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Design and Optimisation of Aqua Silencer

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ABSTRACT

Pollution, particularly air pollution, has become a significant environmental concern due to the harmful emissions from industrial processes and vehicles. The release of toxic gases like carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx) contributes to respiratory diseases, global warming, and environmental degradation. To mitigate these effects, innovative solutions are being explored, one of which is the Aqua Silencer. The word Aqua is used due to the usage of water in the technology. This device functions on the principle of absorption and filtration, where gases pass through a water chamber, undergoing chemical reactions that neutralise harmful components. Additionally, it helps in noise reduction, making it a dual-purpose solution for environmental conservation.

Keyword: - Aqua Silencer , Emission Control , Activated Charcoal , Gas Filtration, Exhaust System

1. INTRODUCTION

The design and optimisation of an aqua silencer focus on reducing exhaust emissions and noise pollution from internal combustion engines. Unlike conventional silencers, it incorporates a water-based filtration system that absorbs harmful gases such as carbon monoxide, nitrogen oxides, and hydrocarbons, significantly reducing air pollution. The primary design consists of a perforated tube that disperses exhaust gases into a water chamber, where absorption and chemical reactions occur to neutralize toxic components. Additional filters like activated charcoal or lime water further purify the gases before release. Optimization involves selecting corrosion-resistant materials, improving gas absorption efficiency with chemical additives, and refining the internal structure to ensure uniform gas flow. By enhancing these aspects, the aqua silencer becomes a more effective and sustainable solution for minimizing vehicle emissions and promoting environmental conservation. By integrating Aqua Silencers in automobiles and industrial machinery, air pollution can be significantly reduced, leading to cleaner air and a healthier environment. This technology provides an eco-friendly alternative to conventional silencers, making it a promising innovation for sustainable development. Noise pollution has become a pressing environmental concern, negatively impacting human health, productivity, and quality of life. Traditional noise reduction methods often have limitations in terms of effectiveness and environmental impact. To address this challenge, aqua silencers offer a promising solution.

Aqua silencers, also known as water wall silencers or hydrodynamic silencers, utilize the unique properties of water to absorb and dissipate sound waves. By passing noisy air or gas through chambers filled with water, aqua silencers can significantly reduce noise levels without the need for harmful chemicals or complex mechanical systems. This paper presents a comprehensive overview of aqua silencers, including their operating principles, design considerations, and applications. The benefits of aqua silencers, such as high noise reduction efficiency, environmental friendliness, and low maintenance requirements, are discussed. Additionally, the challenges and limitations associated with aqua silencer technology are explored.

Overall, aqua silencers offer a sustainable and effective approach to noise control, with the potential to mitigate the adverse effects of noise pollution in various industrial and commercial setting. The Aqua Silencers, also known as water wall silencers or hydrodynamic silencers, are innovative devices designed to reduce noise pollution in industrial and commercial settings. These silencers utilize the unique properties of water to absorb and dissipate sound waves, offering a highly effective and environmentally friendly alternative to traditional noise reduction methods.

1.1 Problem Statement

Noise pollution has become a significant environmental concern in modern society, negatively impacting human health, productivity, and quality of life. Industrial and commercial activities, transportation, and construction projects are major contributors to noise pollution. Traditional noise reduction methods, such as acoustic barriers and mufflers, often have limitations in terms of effectiveness, environmental impact, and maintenance requirements.

The problem lies in the need for innovative and sustainable solutions to mitigate noise pollution, particularly in environments where high noise levels are generated. Existing methods may not provide adequate noise reduction, or they may have adverse environmental consequences.

Therefore, there is a pressing need for a more effective and environmentally friendly approach to noise control. Aqua silencers offer a promising solution by leveraging the unique properties of water to absorb and dissipate sound waves, providing a sustainable and efficient means of noise reduction.

1.2 Commercial Significance

Market and the application both decides the commercial significance of an "aqua silencer ". In general, an aqua silencer is a device or system designed to reduce noise or sound generated often in industrial and commercial settings. Here are some key areas where the commercial significance of aqua silencers comes into play: Noise Control: In manufacturing facilities or industrial plants where water is used in processes (e.g., cooling systems, water pumps), the aqua silencer helps in reducing the sound produced by machinery, pumps, or pipelines. This reduces noise pollution, creating a more comfortable working environment. Regulatory Compliance: In many regions, businesses are required to comply with environmental noise regulations. The installation of aqua silencers can ensure that operations remain within acceptable noise levels to avoid penalties and protect worker health. Ecosystem Protection: In areas where water noise could disturb wildlife (e.g., in rivers, lakes, or coastal regions), aqua silencers can be used to minimize the impact of human activities on local ecosystems. Sustainability: Aqua silencers made from eco-friendly materials can align with sustainability goals, appealing to companies and governments investing in green technologies and practices.

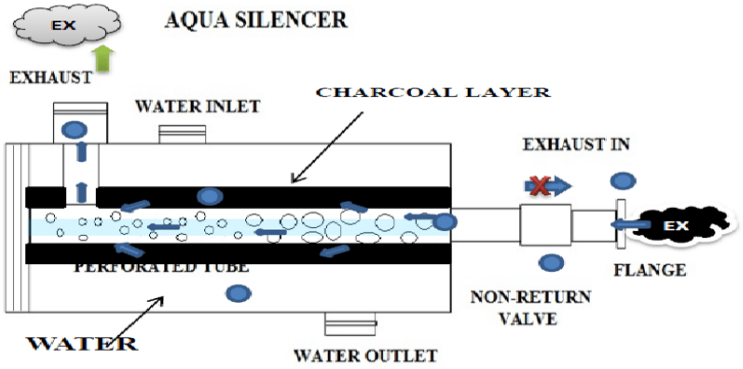

Fig-1 : Schematic diagram of Aqua Silencer

1.3. Advantages And Drawbacks

High Noise Reduction: Aqua silencers can achieve significant noise reduction, often exceeding the performance of other types of silencers.
Environmental Friendliness: Unlike some traditional silencers that may use harmful materials, aqua silencers are environmentally friendly and do not produce any harmful emissions.
Low Maintenance: Aqua silencers require minimal maintenance, as the water within the chambers typically does not need to be replaced or treated.
Versatility: Aqua silencers can be used in a wide range of applications, including industrial facilities, power plants, and HVAC systems.
Maintenance: Depending on the design, some aqua silencers may require ongoing maintenance to ensure they function optimally. For example, components may wear out over time due to constant exposure to water pressure and flow. This could add additional long-term costs.
Clogging and Build-Up: In some cases, the internal components of the silencer may become clogged with sediment, debris, or mineral build-up, especially in areas with hard water. Regular cleaning or maintenance may be necessary to avoid reduced efficiency or malfunction.
Limited Effectiveness in Specific Frequencies: Some models may only reduce certain frequencies of noise effectively. If the source of the noise is in a frequency range that the silencer is not designed to target, the reduction may not be significant

1.4 Objectives

- To Design and construct a functional aqua silencer system that can significantly reduce noise levels in industrial and commercial environments.
- Evaluate the performance of the aqua silencer in terms of noise reduction efficiency ,durability and environmental impact.
- Identify potential applications and optimize the design of the aqua silencer for specific use cases.
- Contribute to a more sustainable and noise-free environment by providing a viable alternative to traditional noise reduction method.

2. LITERATURE REVIEW

R. Sivaprakasam et al. (2015) – In their study, the authors examined the effectiveness of aqua silencers in reducing toxic gases and noise from IC engines. Their research highlighted the role of water as a medium for gas absorption and found that using chemical additives like calcium hydroxide improved the neutralization of harmful pollutants. K. Saravanan et al. (2016) – This study focused on the structural design optimization of an aqua silencer to enhance gas absorption efficiency. The authors tested different perforation patterns in the exhaust tube and found that smaller, evenly distributed perforations improved gas dispersion, leading to better filtrationA. Pradeep et al. (2017) – The authors explored the use of activated carbon and lime water filters in an aqua silencer. Their findings showed that activated carbon efficiently absorbed carbon particles, reducing emissions significantly. The research also emphasized the importance of filter maintenance for sustained efficiency M. Ramesh et al. (2018) – This study investigated the noise reduction capabilities of an aqua silencer in comparison to traditional silencers. The results demonstrated that the water medium effectively dampened noise levels while also assisting in pollutant absorption. The authors proposed modifications in the silencer's chamber design to enhance sound suppression further
AnilKumar et al. (2019) – The research focused on the environmental benefits of implementing aqua silencers in automobiles and industrial applications. The authors analyzed emission reduction data and concluded that the use of an aqua silencer could significantly lower air pollution levels, making it a viable alternative to conventional exhaust systems.

2.1 Methodology

The working process of an aqua silencer begins when exhaust gases from the internal combustion engine enter the silencer through the inlet pipe. These gases, which contain harmful pollutants such as carbon monoxide, unburnt hydrocarbons, nitrogen oxides, and sulfur dioxide, pass through a perforated tube that breaks them into smaller bubbles. This perforation increases the surface area of the gas bubbles, enhancing their interaction with the surrounding water. As the gases travel through the water chamber, a significant portion of the pollutants dissolves in water, reducing their concentration before being released into the atmosphere. Additional filtering materials such as activated charcoal and lime water are often used to improve the absorption of toxic gases. Activated charcoal adsorbs pollutants, while lime water neutralizes acidic components, further reducing harmful emissions. The water medium also plays a crucial role in noise reduction by absorbing the vibrations and pressure waves generated by the exhaust gases, minimizing sound pollution. Baffles or diffuser plates within the chamber create turbulence, which extends the contact time between the gases and the absorbent medium, enhancing the purification process. The treated gases then exit through the outlet pipe, significantly cleaner and less harmful to the environment. Over time, impurities accumulate in the water chamber, necessitating periodic drainage through a drain plug to maintain optimal performance. By effectively controlling emissions and reducing noise, the aqua silencer provides an eco-friendly alternative to conventional silencers while ensuring minimal impact on engine efficiency.

2.3 Chemical reactions

Chemical reaction 1 :-

$$NO2 + 2H2O \rightarrow 2HNO2 + 2HNO3 \text{ (Diluted)}$$

Exhaust Gas Entry: The exhaust gases from the engine enter the silencer. Dissolution in Water: The NO_2 in exhaust dissolves in water, forming nitrous acid (HNO_2) and nitric acid (HNO_3). This reaction helps in absorbing nitrogen-based pollutants. Further Neutralization (Optional): The acidic products may be neutralized using lime water ($Ca(OH)_2$) or other alkaline substances.
Chemical reaction 2 :-

$$Ca(OH)2 + 2HNO3 \rightarrow Ca(NO3)2 + 2H2O$$
$$Ca(OH)2 + 2HNO2 \rightarrow Ca(NO2)2 + 2H2O$$

Reduction of Acidity:- Exhaust gases from internal combustion engines contain nitrogen oxides (NO_2, NO). When dissolved in water, they form acidic compounds (HNO_3 and HNO_2). These acids lower the pH of the water, making it corrosive and environmentally harmful.
Neutralization Process**:-**

- Calcium hydroxide ($Ca(OH)_2$), also known as slaked lime, is added to neutralize these acids**.**
- This reaction converts harmful acidic components into neutral salts ($Ca(NO_3)_2$ and $Ca(NO_2)_2$**)** that are much less harmful.

Chemical reaction 3:-

$$Ca(OH)2 + CO2 \rightarrow CaCO3 + 2H2O$$
$$CaCO3 + H2O \rightarrow CO2 + Ca(HCO3)2$$

Reduces CO_2 Emissions:

- The first reaction helps capture and convert CO_2 into calcium carbonate, minimizing its release.
- The second reaction ensures excess CO_2 remains dissolved, preventing clogging.

Water-Based Filtration:

- The water absorbs exhaust gases, allowing chemical reactions to neutralize pollutants.
- Along with NOx removal (as discussed earlier), CO_2 is also controlled, making the exhaust eco-friendly.

Chemical reaction 4;-

$$Ca(OH)2 + SO2 \rightarrow CaSO3 + H2O$$

The sulphur dioxide present in the exhaust gas also reacts with the limewater and calcium sulphate precipitaes.
Chemical Reaction 5:-

$$CaCO3 + SO2 + H2O \rightarrow CaSO3 + CO2 + H2O$$

From calcium carbonate, calcium sulphite will precipitate and CO2 will be by-products. Because of the small percentage and SO2 presence, the liberation of carbon dioxide is very less. But the liberated CO2 will again combine with calcium carbonate to form calcium bicarbonate.

3. DESIGN AND CALCULATIONS

An aqua silencer is a device designed to reduce the noise and emission levels of internal combustion engines by using water as a medium to absorb sound vibrations and filter exhaust gases. It works on the principle of sound attenuation and gas scrubbing, where the exhaust gases from the engine pass through a perforated tube surrounded by water, allowing noise energy to dissipate and particulate matter to settle. The design of an aqua silencer involves selecting appropriate materials, determining the dimensions of the perforated tube, and calculating the water volume required for effective silencing and filtration. Parameters such as the engine's exhaust pressure, gas flow rate, temperature, and acoustic frequency are considered in the calculation to ensure optimal performance and durability of the device.

3.1 Design Goals

Design goals-The design goals of an aqua silencer focus on reducing the noise and harmful emissions produced by internal combustion engines. It aims to control sound pollution by using water as a medium to absorb and minimize the noise generated during engine exhaust.
Sustainibility- It helps in reducing the emission of toxic gases by filtering them through a series of perforated tubes and activated charcoal, which absorb pollutants before releasing the exhaust into the atmosphere. The overall objective is to create a more environmentally friendly and quieter alternative to conventional silencers without compromising engine performance.

3.2 Calculations

GIVEN :-
Bore Diameter (D)=50mm (Std. Hero Honda motorcycle)
Stroke length (L)=49.5mm
No.of cylinders (n)=1
Engine speed N=8000rpm max
Power=7.91bhp
TO FIND :- 1) Vibrational frequencies
2) Silencer volume
3) Muffler diameter

STEP 1 :-
Cylinder firing ratio (CFR) = RPM/60 (For 2-stroke)
= RPM/120 (For 4-stroke, as a power cycle takes 2 crank Rev.)
= 8000/120
= 66.66HZ

STEP 2 :-
Engine Firing Rate (EFR) = No. of cycles X cylinder firing rate
= 1 X 66.66 Hz
= 66.66 Hz

Step 3 :-
Silencer volume :-
Formula = No.of cylinders X Area of piston X stroke length
Silencer volume (VS) = (π X d^2 X L)/4 *1
VS = 97193.022 cm^3
= 0.097193 lit

STEP 4 :
Total volume of gas :-
Vt = Factor X Vs
Note :- FOS for muffler should be considered 10 to 25 times the original volume for safety , ie taking FOS = 25
{ Conversions :- 1cc=1000 mm^3 & 1 lit = 10^3 m^3 }

- Vt = 25 X 0.097193 = 2.429 lit
= 2.4298255 Litre
= 0.0024298255m^3

Step 5 :-
For calculating Internal diameter of silencer
As, Vt= Factor*vol
Vt = π/4 X D^2 X L (assuming Best fit = 350mm)
0.0024298 = 3.14/4 X D^2 X 350
2429825.33 = 3.14/4 X D^2 X 0.350
D = 0.0094m (efficient for noise level of 30db)
D= 94mm
std. inlet and outlet head pipe= 23.48mm

Step 6 :-
Flow rate (Q)
Formula = Displacement X RPS X (Vol efficiency/2)
Displacement = π X (Bore/2)^2 X Stroke X No.of cylinder

= π X (50/2)^2 X 49.5 X 1
= 97193.022 mm^3
= 97.193 cc

Substituting the values, we get,
Q = 97193.022 X 133.33 X (0.85/2)
Q = 0.005507 m^3/s

Step 7 :-
Velocity of exhaust gas
Q = A.V
0.005507= (π/4) X (0.0025)^2 X V
V =10.32 m/s

Step 8 :-
Back Pressure Calculation
$\Delta P = k \times L/D \times \rho V^2/2$
where, p = 1.176 Kg/m^3
k = 0.02 (friction resistance of perforated tube)
L = 0.035 m
D = 0.025 m (inlet head pipe)
$\Delta P = 0.02 \times 0.035/0.025 \times 1.176 \times 10.32^2/2$
ΔP= 17.892
ΔP+5= 22.892 Pa (Considering Water Column Addition)

Step 9 :-
Heat Dissipation by exhaust gas
Formula = m X C X (T1 - T2)
M (mass flow rate) =ρ X A X V
= 1.176 X π /4 X 0.094^2 X 10
= 0.024 Kg/s.
C = Specific heat capacity of exhaust gas= 1000J/kgk
T1= Inlet Temperature = 400°C
T2= Outlet Temprature= 150°C
Q = m X C X (T1 - T2)
Q = 0.024X 1000 X (400-150)
Q = 5000J/S

Step 10 :-
Heat absorbption by water
Efficiency = Qwater/Qgas X 100
Where, Qwater = M'Water X Cp X (Ta-Tb)
= 0.05 X 4186 X (50 -30)
= 4186 J/S
efficiency= 4186/5000 X 100
= 83%
Conclusion :- Heat dissipation of aqua silencer comes out to be 83%

3.3 Development phases

Reasearch and requirement analysis – Carrying out analysis to test the emissions of the model
CAD Design – CAD model of the Aqua Silencer with its components like Perforated tube, Inlet outlet pipes, Metal case covering etc.

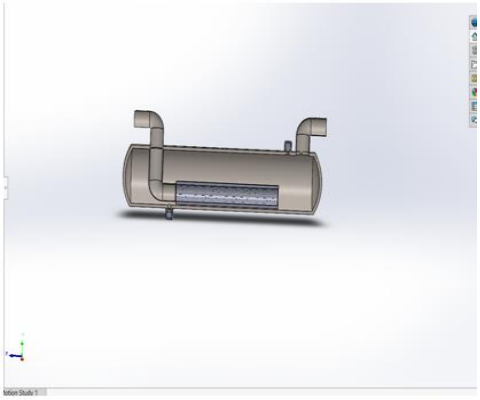

Fig 3.1 Sectional View

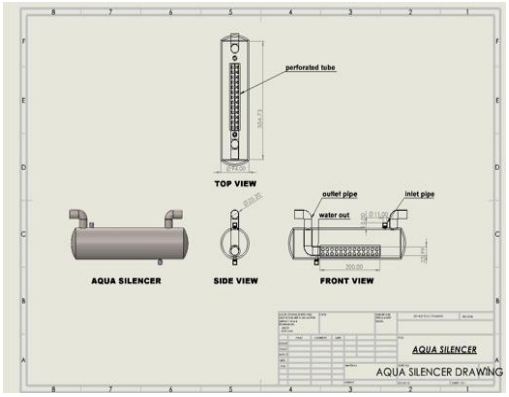

Fig 3.2 Sheet of CAD model

CAD development phase- of an aqua silencer, prototyping involves creating a virtual or physical model based on the initial design to evaluate its feasibility and structural integrity. This stage allows designers to simulate the behavior of the silencer under various operating conditions and make adjustments as needed.
Testing- follows, where the prototype is subjected to performance evaluations such as noise reduction efficiency, emission control, and thermal resistance. These tests help identify any functional or material flaws that could affect the silencer's effectiveness.
Optimization- It is carried out by analyzing the test data and refining the design to enhance performance, reduce material usage, and improve durability. This iterative process ensures that the final product not only meets the required standards but also operates efficiently in real-world applications.

4. COMPONENTS AND THEIR ROLES

A. Outer Casing

The outer casing of an aqua silencer serves as the main structural component that houses and protects the internal elements responsible for emission and noise reduction. It is typically constructed from corrosion-resistant materials such as stainless steel or mild steel to withstand exposure to high temperatures, moisture, and acidic

exhaust gases. The casing provides an enclosed environment where exhaust gases can be processed efficiently before being released into the atmosphere. Inside the casing, the perforated tube, water chamber, absorbent materials, and baffles are securely positioned to ensure optimal interaction between the exhaust gases and the filtration mediums. The outer casing is designed to withstand pressure variations caused by engine exhaust flow while preventing gas leaks. Additionally, it plays a crucial role in containing and directing the gases through different purification stages, ensuring that they pass through water and absorbent materials before exiting. The structural integrity of the outer casing also contributes to noise reduction by containing vibrations and sound waves generated by exhaust gas expansion. In some designs, the casing may feature insulation or additional sound-dampening materials to enhance its efficiency. The casing is equipped with an inlet pipe for receiving exhaust gases and an outlet pipe for discharging the treated gases. To facilitate maintenance, a drain plug is usually integrated at the bottom of the casing, allowing for the periodic removal of used water and collected impurities. The efficient functioning of the outer casing ensures that all internal components operate effectively, contributing to a significant reduction in emissions and noise while maintaining durability and longevity.

Fig 4.1 – Outer Casing

Fig 4.2 – Inlet and Outlet Pipes

B. Inlet and Outlet Pipe

The inlet and outlet pipes in an aqua silencer play crucial roles in directing the flow of exhaust gases through the system, ensuring effective filtration and noise reduction. The inlet pipe is connected to the engine's exhaust manifold and serves as the entry point for high-temperature, high-pressure exhaust gases. As these gases enter the aqua silencer through the inlet pipe, they are directed into the perforated tube, where they are broken into smaller bubbles to facilitate better interaction with the water medium. This process enhances the absorption of harmful gases such as carbon monoxide, hydrocarbons, and nitrogen oxides, reducing their concentration before they escape into the environment. Once the exhaust gases pass through the water chamber and the additional filtration media, such as activated charcoal or lime water, they lose a significant portion of their pollutants. The treated gases then move towards the outlet pipe, which allows them to exit the silencer and be released into the atmosphere with reduced emissions and noise levels. The outlet pipe is designed to ensure a smooth flow of the purified gases without creating excessive backpressure, which could negatively affect engine performance. Proper alignment and sealing of both the inlet and outlet pipes are essential to prevent gas leaks and ensure that all emissions pass through the filtration process. By efficiently channeling the exhaust gases in and out of the silencer, these pipes contribute to the overall effectiveness of the aqua silencer in minimizing environmental pollution and noise disturbances.

C. Perforated Tube

The perforated tube in an aqua silencer plays a crucial role in breaking down exhaust gases and enhancing their interaction with the water medium for effective filtration. As the engine expels exhaust gases into the silencer, they first pass through the perforated tube, which is designed with multiple small holes of specific sizes and patterns. These perforations help in dispersing the exhaust gases into smaller bubbles, significantly increasing their surface area. This process allows for better mixing of the gases with water, improving the absorption of harmful pollutants such as carbon monoxide, nitrogen oxides, and sulfur dioxide. The smaller gas bubbles remain in contact with the water for a longer duration, leading to more efficient dissolution and neutralization of toxic substances. Additionally, the perforated tube helps in reducing the velocity and turbulence of the exhaust gases, which further contributes to noise reduction. The controlled flow through the tube ensures that gases are gradually released into the water chamber, minimizing sudden pressure variations and enhancing the overall efficiency of the silencer. The design and placement of the perforations are optimized to ensure a balance between effective gas dispersion and minimal backpressure on the engine, ensuring smooth operation without compromising performance. Over time, the perforated tube may accumulate carbon deposits and other impurities, necessitating periodic cleaning or maintenance to sustain its functionality. By effectively dispersing exhaust gases and facilitating better pollutant absorption, the perforated tube serves as a key component in the overall working of an aqua silencer, contributing to both emission control and noise.

Fig 4.3 – Perforated Tube

Fig 4.4 - Lime and Water Chamber

D. Drain Plug

The drain plug in an aqua silencer plays a crucial role in maintaining the efficiency and longevity of the system by allowing the removal of used water and accumulated residues. As the exhaust gases pass through the water chamber, harmful pollutants such as carbon particles, unburnt hydrocarbons, and dissolved acidic gases gradually build up, contaminating the water and reducing its effectiveness in filtering emissions. Over time, this accumulation can lead to clogging, decreased gas absorption efficiency, and an increase in backpressure, which may affect engine performance. The drain plug, typically positioned at the lowest point of the silencer, provides a controlled outlet for periodic drainage of the used water and sediment. It is usually made of durable, corrosion-resistant materials such as stainless steel or brass to withstand continuous exposure to moisture and exhaust byproducts. Some designs incorporate a simple threaded cap that can be manually opened, while others feature a valve mechanism that allows for controlled drainage without complete removal of the plug. Regular maintenance through scheduled draining and refilling of clean water ensures that the aqua silencer continues to operate efficiently, preventing excessive buildup of pollutants. In some advanced designs, automatic or semi-automatic draining systems may be implemented to further simplify maintenance. The effective functioning of the drain plug is essential for sustaining the performance of the aqua silencer, ensuring optimal emission control, and maintaining a cleaner.

E. Water and Lime Chamber

The water and lime chamber in an aqua silencer work together to reduce emissions and noise from internal combustion engines. The exhaust gases from the engine first pass through the perforated tube inside the water chamber, where water helps to cool and dissolve harmful pollutants. The water absorbs carbon particles and other impurities, reducing the intensity of emissions before they escape into the atmosphere. After this, the gases move into the lime chamber, which contains calcium hydroxide (lime) that reacts with acidic components like sulfur dioxide and nitrogen oxides, neutralizing them to form less harmful compounds. This chemical reaction helps in further purification by reducing toxic emissions. Additionally, the lime chamber aids in preventing water acidity, maintaining a balanced pH level for effective long-term operation. Through this dual-stage process, the aqua silencer efficiently minimizes air pollution and noise, making it an environmentally friendly alternative to conventional exhaust systems.

5. TESTING AND RESULTS

The PUC (Pollution Under Control) testing procedure for an aqua silencer involves measuring the emission levels of a vehicle to ensure compliance with environmental standards. The vehicle is placed in a controlled testing environment where the exhaust gases are analyzed before and after passing through the aqua silencer. A probe is inserted into the exhaust pipe to collect emissions, and gas analyzers measure pollutants such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and particulate matter. The aqua silencer, which works on water scrubbing and adsorption principles, is expected to reduce the concentration of these pollutants. The emission data is compared with permissible limits set by regulatory authorities, and a certificate is issued if the vehicle meets the required standards. If emissions exceed the limits, the vehicle owner is advised to take corrective measures before retesting. This procedure helps in assessing the efficiency of the aqua silencer in reducing vehicular pollution and ensuring compliance with air quality norms.

5.1 Performance Metrics

Efficiency - The Aqua Silencer has lime and charcoal solution with water levels at 70% capacity, which thus increases the performance of reduced emissions as exhaust gases from the vehicles

Emissions -The impurities level of concentration were reduced by 40-50%. Thus highlighting the advantage of the design reducing Nox, O2, C02, and sulphate emissions causing harm to the environment

5.2 Performance Analysis

The analysis of results from testing an aqua silencer reveals a noticeable reduction in harmful emissions when compared to a conventional exhaust system. Measurements typically show a decrease in pollutants such as carbon monoxide, unburnt hydrocarbons, and nitrogen oxides, indicating improved exhaust filtration. This reduction is primarily due to the water-based absorption system and the use of activated charcoal, which effectively trap and neutralize toxic gases. The water acts as a medium that dissolves some of the exhaust gases, while the charcoal adsorbs and reduces the emission of harmful substances. The overall outcome demonstrates that the aqua silencer not only contributes to cleaner exhaust but also aligns with environmental standards aimed at minimizing air pollution from combustion engines.

Fig 5.1- Before

Fig 5.2 - After

Based on the two PUC (Pollution Under Control) test readings shown in the images, we can summarize the change in exhaust gas composition before and after using the aqua silencer as follows:

Before using the aqua silencer:

- CO (Carbon Monoxide): 0.065%
- CO_2 (Carbon Dioxide): 2.38%
- HC (Hydrocarbons): 857 ppm
- O_2 (Oxygen): 16.75%
- Lambda (λ): 0.971

After using the aqua silencer:

- CO (Carbon Monoxide): 0.038%
- CO_2 (Carbon Dioxide): 0.72%
- HC (Hydrocarbons): 311 ppm
- O_2 (Oxygen): 19.20%
- Lambda (λ): 0.000

Summary:

The use of the aqua silencer significantly reduced emissions. Carbon monoxide dropped from 0.065% to 0.038%, showing a substantial decrease in incomplete combustion products. Hydrocarbons were reduced from 857 ppm to 311 ppm, indicating better fuel burning and lower release of unburnt fuel. Oxygen content increased from 16.75% to 19.20%, suggesting improved exhaust gas dilution or better air-fuel mixture. CO_2 levels dropped from 2.38% to 0.72%, which may reflect reduced combustion intensity or more complete combustion with less carbon output. Overall, these results highlight the effectiveness of the aqua silencer in lowering harmful emissions and contributing to cleaner engine operation.

6. CONCLUSION AND FUTURE SCOPE

The study on the design and optimization of an aqua silencer demonstrates its effectiveness in reducing both emissions and noise levels in internal combustion engine exhaust systems. By analyzing various design parameters such as perforation density, water depth, and filter media composition, it is evident that a well-balanced configuration can significantly enhance the silencer's performance. The use of activated charcoal and limestone as filter media effectively absorbs harmful pollutants, while optimized perforation density and water levels contribute to efficient noise attenuation without causing excessive backpressure. The findings suggest that an aqua silencer is a viable solution for reducing vehicular pollution, making it a promising alternative for sustainable exhaust treatment. However, challenges such as water contamination due to prolonged usage and maintenance requirements must be addressed for long-term applicability. Future prospects for aqua silencers include advancements in self-cleaning mechanisms to enhance the durability of the filtration media and reduce maintenance intervals. The integration of nanomaterials in the filter composition could further improve the absorption efficiency of toxic gases, leading to superior emission control. Additionally, research into hybrid

filtration systems, incorporating electrostatic precipitators or catalytic converters, could enhance pollutant removal rates. The adoption of computational fluid dynamics (CFD) and artificial intelligence-based optimization techniques can refine the design to achieve maximum efficiency with minimal energy losses. With increasing environmental regulations and the growing need for cleaner emission technologies, the development of smart, adaptive aqua silencers capable of real-time monitoring and control can further revolutionize exhaust treatment systems. As sustainable transportation gains momentum, integrating aqua silencers with electric hybrid vehicles or alternative fuel engines could contribute to a more eco-friendly automotive industry.

7. REFERENCES

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[2] "Design and Construction of Aqua Silencer" featured in the *American Journal of Engineering Research (AJER)*, Volume 9, Issue 10, 2020. This research focuses on the design and construction aspects of aqua silencers, detailing components like the perforated tube, outer shell, and activated charcoal layer, along with their roles in emission and noise reduction.

[3] "Design and Fabrication of Aqua Silencer for Emission Control as an Eco-Friendly System" from the *International Research Journal of Engineering and Technology (IRJET)*, Volume 9, Issue 5, May 2022. This paper compares the performance of aqua silencers to regular silencers, emphasizing the role of lime water and activated charcoal in reducing noise and emissions.

[4] "Design and Development of Aqua Silencer" published in the *International Journal of Engineering and Innovative Technology (IJEIT)*, Volume 5, Issue 11, May 2016. This study outlines the methodology for designing and developing an aqua silencer, covering literature study, specimen design, fabrication, assembly, and testing phases.

[5] "Construction and Analysis of an Aqua Silencer for Air Pollution Reduction" from the *International Journal of Research and Analytical Reviews (IJRAR)*, Volume 6, Issue 2, May 2019. This paper presents the construction and analysis of an aqua silencer aimed at reducing air pollution, detailing the components, CAD models, experimental results, and performance comparisons with conventional silencers.