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Reduction 0f NOx Emissions with Three - Way Catalytic Converter For IDI Engine Fuelled With Diesel, JSVO and Their Blends

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Abstract:

Petroleum based fuels are obtained from limited reserves. These are finite reserves which are highly concentrated in certain regions of the world. Currently Jatropha biodiesel is receiving attention as an alternative fuel for diesel engine. The subject of the research presented in this thesis was the development new control strategies for automotive three way catalytic converters in order to fulfill future ultra-low exhaust emission standards. Three way catalytic converter is an effective technique to reduce NOx emissions from diesel engines because of Rh being used as catalyst helps to release the oxygen atoms stored in NOx in the reduction reaction. After these studies succeeded in reducing the NOx emissions from biodiesel by *three way catalytic converter without a significant change of BTE, BSFC and smoke opacity. The main focus of this dissertation is on finding out the best or the most suitable blend of biodiesel which when used gives out least automotive exhaust emissions using a 3 way catalytic converter. A single cylinder water cooled IDI diesel engine was used for investigation. Smoke , NOx ,CO, CO_2 emissions were recorded and various engine performance parameters were also evaluated . The results and discussion based on the effect of 3 way catalytic converter on engine performance and emission characteristics of JB20, JB40, JB60, JB80, JB100 and diesel fuel without 3 way catalytic converter . The engine was tested at high load condition(100% maximum load) and fixed speed 1000 rpm. The performance parameters are measured and recorded for diesel fuel and JB and their blends.*

Keywords: JB , 3way catalytic converter, NOx emissions.

Introduction :

The increasing focus on the environmental impacts of fossil fuel based power generation has led to increased research with the aim of reducing emissions and improving combustion efficiency. The search for alternative fuels which are eco friendly and can be used as a substitute to conventional HC based fuels is in demand due to concerns about depletion of fossil fuel reserves and also growing awareness against global warming [1]. The use of biodiesel is rapidly expanding around the world making it imperative to fully understand the impacts of biodiesel combustion process and pollutant formation. Biodiesel is typically produced through the reaction of vegetable oil or animal fat with methanol in presence of a catalyst to yield glycerin and methyl esters [2, 3,

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4,5]. The methyl esters produced in this process are called biodiesel . this process at production of biodiesel is called trans esterification [5,6,7,8,9,10 and 11]. In the last years ,many researchers have conducted studies on various compression ignition engines using biodiesels. Biodiesel can lower some pollutant and particulate matter emissions. it can be blended with diesel engine without any major modifications. Slightly higher velocity of biodiesel makes it an excellent lubricity additive [12]. Biodiesel is non toxic and biodegradable when introduced in neat form [13] and it is oxygenated fuel which contributed to a more complete fuel burn. Its cetane number is higher than those of vegetable oil and diesel fuel [14] and hence produce less HC emissions.[15,16].Biodiesel does not contain any aromatic components with low sulphur content produces low exhaust emissions. Sulphur dioxide and lower aromatic HC emissions [17,18,19]. The behavior of biodiesel in internal combustion engines is well documented in the literature. Engine performance is slightly lower when using biodiesel because of its lower heating value with respective to that of diesel fuel. The maximum NOx emissions were found for diesel fuel when compared to biodiesel and their blends. All biodiesel blends tests revealed that it can be safely used in the engine requiring no hardware modifications. Biodiesel has also showed interesting results when used 3 way catalytic converter. These studies have shown that engine efficiency does not change significantly. The aim of this paper is measuring regulated emissions such as NOx , CO, CO_2 , HC and soot from 3 way catalytic converter fueled with diesel , biodiesel and their blends.

2. Experimental works

2.1 Properties of test fuels:

Jatropha biodiesel, diesel and their blends was chosen as a test fuels, because it is non edible oil which doesn't conflict with food industries. The current study is focused to use jatropha biodiesel as blend with conventional diesel to improve its properties and reducing NOx emissions. The blending percentage are denoted by B20, B40, B60, B80, B100. The properties of diesel fuel and JBD blends (B20,B40,B60,B80,B100) were measured Table 1. shows the properties of test fuels.

Table 1.The properties of test fuels

Property	Diesel	JB 20	JB 40	JB 60	JB 80	JB 100
Percentage of JBD by volume	0	20	40	60	80	100
Density(kg/ $m^{3)}$	817	837.9	857.7	876.0	883.6	905
Calorific value(kJ /kg)	42,000	40,852	40,141	39,937	39,530	39,000

2.2 Three way catalytic converter technique:

The catalytic converter was used in the present work as shown schematically in figure 1. The catalytic converter is 'Three way catalyst'. This 3 way catalyst was used in an open –loop system.A three-way catalytic converter has three simultaneous tasks:

1) Oxidation of carbon monoxide to carbon dioxide: $2CO + O_2 = 2CO_2$

2)Oxidation of un-burnt hydrocarbons (HC) to carbon dioxide and water: $C_xH_{2x}+2 + [(3x+1)/2]O_2 \_ xCO_2 + (x+1)H_2O$

3) Reduction of nitrogen oxides to nitrogen and oxygen:

$$2NOx \_ xO_2 + N_2$$

Three way catalytic converter can store oxygen from the exhaust gas stream , usually when the air fuel ratio goes lean. When the insufficient oxygen is available from the exhaust stream the stored oxygen is released and consumed. This happens when oxygen is derived from NOx reduction.

3. Experimental Setup:

The properties of blended jatropha biodiesel and diesel fuels are detailed in table 1.the experimental installations used in the present work consists of a single cylinder , water cooled IDI diesel

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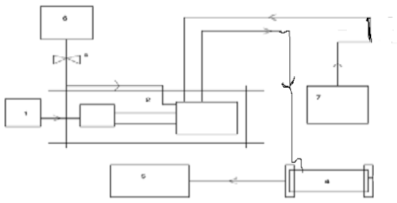
engine. Specifications of this engine are given in table 2. This engine was connected to electrical loading system.



1. Electrical loading, 2. Engine 4. Three way catalytic converter, 5. Gas analyzer 6. Fuel tank, 7. Air drum.

Figure1.Line diagram of three way catalytic converter system.

Table 2. The specifications of test engine

Sl. No.	Particulars	Specifications
1	Make	Field marshal Diesel engines
2	Model	FM-4
3	Rated Brake Power (BHP/kW)	10/7.35110
4	Rated speed (rpm)	1000
5	Number of cylinder	One
6	Bore x Stroke (mm)	120x139.7
7	Compression ratio	17:18
8	Coling System	Water Cooled
9	Lubrication System	Forced Feed
10	Cubic Capacity	1580 cc
11	Injection Pressure	145 kg/cm^2
12	Specific Fuel Consumption	265 gm /kWhr OR 195 gm / bhp /hr
13	Sump Capacity	4.5 Ltr
14	Lubricating oil Consumption	15 g /hr
15	Gross Weight	490 kg

Figure 2. Photograph Of experimental setup

The fuel supply system was connected with the fuel tank and the temperature of intake air, exhaust gas and engine coolant were measured . k type thermometers(The wires from thermocouple data logger which connected to USB cable connected with PC). Circle edge orifice plate was used for measuring air intake mass flow rate.

A U-tube manometer was used for measuring pressure drop across the orifice plate. NOx , CO,CO_2, HC were measured using a AVL fire gas analyser. Figure 2. Shows the schematic diagram of the equipment setup.

4. Results And Discussion :

The result showed that with 3 way catalytic converter NOx was reduced by 14.3, 13.79, 16.6, 5.03, 7.19,and 24.4% for B 100, B 80, ,B60, B40,B 20 and diesel fuel respectively at 100% load. Similarly soot emissions, CO_2, CO were recorded and various engine performance parameters were also recorded. Table 3. Shows the effect of three way catalytic converter on engine performance and NO_X emission with JB 100 fuel relative to the existing engine without three way catalytic converter.

4.1 NO_X Emissions

Brake specific NO_X emissions of diesel engine fueled with different test fuels and their bends at 100% load conditions are illustrated in the tables 3,4,5,6,7 and 8. Kinetics of NO_X formation is governed by Zeldovich mechanism. The principle source of NO_X formation is the oxidation of atmospheric nitrogen at sufficiently high temperature. NO_X formed in cylinder areas where high temperature peaks appear mainly during the uncontrolled combustion. The NO_X emissions of all the biodiesel-diesel blends have been found higher than diesel at higher loads. It is quite obvious, that with biodiesel addition in diesel more amount of oxygen is present in combustion chamber, leading to formation of higher quantity of NO_X in biodiesel-diesel blends fueled engines. From the following tables at 100% load the NO_X emissions from all the biodiesel and their blends are higher than that of diesel. For JB 100, JB80,JB60, JB 40 and JB 20 the maximum amount of NO_X produced at full load are 882(PPM),848(PPM), 806(PPM), 775(PPM), 737(PPM) respectively. For diesel the maximum amount of NO_X produced at full load is 643 (PPM) only. The reason is possibly due to the lower calorific value of biodiesel.

This is the most important emission charteristic of biodiesel the NO_X emission is the most harmful gaseous emission from engines and emission can be reduced by several methods. One of the method is using of three-way catalytic converter on open loop method reducing the NO_X emissions.

The percentage of reduction of NO_X emissions for the fuels JB 100, JB80, JB60, JB40, JB20 and diesel are 14.3%, 13.79%, 16.6%, 5.03%, 7.19% and 24.4% respectively. By using of three-way catalytic converter on open loop method the effect on brake thermal efficiency is negligible. The percentage of brake thermal efficiency for the fuels JB 100, JB80, JB60, JB40, JB20 and diesel are 0.43%, 0%, 0.42%, 0.67%, 0.29% and 0% respectively.

The result related to NO_X emissions and brake thermal efficiency are very much similar to earlier studies reported by Scholl et al.(11) and Nabi et al (12).

Table 3. Reduction process of No_x JB 100 as a fuel at 100% load.

Parameters	Existing Engine	Engine+ 3 way-catalytic converter	NO_X reduction(%)	change in BTE(%)
NO_X (ppm)	882	755	14.3	
BTE (%)	34.13	33.71		0.43(Decrease)

Table 4. Reduction process of No_x JB 80 as a fuel at 100% load.

Parameters	Existing Engine	Engine+3way-catalytic converter	NO_X reduction(%)	change in BTE(%)
NO_X (ppm)	848	731	13.79	
BTE (%)	35.74	35.74		0(No change)

Table 5. Reduction process of No_x JB 60 as a fuel at 100% load.

Parameters	Existing Engine	Engine+ 3way-catalytic converter	NO_X reduction(%)	change in BTE(%)
NO_X (ppm)	806	672	16.6	
BTE (%)	33.59	33.17		0.42(Decreases)

Table 6. Reduction process of No_x JB 40 as a fuel at 100% load.

Parameters	Existing Engine	Engine+3way-catalytic converter	NO_X reduction (%)	change in BTE(%)
NO_x(PPM)	775	736	5.03 %	
BTE (%)	36.69	36.02		0.67 (Decreases)

Table 7. Reduction process of No_x JB 20 as a fuel at 100% load.

Parameters	Existing Engine	Engine+3 way-catalytic converter	NO_X reduction (%)	change in BTE(%)
NO_X(PPM)	737	684	7.19 %	
BTE(%)	39.91	39.62		0.29 (Decreases)

Table 8. Reduction process of No_x Diesel as a fuel at 100% load.

Parameters	Existing Engine	Engine+3way-catalytic converter	NO_X reduction(%)	change in BTE(%)
NO_X (PPM)	643	486	24.4	
BTE(%)	41.09	41.09		0 (No change)

5. Conclusions

The objective of the research work was to effectively reduce the NO_X emissions with controlling device of three-way catalytic converter is connected to the IDI diesel engine when diesel, JSVO and their blends is fuelled in it at 100% load. It was found during exhaustive trial that the fuels like diesel, JB 100, JB 80, JB 60, JB 40 and JB 20 are operated with three way catalytic converter and without three way catalytic converter at 100% load. The three way catalytic converter have proved to be the most effectively reducing the NO_X

emissions .However, various conclusions achieved can be summarized below.

The brake thermal efficiency of JSVO and its blends was found to be lower than diesel, which may be due to lower calorific value and slightly higher viscosity of biodiesel.

Combustion efficiency is not affected by attaching the three way catalytic converter in open loop method. Negligible reduction in brake thermal efficiency was experienced.

For all testing fuels at high loads there is no significant change of brake thermal efficiency.

The exhaust gas temperature of the test fuels (biodiesel), and their blends was found to be lower than that of normal diesel.The NO_X emissions of both the biodiesel-diesel blends have been found higher than diesel at higher loads. For JB 100 fuel maximum amount of NO_X produced at full load is 882ppm. However at diesel maximum amount of NO_X produced at full load was found to be about 643ppm. The results related to NO_X emissions are very much similar to earlier studies reported by Scholl et al.(11) and Nabi et al (12). By the three way catalytic converter with open loop system maximum amount of NO_X emissions reduction was found in diesel fuel is about 24.4% and with no change in brake thermal efficiency because Rh catalyst release the oxygen atoms stored in the NO_X in the reduction process and hence NO_X emissions to the atmosphere significantly reduced in diesel.

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References

[1] E. G. Shay; Diesel fuel from Vegetable Oils Status and Opportunities; Biomass and Bioenergy ; Vol. 4, pp.227-242; 1993.

[2]. Alton R (1998) An experimental investigation on use vegetable oils as diesel engine fuels. Ph. D Thesis, Gazi Univ. Institute of Sci & Technol.

[3]. Abigor, R.D., et al..”Lipase-Catalysed production of Biodiesel fuel from some Negirain Lauric oils.” Eastren Regional Reseach Centre, USDA, 600 East Mermaid Lane, Wyndmoor, PA 19038, U. S. A, 2000.

[4]. Canakci M and Van Gerpen J (2001) Biodiesel production from oils and fats with high free fatty acids. Transactions of ASAE. 44, 1429-1436.

[5] Raghunadham N and Deshpande N V (2004) Effect of bio- edditives on

ICengine performance. Natl Conf, on IC engines, VNIT, Nagpur.

[6]Y. Ali, M. A. Hanna. "Durability testing of a diesel fuel, methyl tallowate, and ethanol blend in a Cummins NI 4-410 diesel engine", Transactions of the ASAE. Vol, 39(03), 793-797, 2001.

[7]Scholl KW, Sorenson SC. Combustion of soyabean oil methyl ester in a direct injection diesel engine. SAE paper no 930934, 1983

[8]Magín Lapuerta, José M. Herreros, Lisbeth L. Lyons, Reyes García-Contreras, Yolanda Briceño, Effect of the alcohol type used in the production of waste cooking oil biodiesel on diesel performance and emissions, Fuel 87 (2008) 3161–3169.

[9]Wu F, Wang J, Chen W, Shuai S. A study on emission performance of a diesel engine fueled with five typical methyl ester biodiesels. Atmos Environ 2009;43(7):1481–5.

[10]Lapuerta M, Armas O, Rodrı´guez-Ferna´ndez J. Effect of biodiesel fuels on diesel engine emissions. Prog Energy Combust Sci 2008;34(2):198–223.

[11]Report on Role of NGOs, and Inform, vol.13, 151-157, Feb. 2002.

[12]Alok Kumar Tiwari, Akhilesh Kumar and Hifjur Raheman; Biodiesel production from jatropha oil (Jatropha curcas) with high free fatty acid.

[13] Lapuerta M, Armas O, Rodrı´guez-Ferna´ndez J. Effect of biodiesel fuels on diesel engine emissions. Prog Energy Combust Sci 2008;34(2):198–223.

[14]. Lapuerta M, Armas O, Rodrı´guez-Ferna´ndez J. Effect of biodiesel fuels on diesel engine emissions. Prog Energy Combust Sci 2008;34(2):198–223.

[15]. Lanjewar A. Biodiesel as an alternative fuel for pollution control in diesel engine. Asian J Exp Sci 2005;19(2):13–22.

[16] Studies on the comparison of performance and emission characteristics of a diesel engine using three degummed non-edible vegetable oils*Biomass and Bioenergy*, *Volume 33, Issue 8*, *August 2009*, *Pages1013-1018*

[17] Breda Kegl (2006). Experimental Investigation of Optimal Timing of theDiesel Engine Injection Pump using Biodiesel Fuel. Energy & Fuels,20:1460-1470.World Academy of Science, Engineering and Technology 75 2011.

[18]. The effect of elevated fuel inlet temperature on performance of diesel engine running on neat vegetable oil at constant speed conditions Renewable Energy Volume 35, Issue 11, Pages 2399-2626 (November 2010)

[19] Sirisomboon P., Kitchaiya P., Pholpho T., and Mahuttanyavanitch W.,"Physical and mechanical properties of Jatropha curcas L., fruits, nuts,and kernels, Biosystems Engineering, Vol. 97, pp. 201-207, 2007.

[20] Tsunemoto, H., Ishitani, H., and Kudo, R., 1996,"Evaluation of Exhaust Oor in a Direct Injection. Diesel Engine," Trans. Jpn. Soc. Mech. Eng., Ser. B, 62 (604), pp.254–260, in Japanese.

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