Impact of Nano Catalyst Coated Catalytic Converter and Fuelled With Ethanol Blend and Dee as Additive In DI Compression Ignition Diesel Engine

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Abstract- **This project aims the effect of ceramics material coating on a new designed catalytic converter is used in diesel fuelled engine with 10% of ethanol blend in addition of 1% of (DEE) Diethyl Ether as fuel additive. The catalytic converter was developed based on catalyst materials consisting of metal oxides such as titanium dioxide (TiO2) and Aluminum oxide (Al2O3) with ceramic substrate. Both of the catalyst materials (TiO2 and Al2O3) are inexpensive in comparison with conventional catalysts (noble metals) such as palladium, platinum and rhodium. In addition, the noble metals are now identified as human health risk due to its rapid emissions in the environment.**

The OEM (Original Engine Manufacturer) catalytic converter was based on noble metal catalyst with honey comb ceramic substrate. The designed and fabricated ceramic substrate coated with oxides of metals is TiO2 and Al2O3. In this study, experimentally found that the TiO2/Al2O3 based catalytic converter are reduce 12%, 23.46%, 19%, 35% and 77.9% for NOx, CO, HC, CO2 and smoke emissions respectively for diesel fuel . It is calculated that the TiO2/Al2O3 based catalytic converter with ethanol 10% in addition of DEE 1% reduces 15%, 52.8%, 39%, 40% and 81.7% higher NOx, CO, HC, CO2 and smoke emissions in comparison to diesel and ethanol. The objective of this paper is to develop a low-cost three way catalytic converter to be used with the newly developed ceramic catalytic converter and emission test results have been presented with discussions.

Index Terms- **Catalytic Converter, Diethyl Ether, Titanium dioxide, Aluminum oxide, Ethanol.**

1. INTRODUCTION

Diesel engine has found wide spread use in on-road vehicle and off-road equipments. However, its exhaust contains a number of hazardous air pollutants and large numbers of fine particles that have been linked to adverse health effects and environmental impacts [1]. There are two ways to increase the yield of products obtained by catalytic reaction and improving the properties of the catalytic material (or) optimizing the catalytic process [2]. Among the alternative fuels, biodiesels have received increasing attention because they are renewable, non-toxic and biodegradable. Use of biodiesels may also prolong engine component life. However, the use of additive is another convenient way to improve emission and performance of biodiesel-diesel blends [3]. The heating value of the blends was reduced with addition of DEE. Front end volatility of the blends was improved by addition of DEE [4]. Addition of TiO_2 , working as an acidic material, was found to decrease the NO_x adsorption capacity through improved Ag dispersion which place an important role in NO_x adsorption consequently, an greater NO_x trapping performance than NSR(NO_x storage and reduction)catalyst was achieved at lower temperature[5]. TiO_2 with wire mesh substance are inexpensive in comparison with conventional catalyst (noble metals) such as palladium (or) platinum and also risk to human health due to their rapid emissions in the environment [6]. The automotive industry is ever more interested towards the development of catalyst diesel particulate filter (CDPF) that can be applied for the collection of soot particles and their direct oxidation at the conditions that are prevalent at the exhaust and CDPF are needful oxide catalysts. Direct catalyst oxidation of soot in CDPF is a complex process which can be described by a set of oxidation mechanism mentioned in the past [7]. The results shows the pore size of the filtration of the layer providing the filtration efficiency it found to be between the characteristic soot particle size and the original DPF wall pore size. It shows that the optimum distribution of filtration thickness along

DPF length should be matched to velocity distribution [8-9]. The loading of active phase over cordierite monolith using slurry of catalyst powder does not lead to good adhesion even with winder and surfactant. It is therefore desirable to grow active phase directly on the monolith surface without winder and without going through making a catalytic powder [10].

2. CATALYTIC CONVERTER CONSTRUCTION

Substrate - is ceramic honeycomb like structure with hundreds of circular path that provides a large surface area for the engine exhaust. Wash coat - A coating that increases the effective surface area of the substrates and facilitates the application of precious metal catalyst onto the surface of the ceramic surface of the ceramic substrate. Catalyst – TiO_2/AL_2O_3 Precious metal catalyst-the heart of catalytic converter, applied to wash coated ceramic substrate.

3. FABRICATION AND DESIGN OF CATALYTIC CONVERTER

The ceramics substrate consists of following refractory materials such as

1. Bells per
2. Quartz
3. Aluminum Oxide
4. Nevveli ball clay

Initially the 35%-45% of Nevveli clay, 20%-25% of Bells per, 10%-15% of quarts and 5%-10% of alumina mixed with 3%-5% of water, also 1%-3% of corrosion and Hollis acid for make a paste. This paste was kept one day at room temperature for well mixing process due to that cracking damages could be resolve. Then the paste was make required shape (circular i.e. substrate) with the help of Die. After that the green substrate was dried two day with room temperature thereafter three days with sunlight. So that the moisture content of the green substrate was partially reduced. If the moisture content was in the substrate means crack would be form on the substrate while firing period. Then the scrap would be removed by applying water on the surface of the substrate. Again it was clean by sponge for the surface smoothness. However this substrate was kept in a furnace fired around 300^0 C- 400^0 C. Finally the substrate was air cooled 3-4 hours using fan.

3.1 Shape, Design and Volume of catalytic converter

The cylindrical shape was considered due to ease of fabrication, minimum assembly time, rigidity and easier maintenance.

Assuming space velocity (for single cylinder engine) = 30000 hr^{-1}

The space velocity is calculated as under

$$\text{Space velocity} = \frac{\text{Volume of flow rate}}{\text{Converter rate flow Volume}}$$

The converter volume was calculated as

$$\text{Converter volume} = \frac{\text{volume of flow rate}}{\text{space velocity}}$$

Volume flow rate = Volume * Number of intake stroke / hr = $(\pi/4)*(0.102)^2*0.25*(1500/2)*60$ = 91.88 m^3 / hr

$$\text{Converter volume} = \frac{91.88}{30000} = 3062.66 \text{ ml}$$

3.2 Shell dimensions, Inlet cone and Outlet cone

The Shell is the central cylindrical part between the two inlet and outlet cones. This part contains circular discs with coated ceramics substrate.

$V_{cylinder} = (\pi/4)*d^2*L$

The inlet cone is longer than outlet cone to take care of any thermal stresses. One end of the cone is matched with exhaust pipe diameter

Volume of Cone = $\pi h/3((r_1)^2 + r_1 + r_2 + (r_2)2)$ = 0.035 m^3

Where (h_1= 0.01 m:r_1=r_2= 0.16 m)

The outlet cone is smaller in size than inlet cone as temperature of the exhaust gases is reduced while flowing through the inlet cone and shell. Thus there is no possibility of thermal stresses.

Volume of Cone = $\pi h/3((r_1)^2 + r_1 + r_2 + (r_2)^2)$

Inlet cone volume=outlet cone volume

4. EXPERIMENTAL TEST, FUEL AND ADDITIVE

The experiments were conducted as a single cylinder four stroke, naturally aspirated, water-cooled C.I engine with eddy current dynamometer. The catalytic converter is fabricated and installed next to the exhaust flange before the tail pipe. The detailed engine specifications are given in table 1

Model and Manufacturer	SV1, Kirloskar oil engines limited
Type of Engine	Vertical, 4-Stroke cycle, Single acting, Single cylinder, high speed compression ignition diesel engine
Displacement	661cc
Maximum Power	8 HP
Max brake power	3.5 kW
Speed	1500 rpm
Compression Ratio	17.5:1
Bore and stroke	87.5 x 110 (mm)
Method of cooling	Water cooled
Flywheel diameter	1262 mm
Injection pressure	200 bar

Table 1. Engine Specification.

Ethanol as a renewable and oxygen containing bio-fuel, contains 35% oxygen that helps complete combustion of fuel and thus reduces harmful tailpipe emissions. Ethanol is a preoperative fuel for vehicle, which can be blended with diesel (bio-Diesel). Ethanol can be produced from wheat, corn, beet, sweet sorghum etc. Ethanol (bio-Diesel) is one of the best tools to fight vehicular pollution. It also reduces particulate emissions that pose a health hazard. Ethanol is a sustainable fuel, as it can be obtained from sugarcane and other renewable energy sources. The DEE is added with the bio-diesel to enhance the combustion. The ceramic material such as aluminum oxide (Al_2O_3) and titanium dioxide (TiO_2) for a catalyst material instead of noble material cause toxity at high temperature.

The following equipment's play an important role to measure exhausts smoke in catalytic converter:

- Pressure Gauge
- AVL smoke meter for smoke density measurement

AVL five gas analyzer for measurement of HC, CO and NO_x.

5. RESULTS & DISCUSSIONS

The following graphs shows that various emission characteristics of VCR diesel engine with and without coating of ceramic substrate by using ethanol-diesel blend 10% with 1% of DEE (Diethyl Ether).

5.1 Performance Characteristics of Ethanol-Diesel Blend

5.1.1. Brake Specific Fuel Consumption (BSFC)

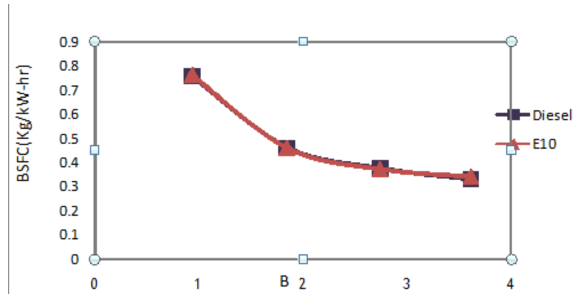

Figure 2. BP vs BSFC

The variation of brake specific fuel consumption with brake power of the engine for proportion of ethanol-diesel blend and neat diesel is shown in Fig.2.The E10 showed better BSFC. BSFC is 0.35 kg/kW-hr for E10 and 0.28 kg/kW-hr for diesel fuel at full load. This is due to the fact that ethanol-diesel has lower heating value compared to diesel; so more ester-based fuel is needed to maintain constant power output. Further, more fuel is required when biodiesel blends operated engine because higher density.

5.1.2. Brake Thermal Efficiency (BTE)

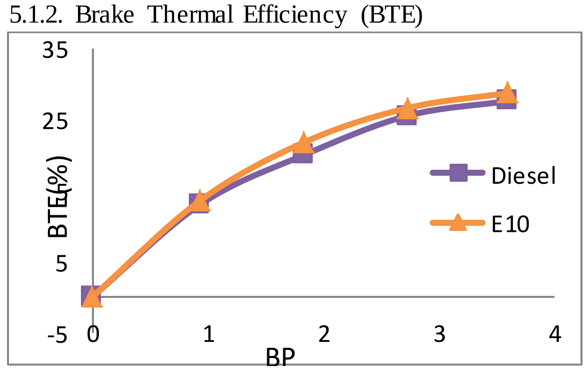

Figure.3. BP vs BTE

The variation of brake thermal efficiency with brake power of the engine for proportions of biodiesel blends and diesel is shown in Fig.3. It is observed that BTE of ethanol-diesel and its blends are slightly lower than that of diesel fuel. This could be attributed to the presence of increased amount of oxygen, which might have resulted in its improved combustion and to closer BTE with diesel.

5.1.3. Exhaust Gas Temperature (EGT)

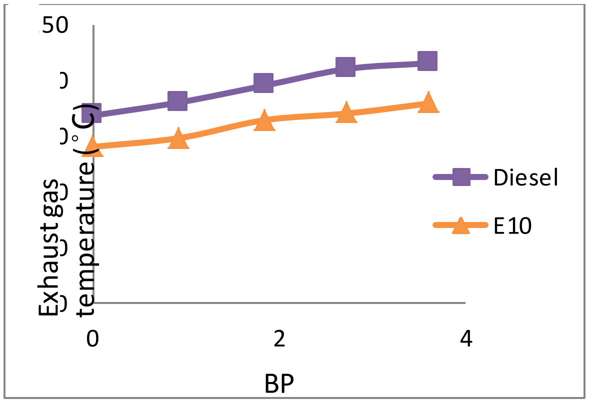

Figure 4. BP vs EGT

The variation of exhaust gas temperature with brake power of the engine for ethanol-diesel blend and diesel is shown in Fig.4. It is observed that EGT of ethanol-diesel and its blend is slightly lower than that of diesel fuel. The maximum EGT of diesel fuel is 240°C and that of E10 is 170°C at full load. The E10 showed lower EGT. This is due to improved combustion provided by the ethanol-diesel with its 11% dissolved oxygen content.

5.2 Emission Characteristics of Catalytic Converter with coating and Ethanol-Diesel Blend.

5.2.1 Carbon Monoxide Emission (CO)

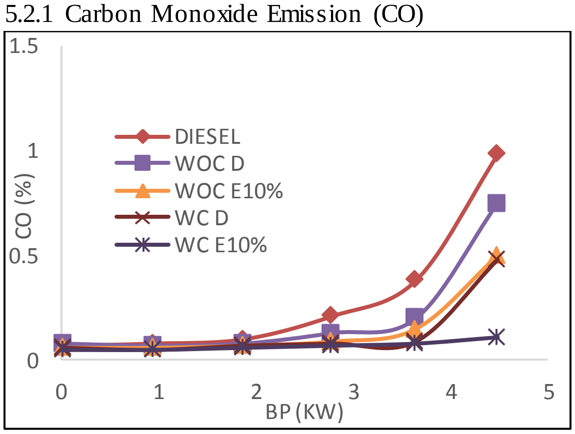

Figure 5. BP vs CO

In this graph shows that various load condition the diesel fuel had maximum CO emission while kept new catalytic converter without coating reduced up to23.46%of CO emission because of the substrate has aluminum content. With coated catalytic converter CO was reduced to 52.8% and also using ethanol the conversion efficiency increases to 88% at full load condition.

5.2.2 Hydrocarbon Emission (HC)

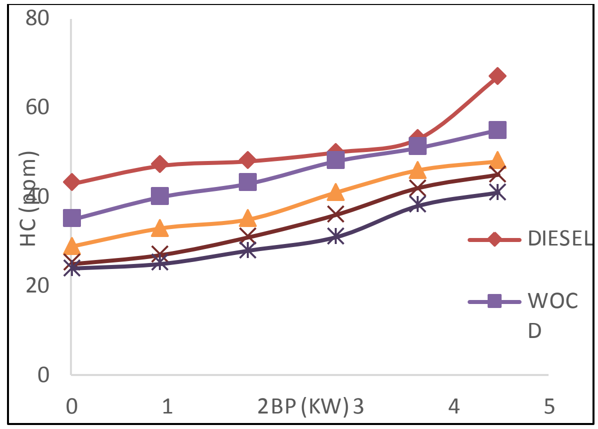

Figure.6. BP vs HC

The unburned hydro carbon (UHBC) of diesel was more in without coated catalytic converter. In the coated catalytic converter the UBHC is reduced due to reduction process of TiO2/Al2O_3 catalyst material. By using of ethanol blend 10% with the additive DEE 1% the conversion efficiency of catalytic converter increase without coating 19% and with coating 39%. The oxygenated ethanol blend and additive DEE enhance the combustion. This is due to increase the air temperature at the end of compression stroke, enhancement in combustion temperature and reduction in charge dilution leads to complete combustion and reduction in hydrocarbon emissions

5.2.3 Carbon dioxide (CO_2)

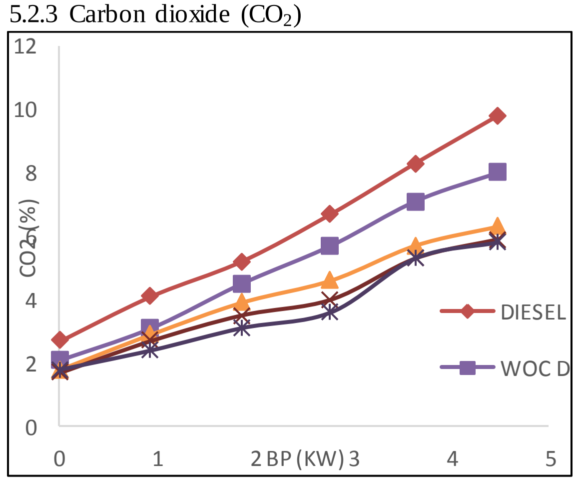

Figure.6. BP vs CO_2

The complete combustion process takes place inside the combustion chamber amount of CO_2 exhaustion by the diesel engine is normally high. But using catalytic converter using with ethanol blend in addition of DEE reduce. By the catalytic converter the amount of CO_2 reduce 35% without coating and 40% with coating of catalytic converter.

5.2.4 Oxides of Nitrogen Emission (NO_X)

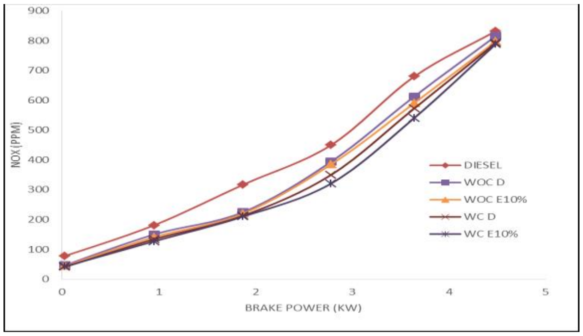

Figure 7. BP vs NO_X

Among all the effective factors on NOx formation, the combustion temperature is the dominating process. Catalytic converter can convert the NOx emission by the Reduction process. Here the catalyst material TiO_2/Al_2O_3 which effectively reduce 12% in without coating and with coating 15% of NOx reduce at 75% of load condition . Ethanol and DEE blending into diesel fuel reduces temperature both by increased heat of vaporization and by reduced flame temperature. Consequently, combustion temperature abates, and hence NOx emissions are significantly diminished. So that NOx emission minimize up to 10% without coating and 20% reduce with coating by using Ethanol blend with DEE. This is 5% increases conversion efficiency of catalytic converter.

5.2.5 Smoke

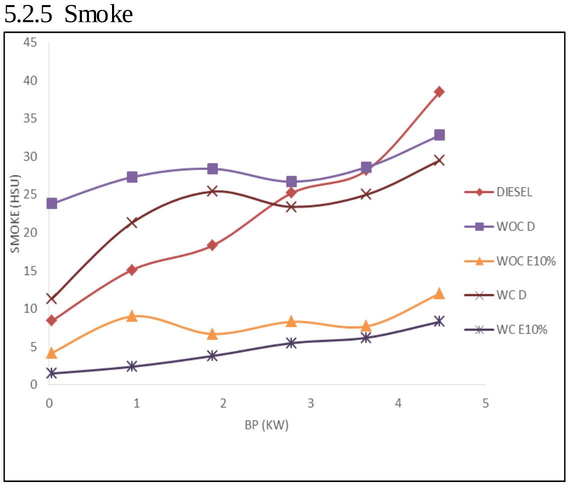

Figure 7. BP vs Smoke

The smoke is produced mainly in the diffusive combustion phase, the addition of oxygenated fuel leads to an improvement in diffusive combustion. On the other hand enhancing the oxygen content in the charge, can overcome poor mixing of the fuel with air, which is responsible for smoke formation in diesel engines. So the Oxides of the material TiO_2/Al_2O_3 can reduce smoke at full load condition also influence of oxygen content of ethanol and DEE opacity of smoke can reduce 77.9% without coating and 81.7% of with coating.

6. CONCLUSION

The following conclusions may be drawn from the experimental study.

- TiO_2 /Al_2O_3 catalyst uncoated ceramic substrate reduce CO emission 23.46% and reduces CO up to 52.8% with coating using Ethanol blend with DEE.
- When using catalytic converter the UBHC reduced due to reduction process of TiO_2/$Al2O_3$ catalyst material. By using of ethanol blend 10% with the additive DEE 1% the conversion efficiency of catalytic converter increase without coating 19% and with coating 39%. By the catalytic converter the amount of CO_2 reduce 35% without coating and 40% with coating of catalytic converter.
- The complete combustion process takes place inside the combustion chamber amount of CO_2 exhaustion by the diesel engine is normally high. But using catalytic converter using with ethanol blend in addition of DEE reduce. By the catalytic converter the amount of CO_2 reduce 35% without coating and 40% with coating of catalytic converter.
- The catalyst material TiO_2/Al_2O_3 which Significantly reduce 12% in without coating and with coating 15% of NOx reduce at 75% of load condition.
- The Oxides of the material TiO_2/Al_2O_3 can reduce smoke at full load condition also influence of oxygen content of ethanol and DEE opacity of smoke can reduce 77.9% without coating and 81.7% of with coating of metal coating.

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