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Experimental Investigation and Emission Reduction Test of Bio Diesel by Using SCI for Di Diesel Engine

M.VARATHAVIJAYAN[1], DR.MR.SWAMINATHAN[2]
1Mechanical Dept. NOVA College of Engineering & Tech, JRG,AP.
[2] Mechanical Dept. ANNA University, Chennai-25

Abstract -- Diesel engines are widely used in many areas like automobiles, locomotive marine engines power generations etc., due to its high power output and thermal efficiency. Even though the diesel engines give more benefits, the human discomforts caused by the pollutant emission of these engines have to be considered. The major pollutant emissions of the diesel engines are particulate matters, smoke and the oxides of nitrogen (NOx). Out of these pollutant emissions, the oxides of nitrogen are considered as the most harmful pollutants to the human health. Emissions of nitrogen oxides (NOx) contribute seriously to air pollution, which is a major environmental problem of NOx react with moisture in the air to form nitric acid, contributing to soil and water acidification in sensitive areas. In the after treatment method, urea solution is sprayed in the exhaust stream which is at a temperature of 3000C to 450oC. At this high temperature of exhaust gas, the urea starts to decompose and form ammonia. The ammonia acts as reduction against and converts the oxides of nitrogen (NO and NO2) into free nitrogen (N2) and water vapour (H2O). There are many techniques being tried to control NOx emission from diesel engine. In this project, the emissions controlled by after treatment of exhaust gases. The selective catalytic reduction (SCR) of NOx is a promising technology for NOx reduction.

I. INTRODUCTION

Selective catalytic reduction systems are the most effective and commonly used post-combustion NO_x reduction processes available. SCR utilize a chemical reaction where vaporized ammonia (NH_3) is injected, via an ammonia injection grid, into the exhaust gas prior to flowing through catalytic modules. The objective is to convert nitrogen oxides (NO_x), to nitrogen and water. The key to optimizing the chemical reaction within the SCR is achieving uniformity of exhaust gas flow rate[2]. Some of the major catalytic industries are Johnson Mathey India Pvt Ltd, Cats Direct, Emitec Emission Controls Private Limited, Automotive Merchandising Corporation, Gencat Limited and Cummins India Limited.

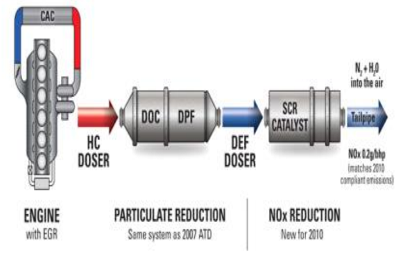


Fig 1: structure of IC engine using SCR

II. FORMATION OF NO_X

NO_x emissions do not form in significant amounts until flame temperatures reach 2800 F. Once that threshold is passed, however, any further rise in temperature causes a rapid increase in the rate of NO_x formation. NO_x production is highest at fuel-to-air combustion ratios of 5–7% O2 (25–45% excess air) [3]. Lower excess air levels starve the reaction for oxygen, and higher excess air levels drive down the flame temperature, slowing the rate of reaction.

III. CATALYTIC CONVERTER AS A POLLUTION CONTROLLER DEVICE

The catalytic converter does a great job at reducing the pollution, but it can still be improved substantially. One of its biggest shortcomings is that it only works at a fairly high temperature. When you start your car cold, the catalytic converter does almost nothing to reduce the pollution in your exhaust.

A. What is catalytic converter?

As the name suggests, it basically converts harmful gases into harmless gases, which are environment friendly, with the help of a catalyst. Engine exhausts having harmful gases like CO, NOx & HC which are converted into harmless gases like CO2, N2 & H2O respectively with the use of catalytic converter.[5]

B. POSITION OF CATALYTIC CONVERTER:

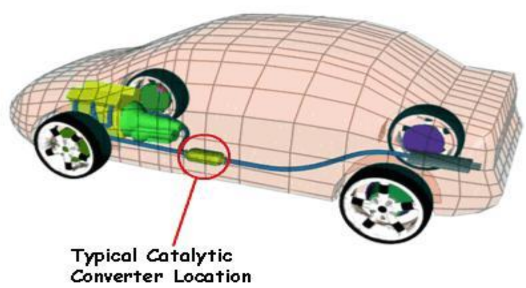


Fig 2: Position of SCR

Selective Catalytic Reduction (SCR) is a means of converting nitrogen oxides, also referred to as NOx with the aid of a catalyst into diatomic nitrogen, N_2, and water, H_2O. A gaseous reductant typically anhydrous ammonia, aqueous ammonia or urea, is added to a stream of flue or exhaust gas and is absorbed onto a catalyst. Carbon dioxide, CO_2 is a reaction product when urea is used as the reductant [7]. The SCR system does not alter the design of the modern Common Rail Diesel (CRD) engine therefore it can continue to deliver excellent fuel economy and durability. Rather, SCR provides emissions after-treatment well into the exhaust stack, in a way similar to the soot containment achieved by the Diesel Particulate Filter (DPF). SCR works by injecting Diesel Exhaust Fluid (DEF) such as Ad Blue, into the hot exhaust stack. [6] DEF works in conjunction with the hot exhaust gases and catalyst to break NOx into two components of our normal atmosphere water vapour and nitrogen.

Table:1 Comparison of properties between bio diesel and diesel

Fuel properties	Unit	diesel	biodiesel
Kinematic viscosity at40◦c	cSt	4.56	5.58
Specific gravity at 15◦c		0.8668	0.8812
Flash point	◦c	72	174
Fire point	◦c	80	185
Pour point	◦c	-18	4
Cloud point	◦c	-3	12
Diesel index		50.6	51.4
Calorific value	kJ/kg	42850	42293

The second objective is to select the catalyst that is to be coated on the monolithic structure such that it ensures the following,

- The catalyst used must be cheaper than the conventional catalyst, platinum.
- The catalyst should not be emptied sooner that it requires frequent re-coating.
- The catalyst should not change its physical and chemical properties when subjected to high temperatures, i.e., it should withstand high temperatures.
- The catalyst should enable the above mentioned reactions effectively and efficiently.
- The catalyst must not form any new pollutants during the process as by products.

IV. BASIC COMPONENTS OF SCR:

- Substrate: is ceramic honeycomb like structure with thousands of parallel channels that provide a large surface area for the engine exhaust.
- Wash Coat: A coating that increases the effective surface area of the substrates & facilitates the application of precious metal catalyst onto the surface of the ceramic surface of the ceramic substrate.
- Catalyst: Precious metal catalyst-the heart of *catalytic converter*, applied to wash coated ceramic substrate.
- Mat: It provides thermal insulation & protects against mechanical shock & chassis vibration.
- Cane: A metal package that encases all the above components.

- Heat Shields: They are used to protect various parts surrounding the catalytic converter, form thermal shocks.

V. COATING PROCESS

Catalytic converters are used in automobile and industries for pollution abatement. They usually consist of cordierite ceramic extruded to form a structure of honeycomb-like cells that extend as channels along the catalytic converter length. A paint-like liquid containing the precious metal catalyst is coated on the channel walls[8].

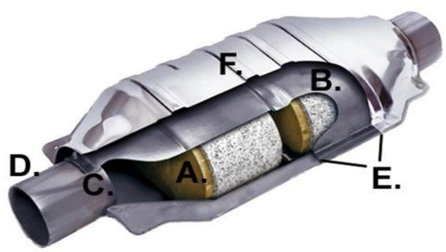


Fig 3: Section view of SCR

Ribbing on the shield offers a final layer of protection against heat damage while reinforcing the structural stability of the entire converter. A ribbed body encases the ceramic to reduce expansion and distortion when the converter reaches its high operating temperature. The ribs form channels that hold the ceramic in proper alignment and protect the cushioning mat from direct exposure to exhaust gases [9].

Table:2 SPECIFICATION OF I.C ENGINES

Terminology	Specification
Engine type	Vertical,4 stroke single cylinder diesel engine, kirloskar oil engines ltd,India.
Power	5 BHP
Speed	1500 rpm
Compression ratio	16.5:1
Bore / stroke	80/110
Aspiration	Naturally aspirated
Injection pressure	200ka/cm^2
Type of cooling	Water cooled

VI. TYPES OF CATALYTIC CONVERTER

There are main types of structures used in catalytic converters. Honeycomb and Ceramic beads. Most cars today use a honeycomb structure.

In a three-way catalytic converter, the converter is positioned in front of the oxidation catalyst. A three-way catalytic converter reduces NOx emissions as well as CO and HC. The three-way catalyst reduces NOx into nitrogen and oxygen[14].

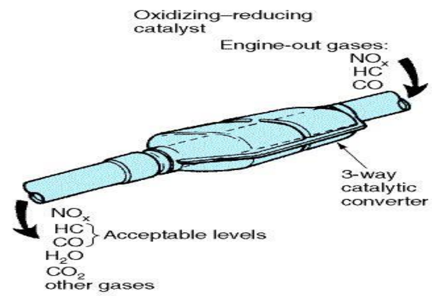


Fig 4: Silencer with SCR

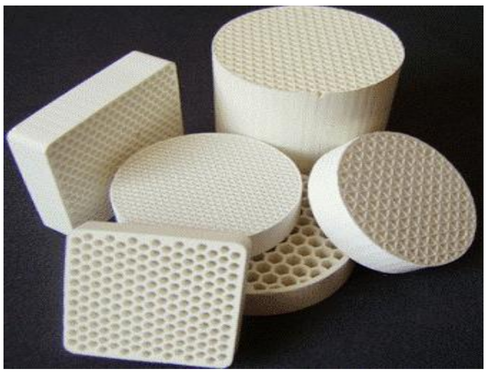
A catalytic is a substance that causes chemical reaction without being changed by the reaction. Noble metals are used as catalysts.

- Oxidation converters: - 70% platinum & 30% palladium is not as efficient as platinum but it is used to reduce overall cost of the unit.
- Reduction converters: - it consists of platinum & rhodium [15].

Table:3 Constituents of IC Engine Exhausts

Major constituents (greater than 1%)	Minor constituents (less than 1%)
Water,H2o Carbondioxides,Co2 Nitrogen N2 Hydrogen H2 Oxygen O2 Carbon Monoxide Co	Oxides of sulphur SOx Oxides of Nitrogen NOx Aldehydes ,HCHO Organic Oxides HCOOH Alcohols CH3OH Hydrocarbons Carbon Monoxides Co Particulates Smoke

A method for producing a ceramic honeycomb structure comprising applying a coating material to an outer peripheral surface of the ceramic honeycomb body to form an outer peripheral wall, the thickness of the coating material applied being determined from the outer diameter of the ceramic honeycomb body and the drying shrinkage ratio of the coating material, such that the outer diameter of the dried ceramic honeycomb structure is within a target outer size ±1.4 mm.



Ceramic Honeycomb

Fig 5: Ceramic honey comb of SCR

A ceramic honeycomb structure is provided with a plurality of open passages extending there through in an axial direction thereof[16].

The reduction catalyst is the first stage of the catalytic converter. It uses platinum and rhodium to help reduce the NOx emissions. When an No or NO2 molecule contacts the catalyst, the catalyst rips the nitrogen atom out of the molecule and hold on to it, freeing the oxygen in the form of O2. The nitrogen atoms bond with other nitrogen atoms that are stuck to the catalyst, forming N2.

For example:

2NO => N2 + O2 or 2NO2 => N2 + 2O2

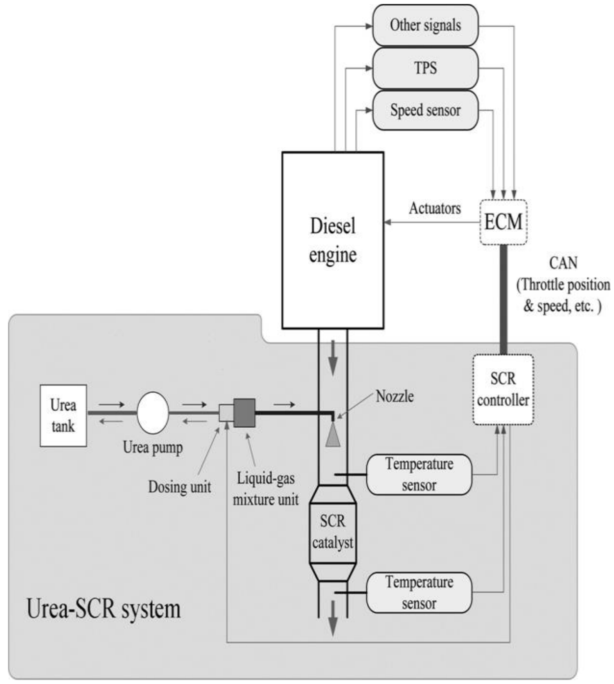


Fig 6: Experimental setup of SCR

An oxidation catalyst is a flow through exhaust device that contains a honeycomb structure covered with a layer of chemical catalyst. This layer contains small amounts of precious metal-usually platinum or palladium-that interact with and oxidize pollutants in the exhaust stream (CO and unburned HCs), thereby [19] reducing poisonous emissions. Sometimes called an OxyCat when used on a diesel engine, it works together with the DPF and EGR valve to remove the bulk of unburned hydrocarbons, soot and NOx from diesel exhaust.

Table:4 Properties of urea solution

Property	Values
Chemical formula	$(NH_2)_2$–CO–H2O
Molecular weight	60.06 g/mole
Urea content	32.5% by weight
Density	1085 kg/m^3
pH	9-11
Appearance	Colourless
Point of crystallization	$-11\ ^{o}C$
Carbon as CO2	Max. 0.4%

The oxidation catalyst is the second stage of the catalytic converter. It reduces the unburned hydrocarbons and carbon monoxide by burning (oxidizing) them over a platinum and palladium catalyst. This catalyst aids the reaction of the CO and hydrocarbons with the remaining oxygen in the exhaust gas[20].

For example:

$2CO + O_2 \Rightarrow 2CO_2$

Monolith:

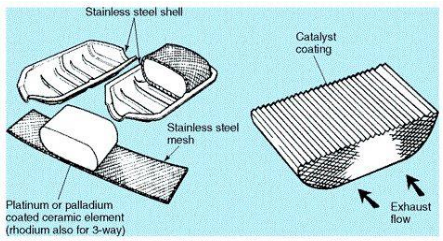


Fig 7: Cut Section view of SCR

- Shell: Manufactures make converter housing of sell of two stamped metal pieces welded to gather to form a round or oval assembly.
- Monolith: It is made from ceramic matter. Honeycomb design has hundreds of cellular passages for the exhaust gases to flow through.
- Flow diffuser: It is situated between converter inlet & catalytic element. It is used to obtain uniform flow of exhaust gases over the entire area. If it is not present then pellet type gases will pass through the center of the element only.

Pellet Type:

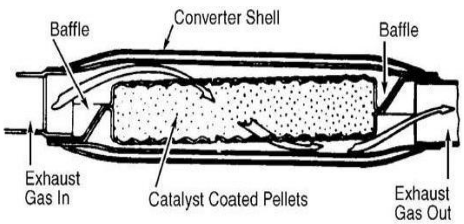


Fig 8: cross Section view of SCR

- Pellet: It consists of a small aluminium oxide pellet of 1/8 to 1/10 of an inch in diameter. They are coated with thin layers of platinum or palladium.
- Baffles: They direct the flow. First of all gases pass through the upper baffles. They have to pass through the pellets & get out through lower baffles. Baffles support & contains the bed.
- Insulation: Situated between inner 7 outer shells. It retarded the transfer of heat so no heat shield is required here.
- Drain plug: It permits removal of catalysts pellets with special requirement.

VII. METHODOLOGY

The NOx reduction process starts with an efficient CRD engine design that burns clean Ultra Low Sulphur Diesel (ULSD) and produces inherently lower exhaust emissions exhaust that is already much cleaner due to leaner and more complete combustion.

VIII. SCR CONVERTER:

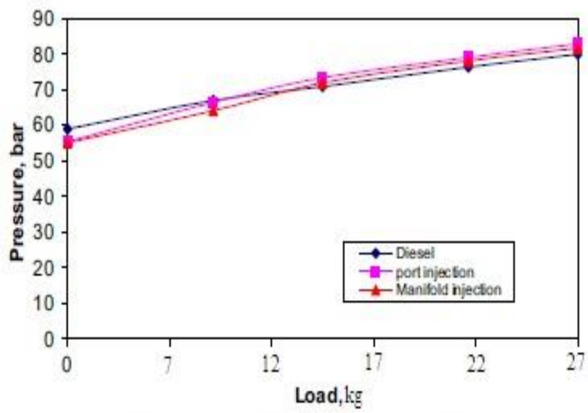
In this catalytic converter, zeolites is used to as a conversion agent where the conversion happens. Exhaust gases and an atomized mist of DEF enter the converter simultaneously. Together with the catalyst inside the converter, the mixture undergoes a chemical reaction that produces nitrogen gas and water vapour.

CATALYST CONTROLER:

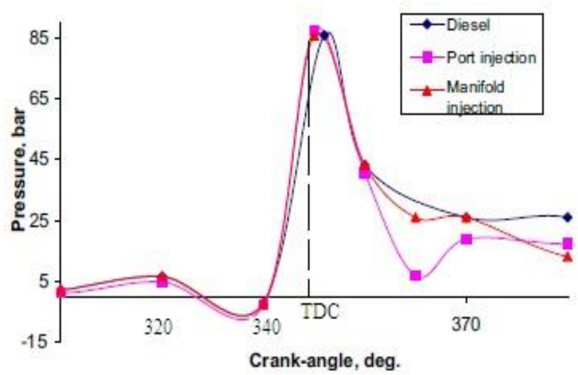
Exhaust gases are monitored via a sensor as they leave the SCR catalyst. Feedback is supplied to the main computer to alter the DEF flow if NOx levels fluctuate beyond acceptable parameters [21].

SCR catalysts are manufactured from various ceramic materials used as a carrier, such as titanium oxide, and active catalytic components are usually oxides of base metals (such as vanadium and tungsten), zeolites, and various precious metals. Each catalyst component has advantages and disadvantages. Some of the major catalytic industries are Johnson Mathey India Pvt Ltd, Cats Direct, Emitec Emission Controls Private Limited, Automotiev Merchandising Corporation, Gencat Limited and Cummins India Limited.

The graph shows the pressure and variation of peak pressure with load for diesel , port injection and manifold injection[24]. The pressure increases the peak pressure also increases for the variation of loads as shows in the graph. The pressure vs crank angle shows the variation of peak pressure with above the TDC of the engine at one revolution of the crankshaft.



Variation of peak pressure with load.



Heat release rate at full load.

BASE METAL CATALYSTS:

Such as the vanadium and tungsten, lack high thermal durability, but are less expensive and operate very well at the temperature ranges most commonly seen in industrial and utility boiler applications. Thermal durability is particularly important for automotive SCR applications that incorporate the use of a diesel particulate filter with forced regeneration [26]. They also have a high catalyzing potential to oxidize SO_2 into SO_3, which can be extremely damaging due to its acidic properties.

Fig 8: SCR pipe of this project

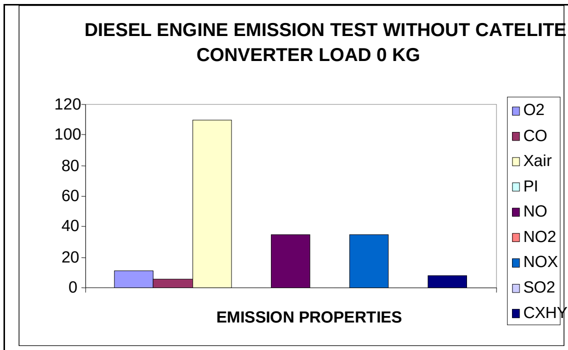
Fig 8: Inner body placed inside of outer body

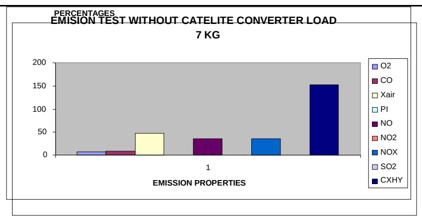
IX. EXPERIMENTAL TEST RESULTS:

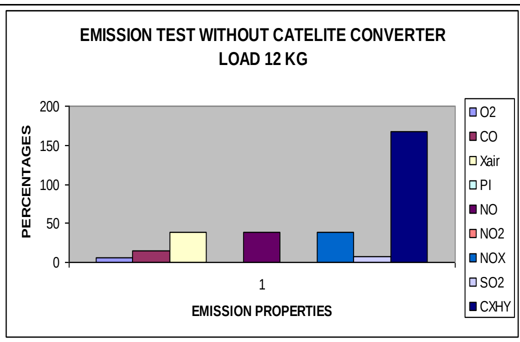
Table:5 Emission test- diesel without scr converter

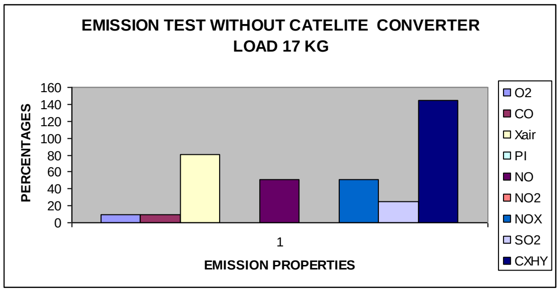
LOAD in KG	POLLUTANTS %								
	O_2	CO	X_{AIR}	PI	NO	NO_2	NO_X	SO_2	C_XH_Y
0	10.9	5.546	110	0	35	0	35	0	8
7	6.7	8.649	48	0	35	0	35	0	153
12	5.8	14.269	38	0	38	0	38	8	168
17	9.3	9.144	81	0	51	0	51	25.3	145

X. EXPERIMENTAL GRAPHS



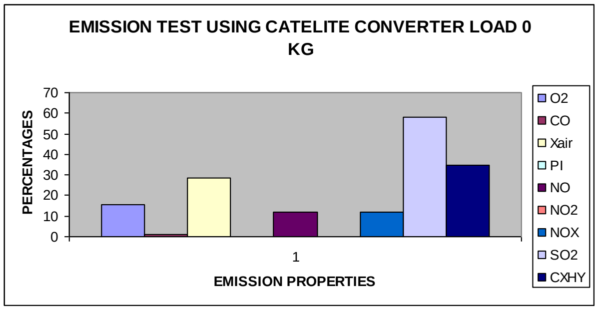


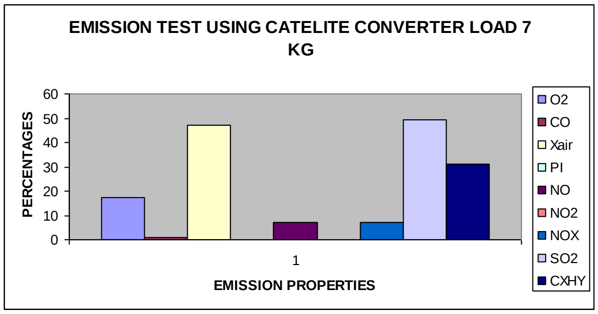


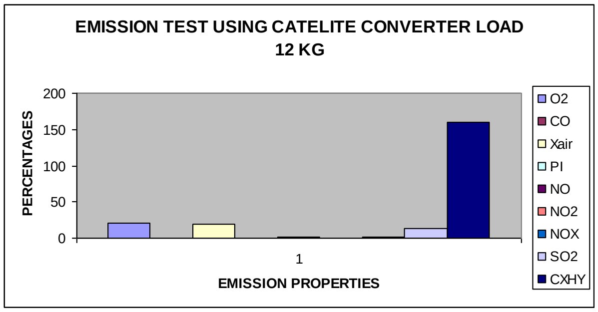


EMISSION TEST- USING SCR CONVERTER:

GRAPHS FOR USING CATELITE CONVERTER







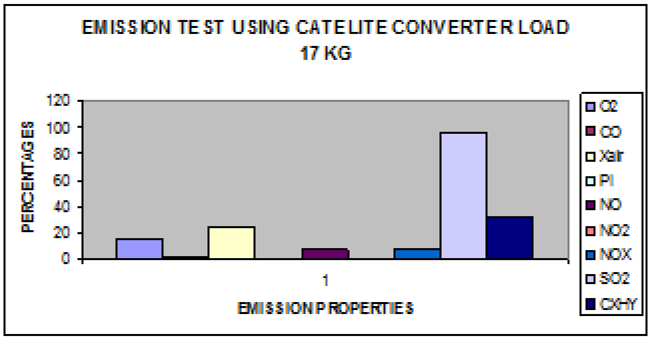


Table: 6 EMISSION TEST- USING SCR CONVERTERCONCLUSION:

LOAD IN KG	POLLUTANTS %								
	O_2	CO	X_{AIR}	PI	NO	NO_2	NO_X	SO_2	C_XH_Y
0	15.4	0.807	28.5	0	12	0	12	58.17	35
7	17.2	1.047	47.2	0	7	0	7	49.46	31
12	20.4	0.273	20	0	1	0	1	13.91	160
17	14.9	1.632	25.3	0	7	0	7	96.17	31

XI. CONCLUSION

By referring through many papers and guidance, the efficiency of selective catalytic reduction can be expected to increase by combination of both urea and zeolites chemical. By increasing the concentration of urea, NO_x can be reducing. These can be analyzing by utilizing the various concentration of urea in selective catalytic reduction technology. Zeolites mix with kaoline the binder to increase the separation process. Experimental test carried out due to various loads conditions. The results showed reduction of various exhaust gas not only NO_X. If using catalytic converter the most harmful gases should be minimized. Pollution should be controlled. The vehicle performance will be increased.

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