Detection of active noise control on the standard motorcycle exhaust Supra X 125 D using PVC pipe technique form Y

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Abstract. This detection aims to obtain noise reduction on the supra X 125D motorcycle exhaust by using the Active Noise Control Method. The technique is done using a Y-shaped PVC pipe to be bolted on the exhaust, which then branch Y PVC is placed loudspeaker with impermeable conditions. The function of this loudspeaker is as a secondary noise to counter the primary noise of the sound of exhaust motorcycle Supra X 125D. The sound generator in this study is the ISD 4004 module, which serves to generate noise to counter the source noise. How this ISD 4004 module works is by recording source noise then recording the source noise and then reversed the phase 180° by phase reversing circuit. So that, the noise generated by the sound generator will hit the source noise and encounter or such as addition of two different phase of sound will result in noise reduction when detected at the end of the Y-shaped PVC pipe. Inverted phase reversed using feed-back resistor 1 kΩ and 2 kΩ input resistors, 16V capacitor 2500μf and as amplifier using ICL 7660 and TL 702 CP. Test results on the highest 1000 rpm rotation engine speed on the Z axis of 2 dB, and at the highest 2000 rpm rotation engine speed also occurs on the Z axis of 1.5 dB.

1. Introduction
Comfort and tranquility in the environment is a thing that is very desired by many people, but unfortunately at this time the noise level of environment has not made comfort in human hearing again. It relate to the development of motor fuel engines, gas turbines, fan, blower and so on that are widely used in factories and also on transportation equipment that emit noise to the environment.

Commercial motorcycle exhaust (made of manufacturer) still emit noise significantly in the environment. The conventional method of silencing is done passively by placing dampers around the noise source or in the damped space. In this study, an active damping method is created by generating different phase of noise i.e 180° with the existing noise source. When both sources of sound are reunited, then both will weaken each other. But all experts are understandable in practice there is no ideal condition, meaning it is not possible zero conditions can be achieved. Therefore, the authors create the design of the Active Noise Control device, which will be tested on the muffler standard Supra X 125D motorcycle.
From some previous research which has been done above, has been reported that is applying active noise control on simulation media of PVC tube pipe by playing sound of speaker 1 and speaker sound 2 with same frequency and seen noise reduction happened to oscilloscope. While the method of damping with carpet made on PVC tube and tested directly on motorcycle exhaust by comparing the noise of exhaust noise before given carpet damper and noise after given carpet damper by calculating the absorbing coefficient of the sound.

In this research, an electronic device capable of generating sound signal to fight the sound of standard exhaust that is same frequency to be considered and make phase shift 180⁰ so that noise reduction can occur. The method that is done, a signal generator ISD 4004 records the sound of the exhaust. A phase shifter function increase the phase of counter sound then translated through the speakers with the phase upside down and encounter with the sound of the exhaust directly.

2. Method

This research is conducted with two stages as follows: (1) Experiment was carried out on a PVC tube that a sound signal and a sound opponent signal was taken through two speakers coming from the same sound source. Here, from an amplifier without a phase reversal device. The distance between the two speakers is adjusted and the measurement direction using the sound pressure level is also set up.

The experimental scheme can be seen in Figure 1 to prove whether there is a noise reduction [1].

![Experimental design using PVC tubes.](image)

Caption: (1) The length of the pipeline is 45 cm; (2) the overall pipe length is 120 cm; (3) diameter of pipe 11.5 cm (4 inch); (4) Pipe angle 45 degree angle.

At the time of the test, occurred echoes on PVC tubes. Acoustical material has been added as anti-echo sound absorbers in the form of carpets. The ratio of the sound energy absorbed by a material to the sound energy coming on the surface of material is defined as the coefficient of sound absorption or the absorption coefficient (\(\alpha\)). It can be explained in the following formula.

\[
\alpha = \frac{W_a}{W_i}
\]

Where:

- \(\alpha\): Coefficient of sound absorption.
- \(W_a\): the sound energy absorbed.
- \(W_i\): the sound energy that comes on the surface of material.

From the test, it is obtained that the absorption coefficient of sound before the carpet damper installed around 78.4 dB and after installed carpet damper around 78.2 dB. The absorption coefficient of sound:
\[ \alpha = \frac{0.2 \text{ dB}}{78.4 \text{ dB}} \]

\[ \alpha = 0.0025 \text{ dB} \]

So, the carpet absorption coefficient is 0.0025 dB.

The form of carpet damper mounted on PVC tube can be seen in Figure 2 below.

Figure 2. Carpet Silencer on PVC Pipes.

Regarding the experiment on PVC tube, the test result is reported as follow:
1. The amount of sound generated by speaker 1 is 78.2 dB.
2. The amount of sound generated by speakers 2 is 78.2 dB.
3. Measurement results with Sound Pressure Level of the speaker 1 and speaker 2 is 77.1 dB. So the noise reduction that occurred in this experiment was 78.2 dB - 77.1 dB = 1.1 dB.

A prototype of active noise control with phase inverting is designed to obtain a greater noise reduction. For more details set-up of noise data retrieval on the exhaust, sketched picture can be seen in Figure 3.

Figure 3. Set-up of noise data retrieval on exhaust

Set-up of the exhaust sound data retrieval of the active noise control device, the design of experimental equipments look as with red circled parts i.e amplifiers, ISD 4004 sound recorders, phase inverters, speakers and PVC pipe tubes.

2.1. Sketch of Measurement Direction on the Muffler
Measurements were made using a half-sphere method with (1) vertical directions (Z); (2) horizontal direction (-X, + X); and (3) axial direction (Y). The measuring has taken from the back, side and top
of the exhaust using the sound pressure level gauge. Variations of measurement directions are performed to obtain various reduction values that occur, as in Figure 4 below:

![Figure 4. Sketch of direction noise measurement of a half-sphere method [3].](image)

2.2 Use of Amplifier and Speaker

Selection of amplifiers in this study is the thing that affects the resulting sound to generate a sound signal that is useful to adjust the size of the sound that will be generated. Amplifier that will be applied to this tool has a fitting such as potentiometer that serves to adjust the amount of frequency released from the amplifier to be equal to the amount of frequency that is removed from the exhaust noise signal.

![Figure 5. Amplifier & Speaker installation process specification amplifier](image)

Caption: (1) Brand: Clarin; (2) Type: Cl 3002 2 Channel and 3 variable potensio; (3) Dimension: Length 17 cm, width 13 cm and thick 4 cm; (4) Weight: 0.25 kg; (5) Current source: DC 12V.

In this active noise control research, the speakers are used as final voice translator output after going through the recording process. The selected speakers are considered quality, so the sound is produced also better. It should have capability to reproduce power of amplifiers as well as possible without losses. Sensitivity is assessed by dB unit. The impedance value will determine the output power of the amplifier. Smaller impedance, greater of power out from the amplifier.
Specifications of speakers: (1) Brand: Alpine series Mk- 820 f; (2) Power: 45 W; (3) Impedance: 4 Ohm; (4) Dimensions: 4 inches

2.3 Inverting Phase Shift Design

To design angle 180° as phase shifter or called inverting circuit by using electronic component, consisting of capacitor, resistor, ICL7660 and Tl 072 CP. The circuit can shift the phase by 180° so that the output of the inverting circuit will be opposite 180° phase with its input. Angles 180°, 225°, 270°, and 315° are obtained from each of the 0, 45°, 90°, and 135° phase angles which are inputs for the inverting circuit.

In the inverting op-amp circuit has the following values: (1) The feedback resistance = 1 kΩ; (2) Input resistance = 2 kΩ; and (3) Input voltage = 12V.

Acquisition voltage (Av), output voltage (Vout) and power supply voltage (Vcc), can be seen in the following Figure 7.

Where:
- \( R_f = 1 \text{k} \Omega = 1000 \Omega \)
- \( R_{in} = 2 \text{k} \Omega = 2000 \Omega \)
- \( V_{in} = 12 \text{V} \)

\[
A_v = \frac{-R_f}{R_{in}}
\]

\[
A_v = \frac{-1000\Omega}{2000\Omega} = -0.5\Omega
\]

\[V_{out} = A_v \cdot V_{in} = -0.5\Omega \cdot 12V = -6V\]

If the given input is 12V, then the resulting output is - 6 V. This assumes that the power supply voltage Vcc used allows the moving output to reach that value. A power supply ± 6V is too small for that, therefore requires a power supply with a voltage rating of at least ± 9V (or approximately ± 150%
\times V_{\text{out}}), to amplify the input voltage of 12V. So obtained: A_v = -6 \text{ V}; V_{\text{out}} = -5.61 \text{ V}; V_{\text{cc}} = \pm 8 \text{ V}; and 2500 \mu\text{F} and 3k resistor. The assembly process and the result of the phase shifting component can be seen in Figure 8.

![Figure 8. Assembling Process and Phase Slider Results.](image)

### 2.4 Active Noise Control ISD4004 Module

After going through the stages of the process of active design of noise control, starting from the selection of materials to consideration of calculation of signal generator and phase shifter. Next step is how to combine all the components as a system that can be seen in Figure 9 as follow.

![Figure 9. Active Noise Control Circuits.](image)

### 2.5 Media Focusing Voice

Extraction of exhaust sound signal data is done by using PVC pipe tube media. It serves to focus the sound to be unidirectional. In this case, the diameter of the PVC pipe tube affects against the fast ripple of sound. The picture of PVC tube media can be seen in Figure 10 below.
Figure 10. Media Focusing Voice.

Where: \( D = 102 \text{ mm}; R = 51 \text{ mm}; \pi = 3.14; f = 16.67 \text{ Hz}; c = 343 \text{ m/s} \)

The acoustic wave propagation in the tube affected by its diameter can be calculated by the formula:

\[
c^l = c \left( 1 - \frac{0.76}{2 \times r \sqrt{\pi}} \right) x \frac{1}{\sqrt{f}}
\]

\[
c^l = c \left( 1 - \frac{0.76}{2 \times 51 \sqrt{3.14}} \right) x \frac{1}{\sqrt{16.67}}
\]

\[
= 343 \left( 1 - \frac{0.76}{102 \sqrt{1.77}} \right) x \frac{1}{\sqrt{4.08}}
\]

\[
= 343 \left( 1 - \frac{0.76}{180.54} \right) x 0.245
\]

\[
= 343 \left( 1 - 4.20 \times 10^{-3} \right) x 0.245
\]

\[c^l = 83.68 \text{ m/s}\]

Thus, the acoustic wave propagation in a 102 mm diameter tube is 83.68 m/s. While the acoustic wave propagation in air is 343 m/s. So it can be concluded that the greater the acoustic wave propagation media, the sooner the sound is also faster.

The next research process continue after the active series of noise control is ready to be assembled. It puts directly testing on Motorcycle Supra X 125 D, in order to prove whether there is noise reduction already can be produced using this tool. The testing done at 02.00 a.m for reason to get a quiet atmosphere. Preparation is done by setting all tools ranging from the installation of speaker-microphone and current supply from batterei to generate anti noise signal. The process of taking exhaust sound data can be seen in Figure 11.

Figure 11. Setting Active Noise Control device for taking exhaust sound data.
After installing the Active Noise Control device and setting the SPL distance to the exhaust, the measuring activity held and can be seen in Figure 12 below.

![Figure 12. SPL distance setting on the muffler.](image)

When installing all equipment and set the SPL distance to the exhaust according to standard accomplished, then the exhaust sound data collection can be taken. It can be seen in Figure 13 as follow.

![Figure 13. Process of Exhaust Sound Data Retrieval.](image)

Finished with the initial exhaust data retrieval process, then tested continue with the exhaust sound generator. Here, with the same engine rotation but the phase wave has been already shifted by 180° as shown in Figure 14.

![Figure 14. Sound Exhaust Testing Process with Anti Noise Phase Shift 180°.](image)
3. Result and Discussion

3.1 Test results of Active Noise Control

Using SPL equipment, the testing accomplished by measuring directly the noise generated by Supra X 125 D motorcycle and comparing its result when using the Active Noise Control device. The engine speeds set-up at 1000 and 2000 rpm, the measuring distance is 1 meter with three measuring direction i.e X, Y and Z. The orientation of measurement can be seen in Figure 15 as follows:

![Measurement direction and orientation](image)

**Figure 15.** Measurement direction and orientation

To change the engine speed in the scale of rpm to frequency (Hz), can be calculated with the following formula:

- Engine Speed (n) = 1000 rpm
  
  \[ \frac{\omega}{2\pi} \times n = \frac{6.28}{60} \times 1000 = 104.667 \]

  Thus Frequency : \[ f = \frac{\omega}{2\pi} = \frac{104.667}{6.28} = 16.667 \text{ Hz} \]

- Engine Speed (n) = 2000 rpm
  
  \[ \frac{\omega}{2\pi} \times n = \frac{6.28}{60} \times 2000 = 209.33 \]

  Then the frequency : \[ f = \frac{\omega}{2\pi} = \frac{209.33}{6.28} = 33.33 \text{ Hz} \]

The following table is the results of noise measurement on exhaust of Supra X 125D without using active noise control and when using active noise control using sound level meter equipment as on Tabel 1. Given, engine rotation variation of 1000 rpm.

| Rotation (rpm) | Frequency (Hz) | Measurement Distance | Measurement Direction | Measurement Result Without ANC | Measurement Result Using ANC |
|---------------|----------------|----------------------|------------------------|-------------------------------|-----------------------------|
| 1000 rpm      | 16.67          | 1 Meter              | Z                      | 66.5 db                       | 64.5 db                     |
| 1000 rpm      | 16.67          | 1 Meter              | Y                      | 65.5 db                       | 64 db                       |
| 1000 rpm      | 16.67          | 1 Meter              | X                      | 65 db                         | 64 db                       |
| 1000 rpm      | 16.67          | 1 Meter              | -X                     | 66 db                         | 64.2 db                     |
According to Table 1, the measurement results have shown the reduction of the sound signal of motorcycle muffler when using the active noise control device. Detection of sound signal data with measurement distance of 1 meter with engine rotation 1000 rpm, the reduction that happened is as follows: Z-axis: 66.5 dB - 64.5 dB = 2 dB; Y-axis: 65.5 dB - 64 dB = 1.5 dB; X axis: 65 dB - 64 dB = 1 dB; Axis -X: 66 dB - 64.2 dB = 1.8 dB. From the noise reduction data that occurs above, the comparison of the standard exhaust noise level without using active noise control and when using active noise control device at 1000 rpm engine speed can be seen in Figure 16 below.

![Figure 16. Comparison between without ANC and using ANC at 1000 rpm rotation of engine.](image)

Highest noise reduction at 1000 rpm engine speed is on the Z axis. Using the active noise controller device, the noise reduction achieve up to 2 dB. The noise measurement results at 2000 rpm engine speed can be seen on Table 2 below.

| Rotation (rpm) | Frequency (Hz) | Measurement Distance | Measurement Direction | Measurement Result |
|----------------|----------------|----------------------|-----------------------|--------------------|
| 2000 rpm       | 33.3           | 1 Meter              | Z                     | 71 db              |
| 2000 rpm       | 33.3           | 1 Meter              | Y                     | 69.9 db            |
| 2000 rpm       | 33.3           | 1 Meter              | X                     | 69.3 db            |
| 2000 rpm       | 33.3           | 1 Meter              | -X                    | 68.8 db            |

Reduction calculation of sound signal data for measurement distance 1 meter with engine rotation at 2000 rpm come about as follows: Z-axis: 71 db - 69.5 db = 1.5 db; Y axis: 69.9 db - 68.9 db = 1 db; X axis: 69.3 dB - 68.3 dB = 1 dB; Axis -X: 68.8 db - 68.2 db = 0.6 dB. From the noise reduction data that occurs above, the comparison of the standard exhaust noise level without using active noise control and when using active noise control device at 2000 rpm engine speed can be seen in Figure 17 as follow.
Figure 17. Comparison between without ANC and using ANC at 2000 rpm rotation of engine.

Highest noise reduction at 2000 rpm engine speed is on the Z axis. Using the active noise controller device, the noise reduction achieve up to 1.5 dB. As already known between source sound and counter noise, in implementation the sound waves are very random and difficult to meet them at zero. Illustration of the randomness of signals on the Z, Y, X axes and the phase shift signal waveform on the illustrated Z axis can be seen in Figure 18.

Figure 18. Illustration Phase Shift Wave Noise Signal on Z-axis [3].

At 4000 rpm engine speed or 66.67 Hz, frequency has increased higher than the previous frequency. In this case, the noise is not only caused from the exhaust but already there is influence of engine vibrations which cause noise. It can be seen in Figure 19 and 20.

Figure 19. Graph of Z-axis exhaust noise without using ANC.
The reduction results between without active noise control and using active noise control device on the exhaust, it can be seen in Figure 19 and 20. The highest noise reduction find out on the Z axis.

![Graph of Z-axis exhaust noise using ANC.](image)

**Figure 20.** Graph of Z-axis exhaust noise using ANC.

Based on Figure 21, we can see that the noise reduction from engine rotation of 1000 rpm to 4000 rpm decreases unequally compared to Figure 18. According to different waveforms and amplitude that must be adjusted with the anti-signal generated from Tools assembled. The noise reduction that occurs on the Z axis ranges from 1.2 dB to 2 dB. Illustration of the randomness of signals on the Z, Y, X axes and the phase shift signal waveform on the illustrated Y axis can be seen in Figure 21 as follow.

![Illustration Phase Shift Wave Noise Signal on Y-axis](image)

**Figure 21.** Illustration Phase Shift Wave Noise Signal on Y-axis [3].

The result of noise measurements for standard exhaust Supra X 125 D on Y axis, it can be seen in Figure 22 below.

![Graph of Y-axis exhaust noise without using ANC.](image)

**Figure 22.** Graph of Y-axis exhaust noise without using ANC.

Based on Figure 22, we can see the level of standard exhaust noise without active noise control starting from 65.5 dB to 78 dB. At 3000 rpm engine speed, the exhaust noise level drops by 1.2 dB. In general, because of the highly variable random signal fluctuation and sound absorption properties at
50 Hz frequency corresponding to the exhaust acoustic material properties and noise absorption corresponding to the sound focusing medium. This influence of PVC tube coated with carpet silencer.

According to the test results of the effectiveness of the active noise control device on the Y axis, it can be seen in Figure 23 below.

![Figure 23. Graph of Y-axis exhaust noise using ANC.](image)

On the Y-axis the noise reductions that occur from the installation of the noise control device are smaller at 1dB to 1.5 dB. This is influenced by the direction of SPL to the exhaust parallel or in line with the Z-axis. On the Y-axis and the X-axis, the direction of SPL is not aligned but from the side. In this case, the measured exhaust noise with this tool becomes different. The highest exhaust noise that can be reduced on the Y-axis by testing is 1.5 dB.

The waveform of phase shift measurements on the illustrated X-axis can be seen in Figure 24 below.

![Figure 24. Illustration of Phase Shift Waves of Noise Signals on X-axis [3].](image)

Based on the measurement results of motorcycle muffler standard without active noise control at engine speed 1000 to 4000 rpm can be seen in Figure 25 below.

![Figure 25. Graph of X-axis exhaust noise without using ANC.](image)
By applying the above graph based on the position of the sound level on the X-axis, the engine will affect the measurement results. On the Z-axis, the influence will be greater against the measurement result because parallel to the exit direction of the exhaust sound. Therefore we can see the level of exhaust noise on the X-axis rise almost the same in every engine speed. Based on the result of noise level reduction test which can be obtained by active noise control device can be seen in the following Figure 26.

![Graph of X-axis exhaust noise using ANC.](image)

**Figure 26.** Graph of X-axis exhaust noise using ANC.

Of the various measurements performed on the X-axis, we have the same reduced noise level such as in Figure 26 above. The highest noise can be reduced on the X-axis of 1 dB, and will increase with the high frequency.

4. **Conclusion**
   a. Preparation of simulation media in the form of PVC pipe tube with Y-shaped modeling, with the addition of carpet in pipe layer to avoid echo during sound testing. The absorption coefficient of the carpet is 0.0025 dB. The result of noise reduction test is 1.1 dB.
   b. Inverted phase reversed using feedback resistor 1 kΩ and 2 kΩ input resistors, 16V capacitor 2500μf and as amplifier using ICL 7660 and TL 702 CP works very well. All series are assembled into one by using acrylic glass that is attached to the amplifier body by bolting.
   c. In accordance to objective of this study is to identify the noise reduction that occurs from the use of tools designed in the form of active noise control device on the exhaust motorcycle Supra X 125D. Test results on the highest 1000 rpm engine speed on the Z-axis of 2 dB, and at the highest 2000 rpm engine speed also occurs on the Z-axis of 1.5 dB.

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