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EXAMINING THE IMPACT OF A MUFFLER AND A PARTICULATE TRAP ON THE LEVEL OF EXHAUST NOISE GENERATED BY A DIESEL ENGINE

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ABSTRACT: An investigation is done to determine the effectiveness of a diesel engine's particle filter in reducing engine exhaust noise. This essay concisely explains the variables that lead to engine and exhaust noise output, as well as the concept of noise suppression. It also provides a solid theoretical framework for sound waves and engine noise. The experimental effort entails designing and developing a particulate trap particularly for the engine in order to control exhaust noise. The inquiry also looks on the reduction in noise level achieved by utilizing a muffler. A comparative experimental investigation is conducted to determine the efficacy of particle traps and mufflers in reducing noise levels.
Keywords: *Engine Noise, Noise Level, Particulate Trap, Muffler.*

I- INTRODUCTION

The exhaust pipe system experiences pressure oscillations. An investigation was conducted to determine the best technique for managing these oscillations with the goal of optimizing their impact on engine performance. Numerous differences can be found in approaches and findings. Pressure fluctuations in conventional exhaust manifolds frequently degrade engine performance by impeding the cylinder's optimal intake and exhaust. The engine is currently having performance issues as a result of the energy being drained from the exhaust system. At maximum load, the energy dissipated would be the same as the heat produced by the given horsepower. This energy presents itself not only in higher exhaust temperatures, but also in pressure fluctuations or waves that cause gas particles to accelerate and decelerate as they travel through the exhaust system. Compression ignition engines generate exhaust pulsations that account for an estimated 10% of the energy contained in the fuel.

Literature Survey

Keisuke Yoshimori et al. developed a novel type of exhaust silencer built of porous sintered aluminum.2. Fluid dynamic analysis was used to investigate noise reduction. It was determined that noise reduction is primarily due to fluid effects caused by the material's gas permeability, taking into account the impact of factors such as velocity profile flattening, heat dispersion, reduced flow turbulence, and smoothing of exhaust pulsation.

Atsuo Shimura3 defined the longitudinal vibration model of the high frequency noise produced by the exhaust system as a beam. Methods for isolating vibration from the front exhaust pipe were investigated in order to reduce noise radiation. The mentioned options include raising the mass of the front pipe, adjusting the smaller Young's modulus of the pipe material, installing flexible pipes with two sections, and other methods.3. Peter et al.4 discussed the Helmholtz resonator, a long-standing industry technology for reducing noise from automotive or machine exhaust systems. A thin, rectangular shell-style muffler piece

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has been designed to effectively reduce exhaust noise. The authors propose using a point impedance technique to calculate the combined system's inherent frequencies and mode shapes. Robert et al. (5) improved the acoustical finite element approach by incorporating geometric characteristics as explicit variables in the matrix equation. Furthermore, they provided a variety of examples demonstrating the impact of geometric shape on acoustical design using novel methods such as automated optimization or minimization of a specific objective function, shape sensitivity calculation, and the creation of a suitable shape to achieve a desired response.5. Fransisco et al. (2006) developed a method for quantifying the sound reduction properties of perforated ducts and investigating the impact of alternative perforated tube layouts on sound reduction, specifically the generation of back pressure by the muffler. The suggested methodology has been tested for practicality, and the results have been validated in a very simple scenario. Douglas et al. (7) created a predictive model to determine the degree to which oxidation catalyst systems will cut emissions in two-stroke engines. They also provided a full description of the restrictions inherent in the models, as well as an examination of gas dynamics and thermodynamic properties. They recommended evaluating a catalyst simulation that could be applied to the full engine model.7. They also conducted study on the typical exhaust noise produced by common engines, as shown in Table 1.

Table-1: Standard Exhaust Noise for Common Engines[2]

Engine Type	Standard Db (A) At a distance of 0.5 m	RPM
Motor Boat Engine	130	3000
Single cylinder Engine for motor cycle	85	1500
Twin cylinder diesel engine	95	1500
Three cylinder diesel engine	110	1500
Four cylinder diesel engine	120	1500

Sound Waves

The following examples can be used to explain the concept of elastic wave transmission. Let's look at a spring that has been relaxed and wound into a coil. The springs' elasticity guarantees that the coils maintain a regular spacing even when not subjected to external forces.2. Now, let one end of the spring to compress rapidly. The compression of the spring causes an accumulation of potential energy. The coils are returned to their original place with the next movement. The wave propagates along the spring in the opposite direction of its origin.3. The elasticity of the medium inside the tube causes compression of the surrounding air as the piston reciprocates, which is subsequently transmitted along the tube. The amplitude of the generated sinusoidal wave is directly influenced by the piston's movement, whereas the frequency of the wave is proportional to the piston's.The density and elasticity of the medium determine the time it takes a wave to travel a given distance. The following equation can be used to determine the sound propagation velocity in air:

$$C^{3} = \sqrt{4P/\rho} \qquad \textbf{(1)}$$

Where, C = sonic velocity in m/s; P = Atmospheric pressure in bar; ρ = Density in kg/cubic meters.

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Combustion Noise

The rate of pressure increase and maximum pressure achieved will be faster if there is more fuel left in the cylinder at the conclusion of the delay time and it burns quickly when ignited.3. Throughout the combustion process, the piston remains nearly immobile and at the top of its stroke. Diesel Knock is an audible disruption that happens during combustion as a result of a sudden and significant increase in pressure and a significant pressure impulse at the piston position. The magnitude of knock responses is determined by the mass ignited.3. It is hypothesized that the premixed flame zones are higher in temperature than the liquid droplet-containing parts. As a result, the knock reaction is expected to spread mostly during the flame's dim phase[4].

Origin of Exhaust Noise

At the end of the firing stroke, the pressure and temperature within the engine cylinder rise significantly.Four When the exhaust valve opens, gas is pumped into the exhaust system via the cylinder. The gasses have both mass and elasticity. After traveling a short distance, the sound produced by discharging gases into the environment without exhaust treatment resembles an explosive pulse with distinct wave fronts. The intensity of these acoustic shock waves is so high that they are unbearable, even for brief periods.

Phenomenon of Exhaust Noise

When the gases are discharged and the exhaust valve is then closed, the gas expands excessively or spreads much further than usual.The number is 6. This creates a partial vacuum, which is later filled by a slug as the gas cools and its vapor condenses. As a result, the exhaust conduit is experiencing significant oscillations. Large pressure waves are repeatedly reflected at high speeds within the pipeline.7. The length of the pipe, as well as the diameter and temperature of the gas, all have an impact on the frequency of the reflected wave. The engine's detonation rate and the natural gas frequency of the exhaust system, which functions similarly to an open-ended organ pipe, work together to produce the loud exhaust boom.7. Typically, the system's higher harmonics correspond to either the fundamental firing rate or a fundamental harmonic. Noise can also be caused by a sudden change in gas column pressure or gas flow acceleration.Eight If there is a tiny delay between the opening of the exhaust valve and the peak pressure, the explosive mixture will travel down the exhaust pipe and may produce a loud noise when it reaches the atmosphere. 9. It is possible that the waves' sound will not be audible. These itemsproduce vibrations with such a low frequency that they are usually regarded as mechanical vibrations.[10]

II. PRINCIPLE OF NOISE SUPPRESSION

Control at the Source

It is possible to successfully reduce combustion noise at the source by strategically designing combustion chambers, precisely adjusting injection time, and modifying fuel spray characteristics.10 Noise can be reduced by meticulously designing equipment or systems to reduce noise emission, or by putting in place measures to confine noise at the source. However, this is not practicable.11 Increased noise arises when the engine's firing frequency coincides with the natural frequency of its structural components. This phenomenon is frequently known as resonant vibration. This problem can be solved by physically isolating

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the engine from the noise-emitting surface, lowering the surface area, or altering the structure's rigidity.11

Control of Transmission Path

- When it is not possible to minimize noise at the source, this is the most effective option. Here are some strategies to consider:
- Path deflection is the deviation of the noise from its original route. When barriers are far larger than the wavelength of the noise they are intended to divert, they can efficiently perform their purpose when placed outside. Deflectors can be arranged to effectively redirect sounds away from the recipient.
- Enclosure: Significant attenuation can be achieved by constructing an enclosure that effectively encloses the receiver source. This type of noise reduction technique is used in power plants to reduce the noise produced by large diesel engines.13
- Absorption occurs when materials such as foil, rubber, felt, fiber, and so on are placed in the route of the noise. These materials have distinctive or inferior transmission properties.
- Impedance mismatch refers to disturbances in the path that acoustic energy takes from the source to the receiver. These interruptions may cause the energy to be reflected back to the source, interfering with the smooth flow of energy. Mufflers and acoustic filters are primarily designed to minimize noise, while some mufflers may also contain sound absorption in the sound transmission channel.

The use of Preventive Measures at the Receiver

Some preventive measures like sound absorbing material or a sound insulating material can be placed to avoid the effect of noise.

Exhaust Noise Suppression

The exhaust noise reduction can be achieved by the following methods:

- When high pressure energy is converted into kinetic energy, heat is generated as a result of friction and turbulence, as seen when a motorcycle is silenced.
- Dissipation: The exhaust is either controlled or routed through an absorbent substance. Nonetheless, this type of drop creates a large barrier to the flow of exhaust gas, which is undesired.
- Reactive configuration: The numerous chambers and connecting tubes are placed in a linear order. This filter selectively reduces frequencies beyond a certain threshold while allowing all sub-audible frequencies to pass through. Because there is no throttling effect, exhaust gases can flow freely, making this type of muffler more widely used.
- Interference type: The exhaust stream separates into multiple partial streams of varying lengths, which then recombine and displace one another in phase.17 oscillations that are 180° out of phase are deleted, while the remaining oscillations are unaltered. Nonetheless, this form of engine is not very useful for engines that must work at variable speeds.

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III. TYPES OF PARTICULATE TRAPS

(a) Wire Mesh Particulate Trap

The trap substrate is made of a crushed woven stainless steel wire mesh placed between perforated cylindrical inner and outer casings. The weaving and rolling of the wire mesh results in a low density and surface to volume ratio on the outside of the annular substrate. In contrast, the inner diameter zone has an increasing density and surface-to-volume ratio.As a result, smaller particles are unable to enter the inner diameter, while bigger particles are caught in the outer mesh encircling the circle. This gradual transition from an open outer diameter mesh to a more closed inner diameter mesh enables the capture of particulate particles at varying depths.Twenty As a result, it prevents particles from accumulating in the mesh's outer region, where they could clog the filter media. The wire mesh is coated with a refractory wash layer, and noble metals are then scattered across it as a catalyst. The wire mesh produces a substantial quantity of turbulent exhaust flow, which effectively serves as a particle trap and an oxidant for the gas.

(b) Silica Fibre Candle Particulate Trap

The candle particulate trap contains nine filtration components. The filtration medium is made up of numerous layers of silicon fiber yarn that are carefully braided in a cross-wire pattern around punched sheet metal support tubes. One end is sealed.These components are known as candle elements because they resemble candle sticks. The diameter of the silicon dioxide yarn thread, which is made up of individual fibers with a diameter of approximately 9 x 10-6, ranges from 0.7 to 1.0 mm. Catalytic oxidation is the technique of putting a refractory wash coat to woven yarn and then soaking the exposed surface with precious metal. The trap oxidizer experiences little mechanical and thermal loads, resulting in minor exhaust gas backpressure. Nonetheless, due to its poor particle retention capacity, it requires frequent regeneration.

(c) Ceramic Foam Trap

The trap is formed of ceramic foam containing either cordierite or alumina. The pores have a narrow distribution, measuring 250-500 µm in width and roughly round in form. They take a downhill path with only a few non-through channels.Twenty These filters tend to be more effective at greater flow rates. Furthermore, they use the impaction trapping principle to enhance the distribution of the deposited soot mass in the ceramic foam's cylindrical volume while maintaining low pressure. This structure reduces the ignition temperature by approximately 50 degrees Celsius by ensuring a more uniform and level distribution of heat and flame during the regeneration process. The trap is made by soaking a ceramic paste in a polyurethane foam matrix

(d) Porous ceramic honeycomb particulate trap

The oxidizer is made up of parallel tunnels with approximately circular cross sections that are made of a porous, cellular ceramic honeycomb structure. Pathways are blocked at both ends in an alternating pattern to give the inlet and exit faces the appearance of black and white squares on a chessboard. The departure passageways are clear at the outlet but blocked at the inlet ends, whereas the inlet passageways are blocked at the outlet's far end. Before reaching the exit channels, exhaust gas must travel at a perpendicular angle through the porous ceramic walls of the input channel. Finally, the particle trap's rear exit chamber receives the

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filtered exhaust gas. The drop in pressure across the filter affects particle removal from the honeycomb trap. When the channels become partially obstructed, additional fuel must be injected to compensate for the drop in power. As a result, more thermal energy is discharged with the exhaust gas, increasing the gas temperature and commencing the oxidation and ignition of the accumulated particulate matter.Twenty-one

The paragraph above describes the many types of trap systems used as post-treatment equipment for diesel engine exhaust gas. Because of its lightweight, low density, and limited heat conductivity caused by its porous network topologies, the porous ceramic honeycomb filter is a less expensive and more efficient alternative to other oxidizers. In this situation, permeability equals strength, temperature resistance, and structural uniformity. As a result, the ceramic honeycomb filter type trap oxidizer is recommended for use in the current study. The goal of this research is to determine how much a muffler and a particle trap can reduce noise levels caused by an engine's noise emissions.

Fabrication of Particulate Trap

Fabrication of Outer Casing

A mild steel sheet measuring 540 mm by 710 mm by 3 mm is selected and polished. The material is then rolled and connected along its length to form a cylindrical outer shell measuring 170 mm in diameter. The welded section has been polished and cleaned. To reduce sound reflection and exhaust noise, the internal surface of the outer casing is coated with ceramic material, which is known for its strong resistance to high temperatures, corrosion, and sound insulation.The number is 6. As a result, the exterior shell with the requisite dimensions is built and depicted in Figure 1.

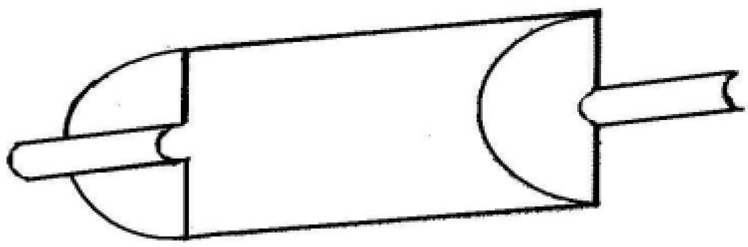

Fig.-1: Trap Outer Casing

Fabrication of Inner core

A 79 mm x 300 mm perforated sheet with 6 mm holes is rolled into a 25 mm perforated tube. The welded section has been polished and cleaned. A total of twenty-four perforated tubes were made. A circular sheet of 170 mm diameter and 3 mm thickness is chosen. It is then drilled with 24 identical holes, each with a diameter of 25 mm, spaced in a zigzag pattern. A perforated tube is then welded to each opening, and the process is repeated for the remaining tubes. A circular sheet is welded onto the other end of the perforated tubes to close them. This sheet has a diameter of 170 mm and a thickness of 3mm. The remainder of the basic circular sheet has many openings to allow exhaust gas to escape.7. After the inner core has been created, the chosen catalyst is applied to both the inner and outside surfaces. As a result, the inner core is prepared and displayed in Figure 2.

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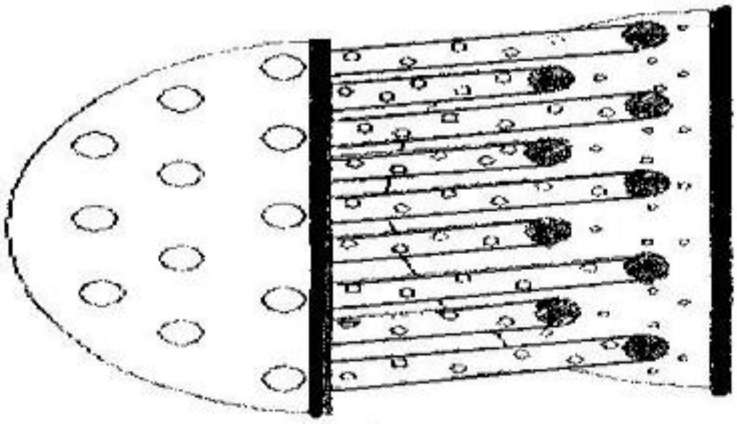

Fig.-2: Sectional view of the trap inner core

Assembling of Inner Core and Outer Casing

The inner core is then inserted within the outer shell, leaving a 20-cm gap at each end. The inner surface of the outer casing is then attached to the perimeter of the circular sheets by welding. Two circular sheets, each having a diameter of 170 mm, are drilled with a 60 mm center hole. It is then soldered securely to the outer shell over its whole circle. To create the entry and exit channels, two basic tubes with a diameter of 60 mm are acquired and welded to the outer casing's end plates through the apertures.

IV. EXPERIMENTAL

Figure 3 shows the experimental setup. The study used a 3.78 KW, four-stroke, water-cooled, single-cylinder, direct-injection, vertical diesel engine with a speed of 2000 rpm. The engine is mounted on the bed and comes with the necessary connections for cooling water and lubrication. The gasoline comes from a tank with a three-way valve that allows the gas to flow through the burette or directly from the tank.The number is twelve.

RESULTS AND DISCUSSION

Exhaust Temperature

Figure 4 shows how the engine's brake power affects exhaust gas temperature, comparing scenarios with and without a muffler and particulate filter. The temperature of the exhaust gradually climbs until it reaches 20% of the load. When the load exceeds 20%, the exhaust temperature quickly rises.

Engines with particle traps see a lower rise in exhaust temperature under low loads and a greater rise in exhaust gas temperature under high loads. The temperature of the exhaust gas decreases marginally within the muffler casing. The drop is less noticeable at low loads, but it is significantly amplified at greater loads.

With the trap installed, the engine's exhaust temperature increases by about 10% at maximum load and 5% under low load conditions. The exhaust temperature of the muffler drops by around 2% and 3% at low and maximum loads, respectively.

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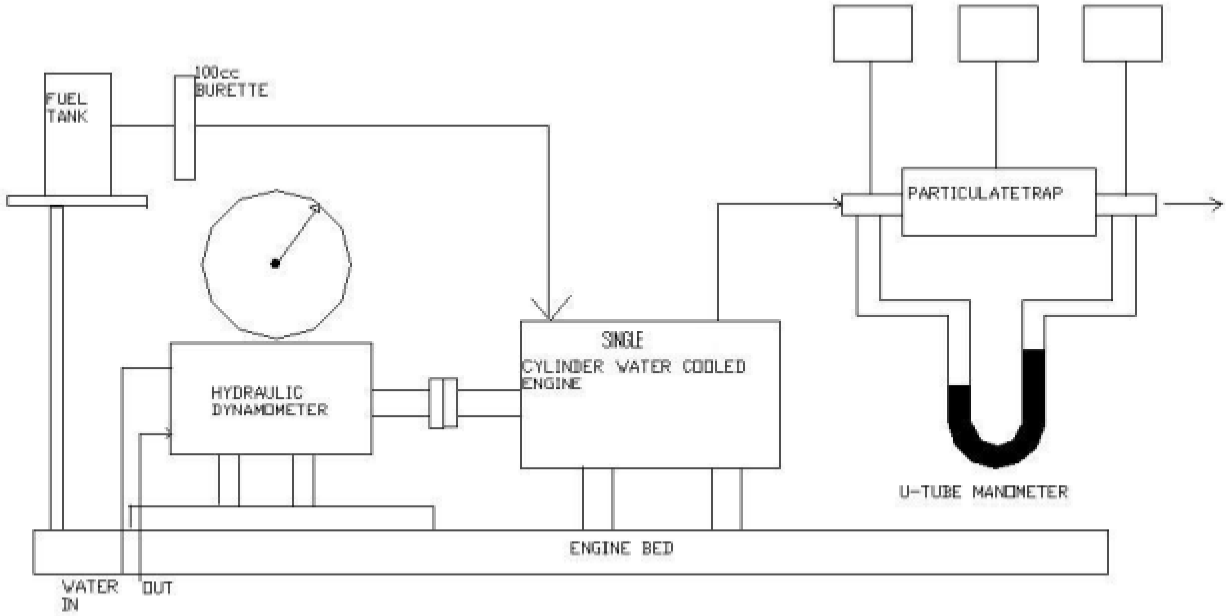

Fig.-3: Experimental setup for Noise Measurement

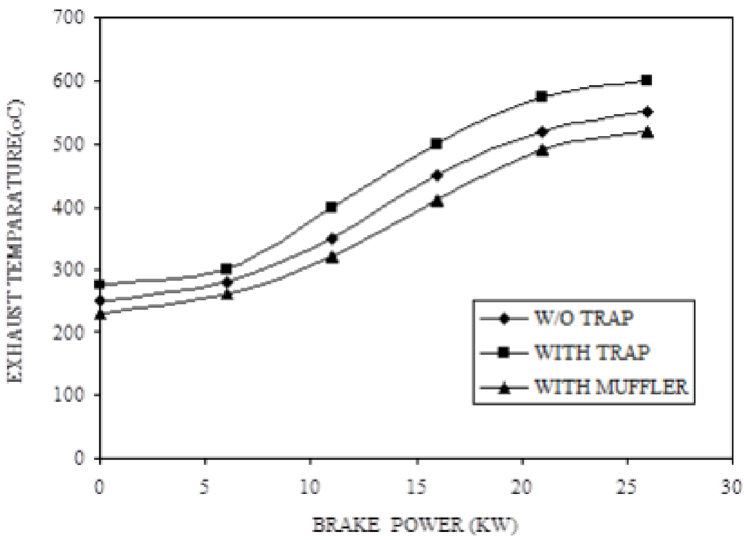

Fig.-4: Variation of exhaust temperature with brake power

Brake Thermal Efficiency

Figure 5 depicts the relationship between brake power and brake thermal efficiency. The graph shows a favorable association between increasing load and improving the engine's braking thermal efficiency. The brake thermal efficiency rises rapidly until it reaches 40% of the load, at which point it gradually increases at a slower pace.Seventeen It has been discovered that engines equipped with particle traps burn more gasoline than engines without them, resulting in lower brake thermal efficiency for the engine with the particulate trap. When an engine is fitted with a trap, its braking thermal efficiency is reduced by around 8% under maximum load. Similarly, installing a muffler reduces emissions by about 3%.The number is 18.

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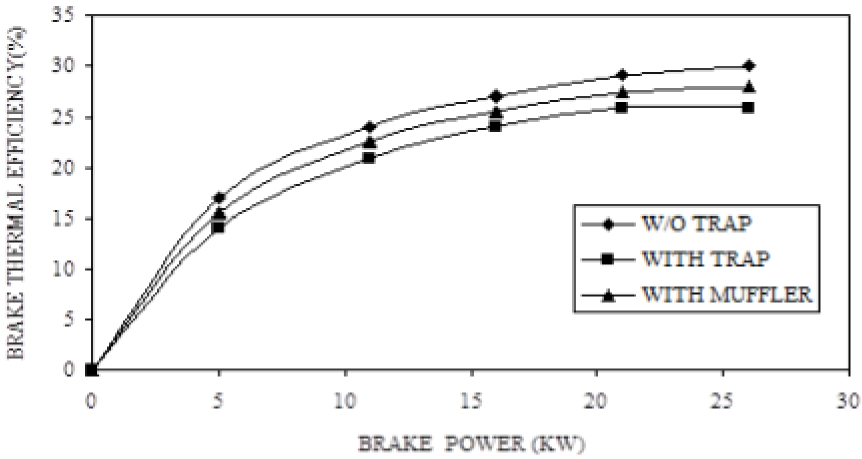

Fig.-5: Variation of brake thermal efficiency with brake power

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