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STUDI EKSPERIMENTAL ACTIVE NOISE CONTROL PADA MOTOR PENGGERAK PESAWAT UAV NOISE VIBRATION CENTER BERMESIN DLE GAS ENGINE 30

Alfisyahrin[1*], Ikhwansyah Isranuri[2], Syukriyadin[3], Habiburrahman[4]

[1]Department of Electrical Engineering, Faculty of Engineering, Universitas of Syiah Kuala
[2]Department of Mechanical Engineering, Faculty of Engineering, Universitas of Sumatera Utara
[3]Department of Electrical Engineering, Faculty of Engineering, Universitas of Syiah Kuala
[4]Department of Mechanical Engineering, Faculty of Engineering, Universitas of Sumatera Utara

Abstract

Abstrak—The noise that occurs at the USU UAV Noise and Vibration Center ranges between 90-100 dB. The engine used is a 2-stroke engine which certainly has high noise. The engine drive motor determines the high rotation and contributes to the noise. The method used to reduce noise is ANC. ANC in this study focused only on the drive motor. The results obtained are after comparing the noise before using ANC and after using ANC. The noise reduction obtained is at a rotation of 3000 rpm with a distance of 1.25 m of 1.36 dB.

Keywords:
Drive motor, noise, ANC, UAV, NVC, X,Y,Z axis.

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Corresponding Author:
Alfisyahrin
Department of Electrical Engineering, Universitas of Syiah Kuala, Indonesia
Email: alfisyahrin@usk.ac.id

1. Introduction

In today's modern era, unmanned aerial vehicles (UAV) have become a tool that can be used in all aspects of society. They are commonly used for hobbies, commercial purposes, and even in the military. They can also be used for civilian purposes, such as non-military security, firefighting, construction site monitoring, and even for advanced photography and videography. Noise on aircraft is a concentration of research that is continuously carried out to obtain aircraft that have low noise levels and avoid excessive noise pollution that can cause harm to drone users, especially if drones are used in their function as a military tool, of course drones that have vibrations and noise in the engine will not be effective if used as spy planes or as unmanned fighter planes.

However, as with any other machine, noise is unavoidable. Noise issues in unmanned aircraft are a growing focus of research every year. Most aircraft noise originates from the propeller, rotor, and engine systems. Noise from an aircraft engine is a combination of two noise sources: the propeller and the engine itself. The DLE Gas Engine 30 is a key component of the third-generation USU Mechanical Engineering UAV. It functions as a propulsion motor that drives the propeller, generating thrust for the aircraft. It is a 2-stroke engine, making it more noisy than a 4-stroke engine. Therefore, to address this noise, ANC (Active Noise Control) was introduced, which is one possible noise control technique. ANC works by comparing a noise signal from a noise source with a noise signal from a microphone that has the same signal but is in reverse phase with the noise source. By comparing these two signals, the final noise signal is expected to have a reduced noise level.

The measurement method uses a spherical technique by placing the ANC position on the X, Y, Z axes and the measurement point on the X, Y, Z axes with a measuring distance of 1.25 m. Considering the importance of noise reduction, the noise signal approach to unmanned aircraft engines is a technology that is useful for reducing vibrations originating from unwanted engine noise. The principle of its operation is by producing sound waves of sufficient strength to reduce the sound wave signal from the noise source. ANC plays a role in reducing the noise so that the benefits for the work environment do not cause chaos due to noise, both for humans and other objects. In this case, ANC will be applied to unmanned aircraft located in the NVC (Noise and Vibration Research Center) laboratory at the University of North Sumatra. Active Noise Control is a noise control technique using electronic instruments designed according to the noise parameters of the noise source. The noise countermeasure is carried out by inverting the phase of the source noise using the designed electronic instrument. The experimental study conducted this time was limited only to the UAV propulsion motor with a DLE Gas Engine 30 engine from the USU NVC laboratory.

A. UAV (Unmanned Aerial Vehicle)

Unmanned Aerial Vehicles (UAV) are flying machines that can be controlled remotely, or aircraft that fly without a crew member. There are two main variations of unmanned aircraft: remote control, and autonomous flight based on a program pre-flight. The aircraft's control is entirely handled by an autopilot system, based on parameters set by the user before flight. UAVs can carry cameras, sensors, communications equipment, and various other equipment. These types of aircraft are widely used in the military.

Figure 1.1 Indonesian unmanned aerial vehicle (UAV) (http://tech.dbagus.com/pesawat-tanpa-awak-buatan-indonesia)

B. Unmanned Machine

This drone uses a DLE 30 engine. This type of engine is a gasoline engine similar in size to a glow engine. Electronic ignition provides a quick initial spark. Timing is automatically adjusted for peak power across the rotations per minute (RPM) range and is designed for aviation, ensuring the best power-to-weight ratio and performance.

The DLE 30 gasoline engine can be seen in Figure 2.2 below.

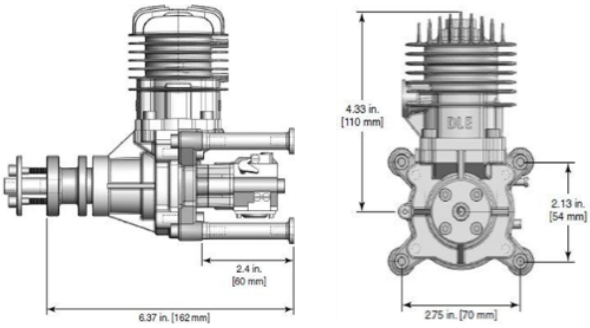

Figure 1.2 DLE Gasoline Engine 30
(https:// =DLE+Gasoline+Engine+30+110cc+engine+pesawat)

C. Aerodynamic Noise.

Sound is defined as a series of waves propagating from a vibrating source as a result of changes in density and air pressure, or changes in pressure that can be detected by the ear. Sound waves in fluids are mostly produced through the vibrating surface of a solid substance within the fluid. The decibel unit indicates the sound pressure level [4]. Its magnitude is above the reference of 20 x 10-6 N/m2. The decibel is also a logarithmic unit for describing a ratio.

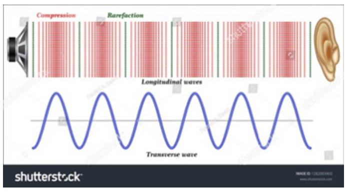

Figure 1.3 Sound waves in media [4]

Humans can only hear sounds within a certain frequency range that elicits a response and does not interfere with the function of the auditory system. The range of frequencies audible to humans is between 20 Hz and 20,000 Hz. Sounds can be grouped into several categories based on their frequency:

1. Infrasonic: frequency < 20 Hz
2. Audiosonic: frequency 20-20,000 Hz
3. Supersonic: frequency > 20,000 Hz

D. Noise

Noise is unwanted sound or noise that can disrupt health and environmental comfort, expressed in decibels (dB). Over time, most production machines, transportation equipment, and anything that improves human quality of life have been associated with noise. Noise can propagate through many pathways, known as noise paths [7].

Noise sources can be grouped into three categories:
1. Intrinsic noise sources arise from random fluctuations within a physical system, such as thermal and shot noise.
2. Man-made noise sources, such as motors, switches, and digital electronics.
3. Noise sources due to natural disturbances, such as lightning and sunspots.

In Table 1.1 you can see examples of the maximum noise levels permitted for several sound sources.

Tabel 1.1 Contoh tingkat kebisingan suara berdasarkan sumbernya [8]

Sound sources (noise) Examples with distance	Sound pressure Level L_p dB SPL
Jet aircraft, 50 m away	140
Threshold of pain	130
Threshold of discomfort	120
Chainsaw, 1 m distance	110
Disco, 1 m from speaker	100
Diesel truck, 10 m away	90
Kerbside of busy road, 5 m	80
Vacuum cleaner, distance 1 m	70
Conversational speech, 1 m	60
Average home	50
Quiet library	40
Quiet bedroom at night	30
Background in TV studio	20
Rustling leaves in the distance	10
Hearing threshold	0

E. How Active Noise Control Works

Active noise control works by providing a noise-controlling sound to the noise source, or in other words, sound counteracts sound. This sound reduction occurs when the "anti-noise" sound wave is 180° out of phase with the noise source.

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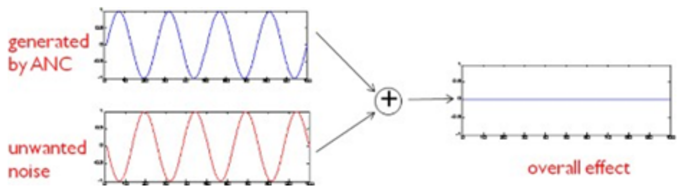

Figure 1.4 Destructive interference process in ANC
(https://Process+interferensi+destruktif+pada+ANC&safe)

Schematically, the noise formation mechanism can be seen in Figure 1.5

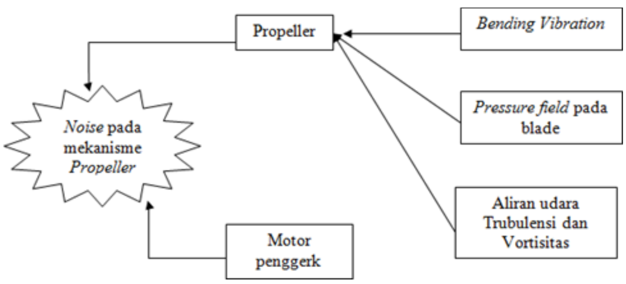

Figure 1.5 Noise Generation Mechanism on the propeller

2. Method

A. Set Up and Data Collection

In this experimental study, reduction was performed by contrasting the primary noise with the secondary noise produced by the loudspeaker. The loudspeaker was placed on a prefabricated stand with a spherical shape on the x+, x-, z+, and z- axes. Testing and data measurements were conducted by placing the sound level meter at varying distances, starting from 0.75 m, 1 m, and 1.25 m. These measurement distances were selected based on the results of experimental studies where the ANC was effective in reducing sound at low frequencies, in this case the low sound frequency range of 20 Hz to 500 Hz.

Measurements were also performed on the x+, x-, y+, y-, z+, and z- axes. In this study, measurements were performed at engine speeds of 3000 rpm, 3500 rpm, 4000 rpm, 4500 rpm, and 5000 rpm. The engine speeds for the measurements were standardized according to ISO 5130.

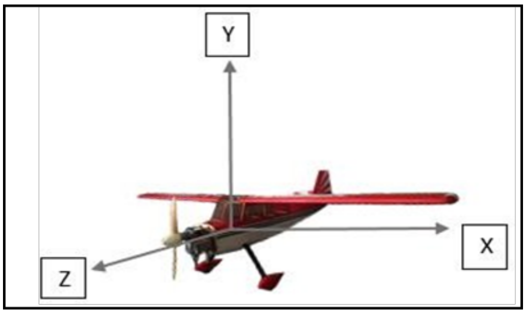

Figure 2.1 Measurement direction

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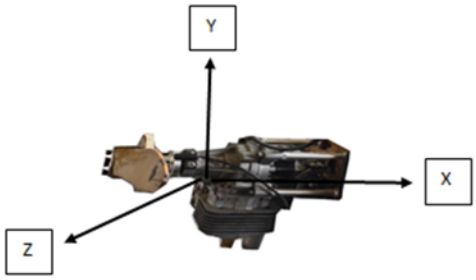

Figure 2.2 Measurement direction on the machine

Figure 2.3 Data collection process

Figure 2.4 ANC Instrument Electronics

In this study, data collection was conducted outdoors at night to achieve the lowest possible environmental noise levels. Testing was conducted by running the engine of the USU NVC drone at varying speeds controlled by a remote control. Engine speed was measured using a tachometer, which directly reads engine speed. Noise levels were then measured using an SPL meter on the USU NVC drone.

B. Parameter Kajian Pada Metode Active Noise Control

To determine the parameters in the kinematic study of the ANC method, the input and output that work on the working principle of the ANC method are identified. Based on the analysis, the parameters that work on the ANC method are input parameters, namely aircraft noise at certain engine speeds, and output parameters, namely the final noise after noise control. And there are also parameters that can affect the output parameters, namely the controlled parameters that surround, environmental noise, measurement distance, and noise counter/ANC. To make it easier, see the illustration in the image below.

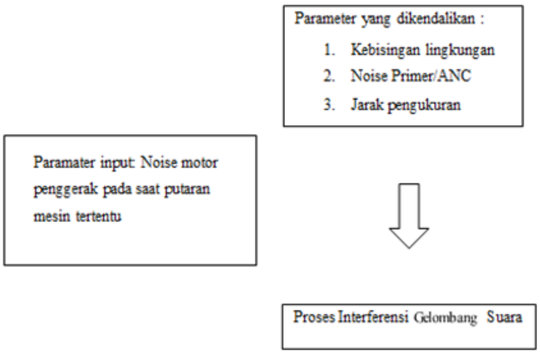

Figure 2.5 Study parameters in the ANC method

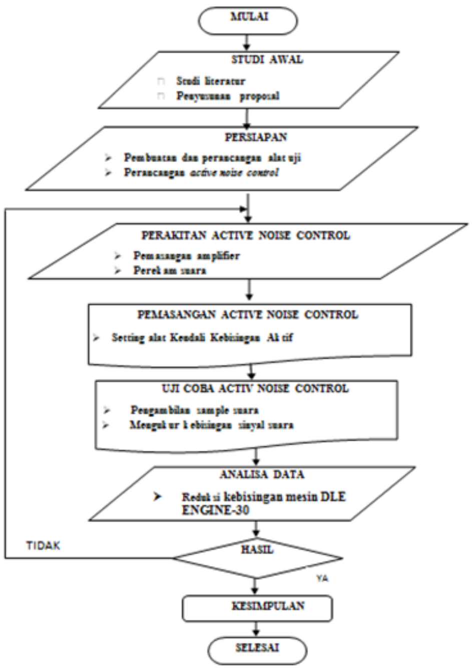

Figure 2.6 Active Noise Control Flowchart

3. Result and Discussion

A. Measurement Result Data After Using Active Noise Control Instrument

After noise measurements were performed using the ANC instrument, the recorded sound was captured using a microphone placed parallel to the speaker at the end of a spherical metal rod. This was done to ensure the sound captured and the sound emitted by the speaker were in phase. The sound was then processed by the ANC instrument to counteract the noise from the source.

1) At a distance of 1.25 meters
From table 4.1, the data on the difference in noise levels are as follows:

Table 3.1 Reduction value at a distance of 1.25 meters

N (rpm)	Sound Pressure Level Reduction (dB) Distance 1.25m					
	x+	x-	y+	y-	z+	z-
2000	-2,5	-1,7	-0,5	-1,6	1,9	3
2500	-1,3	-1,4	-0,8	-1,2	-1,2	-0,6
3000	-0,2	-1,1	-1,8	-2,1	-1,7	-0,6
3500	-0,9	-1	-0,7	-0,9	-0,8	-1,2
4000	-1,2	-0,9	-4,2	-2,2	1	-0,9

• X+ axis

On the x+ axis we can see a comparison of the magnitude of the sound pressure level value at a distance of 1.25 m in the image below:

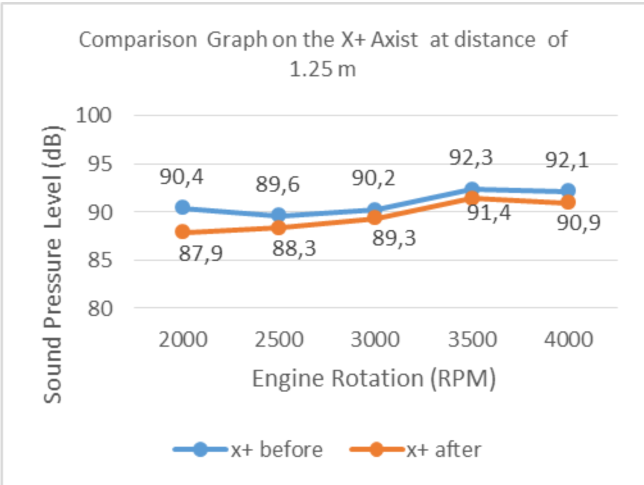

Figure 3.1 Noise comparison graph on the x+ axis at a distance of 1.25 m

From Figure 3.1 above, it can be seen that noise reduction occurs at 3500 rpm with a sound pressure level reduction value of 0.9 dB. Meanwhile, at 2000 rpm, 2500 rpm, and 3000 rpm, there is an increase in noise levels with the largest increase in sound pressure levels at 3000 rpm of 0.2 dB.

• X-axis

On the x-axis we can see a comparison of the magnitude of the sound pressure level values at a distance of 1.25 m in the image below:

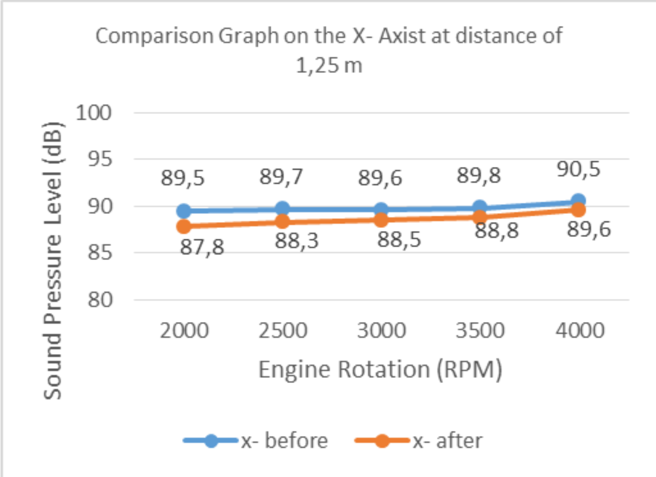

Figure 3.2 Noise comparison graph on the x-axis at a distance of 1.25 m

Figure 3.2 shows that there is no drastic reduction in noise levels at engine speed. The highest increase in sound pressure level occurs at 4000 rpm with an increase of 0.9 dB, and the lowest increase in sound pressure level occurs at 2000 rpm with an increase of 1.7 dB.

• Y+ axis

On the y+ axis we can see a comparison of the magnitude of the sound pressure level value at a distance of 1.25 m in the image below:

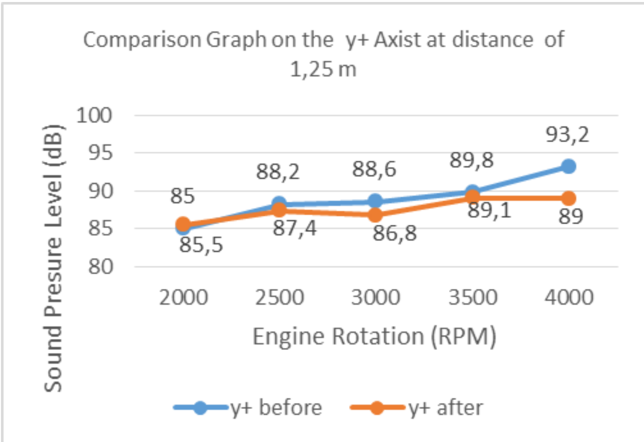

Figure 3.3 Noise comparison graph on the y+ axis at a distance of 1.25 m

Figure 3.3 above shows that there has been an increase in noise reduction. The increase in noise level naturally amplifies the previous noise. The highest increase in noise level occurs at 2000 rpm, with an increase of 0.5 dB, and the lowest increase in sound pressure level occurs at 4000 rpm, with an increase of 4.2 dB.

• Y-axis

On the y-axis we can see a comparison of the magnitude of the sound pressure level values at a distance of 1.25 m in the image below:

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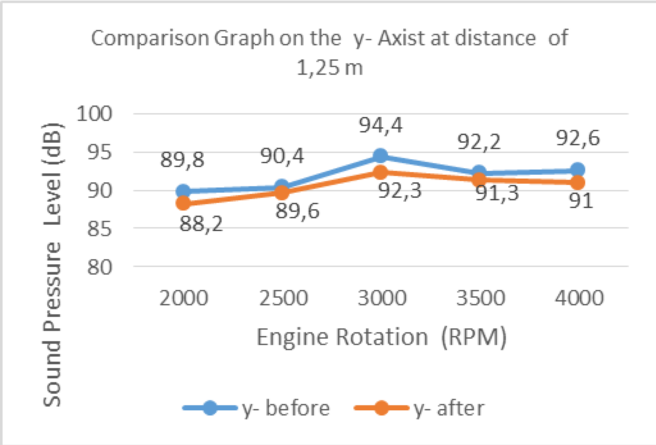

Figure 3.4 Noise comparison graph on the y-axis at a distance of 1.25 m

From Figure 3.4 above, it can be seen that there is no noise reduction, but instead there is an increase in noise at engine speeds of 2000 rpm, 2500 rpm, and 3000 rpm with the largest increase in sound acoustic pressure level occurring at 3000 rpm of 2.1 dB. Meanwhile, at 3500 rpm, there is an increase in reduction of 0.9 dB.

• Z+ axis

On the z+ axis we can see a comparison of the magnitude of the sound pressure level value at a distance of 1.25 m in the image below:

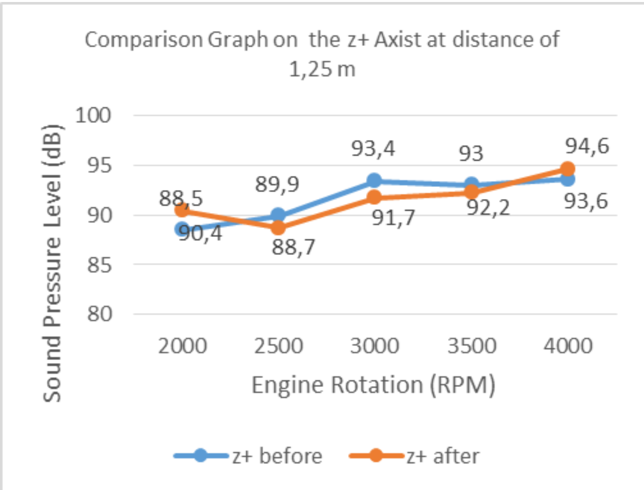

Figure 3.5 Comparison graph on the z+ axis at a distance of 1.25 m

From Figure 3.5 above, it can be seen that there has been an increase in noise reduction at engine speeds of 2000 rpm, 2500 rpm, and 3000 rpm with the largest sound pressure level reduction value occurring at 2000 rpm of 1.9 dB. Meanwhile, at engine speeds of 3500 rpm and 4000 rpm, there was an increase in noise levels with the largest increase in sound pressure levels occurring at 4000 rpm with an increase of 1 dB.

• Z-axis

On the z-axis we can see a comparison of the magnitude of the sound pressure level values at a distance of 1.25 m in the image below:

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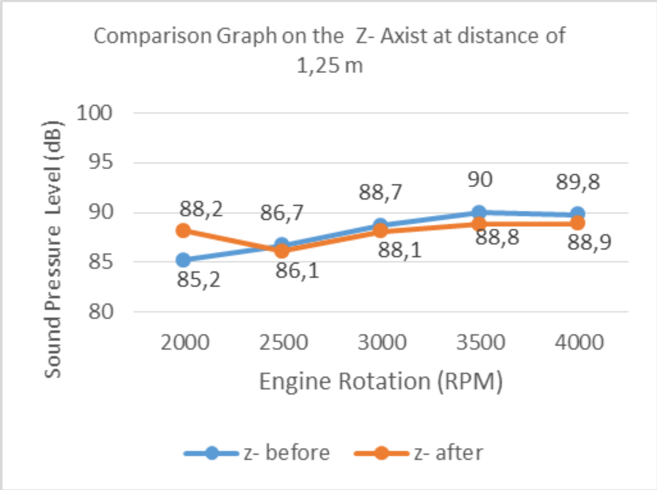

Figure 3.6 Comparison graph of noise in the z-axis at a distance of 1.25 m

From Figure 3.6 above, it can be seen that noise reduction has occurred at 3000 rpm, 3500 rpm, and 4000 rpm, with the largest reduction occurring at 3000 rpm with a sound pressure level of 0.6 dB. The highest increase occurred at 2000 rpm, amounting to 3 dB.

2) Noise contour at a distance of 1.25 meters

Based on the table below, you can see the noise contour for each engine rotation in the graphic image below.

Table 3.1 Measurement results at a distance of 1.25 meters

N (rpm)	Sound Pressure Level (dB) distance 1.25 m					
	x+	x-	y+	y-	z+	z-
2000	90,4	89,5	85	89,8	88,5	85,2
2500	89,6	89,7	88,2	90,4	89,9	86,7
3000	90,2	89,6	88,6	94,4	93,4	88,7
3500	92,3	89,8	89,8	92,2	93	90
4000	92,1	90,5	93,2	92,6	93,6	89,8

Table 3.2 Measurement results at a distance of 1.25 meters

N (rpm)	Sound Pressure Level (dB) Distance 1.25m					
	x+	x-	y+	y-	z+	z-
2000	93	91,7	94,1	95,1	95,4	90,6
2500	93,5	92,5	95,2	95,8	94,6	92,3
3000	94,7	93,9	96,3	96,9	95,5	93,8
3500	95,3	93,3	96,8	96,2	96,8	93,2
4000	95,6	94	98,7	98	98	91,6

Based on table 3.1 and table 3.2above, the noise contour for each engine rotation can be seen in the graphic image below.

- Engine speed 3000 RPM

At an engine speed of 3000 rpm, the shape of the noise contour can be seen as in the image below:

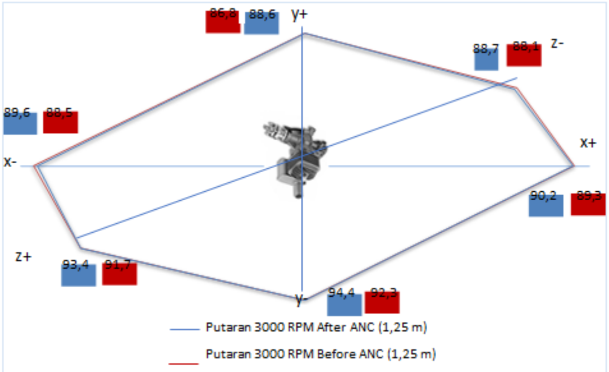

Figure 3.7 Noise contour (dB) at 3000 rpm at a distance of 1.25 m

Figure 3.7 above shows the noise contour at 3000 rpm at a distance of 1.25 meters. It can be seen that noise levels on all measurement axes were reduced after using the active noise control device. The highest noise level was on the y-axis both before and after using the active noise control device.

- Engine speed 3500 RPM

At an engine speed of 3500 rpm, the shape of the noise contour can be seen as in the image below:

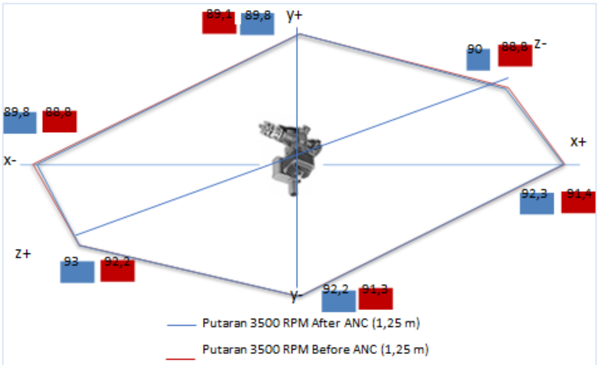

Figure 3.8 Noise contour (dB) at 3500 rpm at a distance of 1.25 m.

From Figure 3.8 above, the noise contour at 3500 rpm at a distance of 1.25 meters can be seen. It can be seen that the noise level on all measurement axes is reduced or reduced after using the active noise control device, while the highest noise level is on the z+ axis both before and after using the active noise control device.

- Engine speed 4000 RPM

At an engine speed of 4000 rpm, the shape of the noise contour can be seen as in the image below:

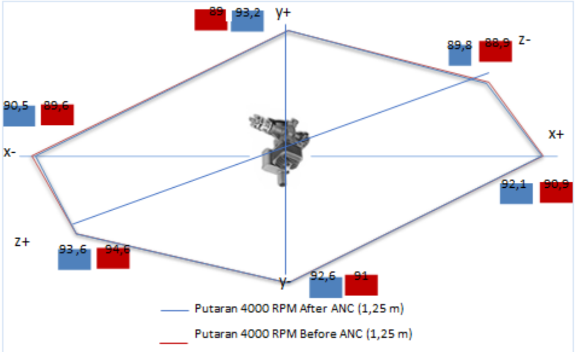

Figure 3.9 Noise contour (dB) at 4000 rpm at a distance of 1.25 m

From Figure 3.9 above, we can see the noise contour at 4000 rpm at a distance of 1.25 meters. It can be seen that the noise level on the x+, x-, y+, and y- axes experienced noise reduction after using the active noise control device. Meanwhile, on the z+ and z- axes, noise amplification occurred after using the active noise control device.

• Average Noise Value After Using Active Noise Control Devices.

Using the same formula to calculate the average noise value above, the average noise value after using active noise control equipment is obtained as shown in the table below:

Table 3.3 Average noise values after using active noise control devices

N (rpm)	Average Sound Pressure Level (dB)		
	Distance 0,75 m	Distance 1 m	Distance 1,25m
2000	89,4	88,1	88
2500	91	90	88
3000	93,6	91,2	89,4
3500	93,9	92,7	90,2
4000	93,9	92	90,6

The table above shows the average noise levels after using the active noise control device at all engine speeds at each measurement distance. The highest noise levels were at 4,000 rpm and 3,500 rpm at a distance of 0.75 meters, and the lowest noise levels were at 2,000 rpm and 2,500 rpm at a distance of 1.25 meters. The noise levels at each distance did not increase consistently. This may be due to uneven noise reduction.

3) Noise Reduction Rate (NRR)

Noise Reduction Rate or NRR is the reduction rate obtained from the average reduction value that occurs, namely the total noise value before using the active noise control device minus the total noise value after using the active noise control device and divided by the number of measurement axes, which can be formulated as follows:

$$NRR = \frac{\Sigma \text{ Noise Level before ANC} - \Sigma \text{ Noise Level After ANC}}{Number\ of\ Data\ Capture\ Axes}$$

With the formula above, the noise reduction rate value is obtained for each distance rotation in the table below:

Table 3.4 NRR Values

N (rpm)	Average Sound Pressure Level (dB)		
	Distance Jarak 0,75 m	Distancen 1 m	Distance 1,25 m
2000	-10,3	0,93	-4,53
2500	-1,76	0,85	0,98
3000	0,1	0,86	1,36
3500	0,88	0,9	0,91
4000	1	0,96	1,3

The table above shows that at engine speeds of 3000 rpm, 3500 rpm, and 4000 rpm, the NRR value at all measurement distances is positive, indicating that no noise reduction occurs. The highest NRR value that does not reduce noise is at 3000 rpm at a distance of 1.25 meters, where the NRR value obtained is 1.36 dB.

4. Conclusion

The reduction occurred after averaging several variations of rotation at 3000 rpm, at a measuring distance of 1.25 m, with a value of 1.36 Db.

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