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INVESTIGATION OF NITROGEN REDUCTION IN FOUR STROKE PETROL ENGINE USING ZEOLITES AS ADSORBENT

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ABSTRACT: Nitrogen Oxides (NO_x) emissions are one of the major pollutants emanating from automobiles and industrial plants. Due to their harmful effect on the environment and human health, strict regulations on the acceptable amount of NO_x that can be released from automobiles have been enacted. It is also one of the major sources of acid rain. It is also a harmful greenhouse gas which leads to global warming. Method like Pressure swing adsorption (PSA) is an established technology for achieving high NO_x reduction from power plants which undergoes continuous modifications due continuous stringent emission regulations. However, it cannot be used in automobiles and is difficult to accommodate in two wheelers as well as it is not cost effective. Hence, in this investigation we are using zeolite materials as adsorbent in a compact manner to reduce nitrogen in air before carburation in 4 stroke petrol engines. This show that zeolite is good adsorbent selective to NO_x. In view of this study purpose we have used the adsorbent in real time running motorcycle. It gives better results of nitrogen reduction and it enriches oxygen. Hence, it reduces and minimizes the cost of fuel even more in efficient way.

KEYWORDS: engine, emission, nitrogen, molecular sieve, adsorbent.

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1. INTRODUCTION

Emission reduction from automobiles is one of the major concerns in today's world. Consequently, there is an increase in harmful emissions. Among these harmful gases is NOx: oxides of nitrogen which include NO and NO_2 [1, 6]. When nitrogen is released during fuel combustion, it combines with oxygen atoms to create nitric oxide (NO). This further combines with oxygen to create nitrogen dioxide (NO_2). Nitric oxide is not considered to be hazardous to health at typical ambient concentrations, but nitrogen dioxide is hazardous to health. Nitrogen dioxide and nitric oxide are referred to together as oxides of nitrogen (NO_x). NO_x is produced from the reaction of nitrogen and oxygen gases in the air during combustion, especially at high temperatures. In areas of high motor vehicle traffic, such as in large cities, the number of nitrogen oxides emitted into the atmosphere as air pollution [27, 28] can be significant. NOx gases are formed whenever combustion occurs [29, 30] in the presence of nitrogen – e.g. in car engines; they are also produced naturally by lightning. These emissions are created health hazards to humans like respiratory problems, heart disease, lung disease, etc.

1.1 Prevention

Selective catalytic reduction (SCR) of NOx is one of the technologies for the reduction of NOx. This technology is only suitable for power plants but not for vehicles. Hence another method Pressure swing adsorption (PSA) is used [1]. Some of the advantages of the SCR system are the high efficiency, selectivity, and economics of the systems. Both the above methods are difficult to implement in automobiles [6, 7]. We have modified air filter assembly with zeolite materials to reduce nitrogen before intake for combustion in real time four stroke petrol engines experimentally and checking the emissions [23, 26]. No past work has carried out this analysis according to the authors' knowledge.

2. MATERIALS AND METHODS

Adsorption is the phenomenon of accumulation of a large number of molecular species at the surface of liquid or solid phase in comparison to the bulk. The process of adsorption arises due to the presence of unbalanced or residual forces at the surface of the liquid or solid phase. These unbalanced residual forces tend to attract and retain the molecular species with which it comes in contact with the surface. Adsorption is essentially a surface phenomenon. Adsorption is a term which is completely different from Absorption when both Adsorption and Absorption processes take place simultaneously; the process is called sorption [1]. Adsorption process involves two components Adsorbent and Adsorbate. The adsorbent is the substance on the surface of which adsorption takes place [8]. Adsorbate is the substance which is being adsorbed on the surface of the adsorbent. Adsorbate gets adsorbed.

2.1 Zeolites For Adsorption

Zeolites are microporous, hydrated alumino silicate minerals commonly used as commercial adsorbents and catalyst [10, 11]. There are over 200 synthetic zeolites that have been synthesized by the process of slow crystallization of a silica-alumina gel in the presence of alkalis and organic templates. Many more such structures could theoretically be made. In addition to variations in structures, zeolites can also be made with a variety of other atoms in them to make them chemically interesting and active [4, 5]. The product properties depend on reaction mixture composition, pH of the system, operating temperature, pre-reaction 'seeding' time, reaction time, as well as the templates, used. In the sol-gel process, other elements (metals, metal oxides) can be easily incorporated. The silicate sol formed by the hydrothermal method is very stable. Here we have used Zeolite as adsorbent and Nitrogen as adsorbate [4]. The SEM images of adsorbent are shown in Figure.1.a and Figure.1.b for surface morphological of adsorbent.

2.1.1 Properties of Materials

1) Physical properties of zeolite 5Å
2) Parameters Value
3) Pellet radius (average), m = 0.00135
4) Pellet density, kg/m^3 = 1083
5) Pellet porosity = 0.30
6) Crystal diameter, mm = 2.0
7) Adsorbent specific heat, J/ Kg K = 920

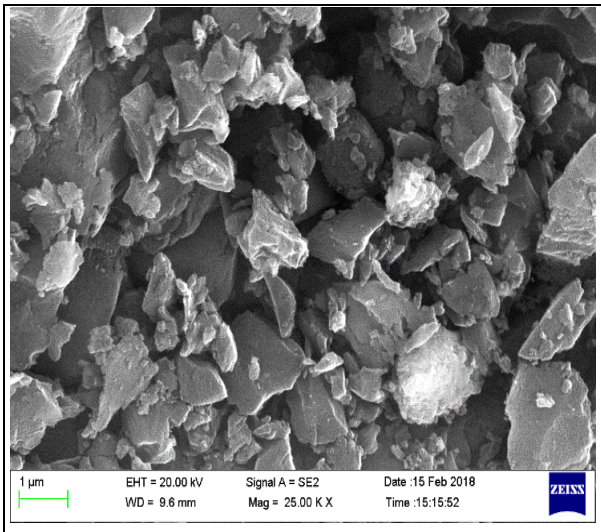

Figure.1.a SEM images

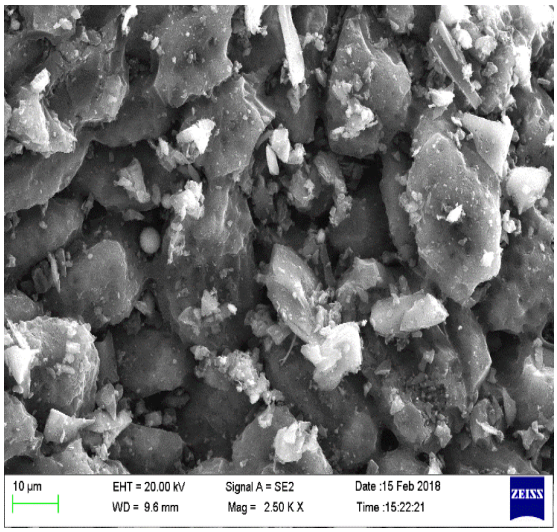

Figure.1.b SEM images

2.2 Design and Modification of Air Filter with Zeolite

The Modified air filter was filled with zeolites materials with air filter's maximum capacity [2, 3]. Then the filter was covered with aluminum meshes. It showed in the following Figure.2, Figure.3 and Figure.4.

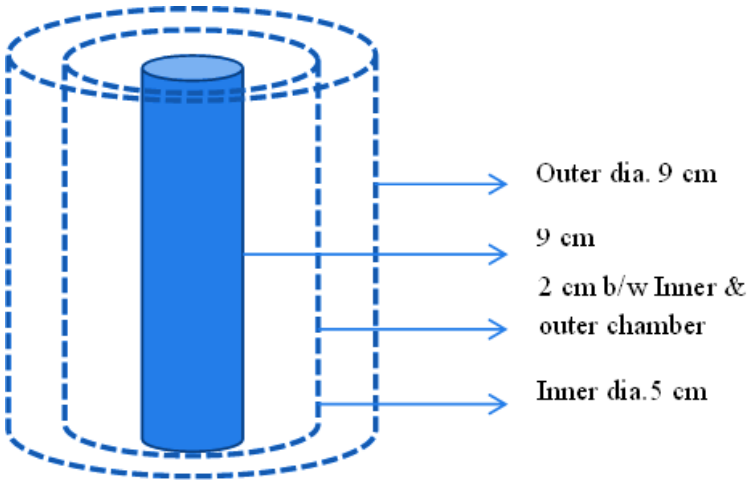

Figure.2 Design of Adsorbent bed.

2.2.1 Volume Calculation

Height of reactor	=	9 cm
Inner hollow cylinder diameter	=	5 cm
Outer diameter	=	9 cm
Volume of Zeolite occupied	=	(Outer cylinder volume – Inner cylinder volume)
	=	$(0.78 \times 9^2 \times 9) - (0.78 \times 5^2 \times 9)$
	=	568.62 -175.5
	=	393.12 cm^3 (i.e., 393.12 ml)

2.3 Ideal Air Fuel Ratio

1) Air has around 79% of nitrogen and 21% of oxygen. Hence, 23.2 mass-percent of air is

   Consider,

   Fuel + air (oxygen)→carbon dioxide + water

   $C_8H_{18}+[12.5(O_2)]x[100/23.2]\rightarrow 8CO_2+9H_2O$

   $$\frac{AIR}{FUEL} = \frac{((12.5*16*2)*4.3)}{(8*12)+(1*18)} = \frac{1716}{114} = 15.05$$

Consider, The Ideal air fuel ratio is around 14.7:1

Figure.3 Actual Bed image **Figure.4 Modified Bed with packed Zeolite**

2.4 Emission Controller & Engine Specifications

We have used AVL 437 SMOKE ANALYZER for testing the emission gases in HONDA ACTIVA (110 cc). The specifications are given in Table.1.

2.4.1 For AVL Gas Analyzer

Table.1 Specification of the gas analyzer

S. No	Particulars	Specifications
1	Accuracy and Reproducibility	± 1% full-scale reading
2	Measuring range	0-100% capacity in % 0-∞ absorption m^{-1}
3	Measurement chamber	effective length 0.430 m ± 0.005 m
4	Heating Time	220 V (approx. 20 min)
5	Light source	Halogen bulb 12 V/ 5W
6	Color temperature	3000 K ± 150 K
7	Detector	Selenium photocell diameter 45mm Max. sensitivity in light,
8	In Frequency range	550 to 570 nm. Below 430 nm and above 680 nm sensitivity is less than 4% related to the maximum sensitivity
9	Maximum smoke	210°C Temperature at the entrance

2.4.2 Analyzing Method-Non-Dispersive Infra-Red (NDIR)

These detectors are the industry standard method of measuring the concentration of carbon oxides (CO & CO_2). Each constituent gas in an exceedingly sample can absorb some infra-red at a specific frequency. By shining an infra-red beam through a sample cell (containing CO or CO_2), and measuring the amount of infra-red absorbed by the sample at the necessary wavelength, an NDIR

detector can measure the volumetric concentration of CO or CO_2 in the sample [9]. A chopper wheel mounted ahead of the detector regularly corrects the offset and gain of the analyzer and permits one sampling head to live the concentrations of two different gases, shown in Figure.5.

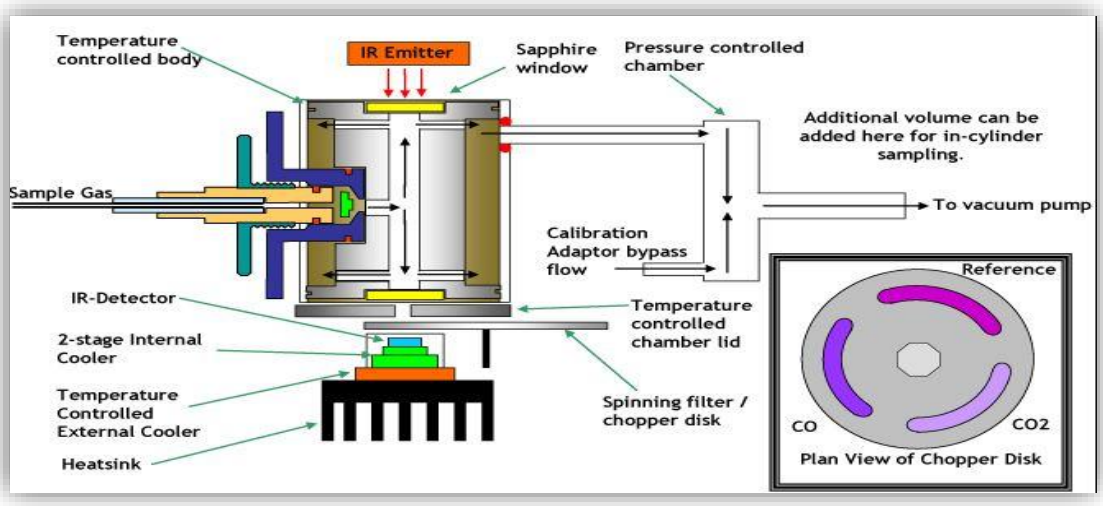

Figure.5. Infra-red CO analyzer

Chemiluminescence method of NOx measurement

The chemiluminescence method for gas analysis of oxides of nitrogen relies on the measurement of light produced by the gas-phase titration of nitric oxide and ozone. NO is a relatively unstable molecule which will oxidize to NO_2 (especially) in the presence of O_3. This reaction produces a quantity of light for each NO molecule which is reacted. This light can be measured using a photomultiplier tube or solid-state device [11, 12, 19]. If the volumes of sample gas and excess ozone are carefully controlled, the light level in the reaction chamber is proportional [20, 25] to the concentration of NO in the gas sample. If the amount of ozone present is sufficient to react all of the nitric oxides, then the quantity of light produced by the reaction will be proportional [22,24] to the concentration of nitric oxide in the gas sample.

2.4.3 For Engine-Honda Activa 3G

Table.2 Specification of Honda Activa

S. No	Particulars	Specifications
1	Type	Fan Cooled, 4 Stroke, SI, BS-4 Engine
2	Displacement	109.19 cc
3	Max net power	5.91 kW (8 bhp) @7000 rpm
4	Max net torque	8.94 Nm @ 5500 rpm
5	Bore	50 mm
6	Stroke	55.6 mm

7	Compression ratio	9.5:1
8	Air filter type	Viscous paper filter
9	Starting method	Kick/Self
10	Max speed	8 mph

2.4.4 Emission Testing

Emissions testing determine the level of air pollutants emitted from the exhaust of a motor vehicle. An emission take a look at cycle could be a protocol contained in associate emission customary to permit repeatable and comparable mensuration of exhaust emissions for various engines or vehicles. Test cycles specify the specific conditions under which the engine or vehicle was operated during the emission test. There are various test cycles issued by various national and international governments and dealing teams [6, 7]. Specified parameters in an exceedingly take a look at cycle embody a variety of operational temperature, speed, and load [13, 15]. Ideally, these area units fixed to accurately and realistically represent the vary of conditions underneath that the vehicle or engine are going to be operated in actual use. Because it's impractical to check associate engine or vehicle underneath each doable combination of speed, load, and temperature, this may not actually be the case. Vehicle and engine makers might exploit [14, 16, 21] the restricted range of take a look at conditions within the cycle by programming their engine management systems [17, 18] to regulate emissions to regulated levels at the specific take a look at points contained within the cycle however produce an excellent deal additional pollution underneath conditions old in real operation however not drawn within the take a look at cycle. These results in real emissions higher than the standards are supposed to allow, undermining the standards and *public health*, some of the conditions for testing are pressure, temperature and load condition.

2.4.5 Working Procedure

Initially, the bike was used for the experiment purpose.

1. The bike was turned ON and the engine was heated up for a certain period. Initially, the bike has a normal filter without zeolite particles.
2. After a certain period, the probe of the analyser was inserted into the exhaust of the bike.
3. On idle conditions, the readings were noted for 5 seconds by the computer record.
4. The engine was made to run for 7-10 minutes, and final reading was tabulated
5. Next, the engine of the bike was switched off. By using screwdrivers, spanners, torques wrenches, bits with size 10mm and 12 mm the bike's parts were removed.
6. After that the air filter of the bike was removed and new aluminium meshed zeolite bed was fixed.Again, the engine is turned ON and made to run for a certain period.
7. The probe of the analyser was placed in the silencer, and the results were noted by the computer for 5 seconds.

8. Finally, the engine was made to run for around 7-10 minutes, and values were tabulated.

3. RESULTS AND DISCUSSION

The following graphs were plotted based on real-time data from the actual experiment.

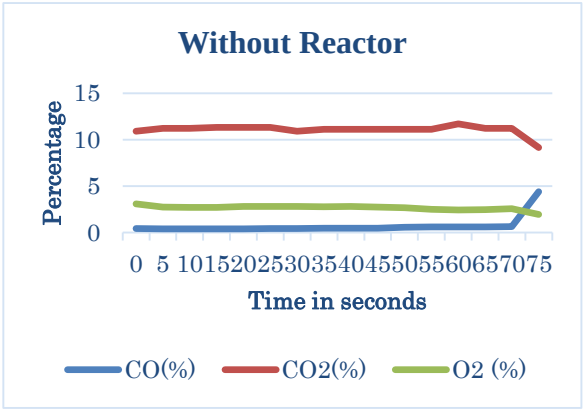

Figure.6 Time vs CO, CO_2, O_2 (without reactor)

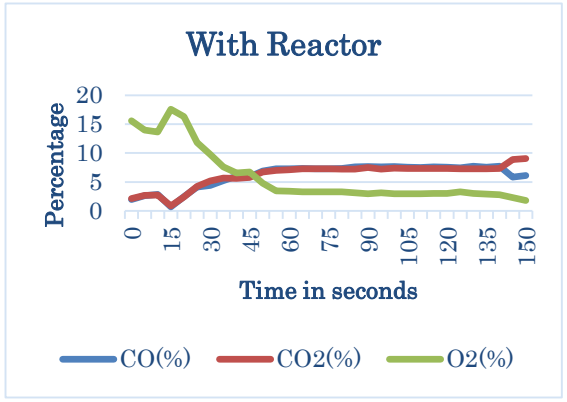

Figure.7 Time vs CO, CO_2, O_2 (with reactor)

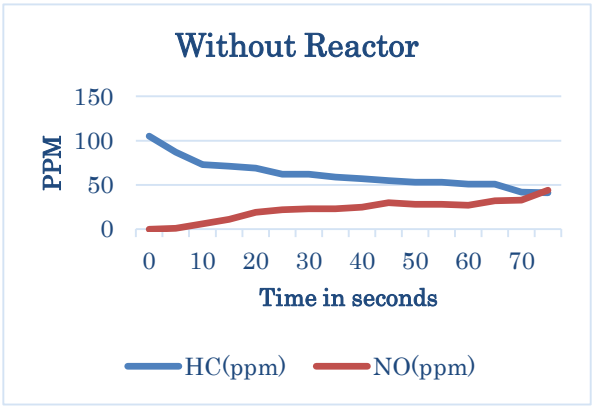

Figure.8 Time vs NO, HC (without reactor)

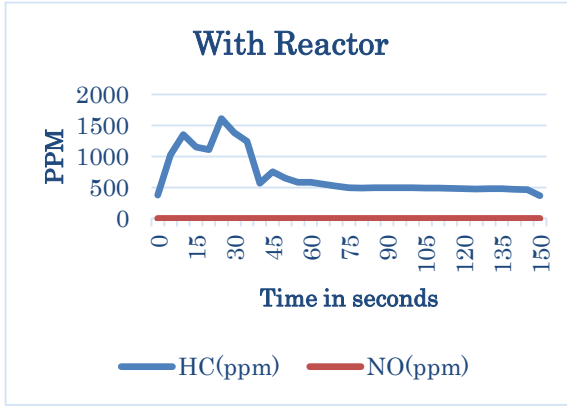

Figure.9 Time vs NO, HC (with reactor)

3.1 Inference From Graph

3.1.1. Without reactor

From the above graphs (**Figure.6 & Figure.8**) we can infer for an idle condition

1) At the start, more HC was intake to start the combustion then it was reduced to the required amount of burning.
2) Even though there was small ups and downs, the percentage of CO is almost constant during idle condition
3) CO_2 was also maintaining a constant level but it is greater than CO content while comparing. It was due to complete combustion of fuel.
4) O_2 was slowly decreased from start to burning fuel mixture for an idle condition. This was due to the combustion of fuel & emission of CO, CO_2 and NO.

5) NO was gradually increased from the start of the engine. This was due to the high temperature and burning of a lean mixture. Moreover, the Automobiles are designed to burn fuel only at the lean mixture. Hence it may emit more.

3.1.2 With reactor

From the above graphs (**Figure.7 & Figure.9**) we can infer for an idle condition.

1) HC was so high during an initial condition of combustion. Normally, it is kept at high because to start ignition. But here it is due to the accumulation of more O_2 in the intake.
2) The content of CO was continuously increasing in idle condition. It is due to the incomplete combustion of the fuel mixture. It shows that the lean mixture with more O_2 during combustion.
3) The emission of CO_2 was very less compared to the without reactor CO_2 emission. It is due to the incomplete combustion of HC fuel inside the cylinder.
4) O_2 was very much high during starting. It is due to the adsorption of nitrogen molecules on zeolites. But it was slowly increasing because of saturation of zeolites.
5) There was zero ppm NO gas in emission. It is due to the adsorption of nitrogen molecules while in-take before carburettor by zeolites materials.
6) Hence, we can conclude that nitrogen adsorbed, oxygen can be enriched.

4. CONCLUSION

On considering ideal condition, from this experiment, it can be inferred that zeolite can adsorb nitrogen molecules at normal pressure and temperature. The values from this experiment show that the PPM of NO, HC and percentages of O_2, CO, and CO_2 molecules before and after the usage of zeolite in the air filter were identified their difference. The values showed the effectiveness of zeolite on adsorbing nitrogen molecules. Initially, without the filter, there was a tremendous increase in the value of NO. But after the use of zeolite, there was a significant drop in NO. Overall this experiment was identified as for reducing the amount of NO content in the emission gas by using zeolite, which can enrich O_2 gas for the combustion.

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CONFLICT OF INTEREST

Authors have no any conflict of interest.

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