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A Case Study on Working of Aqua Silencer

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***Abstract*—This Automobiles are not only sources of air pollution, other sources such as electric power generating stations, domestic fuel consumption, industrial processing, etc. also contribute heavily to the contamination of our environment, so serious attempts must be made to conserve the environment from degradation. An aqua silencer is an attempt and the main idea is to control the emission and noise. An aqua silencer is fitted to the exhaust pipe of the engine. The sound produced under water is less hearable than it is produced in the environment. This mainly because of small sprockets in water molecules, with charcoal layer and outer layer applying thermal conducting material, using backpressure process thus lowering its amplitude and lowers the sound level. Because of this property of water is used in this silence, hence the name is AQUA SILENCER. The noise and smoke level are considerably less than the conventional one, it is cheaper, no need for a catalytic converter, and easy to install. Serious attempts must be made to conserve the earth's environment from degradation. An aqua silencer is an attempt in this direction**

Keywords—Automobiles; Aqua silencer; Charcoal layer; air pollution, Thermal conducting material.

I. INTRODUCTION

Nowadays Air pollution is a major problem. The main pollutants contribute by automobiles are nitrogen oxides (NOx), volatile organic compounds (VOCs), carbon monoxide (CO), carbon dioxide (CO_2), particulates, sulphur dioxide (SO_2), and lead. Etc. Air pollution causes a dangerous physical effect on the human body, animals, and environment. So serious attempts must be made to conserve the earth's environment from degradation. The reason why we choose aqua silencer is, nowadays the pollution causes physical unwell effects to the mortals and additionally the environment. The aqua silencer system is designed for replacing commonly used single unit silencers in the engine with its slender structure and less weight. It plays an important role in control the noise and emission of gases from engines. The main reason to use aqua silencer is that nowadays air pollution is increasing rapidly. This system reduces the dangerous exhaust gases from automobiles. These emissions are controlled by the activated charcoal layer around the perforated tube and lime water. The charcoal layer having a high capacity to absorb emission gases from the engine. These types of charcoal layers with lime water react chemically with emission gases and change the chemical structure of emission gases. The smoke or emission gases and noise levels in aqua silencers are very less than the commonly used silencers. [1]

II. WHAT IS A AQUA SILENCER

"Aqua Silencer" is an attempt made to deal with the control of overall emissions & undesirable sound at the tailpipe of a vehicle, before it is emitted to the atmosphere. It can be fitted along with or instead of the catalytic converter at the tailpipe of the exhaust system of a vehicle. The sound produced due to the operation of an engine can be controlled using water as the sound produced underwater is less hearable than produced in the environment. This mainly because of small sprockets in water molecules, which lowers its amplitude thus, lowers the sound level. Because of this property, water is used in this silencer & hence its name, "Aqua Silencer". Also, there is no effect of it after its installation on the fuel efficiency of a vehicle, which may be petrol-powered or diesel-powered. Exhaust emissions can be controlled using a layer of activated charcoal which is highly porous & possesses few extravagances & has high adsorption properties, so it attracts the hazardous gases towards it & releases much less position to the environment. The level of noise & smoke coming out of "Aqua Silencer" is considerably less compared to conventional silencer; also it is cheaper to build & maintain. There is no need for a catalytic converter getting fitted with it, give no rise to any complications in assembling it and easy to install.[6]

III. SILENCER TYPES

Despite the terms and myriad of configurations, the silencer can be broken into three fundamental types:

i. Reactive
ii. Absorption
iii. Combination

In addition to the three main silencer types, other functions such as spark arresting, emission control, heat recovery, etc., may also be incorporated into the silencer design. Each type of silencer has specific performance attributes that can be used independently or in combination to produce the required IL for a specific application. Several additional silencer styles and options are also reviewed in the following sections. [2]

A. Reactive Silencer

Reactive silencers generally consist of several pipe segments that interconnect with several larger chambers. The noise reduction mechanism of the reactive silencer is that the area discontinuity provides an impedance mismatch for the sound wave traveling along the pipe. This impedance mismatch results in a reflection of part of the sound wave back toward the source or back and forth among the chambers. The reflective effect of the silencer chambers and piping (typically referred to as resonators) essentially prevents some sound wave elements from being transmitted past the silencer. The reactive silencers are more effective at lower frequencies than at high frequencies and are most widely used to attenuate the exhaust noise of internal combustion engines. A generic

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reactive engine silencer comprised of two proportionally sized chambers with a pair of interconnecting tubes.

B. Absorption Silencer

Absorptive silencers contain fibrous or porous sound-absorbing materials and attenuate noise by converting the sound energy propagating in the passages into heat caused by friction in the voids between the oscillating gas particles and the fibrous or porous sound-absorbing material. The absorptive characteristics of materials are discussed further. Absorptive silencers usually have relatively wideband noise reduction characteristics at middle and higher frequencies. It is often used to attenuate the engine intake noise or supplement the performance of reactive silencers for engine exhaust noise control. The sound-absorbing materials are generally held in position by the use of a perforated metal liner. Knowledge of the structural content of an exhaust system is important when considering the inclusion of a catalytic element or Selective Catalytic Reduction (SCR) system in conjunction with the silencer. Particulate migration of the insulation into the exhaust stream over a while can cause the catalytic element to become fouled and substantially impact or impede its performance.

C. Combination Silencer

Some silencers combine both reactive and absorptive elements to extend the noise attenuation performance over a broader noise spectrum. Combination silencers are also widely used to reduce engine exhaust noise.

D. Spark Arresting Silencer

Some Federal state, local and municipal by-laws often dictating exhaust installations have provisions for arresting sparks from internal combustion engines. If an engine is to be used in an area where there is potentially dry vegetation of other combustible materials that are likely to be ignited by any hot carbon passing through the exhaust, one must incorporate spark-arresting capabilities into the silencer. Most approved spark arresting systems will employ diffusers or modified interconnecting tubes that create a centrifugal flow action in the exhaust to direct carbon particulate into a collection chamber. The particulate trap should be periodically inspected and cleaned to ensure the proper functionality of the spark arresting capabilities of the silencer.

E. Catalytic Silencer

To enhance exhaust gas emission control one may incorporate a catalytic converter element into a silencer to reduce the Oxides of Nitrogen, Carbon Monoxide and Non-Methane Hydrocarbons (NMHC) discharged in the exhaust stream. A catalytic converter is comprised of a catalyst and an oxidation catalyst. The beds reduce them into benign N2 and H2O, while the oxidation catalyst reacts with CO and HC to form water vapor and carbon dioxide. Inclusion of the catalytic element into the body of an exhaust silencer can reduce the cost of a combination system by eliminating the need for a separate acoustic silencer as well as specialized catalyst housing and tracking system.

F. Heat Recovery Silencer

Most of the energy available in the fuel used in reciprocating and gas turbine engines are rejected in the form of heat. A reciprocating engine running at full load converts about one-third of the available energy into useful work, while the remaining two-thirds of the available energy is lost in the form of heat rejection. In a prime power installation where the rejected heat can be used to provide energy to auxiliary applications, a heat recovery silencer can yield attractive savings. Typical applications of heat recovery silencers for internal combustion engines include hot water heating, steam generation, heat transfer fluid heating, etc.

G. Tuned Silencer

When the low-frequency noise within a narrow band is extremely high, the tuned silencer can be designed to combat the specific offending frequencies. Tuned silencers consist of pipe segments and cavities that are used to produce a low-frequency resonance at a required frequency. The accurate prediction of the tuned (resonance) frequency is extremely important to facilitate a match of the peak frequency for reducing the narrow band noise to a desirable level. A small deviation of the silencer resonance frequency from the peak frequency of the noise will greatly degrade the silencing ability.

H. Active Silencer

Active silencing, or sound cancellation systems, employs detectors used in sensing the noise in an exhaust pipe, and a loudspeaker that is used to reintroduce an inverted signal has been developed to reduce low-frequency noise. The theoretical effect of reintroducing an inverted signal will result in the complete elimination of sound from the exhaust silencer. Although the idea of sound cancellation is very simple and attractive, there are a variety of complications and problems arising from erratic fluctuations in the sound source. Active silencing is relatively expensive at present, and its acoustic attenuation performance at high frequencies is also limited. Widespread use will be dependent upon the continued development of lower-cost systems with improved performance realized through the use of better analytical algorithms, transducers, and processors.[Figure1][5][8]

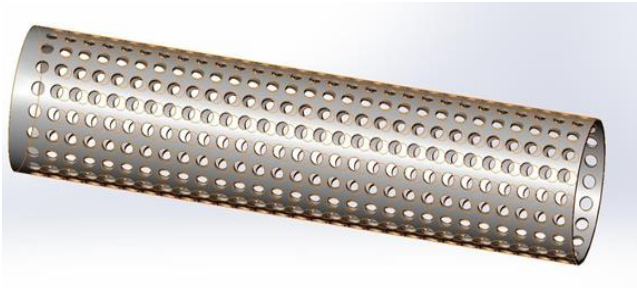

Figure1. Model of perforated tube in Solid Edge

A generic exhaust system collects hot exhaust gases from the engine and discharges them to the environment as quietly and efficiently as possible. An exhaust arrangement with minimized backpressure and satisfactory noise attenuation characteristics will usually be the result of a well-specified

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system. The exhaust termination points should not be close to the air intake system for the engine or the ventilation system of adjacent structures and should comply with all federal, state, and local regulations. Physical characteristics of the equipment room can also determine the specific configuration of an exhaust system layout and should be considered at the conceptual layout phase of the design.[3]

A. *Exhaust Silencer*

The most widely used structural shapes of silencers are the cylindrical configurations with end-inlet/end-outlet, side-inlet/end-outlet, and side-inlet/side-outlet. When a silencer is installed on top or inside of the enclosure, the side-inlet/end-outlet configuration is most popular. This enables a minimum of piping. Hockey puck and rectangular shape silencers are used sometimes due to space limitations. Silencers require traps to drain moisture. Traps installed at the lowest point of the silencer prevent rainwater from reaching the engine.

B. *Exhaust Accessories*

Most exhaust systems will be comprised of flexible connectors, connecting piping, an exhaust silencer, stack, and rain caps. All exhaust systems must be isolated from the engine with flexible connections to reduce or eliminate the possibility of structural damage caused by cyclic vibration. A flexible connection is also used to isolate the weight of the exhaust system from the engine to allow relative shifting of exhaust components due to thermal growth. Thermal growth of exhaust piping must be anticipated and supporting members as well as fixed points should be placed to avoid excessive load on supporting structures and minimize transverse loading on the flex connector.[8] As a dual system that uses separate silencers and flow paths for each engine outlet. A flexible Y Connector may also be used to merge the exhaust gases from a dual outlet engine into a single inlet silencer where space permits. Mounting bands and supports should be designed to withstand all seismic, thermal, and dead loads at the elevated temperatures that will be encountered during service. A wall or roof insulating thimble is generally required when the exhaust system passes through a combustible wall or roof and should be compliant with all applicable federal, state, and local fire codes. Rain caps are traditionally used to prevent precipitation from entering the exhaust system when the generator is idle.

C. *Thermal Insulation*

Thermal insulation blankets may be needed to wrap the exhaust system to prevent excessive heat radiation into the generator room or to protect service personnel from exposure to extremely hot piping components. Flexible pipe connections, when insulated, must expand and contract freely within the insulation. The majority of insulation products traditionally used in engine exhaust systems consist of either an aluminum wrapped or a material clad insulation layer. Determination of the maximum exterior temperature of an insulated exhaust component will depend on many factors and is often difficult to predict without specific knowledge of the exact service environment. Factors such as the ambient temperature and airflow across the piping elements can greatly affect the heat flux from the system and have a direct impact on the expected surface temperature of the system.

V. SYSTEM EVALUATION

A. *System Noise*

It is extremely important to evaluate the total system when specifying an exhaust silencer for a specific installation. As we have discussed several factors such as breakout, raw source levels, and spatial constraints can play significant roles in silencer selection and design. For example, a silencer might theoretically reduce the exhaust noise of an engine to 60 dBA at 10 feet without effectively silencing or isolating the engine intake, mechanical casing noise, etc. Many silencers have been incorrectly specified and installed in environments where the measured noise level in the area is considerably higher than the level produced by the silenced engine. General knowledge of acoustics and sound will help in identifying potential factors that could impact the overall noise levels of installation but a silencer manufacturer or acoustic consultant should be engaged when an unknown or difficult situation arises. As a final evaluation of an installed system, the radiated sound pressure level at a given distance from the source should be measured and compared against the acoustical specification.

B. *System Backpressure*

It is essential to the performance of a generator set that the installed exhaust system does not exceed the engine manufacturer's maximum exhaust backpressure limit. The pressure drop of the exhaust system includes losses due to piping, silencer, and Termination. High back pressure can cause a decrease in engine efficiency or an increase in fuel consumption, overheating, and may result in a complete shutdown of the generating system potentially causing significant damage. Pressure drop is measured in a straight length of pipe 3 to 5 diameters from the last transition change after the turbocharger outlet.[6]

VI. WORKING PRINCIPLE

Hot gas along with the sound wave generated at the end of the exhaust stroke is sent to the exhaust manifold through the exhaust valve. From exhaust valve to tailpipe the exhaust gas passes through different stages

Stage 1: In stage one exhaust gas(Temperature varies from 300°C to 700°C, depends on load condition) passes through O2 sensor, The O2 sensor checks the air-fuel ratio it measures the residual oxygen content of the exhaust gas and then sends a signal to the engine control unit in the form of an electric voltage. This voltage allows the control unit to detect whether the mixture is too lean or rich. If the mixture is too rich, then the control unit decreases the quantity of fuel in the A/F ratio and increases it if the mixture is too lean.

Stage 2: As we know Exhaust manifold is made up of cast iron or stainless steel which are poor conductors of heat, so Exhaust gases entering the Aqua silencer will have Temperature varies from 300°C to 700°C.

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In stage two the exhaust gases pass through the inlet of the Aqua silencer and then the perforated tube where the temperature of the exhaust gases is reduced in a small amount and the high mass of bubble is converted into the low mass of bubbles due to the cross-section of the tube.

Stage 3: In stage 3 these gases pass through the charcoal layer where purification of exhaust gas takes place. This charcoal layer is highly porous and possesses extra free valence so it having high absorption capacity. During this, the gases get in contact with lime water they chemically react with it and reduces its concentration. The charcoal layer is covered with an outer shell that is filled with water which reduces the noise. The sound produced in the water having less amplitude than the sound produced in the atmosphere. It happens because the water molecule lowers its amplitude.

As we know During the operation when exhaust gas makes contact with the water (temperature of the exhaust gas varies from 300°C to 700°C, depends on load condition) It will increase the temperature of the water, so to minimize the evaporation of water, The outer shell is coated with good thermal conducting material to absorb heat from the water and also the outer shell is exposed to outer environment the cooling of the outer shell will be done by air.

Stage 4: In stage 4 gases, after passing over the charcoal layer some of the gases may be get dissolved into the water. Finally, exhaust gases escape through opening at the top of the container into the atmosphere passing through the tailpipe.

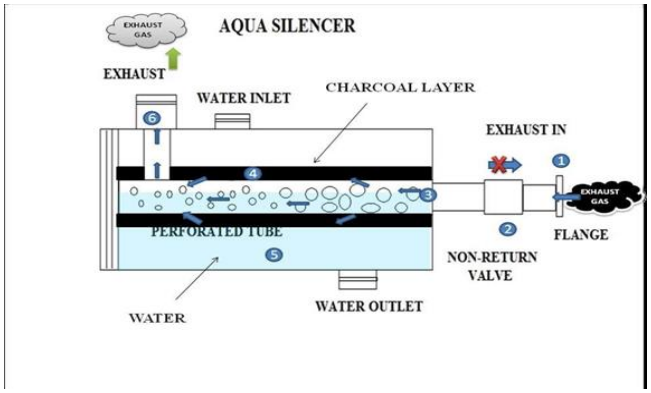

Figure 2: Working of Aqua Silencer

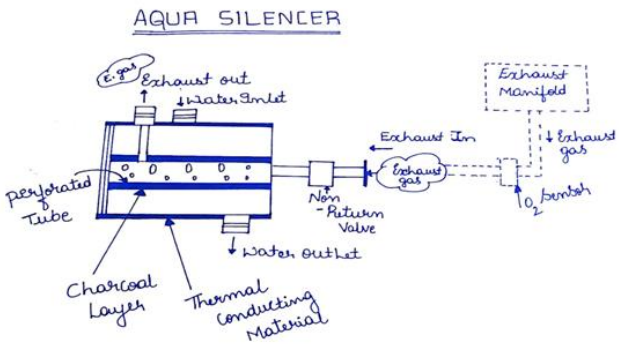

Figure 3: Structure of Absorption of Gases

VII. EFFECT OF DISSOLVED GASES ON WATER

In this system water is a very good absorbing medium. In aqua silencer gases made to dissolve in water when these gases from the engine get dissolved in water, they form acid, carbonates and bicarbonates, and also with the help of charcoal layer and outer thermal conducting material which is used for heat dissipation.[figure3]

i. Action of dissolved SOx
ii. Action of dissolved CO_2
iii. Effect of dissolved NOx

A. The Action Of Dissolved Sox

In When SOx is treated with water, it form SO_2, SO_3, SO_4, H_2SO_4, i.e. sulfur Acid (H_2SO_3,), it produces Hydrogen Sulphide which causes egg smell and causes corrosion of metals.

B. The Action Of Dissolved CO_2

In The dissolved carbon dioxide forms bicarbonate at less PH and Carbonates at greater level PH. This levels 40 to 400 mg/liter. Form a scale in pipes and boilers. The carbon dioxide mixes with water to form Carbonic acid. It causes greenhouse effect.

C. The Action Of Dissolved NO_x

The Nitrogen in water under goes Oxidation to form ammonia, Nitrate, Nitric acid. This synthesis of protein and amino acids is get effect by Nitrogen. Nitrate usually occurs in trace quantities in surface water. A limit of 10 mg per liters Nitrate is affordable.

VIII. METHODS TO CONTROL WATER POLLUTION

A. Lime Water Wash Method

The water is treated with the calculated quantities of slaked lime. After mixing the heavy precipitates settle down as sludge at the bottom of the tank is removed from time to time.
Lime can neutralize any acid present in the water.
The precipitates dissolved carbon dioxide as calcium carbonate and convert bicarbonate ions into carbonates.
The equation are given below:

1. $Ca(OH)_2 + SO_2 \longrightarrow CaSO_3 + H_2O$

2. Neutralizes any acid in water

$$2HCL + Ca(OH)_2 \longrightarrow CaCl_2 + 2H_2O$$

$$H_2SO_4 + Ca(OH)_2 \longrightarrow CaSO_4 + 2H_2O.$$

3. Precipitate Bicarbonate as Calcium Carbonate

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3 + 2H_2O$$

4. Convert Bicarbonate ions (like $NaHCO_3$, $KHCO_3$), etc into carbonates

$$NHCO_3 + Ca(OH)_2 \longrightarrow CaCO_3 + H_2O + Na_2CO_3$$

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B. Absorption Process

Activated charcoal is available in granular or powdered form. As it is highly porous and possesses free valencies. So it possesses a high absorption capacity. Activated carbon is more widely used for the removal of taste and odorous from the public water supplies. Because it has excellent properties of attracting gases, finely divided solid particles, and phenol type impurities, The activated carbon, usually in the powdered form is added to the water either before or after the coagulation with sedimentation.[5]

IX. MATERIAL SELECTION

The proper selection of material for the different parts of a machine is the main objective in the fabrication of a machine. For a design engineer, it is must be familiar with the effect, which the manufacturing process and heat treatment have on the properties of materials. The Choice of material for engineering purposes depends upon the following factors:

- Availability of the materials
- Suitability of materials for the working condition in service
- The cost of materials
- Physical and chemical properties of the material
- Mechanical properties of a material.

The mechanical properties of the metals are those, which are associated with the ability of the material to resist mechanical forces and load. We shall now discuss these properties as follows:

a. **Strength** : A material can resist the externally applied forces.
b. **Stress** : Without breaking or yielding. The internal resistance offered by a part to an externally applied force is called stress.
c. **Stiffness** : Material can resist deformation under stress. The modules of elasticity of the measure of stiffness.
d. **Elasticity** : It is the property of a material to regain its original shape after deformation when the external forces are removed. This property is desirable for material used in tools and machines. It may be noted that steel is more elastic than rubber.
e. **Plasticity** : It is the property of a material, which retains the deformation produced under load permanently. This property of the material is necessary for forging, in stamping images on coins and ornamental work.
f. **Ductility** : It is the property of a material enabling it to be drawn into the wire with the application of a tensile force. A ductile material must be both strong and plastic. The ductility is usually measured by the terms, percentage elongation, and percent reduction in area. The ductile materials commonly used in engineering practice are mild steel, copper, aluminum, nickel, zinc, tin, and lead.
g. **Brittleness** : It is the property of material opposite to ductile. It is the property of breaking of a material with little permanent distortion. Brittle materials when subjected to tensile loads snap off without giving any sensible elongation. Cast iron is a brittle material.
h. **Malleability** : It is a special case of ductility, which permits material to be rolled or hammered into thin sheets, a malleable material should be plastic but it is not essential to be so strong. The malleable materials commonly used in engineering practice are lead, soft steel, wrought iron, copper, and aluminum.
i. **Toughness** : It is the property of a material to resist the fracture due to high impact loads like hammer blows. The toughness of the material decreases when it is heated. It is measured by the amount of absorbed after being stressed up to the point of fracture. This property is desirable in parts subjected to shock and impact loads.
j. **Resilience** : It is the property of a material to absorb energy and to resist rock and impact loads. It is measured by the amount of energy absorbed per unit volume within the elastic limit. This property is essential for spring material.
k. **Creep** : When a part is subjected to constant stress at a high temperature for a long period, it will undergo a slow and permanent deformation called creep. This property is considered in designing internal combustion engines, boilers, and turbines.
l. **Hardness** : It is a very important property of metals and has a wide Verity of meanings. It embraces many different properties such as resistance to wear scratching, deformation, and machinability, etc. It also means the ability of the metal to cut another metal. The hardness is usually expressed in numbers, which are dependent on the method of making the test. The hardness of a metal may be determined by the following test.

    i. Brinell Hardness Test
    ii. Rockwell Hardness Test
    iii. Vickers Hardness (also called Diamond Pyramid) test
    iv. Share Scale Scope.

The knowledge of materials and their properties is of great significance for a design engineer. The machine elements should be made of such a material that has properties suitable for the conditions of operations. In addition to this, a design engineer must be familiar with the manufacturing processes and the heat treatments have on the properties of the materials. In designing the various part of the machine it is necessary to know how the material will function in service. For these certain characteristic or mechanical properties mostly used in mechanical engineering, practice is commonly determined from standard tensile tests. In engineering practice, the machine parts are subjected to various forces, which may be due to either one or more of the following.

i. Energy transmitted
ii. Weight of machine
iii. Frictional resistance
iv. The inertia of reciprocal parts

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v. Change of temperature
vi. Lack of balance of moving parts.

The selection of the materials depends upon the various types of stresses that are set up during operation. The material selected should stand it.[7] Other criteria for the selection of metal depending upon the type of load because a machine part resists load more easily than a live load and live load more easily than a shock load. The selection of the material depends upon the factor of safety, which in turn depends upon the following factors.

i. Reliabilities of properties
ii. Reliabilities of applied load
iii. The certainty as to the exact model of failure
iv. The extent of simplifying assumptions
v. The extent of localized
vi. The extent of initial stresses set up during manufacturing
vii. The extent of loss of life if a failure occurs
viii. The extent of loss of property if a failure occurs.

Material selected in m/c Base plate, motor support, sleeve, and shaft Material used Mild steel.

1. REASONS

The reasons to utilize these are as follows

- Mild Steel is readily available in market
- It is economical to use
- It is available in standard sizes
- It has good mechanical properties i.e., it is easily machinable
- It has a moderate factor of safety because the factor of safety results in unnecessary wastage of material and heavy selection. The low factor of safety results in unnecessary risk of failure
- It has a high tensile strength.

A. Properties of Mild Steel

M.S. has a carbon content from 0.15% to 0.30%. They are easily wieldable thus can be hardened only. They are similar to wrought iron in properties. Both the ultimate tensile and compressive strength of these steel increases with increasing carbon content. They can be easily gas welded or electric or arc welded. With an increase in the carbon percentage walkability decreases. Mild steel serves the purpose and was hence was selected because of the above purpose.

B. Bright Material

It is a machine drawn. The main basic difference between mild steel and bright metal is that mild steel plates and bars are forged in the forging machine by means is not forged. But the materials are drawn from the dies in the plastic state. Therefore the material has good surface finish than mild steel and has no carbon deposits on its surface for extrusion and formation of engineering materials thus giving them a good surface finish and though retaining their metallic properties.

X. ADVANTAGES

- Control air pollution
- Reusable
- The maintenance cost is less
- The operating cost is less
- Compact in size
- The same concept can be used for heavy vehicles
- The excessive dose of activated carbon is not harmful
- The treatment process is very simple
- The efficiency of removing colour, impurities and is quite high
- It can be easily regenerated. It has excellent properties of attracting gases.

XI. DISADVANTAGES

- Once a year, there is a requirement of filling of lime water
- More requirement of space
- The weight of the silencer get increases.

XII. CONCLUSION

An Aqua Silencer having more efficiency to reduce emission gases from the engine using lime water, charcoal layer and a perforated tube with the use of perforated tube back pressure always remains a constant, and sound level of exhaust reduces. Contamination of water remains very less in aqua silencers. In this system, fuel consumption remains the same as conventional silencers because of the use of the perforated tube. Due to the use of water as a medium sound reduces these system having pollution free emission and smokeless. This system is very cheap. This system is used for both four-wheelers and two-wheelers. It plays an important role in industries. It is smokeless and pollution-free emission and also it is very cheap. This aqua silencer's performance is almost equivalent to the conventional silencer.

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