Emission control in modified KIRLOSKER TV-1 diesel engine by Aqua silencer

S.Maniamramasamy[1], P.Kaviyarasu[1],B.Ravish kumar[2], R.Ranjith kumar[2], M.Ramar[2]
1-Assistant Professor, MAM School of Engineering, Trichy, Tamil nadu,
2- UG Student, MAM School of Engineering, Trichy, Tamil nadu,
rksmaniam@gmail.com, aerokaviyarasu@gmail.com, ravish510@gmail.com

***Abstract*— In the modern world Diesel engines are playing a vital role in Road and sea transport, agriculture, mining and many other industries. Considering the available fuel resources and the present technological development, Diesel fuel is evidently indispensable. In general, the consumption of fuel is an index for finding out the economic strength of any country. This paper is an attempt to reduce the toxic content of diesel exhaust, before it is emitted to the atmosphere. This system Reduction of obnoxious Exhaust particulates The principle involved is by bubbling the exhaust gas through the scrubber tank containing an alkaline solution, here the temperature of the gases are reduced, while most of the oxides of nitrogen in the exhaust are rendered non – toxic. The highly dangerous carbon monoxide is not such a menace in diesel exhaust, as it does not exceed 0.2 percent by volume, where as in petrol engines the CO content may be as high as 10 %. A lime stone container in the scrubber tank reduces the considerable percentage of sulphur – di – oxide presents in the exhaust. The provision of suitable baffles in the scrubber tank aids the turbulence so that, thorough scrubbing takes place. The bell – mouth solution, while reducing the back pressure.**

Keywords: **alkaline solution, aqua silencer, Emission control, scrubber tank etc…**

I. INTRODUCTION

The exhaust gas contains carbon – di – oxide, sulphur – di – oxide, carbon monoxide and other oxides of nitrogen. At full load, the temperature of the exhaust gas will lie anywhere between 500°C to 700°C.The pressure of the exhaust gas depend upon so many factors viz.,

1. The design of exhaust gas manifold
2. Magnitude of valve overlap
3. Engine speed
4. Number of cylinders
5. The length of the exhaust gas flow path, etc,

The design of exhaust gas manifold is very important in case of high speed diesel engines. In order to maintain the exhaust gas pressure within required limits, the exhaust gas manifold is designed so that, the gases which come out of the cylinder flows very smoothly, before it is let out to the atmosphere.

II. CONSTRUCTIONAL FEATURES

A. *Outlet Pipe From the Engine (or) Inlet to the Scrubber Tank*

The outlet pipe from the engine was connected to the scrubber tank. The nominal bore of the pipe is 50mm, which is also the inlet diameter of the scrubber tank. The shape and length of the pipe is decided according to the space availability to keep the flow resistance to a minimum.

B. Scrubber – Tank Assembly

The scrubber tank is fabricated in three stages and it contains the following sub assemblies.

1. Tank.
2. Bell – Mouth.
3. Lime stone container
4. Level plug – Drain Assembly.

C. Tank Fabrication

The tank is made of standard steel plates of 3mm thickness of quality structural steel conforming to BIS: 226, Designation ST 42S. The tank is fabricated using Electric Arc Welding process to withstand a maximum pressure of 0.8N/mm^2 [8Kg/Cm^2], with leak – proof.

Design considerations: The tank is 5 liters capacity keeping in view the size of Bell-mouth and lime stone container, which are to be accommodated inside. The maximum water content of the tank is about 3 liters, corresponding to 115mm of water level from the bottom of the scrubber tank. Suitable baffles are provided which will encourage through scrubbing of the exhaust gas. The baffles also prevent entry of water into the stone container to a considerable extent.

D. Bell – Mouth Fabrication

The bell – mouth is made of standard steel plates of 3mm thickness of quality structural steel conforming to BIS: 226, Designation ST 42S.

E. Level Plug cum Drain

Fabrication: The level plug cum drain is fabricated using 12.7mm nominal bore pipes fittings and conforming to BIS: 1369 where, fabricated using electric arc welding. The surface is rough ground in order to have better finish.

Design consideration: The level plug is designed to maintain a level of 115mm inside the tank. Instead of providing a separate drain plug, a tee welded at the bottom of the level pipe to accommodate the drain plug. The whole assembly can be unscrewed and taken out of the tank for periodic maintenance and repair by unscrewing the thread, which is fastening it to the boss, which is welded to the bottom of the tank. Water level indicator is fixed in the tee joint, which shows the level of water in the scrubber tank. During the

evaporation period this will be useful to maintain the level of water.

F .Outlet Pipe from the Scrubber Tank

The outlet pipe from the scrubber tank is fabricated using standard medium duty pipes, which are conforming to BIS 1369. The nominal bore of the pipe is 60mm, which is also the diameter of the inlet pipe. The flange at the end is to suit the flange on the outlet of the lime stone container. The shape and length of the pipe are to keep the flow resistance to a minimum.

III. WORKING PRINCIPLE

The problems that arise from the Diesel utilization in inflammable environment may be listed as follows:

1. Gases and particulate in engine emission
2. Heat and Humidity
3. Risk of explosion and fires
4. Transportation and storage of fuel
5. High speed in long hauls
6. Risk of trackless vehicles entering inadequately ventilated areas
7. Noise

This section examines the first two of these problems and suggests means by which they may be reduced or overcome.

A. Gases and Particulates in Diesel Exhaust

In addition to heat and water vapor, the pollutants in diesel exhaust are,

a) Carbon monoxide (CO)
b) Carbon dioxide (CO_2)
c) Oxides of Nitrogen (NOx)
d) Sulphur dioxide(SO_2)
e) Particulate and Unburned Hydrocarbons (UBHC)
f) Respirable Combustible Dust (RCD)

The above polluting contents in the diesel engine exhaust are to be controlled by the scrubbing method, details of which are followed.

B. Expansion and Scrubbing

The high temperature high pollutant exhaust gas is allowed to pass through the bell – mouth assembly of the scrubber in the first phase. The bell – mouth at the inlet/outlet is approximately 2 ½ times more in an area is that of the inlet. This allows the exhaust gas to expand considerably. This expansion allows the gas to cool, because the temperature is a function of pressure. This considerable reduction of backpressure allows for the additional involved due to the introduction of water and lime stone container. The venture effect of the bell – mouth is minimized because the exhaust gas escapes out of the bell – mouth randomly along the periphery. After expansion, the emission comes in contact with water; (which could be otherwise being any alkaline solution) where the obnoxious products of combustion are scrubbed when bubbled through it. The bell – mouth also allows for more contact area with water, so that effective cooling takes place within the short span of time available for the gas to pass through the water. The length of bubbling can be increased by the water level in the scrubber tank, as shown in fig.1.

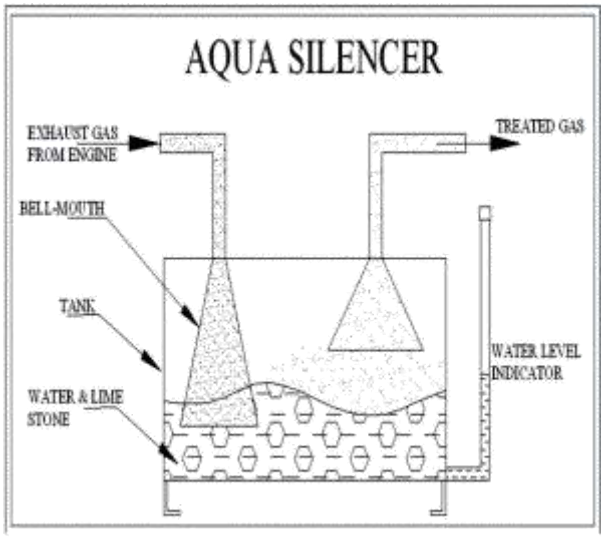

Fig.1. Aqua silencer

Fig.2. Fabricated Aqua silencer

But this will be increased result in an abnormal backpressure, which inadvertently affect the performance of the engine. And for this reason the bell – mouth is a multipurpose component, to allow for reduction in back pressure, and provides for an increased contact area with the scrubbing agent. After bubbling through the water, it comes in contact with baffles, which encourage turbulence of the exhaust gas within and below the water surface without unduly increasing the back pressure of the exhaust. This allows for the thorough scrubbing of the emission, so that more obnoxious product is absorbed in the allowed time. As our fabricated aqua silencer shown in Fig.2. The baffles are of invaluable help to reduce the carryover of water particles which are converted into steam, which otherwise will escape out of the system. A lime stone container, which is provided above the baffles, allows the exhaust emission to pass through limestone radically. Now due to high temperature of the exhaust gas and the high chemical reaction prone lime stone, the products of combustion to go through a series of chemical reactions. The chemical reactions in their different phases are explained later in this topic. The extent of scrubbing can be analyzed by using an ORSAT apparatus very easily. The procedure and results are explained in the subsequent chapter. The area at any particular and results are explained in the subsequent topics.

The area at any particular section in the whole system is more than the outlet of exhaust manifold of the engine, which contributes to the reduction of backpressure of the system as a whole.

IV. DETAILS OF CHEMICAL REACTIONS

In the scrubber tank water is used as a alkaline solution mainly to dissolve the Unburned Hydro Carbons (UBHC). By this method, the UBHC, even if it is in glowing conditions, it is dissolved in water; thereby it is suppressing a spark which could escape from the engine to the inflammable environment.

A. Chemical Reaction-I

The obnoxious product of combustion is NOx – the oxides of Nitrogen. Water will absorb the oxides of Nitrogen to a larger extent. The following chemical reaction will enhance the proof, for the above statement.

$$NO_2 + 2H_2O \longrightarrow 2\,HNO_2 + 2HNO_3 \text{ (Diluted)} \quad \text{- (1)}$$

B. Chemical Reaction-II

If a small amount of limewater is added to scrubber tank, further reaction takes place as below.

$$Ca(OH)_2 + 2HNO_3 \longrightarrow Ca(NO_3)_2 + 2H_2O$$

$$Ca(OH)_2 + 2HNO_2 \longrightarrow Ca(NO_{2)2} + 2H_2O \quad \text{- (2)}$$

C. Chemical Reaction-III

When the carbon-di-oxide present in the exhaust gas comes in contact with the limewater, calcium carbonate will precipitate. The calcium carbonate when further exposed to carbon-di-oxide, calcium-bi-carbonate will be precipitated. The following is the chemical reaction,

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

$$CaCO_3 + H_2O + CO_2 \longrightarrow Ca(HCO_3)_2 \quad \text{- (3)}$$

D. Chemical Reaction-IV

The sulphur-di-oxide present in the Diesel Exhaust also reacts with the limewater. But the small trace of sulphur-di-oxide makes it little difficult to measure the magnitude of the chemical reaction, accurately. The following equation gives the chemical reaction and calcium sulphite will precipitate.

$$Ca(OH)_2 + SO_2 \longrightarrow CaSO_3 + H_2O \quad \text{- (4)}$$

Because CO is chemically balanced and stable, it will not readily react with water or with any by – products, which is resulted from the above reactions. Also the negligible volume (0.2%) of CO present in the Diesel emission is not such a menace, when compared to the petrol engine exhaust which as high as 10% of CO.

Even though, the limewater absorbs a part of the oxides of Nitrogen, carbon-di-oxide, the time limitation for the reaction take place allows a considerable percentage to escape. But, the stone container, which is provided with limestone or calcium carbonate, ($CaCO_3$), encourages further chemical reaction, in the presence of steam, which evaporates from the scrubber tank due to the high exhaust temperature (400°C - 700° C). The following are the chemical reactions for the oxides of Nitrogen (NOx) Carbon-di-oxide (CO_2) and Sulphur-di-oxide (SO_2).

E. Chemical reaction-V

From calcium carbonate, calcium sulphite will precipitate and CO2 will be by-product. Because of the small percentage and SO2 presence, the liberation of Carbon dioxide is very less. But the liberated CO_2 will again combine with $CaCO_3$ to form calcium bicarbonate as mentioned in equation 5.

$$CaCO_3 + SO_2 + H_2O \longrightarrow CaSO_3 + CO_2 + H_2O \quad \text{- (5)}$$

F. Chemical reaction-VI

The presence of steam makes it possible to have a preliminary reaction with oxides of nitrogen, in the following manner;

$$4NO_2 + 2H_2O \longrightarrow 2HNO_2 + 2HNO_3 \quad \text{- (6)}$$

G. Chemical reaction-VII

The resultant products when come in contact with calcium carbonate the following reaction takes place

$$CaCO_3 + 2HNO_3 \longrightarrow Ca(NO_3)_2 + CO_2 + H_2O$$

$$CaCO_3 + 2HNO_2 \longrightarrow Ca(NO_2)_2 + CO_2 + H_2O \quad \text{- (7)}$$

[i.e.,] calcium Nitrate Ca $(NO_3)_2$ and calcium Nitrite $Ca(NO_2)_2$ are the by products, and CO_2 is liberated. The liberated CO_2again combines with calcium carbonate to form calcium bicarbonate

H. Analysis of Exhaust Emission

Emissions from diesel engines can be classified in same categories as those from the gasoline engines but the level of emission in these categories varies considerably. A sample of diesel exhaust may be free from smoke, odorless, and have no unburned hydrocarbons (UBHC) or it may be heavily smoke laden, highly mal-odorous and can have heavy concentration of UBHC.

It shows the approximately the possible variations in concentration of different constituents of diesel exhaust. The concentration is deceptively low in diesel engines, as compared to petrol engines. However, as the specific air consumption in diesel engines is always high due to excess air, the total amount of pollutants is nearly same in diesel and petrol engine exhaust. Hence, diesel exhaust emissions are as great concern as of petrol engines. Engine type and the mode of operation are two main factors, which influence the exhaust emissions from a diesel engine.

Table.1. Range of concentration of different constituents of Diesel Exhaust

S.No	Constituent	Min.	Max.
1.	Hydrocarbon,(HC)	A few ppm	1000 ppm
2.	NOx	100ppm	2000 ppm
3.	RCD	few	100 ppm
4.	CO	zero	2 percent

Table.2. Emission levels of 4 – stoke normally aspirated engine at medium speed & high speed

S.No	Emission	Medium Speed	High Speed
1.	Hydrocarbon	Low	High
2.	NOx	Low	Low
3.	RCD	Low	High
4.	SMOKE	High	High

Effect of mode of operation on diesel exhaust idle, full load at rated speed, and acceleration at full rack are the three modes of operation which have been found to significantly affect the emission levels in diesel exhaust as can be seen.

During the idle mode the concentration of HC, NOx and aldehyde emissions are lower than other modes the emissions at idle are less significant than during any other mode. The acceleration mode has profound influence on odor. Highest odor occurred when full rack acceleration was encountered. Smoke levels are also high during acceleration emissions at full load relative to emissions at other operational modes very significantly with engine type. Four – stroke normally aspirated engines smoke very much at rated full load.

V. Results and Discussions

KIRLOSKER TV 1 diesel engine has been selected to test the aqua silencer for controlling sound and emission from engine exhaust. At first, impure and non-treated exhaust from the engine was tested in the AVI apparatus.

Then, the treated exhaust gas coming through the scrubber tank was tested in the AVI apparatus. The AVI apparatus observations of before and after treatment of exhaust gases are shown in the following two separate observation tables.

The results obtained from the observations are given in percentage reduction of gases. The variation in the percentage gives amount of pollutants control by this paper.

SPECIFICATIONS: Scrubber Tank

Alkaline solution -Lime Water ($Ca(OH)_2$)
Water level from bottom - 100mm
Chemical -Lime stone ($CaCO_3$)

Bell mouth bottom portion

Submerged in the alkaline solution - 25mm

Engine Details

Engine	-	KIRLOSKER TV 1
Type	-	vertical 4 stroke
No. of cylinder	-	One
Cylinder Dia.	-	0.0875mm
Stroke	-	0.11 mm
Speed	-	1500 rpm
Power	-	5.2 kW

Table.3. Result Tabulation

% of load Applying	NOx (ppm)		Amount of PM (g/min)		Smoke Density (HSU)	
	With out AQUA Silencer	With AQUA Silencer	With out AQUA Silencer	With AQUA Silencer	With out AQUA Silencer	With AQUA Silencer
0	65.93	38.82	0.010	0.003	7.2	2.35
24.57	175.76	112.60	0.012	0.008	15.15	5.25
49.13	295.20	223.45	0.016	0.010	16.65	7.3
73.71	406.88	311.90	0.022	0.014	22.9	8.6
100	618.70	433.68	0.026	0.019	26.85	15.55

Table.4. Tabulation for Percentage of Reduction

% of load Applying	% of NOx Reduction		Amount of PM		Smoke Density	
	ppm	%	g/min	%	HSU	%
0	27.11	41.11	0.007	70	4.85	67.36
24.57	63.16	35.93	0.004	33.33	9.9	65.34
49.13	71.75	24.30	0.006	37.5	9.35	56.15
73.71	94.98	23.34	0.008	36.36	14.3	62.4
100	185.02	29.90	0.007	26.92	11.3	42.8

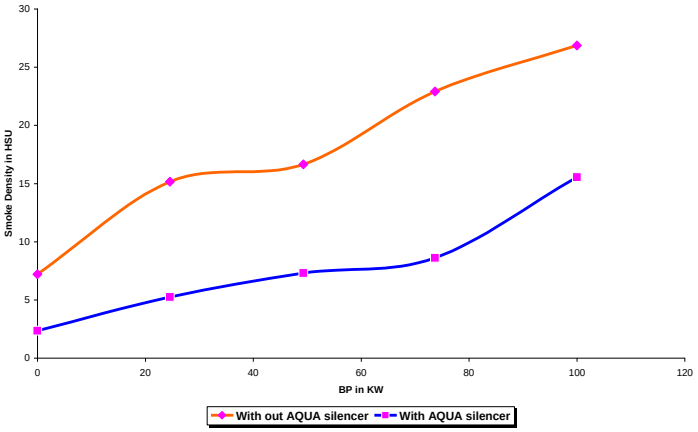

Fig .3. BP Vs Smoke Density

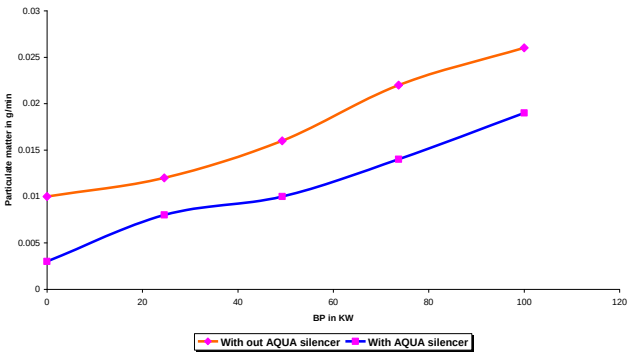

Fig.4. BP Vs Particulate Matter

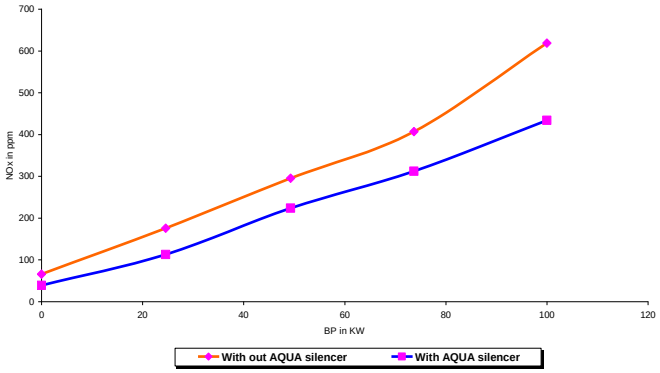

Fig.5. BP Vs NOx

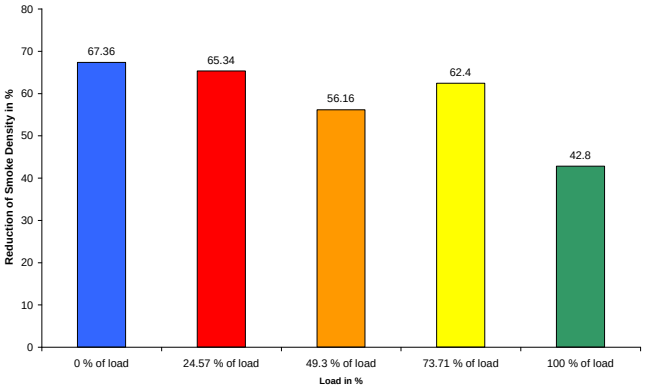

Fig.6. Load Vs Reduction of Smoke Density

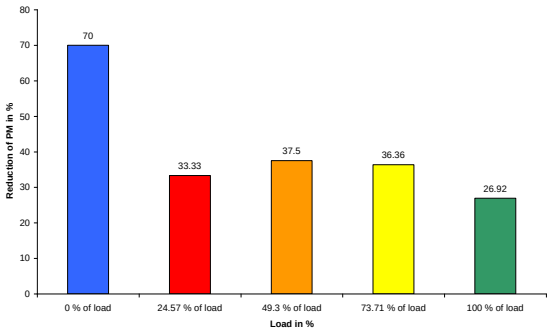

Fig.7. Load Vs Reduction of Particulate Matter

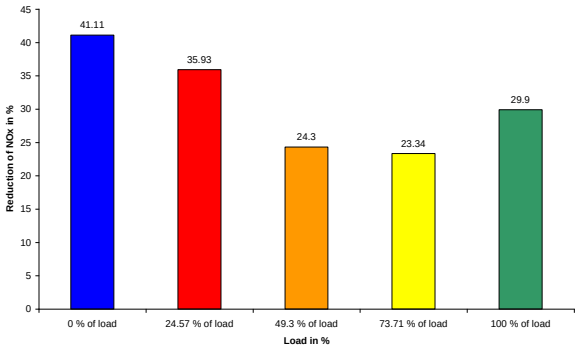

Fig.8. Load Vs Reduction of NOx

VI. CONCLUSION

The aqua silencer is more effective in the reduction of emission gases from the engine exhaust gas using perforated tube. By using perforated tube the back Pressure. Will remain constant and the sound level is reduced. Using the perforated tube the fuel consumption remains same as conventional system. By using water as a medium the sound can be lowered and also by using activated charcoal in water. We can control the exhaust emission to a greater level. The water contamination is found to be negligible in aqua silencer, because the amount of acidity level in aqua silencer is expected to be below the dangerous acidity. i.e. 250mg/lit. It is smokeless and pollution free emission and also very cheap. The aqua silencer's performance is almost equivalent to the conventional silencer. In No load condition, by using AQUA Silencer the NOx will be reduced to 29.9%, the Particulate Matter will be reduced to 70%. In the Smoke Density will be reduced to 67.36%.

REFERENCES

[1] HsiehaWD, ChenRH, WuTL, LinTH .Engine performance and pollutant emission of an SI engine using ethanol–gasoline blended fuels. Atmos Environment (2002) ; Vol-36, pp 403–410.

[2] C. A. Okoronkwo , C. C. Dr. Nwachukwu, L.C. Dr. Ngozi and J.O. Igbokwe, "The Effect of Electromagnetic Flux Density on the Ionization and the Combustion of Fuel (An Economy Design Project)" American Journal of Scientific and Industrial Research, ISSN: 2153-649X doi:10.5251/ajsir. (2010).Vol 1, Issue 3, pp 527-531.

[3] P. Govindasamy, S. Dhandapani, "Experimental Investigation of the Effect of MagnetiC Flux to Reduce Emissions and Improve Combustion Performance in a Two Stroke, Catalytic-Coated Spark-Ignition Engine" International Journal of Automotive Technology, (2007) Vol. 8, No. 5, ,
pp. 533-542

[4] RezaniaA, Rosendahl LA. Thermal effect of a thermo electric generator on parallel micro channel heat sink Energy (2012) Vol-3, Issue 7, pp 220–227.

[5] Martinez JG, VianD, AstrainA, Rodriguez BerrioI. "Optimization of the heat exchangers electric generation system", Journal of Electron Mater (2010) Vol-39 , pp 1463–1468.

