condition is affected by the high pressure of inlet air which used in the combustion process is mixed with emission gas and reduces the amount of oxygen. The part of the exhaust system consists of exhaust manifold, resonator, catalytic converter, muffler, and connecting pipes.

1.2. The modified of exhaust manifold on reducing pollution particle
Exhaust manifold is commonly modified to create optimum by considering parameters include pipe diameter, length, and geometry. The exhaust manifold is installed to prevent exhaust gases from entering the combustion chamber. Manifold tube Intake and exhaust diameter aim to maintain exhaust gas backflow. The increment diameter of exhaust manifold hole can reduce exhaust gas flow to the combustion chamber[10]. Moreover the angle of manifold elbow also affected on back pressure forming process. Exhaust manifold with 90° bend angle reduce amount of emission gas flows back to the combustion chamber[11]. A Reactive muffler has resonator chamber to reduce low-frequency noise generated by combustion process. The Reactive muffler can be modifying as U-shaped corrugated pipes which reduce noise pollution significantly above the upper cut-off frequency range[12]. Furthermore perforation area inside the muffler aim to reduce back pressure and emission gas especially NOx[13]. The study on the combustion process in an automotive vehicle can be done through a simulation process by software[7] [8] [13][14]. The results of the simulation process can be described through qualitative data such as velocity vector, temperature, and pressure couture. Simulation study should be accompanied by a validation process to get relevant data that close to the real condition[15].

Muffler can be classified as absorptive and reactive based on its function. The reactive muffler dissipates noise energy in specific geometry. Circular muffler absorb in the frequency range less than 200 Hz. Meanwhile rectangular muffler has better performance to absorb noise more than 200 Hz [16]. Although the main function of muffler is to reduce noise pollution, muffler temperature distribution also affected on fuel consumption by reducing back pressure effect [17]. This study is conducted an experiment to determine the effect of different geometry on modified muffler shape which used on 4 strokes motorcycle, Jupiter Z 110 cc. The effects of mufflers on motorcycle performance are described on torque and power graphics. Furthermore, this study explains the muffler geometry effect on noise reduction from combustion process.

2. Methodology
This experiment conducted on 3 types of mufflers which consist of standard, 3v3, and scorpion type as shown in figure 1, figure 2, and figure 3. The performance of motorcycle measures by chassis dynamometer 3.2. The data of motorcycle performance which obtained dynamometer test is torque and power on specific angular velocity (RPM). Tachometer is used ensure the speed of motorcycle is at certain rpm in testing process. Muffler noise measures with digital noise analyser.

Experiment procedure begins with turning on and running the machine without intercooler at idle condition. Then set up the carburettor in stoichiometry condition to prevent too rich and lean air fuel ratio in combustion process. Engine performance tests with dynamometer between 2000 - 10000 rpm with increment of 1000 rpm in each data retrieval.
3. Equations and Mathematic

The motorcycle performances are described on torque, power, and brake specific fuel consumption ($B_{sfc}$). There are several equations that can be used in this study including:

\[ B_{sfc} = \frac{m_f}{W_b} \]  \hspace{1cm} (1)

\[ W_b = \eta_m \cdot W_i \]  \hspace{1cm} (2)

\[ W_i = W_{net} \cdot N \]  \hspace{1cm} (3)

\[ W_{net} = \eta_t \cdot Q_{in} \]  \hspace{1cm} (4)

With:

- $B_{sfc}$ : Brake specific fuel consumption (kg/hp.hr)
- $m_f$ : Mass fuel consumption (kg/hr)
- $W_b$ : Brake horse power (hp)
- $W_i$ : Indicative horse power (hp)
- $W_{net}$ : Mean horse power (hp)
- $Q_{in}$ : Inlet Energy (kJ)
- $N$ : Angular velocity (rpm)
- $\eta_m$ : Mechanical efficiency
- $\eta_t$ : Thermal efficiency

In this study the power and torque data from the motorcycle were obtained from the result of dynamometer test. Meanwhile the mass flow fuel consumption can be calculated using Pyrex and a digital stopwatch.
4. Result and Discussion

4.1. The difference of geometry muffler on motorcycle performance

The effect of different muffler geometry on motorcycle performance is discussed in this section. The performance of motorcycle which analysed in this section is power and torque from dynamometer test. Torque is described as the force to pull vehicle and causes rotation. A higher torque level at low engine RPM indicates the motorcycle pulls some load without much effort and speed losses. The torque resulting by dynamometer test is shown in figure 4. Torque produced by the engine increases along with motorcycle RPM increment. Increased speed on the motorcycle causes increased fuel consumption and produces high torque on the engine. “In figure 4 shows that a motorcycle with scorpion muffler type produces higher torque compared to standard muffler. The 3v3 muffler produces the lowest torque compared with the other type. Moreover different types of mufflers also affected on the maximum rpm that can be achieved by the engine. Standard muffler has the shortest range of angular velocity in 7500 rpm. Meanwhile the modified mufflers have longer range where the maximum range of 3v3 muffler is 9000 rpm and scorpion muffler 9500 rpm.

Power is the result of multiplication between torque and angular velocity (RPM). The higher torque and angular velocity (RPM) that produced by the engine resulted higher the power output. The power resulted by dynamometer test is shown in figure 5. The graphics of torque and power have similar trend line. The installation of 3v3 mufflers resulted unsatisfied performance on a 110 cc Jupiter Z motorcycle. It has lowest torque trend line which gain less power among another muffler. High rpm and torque on scorpion muffler resulted higher engine power in motorcycle. Higher engine power has an impact on shorter acceleration time.

![Figure 4. Torque as a function of angular velocity of dynamometer test result in various mufflers type without intercooler](image-url)
At the highest point of rpm, engine throttle is fully open rapidly and the combustion process occurs in rich conditions. In this point the fuel combust incompletely and result lower power. This combustion process produce high amount of harmful pollution such as CO, C, CO₂ and unburned fuel. These exhaust gas can flow back into the engine and ruin combustion process. When a motorcycle with 3v3 muffler reaches maximum rpm, it has higher power compared to another muffler. This condition may be affected by the effectiveness of 3v3 muffler in reducing back pressure.

4.2. The difference of geometry muffler on noise reduction
The main function of the muffler installation is to reduce the noise which generated by the combustion process. Noise reduction which affected by muffler installation is shown in figure 6. Standard mufflers produce sounds with intensity of 101.7 db. This noise level can damage human hearing system in 2 hour. Scorpion muffler is effective in reducing noise in the motorcycle. Scorpion mufflers are equipped with a resonator chamber, perforated pipe and long exhaust pipe. This installation absorbs noise pollution generated by the engine effectively until 99.4 db. Meanwhile the 3v3 muffler produces higher noise pollution than standard muffler with intensity of 102.2 db. Exhaust pipe in 3v3 muffler has a shorter size than the scorpion muffler. The shorter size of exhaust pipe causes back pressure condition on exhaust gas.
5. Conclusions

The scorpion muffler is effective to reduce noise pollution and resulted high power on Jupiter z 100 cc. This type of muffler is suitable to increase the motor cycle performance. The installation of 3v3 muffler decrease torque and power in motorcycle. Moreover the installation of 3v3 muffler type raises noise pollution level which generate by engine combustion process.

6. References

[1] Setyono G, Arifin AA. EFFECT OF ETHANOL-GASOLINE MIXES ON PERFORMANCES IN LAST GENERATION SPARK-IGNITION ENGINES WITHIN THE SPARK-PLUG NO GROUND-ELECTRODES TYPE. Mek J Tek Mesin 2019; 5: 19–26.
[2] Mahalingam A, Dinesh, Munuswamy B, et al. INVESTIGATION ON THE EMISSION REDUCTION TECHNIQUE IN ACETONE-BIODIESEL ASPIRATED DIESEL ENGINE. DOI: 10.21894/jopr.2018.0020.
[3] Su DS, Müller JO, Jentoft RE, et al. Fullerene-like soot from EuroIV diesel engine: Consequences for catalytic automotive pollution control. In: Topics in Catalysis. Springer, 2004, pp. 241–246.
[4] Kathiravan Bahir R. An Experiment on Noise and Emission Control in a Modified Exhaust System Energy system technology for power electronics View project Natural Fibers and its composites View project An Experiment on Noise and Emission Control in a Modified Exhaust System, http://www.ripublication.com (2018, accessed 2 June 2020).
[5] Setyono G, Kawano DS. PENGARUH PENGGUNAAN BUSI BERELEKTRODA NIKEIL, PLATINUM DAN IRIDIUM TERHADAP PERFORMA MOTOR BENSIN TORAK SPARK IGNITION ENGINE (SIE) 4 LANGKAH 1 SILINDER.
[6] Setyono G, Kawono DS. Pengaruh Penggunaan Variasi Elektroda Busi terhadap Performa Motor Bensin Torak 4 Langkah. J SAINTEK; 11, www.kopertis7.go.id, (2014, accessed 4 June 2020).
[7] Obodeh O, Ogbor AD. Improving the performance of two-stroke motorcycle with tuned adjustable exhaust pipe. Res J Appl Sci Eng Technol 2009; 1: 59–65.
[8] Mangukiya S. Optimizing the Design of Intake & Exhaust System of a Single Cylinder Motorcycle Engine for Formula Student Vehicle, http://www.ripublication.com (2018, accessed 6 May 2020).
[9] Sharma T, Khan Z, George J. INQUISITIVE ANALYTICS OF DIVERSE EXHAUST SYSTEM CONTINGENT TO POLLUTION. Int Res J Eng Technol 2008; 1226.
[10] Rojan MA, Alias Z, Bakar SA, et al. Enhancement of MODENAS CT115’S motorcycle muffler performance by optimization of backpressure. DOI: 10.1088/1757-899X/670/1/012063.

[11] Tkaczyk M. CFD Tests of the Exhaust System of a Sports Motorcycle. J KONES ; 25, https://content.sciendo.com/view/journals/kones/25/4/article-p429.xml (2019, accessed 6 May 2020).

[12] Xue F, Sun B. Experimental study on the comprehensive performance of the application of U-shaped corrugated pipes into reactive mufflers. Appl Acoust 2018; 141: 362–370.

[13] Mishra PC, Kar SK, Mishra H. Effect of perforation on exhaust performance of a turbo pipe type muffler using methanol and gasoline blended fuel: A step to NOx control. J Clean Prod 2018; 183: 869–879.

[14] Meena R, Ramachandra P, Dube A. A 3D-CFD Study of Flow Dynamics on Mixture Preparation for Fuel Injected Motorcycles.

[15] Lillahulhaq Z, Maulana HS. Pengaruh Model Turbulensi Aliran Terhadap Simulasi Numerik Aircurtain. Mek J Tek Mesin 2019; 5: 27–42.

[16] Ranjbar M, Arslan H, Dalkılıç B, et al. On Muffler Design for Transmitted Noise Reduction Multidisciplinary Design Optimization of Auxetic Structures View project Review on applications of the AUXETIC beams View project On Muffler Design for Transmitted Noise Reduction, https://www.researchgate.net/publication/320895026 (2017, accessed 10 May 2020).

[17] Mishra PC, Kar SK, Mishra H, et al. Modeling for combined effect of muffler geometry modification and blended fuel use on exhaust performance of a four stroke engine: A computational fluid dynamics approach. Appl Therm Eng 2016; 108: 1105–1118.