Analysis of Emission Control from an Exhaust Gas by Dual Type Scrubber Technology

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Abstract - **In present scenario, the environmental pollution is major problem in the world. The vehicles generate pollutants such as unburned hydrocarbons (UHC), oxides of nitrogen (NO_X), carbon dioxide (CO_2) and lead and other particulate emissions. These pollutants are the root cause for the air pollution. Scrubber is a device used to control the gaseous and solid pollutants from industrial exhaust streams. In this project dual type scrubber was designed and fabricated. After that the setup was used in the diesel engine to reduce the pollution by chemical absorption method. The rate of absorption of the pollutants mainly depends on the nature of the absorbent used. Emission rates of CO_2, NO_X, HC, CO of a diesel engine had analyzed and the results were taken. The various chemical absorbents such as Water, Potassium hydroxide, Magnesium hydroxide are used for experimental works. After that results were taken and compared with actual readings. These results shows that performance of engine was increased and emission get reduced by using the dual type scrubber technology.**

Keywords - **Exhaust gas Emissions, Dual type scrubber, various chemical absorbents.**

I. INTRODUCTION

Today the world faced major problem is environmental pollution. The vehicle exhausts generate pollutants such as carbon dioxide, unburned hydrocarbon, oxide of nitrogen and lead and other particulate emissions. These pollutants are the root cause for the air pollution. The pollutants prevalent in the atmosphere today is harmful to the health of human particularly children and those with affected with lung diseases. These gases are responsible for acid rain formation. Considering the harmful effects of some pollutants as a severe problem, the research towards the emission control has to reach the peak. Hence emission control devices have developed by several researchers for simultaneous control of oxides of sculpture (SO_x), carbon monoxide (CO),oxides of nitrogen (NO_x) and hydrocarbons (HC) particulate in automobile engine exhaust.

Here scrubber technology is used to control the emission from various sources. If the exhaust stream contains both gases and particles, wet scrubber is generally only single air pollution control device that can remove both types of pollutants.

In this project wet scrubbers are used to dry dust collection creates excessive explosion on hazards, when the dust collection is combined with acid gas removal, and chemical reaction takes place and the dust is collected as slurry.

Wet scrubbers are capable of removing the pollutants by the action of the chemical absorbers. Inconvenient are the occurrence of corrosion and a wet plume of entrained droplets that can only be eliminated by high-efficiency fibrous mat demisters.

Scrubber systems are a diverse group of air pollution control devices that can be used to remove particles and gases from industrial exhaust streams. In traditional method the scrubbers have referred as pollution control devices that use liquid to “scrub” unwanted pollutants from a gas stream. Recently, thescrubberis also used to describe systems this inject a dry reagent or slurry into a dirty exhaust stream to "scrub out” acid gases. Scrubber is the primary device that control gaseous emissions, especially acid gases.

Wet scrubber is a used to describe a variety of device that is used to remove pollutants. In a wet scrubber, the dirty gas stream is going into contact with the scrub liquid by spray it with the liquid, by forcing it through a pool of liquid, or by some other contact method.

The design of any air pollution control device (wet scrubbers are no exception) based on the nature of the air pollutants and the industrial process conditions involved. Dust properties and exhaust gas characteristics, if particles are present, primary importance. Scrubbers are designed to collect particles and/or gaseous pollutants. Wet scrubbers remove pollutant gases dissolving or absorbing them into the liquid. Also, the resultant scrubbing liquid must be treated to any ultimate discharge or reused in the plant.

A wet scrubber's ability to collect small sized particulates is directly proportional to power input into the scrubber. Spray towers are used to collect particulates larger than 5 micrometers. To obtain high efficiency removal of 1 micrometer particles generally requires high energy devices such as ventures devices such as condensation scrubbers.

Additionally, a properly operated and designed entrainment separator/mist eliminator is important to achieve high removal efficiency.

Wet scrubbers, chemical liquids that remove gaseous pollutants are referred to as absorbers. Good gas and liquid contact is essential to obtain high removal efficiencies in absorbers. A number of wet scrubber designs is used to remove gaseous pollutants, we use the dual type scrubber i.e. combination of packed bed type and spray type.

Wet scrubbers are achieve high removal efficiencies for particles or gases and, in some instances, can achieve high removal efficiency on both pollutants in the same system. However, in many cases, the best operating conditions for particle collection is the purest for gas removal. In general, obtaining high simultaneous gas and particle removal efficiencies requires that easily collected (i.e., that the gases are very soluble in the liquid or that particles are large and readily captured).

Wet scrubbers can serve two different duties, namely the absorption of vapor or, water-soluble gases and arresting dust.

Dissolution of soluble gases is basically driven by:

Contacting surface is available for mass transfer between the gas phase and the liquid, Difference between actual concentration and equilibrium conditions.

Hence, absorption normally requires a very large gas to liquid interface surface. Dust particles arrested by wet scrubbing proceeds by high velocity impaction of dust particles in their contact with droplets. After the initial impact the relative velocity becomes too small to create collisions, so the initial contact of particles, droplet drives almost entirely a successful separation of dust and is little helped by providing supplemental surface.

In spray tower scrubbers, liquid is sprayed through a number of tubes through nozzles. In this scrubber, the gas stream and absorbers are allowed to flow in counter flow direction. Therefore, both gas and liquid phase provide energy for the gas and liquid contact. Then chemical reactions take place and the pollutants are collected.

In packed tower or wet-film scrubbers, liquid is sprayed over packing material contained between support trays. A liquid film coats the packing through the exhaust gas stream is forced. Pollutants are collected as they are passed through the packing, contacting the liquid film.

In the dual type scrubber, the spray type to be placed at the top of the packed type in the scrubber. The chemical absorber is first allowed to spray through several tubes and then pass over the packing materials of the packed bed. The exhaust gas first enters the bottom of the packed bed and then against the sprayed absorbers in the spray type. Then pollutant gets deposit at the bottom. The exhaust gas after the removal of pollutants is passing through top.

The various chemical absorbers used in this setup were water, potassium hydroxide, magnesium hydroxide. The results were taken by using these absorbents and compared with the actual readings.

II. EXPERIMENTAL SETUP& COMPONENTS

The experimental setup is the main element in controlling the pollutants from engine exhaust. So it is very concern to design the experimental setup.

Fig. 1 Dual type scrubber setup

This setup consists of following sub-components:

- Absorption column 1
- Absorption column 2
- Bottom tank
- Column head
- Sieve plate

A. Absorption column 1

Absorption column is the filtering component in this experimental setup. It is dumped with ceramic packing material which provides greater gas- liquid contact area

Fig. 2 Absorption column 1

B. Absorption column 2

Absorption column is the filtering component in this experimental setup. It is fitted with spray pipe which provides greater gas- liquid contact area. This will act as a spray type region.

Fig. 3Absorption column 2

C. Bottom tank

Fig. 4 Bottom tank

Bottom tank is used to store the absorbing liquid. It also gives stability to whole setup by having bottom large surface area. It should be corrosive resistance to store the chemical liquids for larger period. It has ports to supply the absorbing liquid to column head and to easily drain those liquids.

D. Column head

Column head has a sprayer arrangement to spray the absorbing liquid in the column. It has liquid inlet port with flow controlling valve and one outlet port for exhaust gas.

Fig .5 Column head

E. Sieve plate

Sieve plate is provided in the column for holding ceramic material.

Fig.6Sieve plate

III. MATERIALS & ABSORBING LIQUIDS

A. Packing material

For fabricating the packed bed scrubber technology we are using Rasching rings type ceramic material. Random packing method is used to increase the contact area of absorbent and gas.

Fig. 7 Ceramic packing

B. *Absorbing liquids*

The following working absorbents used for the testing purposes are

1. Water
2. Potassium hydroxide – KOH (in diluted form)
3. Magnesium hydroxide – Mg (OH) $_2$ (in diluted form)

IV. WORKING

The exhaust gas from the engine is passed to the bottom of the absorption column 1 through the inlet port in this column and the ceramics packaging in this column holds the unwanted particles and dust in the exhaust gas.

Then exhaust gas from the absorption column 1 is passed to the absorption column 2 and column head. In this absorption column 2 and column head, the water (H_2O) and potassium hydroxide (KOH), magnesium hydroxide (Mg (OH) $_2$) absorbents are sprayed to the exhaust gas and then the following chemical reactions will occurred.

i. Potassium hydroxide absorbs carbon dioxide readily from exhaust gas. This will produce the suspension of potassium carbonate formed:

$$2KOH\ (aq) + CO_2\ (g) \rightarrow K_2CO_3(s) + H_2O\ (l)$$

ii. Magnesium hydroxide reacts with carbon dioxide to give magnesium carbonate and water:

$$Mg\ (OH)_2\ (aq) + CO_2\ (g) \rightarrow MgCO_3\ (s) + H_2O\ (l)$$

iii. The water is react with nitrogen dioxide in exhaust gas to give nitric acid:

$$2\ NO_2 + H_2O \rightarrow HNO_2 + HNO_3$$

Nitrous acid then decomposes as follows:

$$3\ HNO_2 \rightarrow HNO_3 + 2\ NO + H_2O$$

Where nitric oxides will oxidize to form nitrogen dioxide that reacts with water, ultimately forming nitric acid

$$4\ NO + 3\ O_2 + 2\ H_2O \rightarrow 4\ HNO_3$$

After the above all reactions completed the emissions in exhaust gas get reduced and then the exhaust gas is delivered to atmosphere through the exhaust port in the column head.

V. RESULTS AND DISCUSSION

A. *Actual emission rates from the four stroke diesel engine (without setup)*

TABLE I
Actual emission rate

FUEL INLET (Cl/min)	CO (%vol)	HC (ppm)	CO_2 (%vol)	O_2 (%vol)	NO_x (ppm)	SPEED (rpm)
16.8	0.06	54	1.8	24.38	220	1328
18.0	0.05	37	1.9	25	246	1480
18.6	0.06	34	2.3	25	258	1504
18.8	0.06	35	2.7	25	250	1510
19.7	0.07	37	2.9	25.03	266	1622
20.5	0.08	33	3.0	25.02	276	1734

B. *Emission Rates from the Four Stroke Diesel Engine by Dual Type Scrubber Setup*

i. ***Using water as absorbent:***

TABLE II
Emission rates using water as absorbent

FUEL INLET (Cl/min)	CO (%vol)	HC (ppm)	CO_2 (%vol)	O_2 (%vol)	NO_x (ppm)	SPEED (rpm)
16.6	0.05	26	1.9	24.2	158	1310
17.1	0.04	35	2.2	24.88	175	1380
17.4	0.05	38	2.2	24.88	197	1428
17.7	0.05	36	2.3	25	215	1454
18.2	0.06	35	2.4	25	240	1494
21.6	0.06	31	2.5	25	254	1624

ii. ***Using magnesium hydroxide ($Mg(OH)_2$) as absorbent:***

TABLE III
Emission rates using Mg (OH) $_2$ as absorbent

FUEL INLET (Cl/min)	CO (%vol)	HC (ppm)	CO_2 (%vol)	O_2 (%vol)	NO_x (ppm)	SPEED (rpm)
16.9	0.05	5	1.7	23.88	147	1456
17.2	0.05	10	1.5	24.4	158	1482
17.6	0.04	14	2	24.88	190	1556
18.0	0.04	5	1.6	25	212	1584
18.6	0.03	7	1.7	25	238	1606
19.1	0.03	8	2.2	25	261	1698

iii. ***Using potassium hydroxide (KOH) as absorbent:***

TABLE IV
Emission rates using KOH as absorbent

FUEL INLET (Cl/min)	CO (%vol)	HC (ppm)	CO_2 (%vol)	O_2 (%vol)	NO_x (ppm)	SPEED (rpm)
16.8	0.02	8	0.3	24.88	141	1366
17.1	0.01	7	0.6	25	190	1424
17.5	0.02	7	0.6	25	203	1528
18.0	0.02	3	0.6	25.03	218	1576
18.4	0.02	8	1	25.03	248	1604
19.3	0.03	13	1.1	25	267	1698

C. Engine Exhaust Gas Emissions With And Without Dual Type Scrubber Setup

i. Various HC emissions from the diesel engine based on fuel inlet

When the inlet fuel to the engine increases HC emission reducing with slight deviations. In the below graph KOH and Mg (OH) $_2$ reduces the HC emission when comparing to other absorbent. But water has only small variation in controlling HC emission.

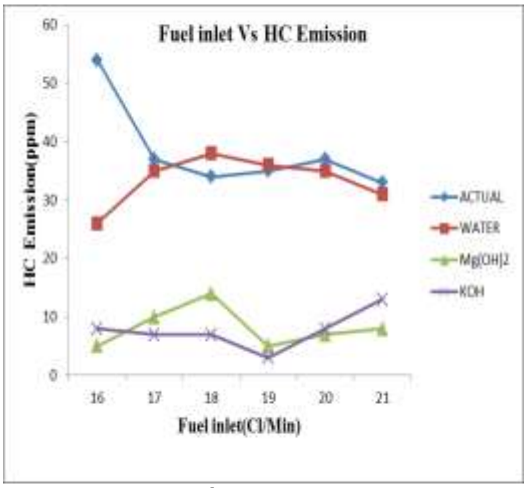

Fig. 8 Various HC emissions from the diesel engine based on fuel inlet

ii. Various CO emissions from the diesel engine based on fuel inlet

The amount of CO emission increases with increase in fuel inlet because of large quantity of fuel used which had large quantity of carbon. This emission was reduced consistently by KOH and Mg (OH) $_2$. The graph shows that KOH gives good results than Mg (OH) $_2$. Water gradually reduces CO emission.

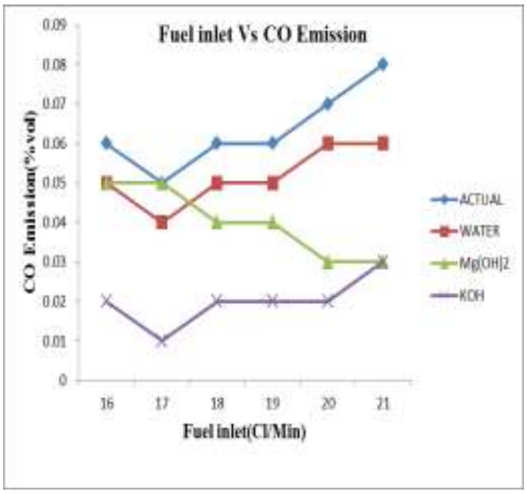

Fig. 9 Various CO emissions from the diesel engine based on fuel inlet

iii. Various CO_2 emissions from the diesel engine based on fuel inlet

CO_2 emission from the engine exhaust was gradually increasing. In the below graph we can find that KOH absorbed CO_2 emission fully for small amount of fuel inlet condition. Mg (OH) $_2$ also absorbed it very well. Water had some little impact in CO_2 absorption

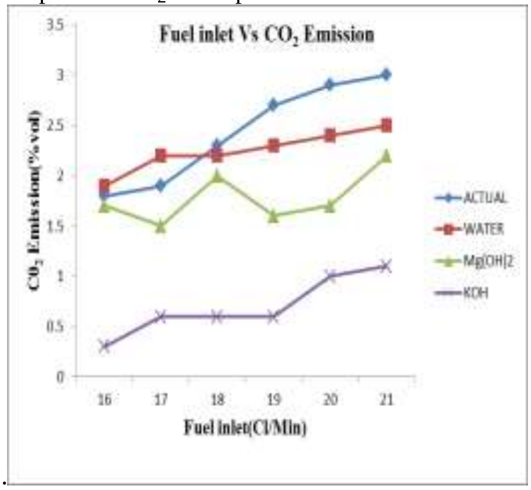

Fig. 10 Various CO_2 emissions from the diesel engine based on fuel inlet

iv. Various O_2 emissions from the diesel engine based on fuel inlet

O2 is also liberated from engine exhaust gas. It was almost constant for all fuel inlet conditions. Among three different solutions, water and Mg (OH) 2 only absorbs this O2 emission for more than the others.

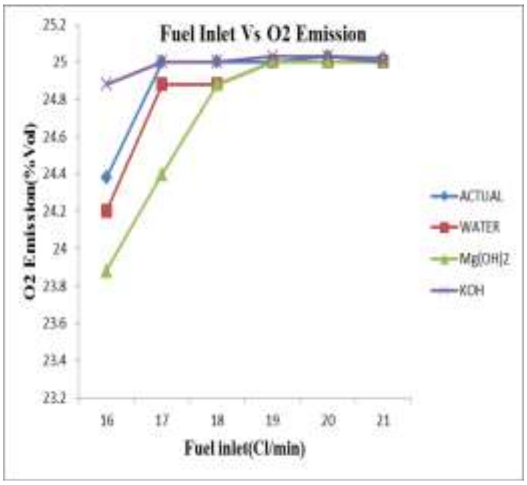

Fig. 11 Various O2 emissions from the diesel engine based on fuel inlet

v. Various NO_X emissions from the diesel engine based on fuel inlet

These NOx emissions will increases when more amount of fuel is burnt. So from the above graph Mg (OH) $_2$ and water reduces the NO_Xemission greatly. But other absorbent

KOH also reduce the NOx emission to the notable extension.

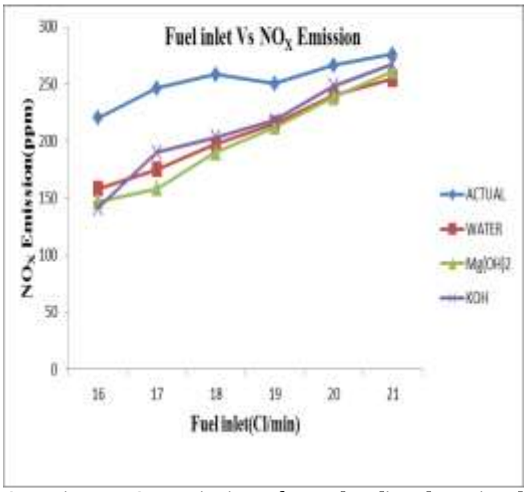

Fig. 12 Various NO_X emissions from the diesel engine based on fuel inlet

vi. Various O_2 emissions from the diesel engine based on engine speed

O_2 emission from the engine was almost constant for higher engine speed conditions. Water and Mg (OH) $_2$ absorbed O_2 comparatively more with other absorbent.

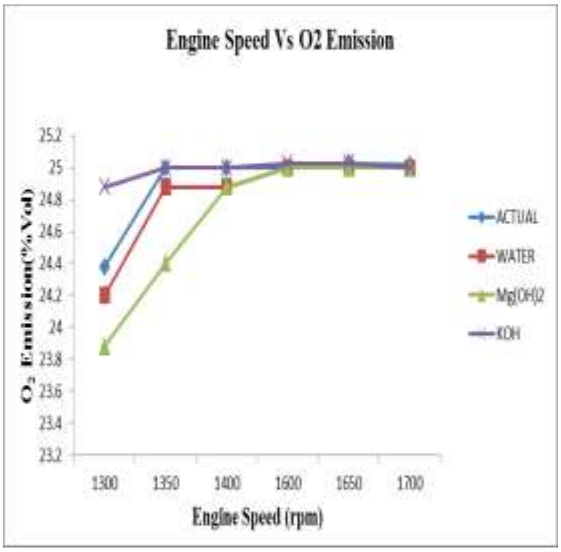

Fig. 13 Various O_2 emissions from the diesel engine based on engine speed

vii. Various CO_2 emissions from the diesel engine based on engine speed

Almost all CO_2 emission from engine at different speed was absorbed by KOH. Mg (OH) $_2$also absorbs this emission considerably. Water has little that much effect in absorbing CO_2. After some stages water got saturated with this absorption.

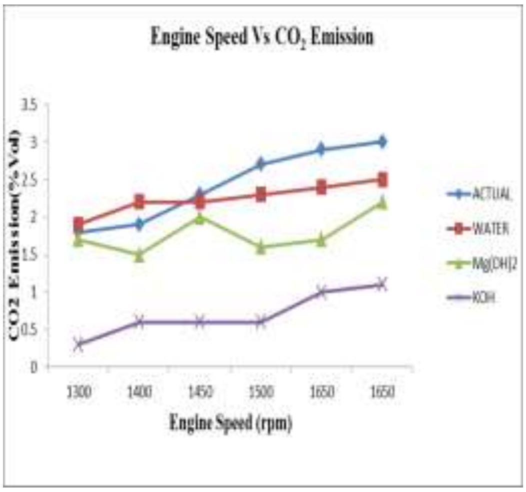

Fig. 14 Various CO_2 emissions from the diesel engine based on engine speed

viii. Various CO emissions from the diesel engine based on engine speed

KOH absorbs more amount of CO at different speeds. At More speed Mg (OH) $_2$ started absorbing this pollutant more than water

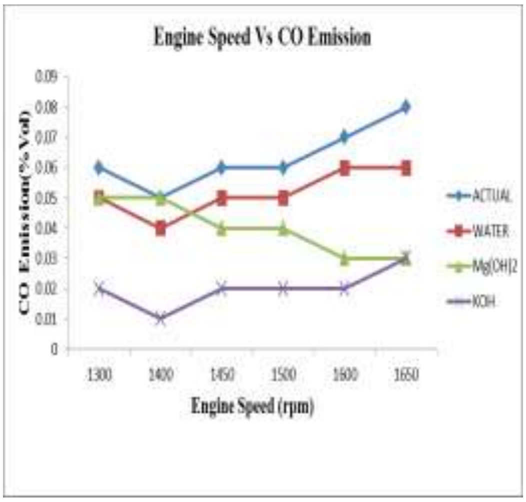

Fig. 17 Various CO Emissions from the Diesel engine based on engine speed

ix. Various HC emissions from the diesel engine based on engine speed

HC emission from engine gradually decreases when engine speed increases. This emission was reduced with more effect by KOH and Mg (OH) $_2$. Water also reduced HC emission gradually.

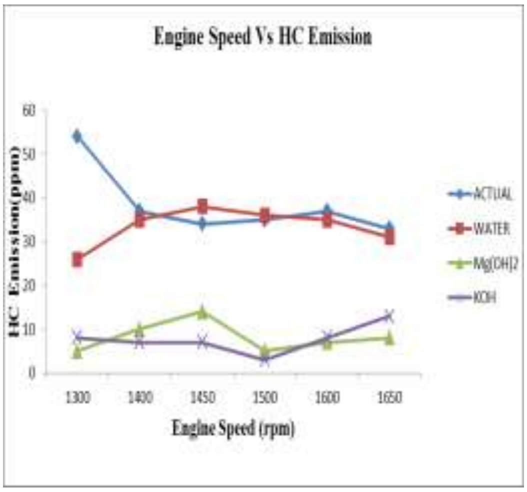

Fig. 18 Various HC emissions from the diesel engine based on engine speed

x. Various NO_X emissions from the diesel engine based on engine speed

Mg $(OH)_2$ absorbed more NO_X emission from the engine when comparing with other two absorbents. Both water and KOH had good effect in absorbing this pollutant.

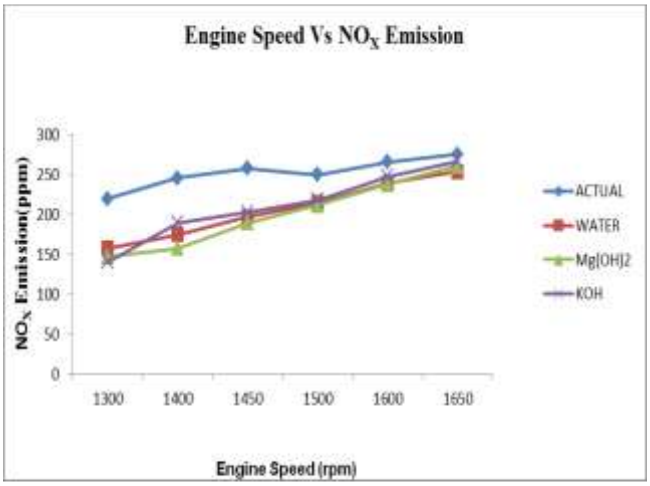

Fig. 19 Various NO_X emissions from the diesel engine based on engine speed

CONCLUSION

In diesel engine various pollutants such as CO, CO2, HC, and NOx are highly emitted. Dual type scrubber setup was designed and fabricated. Then the setup can be used as a source to reduce the various pollutants from the emission and to produce ecofriendly environment. The various absorbents such as water, KOH, Mg $(OH)_2$ were used to spray in the dual type scrubber to reduce the emission**.** We found KOH was well suited for reducing the CO and CO_2 emissions after the analyses of various emissions by using different absorbents. Mg $(OH)_2$ was best choice for removal.

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