Influence of Nano Magnetic Fluid Coated Conventional Catalytic Converter Over Automotive Emission

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***Abstract*—As the emission from vehicles has become a hazardous problem of the whole world since it contributes a major role in air pollution. Various technical researches are in process to control the rate of emission from the automotive engines. The methods used to control the emissions are 1. Fuel modification, 2. Engine geometry modification and 3. After treatment. This paper defines about the after treatment of exhaust gases by the modification and experimental test on the nano magnetic fluid coated conventional catalytic converter on single cylinder DI diesel engine. Here the comparison of the catalytic converter coated with nano magnetic fluid (Fe_3O_4) is shown the quite more efficiency. The main object of using magnetic fluid is to increase the performance of catalytic converters at an economical price. Nano magnetic fluid coating decreases the CO emission up to 1.5% and HC emission was reduced up to 20ppm over conventional catalytic converter.**

Keywords*— Ferrous oxide, Catalytic converter , Wash-coat, Nano magnetic fluid

I. INTRODUCTION

In order to reduce the automotive pollution our modern vehicles are equipped with catalytic converter that reduces the emission of harmful gases. The emissions from the diesel engine are harmful to the surrounding as CO decreases the ability of blood to carry oxygen while mixing with hemoglobin and results asphyxia [1]. NOx irritates airways especially to the lungs and led to acid rain and lung diseases. Catalyst used in catalytic converter is simply increasing the rate of the reaction without itself changing the process [2]. With catalyst the rate of reactions becomes faster with less energy of activation, at the same temperature and at the same concentration as compared to non-catalyzed reaction. The most effective after treatment process for reducing engine emission is catalytic converter found in automobiles [3, 4]. Three-way catalytic converters are mostly preferred, because it is advancing in technical aspects and for controlling of emission it is regarded as an oxygen storage device. At catalytic converter, both oxidation and reduction process takes place where oxidation of HC & CO and reduction of the NOx [5]. This catalytic converter can tolerate temperature about 1000ºC. Optimum pollutant emission is achieved at the stoichiometry with variation of air fuel ratio. When A/F ratio is 1+0.1 or 1-0.1 then it gives efficiency more than 90%.

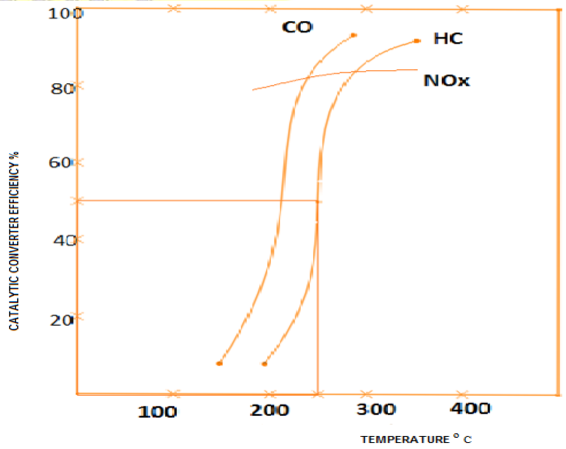

Fig. 1. Temperature against catalytic converter efficiency.

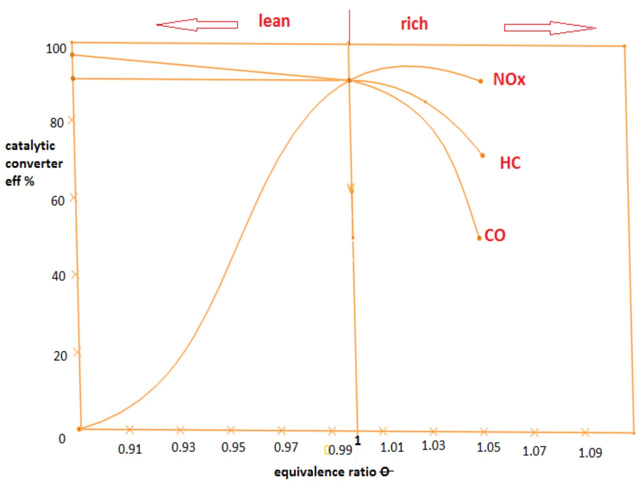

Fig. 2. Equivalence ratio against catalytic converter efficiency.

Before the conversion of harmful gases it requires elements 1. Lambda sensor (oxygen sensor) as it helps in correct operation of the catalyst by knowing the amount of oxygen present at the exhaust. It detects the mixture is too weak or strong. It provides a voltage pulse when there is no oxygen in the exhaust gas and by this only can able to reach the A/F ratio stoichiometric point. 2. Microprocessor to control the oxygen sensor signal for controlling the amount of fuel to be injected so that exhaust gas should be close to stoichiometric point. 3. EFI (electronic fuel mixture) as it delivers the air/fuel in stoichiometric ratio. In a three way catalytic converter it is used to control system to provide feedback signal of composition gas. It is used for controlling to maintain the air fuel ratio. Most of three way catalytic converter having ceramic monolith honeycomb structure [6]. Honeycomb structure provides a larger surface area and less pressure drop for gases flowing through them.

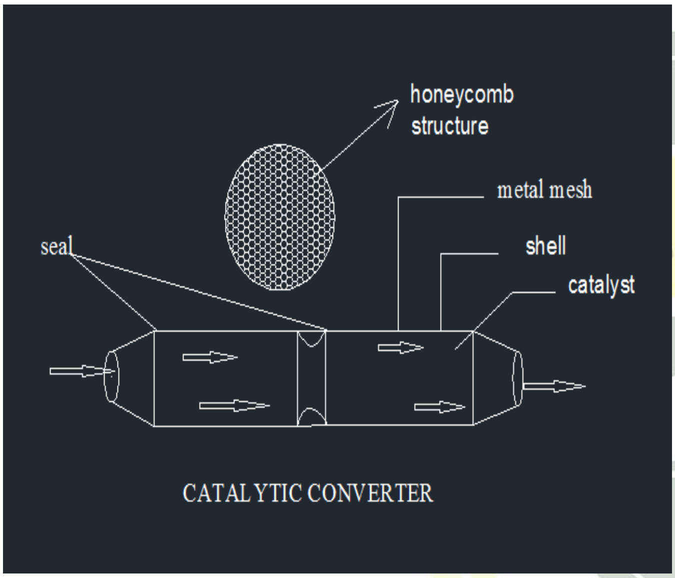

Fig. 3. Catalytic converter component and honeycomb structure.

Fig. 4. Photographic view of nanoparticles coated catalytic converter.

Catalyst generally increases the rate of reaction by decreasing the activation energy so far as compared to the uncatalyzed reaction. The performance phenomenon totally depends on the types of catalyst used in the catalytic converter because it increases the reaction rate without change in concentration [7-9]. So mostly noble metal and metal oxide are carried out for the catalytic conversion in the catalytic converter. Ceramics are prepared at high temperature in oven known as a kiln. But we are mostly using the monolith because it possess large surface area and high flow rates and less pressure drops as compared to ceramics. The monolith is made of synthetic cordierite ($2MgO*2Al_2O_{3.}5SiO_2$) which having low expansion on heating and consist of a parallel channel. Coating of nanoparticles on the catalytic converter is done by using a wash coat method. This wash coat of nano metal oxide particles is used to increase the surface area, improve the catalytic oxidation and reduction of polluted gases. Nano magnetic fluid coating at the catalytic converter exhibit high thermal and physical properties.

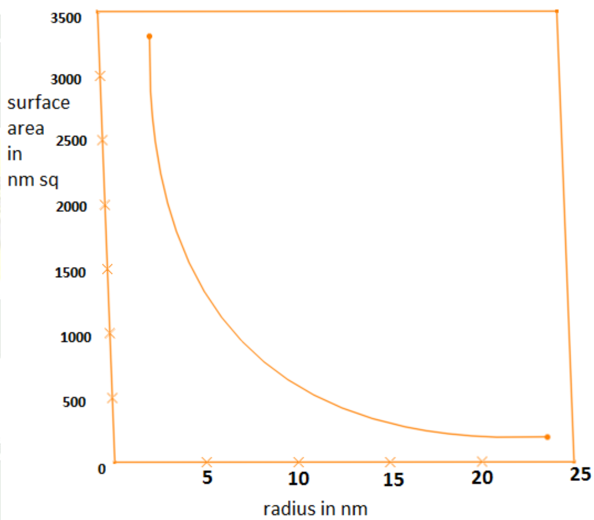

Fig. 5. shows surface area is inversely proportional to radius.

The ratio of surface area to volume is inversely proportional to the radius of the particle. So as the radius decrease, the ratio of surface area to volume increases then it led to more surface area so more catalytic process takes place. The main reason of using this type of coating is to increase exhaust surface area and reduce the amount of catalyst required. The iron oxide nanoparticles is selected because it is cheaper in cost as compared to platinum and palladium. Nano magnetic fluid is potentially used in the catalytic converter with different proportions (0.5 and 1g).

II. PROPERTIES OF NANO MAGNETIC FLUID PARTICLES (FE-SEM)

The electron gun in field emission microscope works under the high energy microscope by high energy electric field to emit electron from the filament. A stronger electron beam focused on the smaller spot size, allowing greater resolution. The main advantage of an electron microscope is greater depth of field and high resolution and very small wavelength electron beam allows for high resolution. Additionally, it gives chemical information about the sample simultaneously can be acquired. While scanning under the electron microscope gives details about the nano particle shape and structure. FE-SEM (Field emission scanning electron microscopy) method is used for investigating the nano particle. The picture of nano magnetic fluid particle is shown by the FE-SEM has obtained from all the energy ablated laser energy having a spherical shape with a particle size of less than 100 nm. It is observed that the particle size of nano particle is increasing with the laser energy. The picture is shown below for the nano magnetic fluid particle that is observed under the FE-SEM. Nano particle scanned under electron microscopy where its structure and morphological structure are obtained. Now it is confirmed that nano magnetic fluid is spherical in shape. The size of the diameter obtained varies from 38-54 nm.

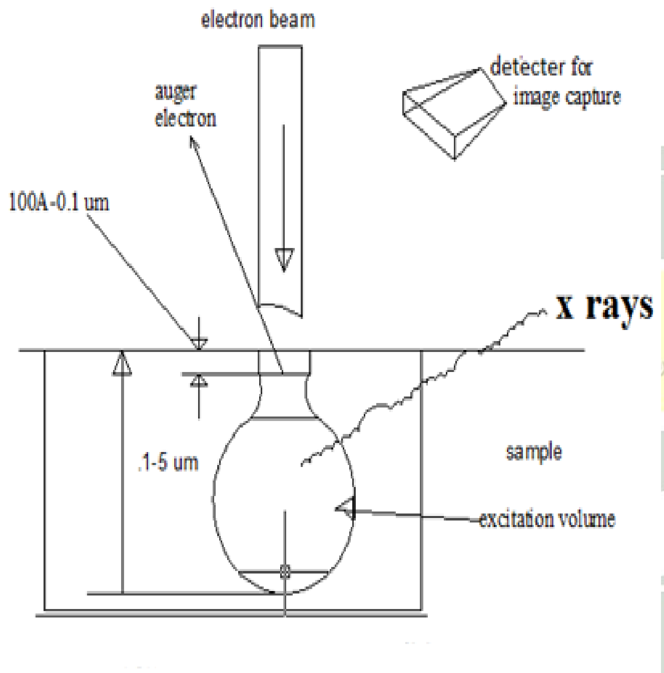

Fig. 6. FE-SEM

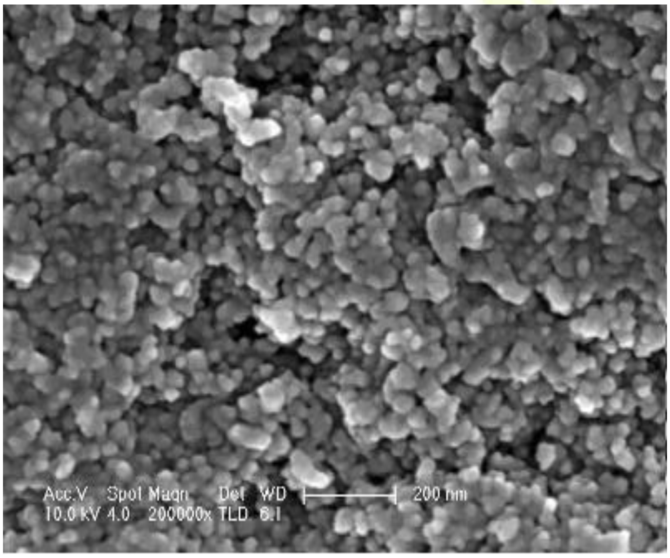

Fig. 7. SEM image of nano magnetic particles M

III. NANOPARTICLES COATING PROCESS

Sodium silicate solution is used in the wash coat material to increasing the strength of nano particle [10]. To get 10% of the nano magnetic fluid slurry, 10g of nano magnetic particle added to the 90g of sodium silicate. In homogenizer, slurry is mixed for two hours. Coating of the nano magnetic fluid particle did under dip coating (wash coat) process. Then it is kept under three hours at 120ºC in oven. The nano magnetic fluid particle is chosen because of the high thermal stability and durability. The full process summary nano particle coating at catalytic converter is given at below figure.

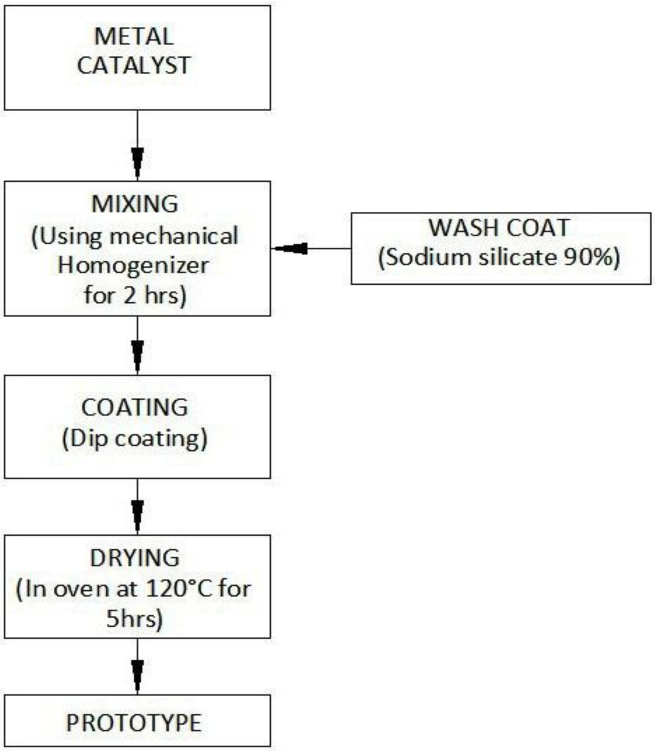

Fig. 8. Process of coating

IV. CHEMICAL REACTION AT CATALYTIC CONVERTER

HC, CO_2 and NO_X are the emissions that are released from the engine exhaust. In the catalytic converter two types of reaction takes place are catalytic oxidation and catalytic reduction. At reduction, the reduction of NOx takes place where it reduces to form pure nitrogen and oxygen. At the oxidation, the free oxygen reacts with the HC, NOx and after oxidation it convert into the H_2O and CO_2 [11, 12]. Because of the presence of the oxygen buffer in nanoparticles led to the oxidation and reduction reaction. Detail of catalytic reactions is shown below.

Reduction of nitrogen to elemental nitrogen and oxygen.

$$NO_x \rightarrow N_x + O_x$$

Oxidation of carbon mono oxide to carbon dioxide and hydrocarbon to carbon dioxide and water.

$$CO + O_2 \rightarrow CO_2$$

$$C_xH_{4x} + {}_{2x}O_2 \rightarrow {}_xCO_2 + {}_{2x}H_2$$

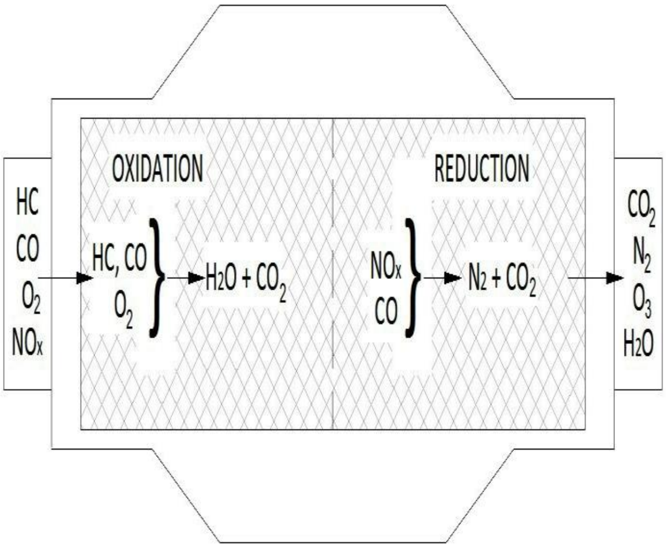

Fig. 9. Oxidation and reduction at catalytic converter

V. EXPERIMENTAL PROCEDURE AND ENGINE SETUP

The experiment is conducted in the on KIRLOSKAR TVL. The engine power generation is about 5.2 KW where it runs at the 1500 rpm and its pressure required during injection is 220 bar. The air flow rate is obtained by volumetric basis. Here to analyze the gas AVL five gas analyzer and smoke density is observed at the smoke meter. Stop watch and burette is used to measure fuel consumption for a specified time interval. The experimental setup, its specifications and few components are discussed below.

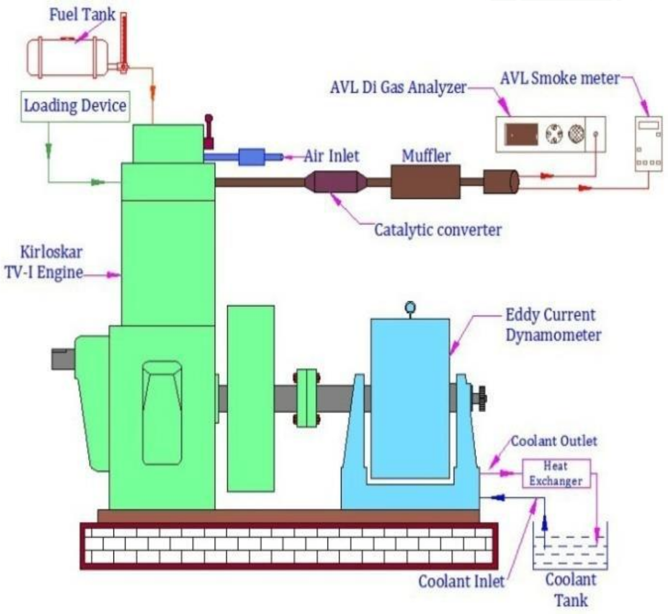

Fig. 10. Systematic diagram of experimental Setup

Fig. 11. Photographic view of experimental setup

VI. RESULT AND DISCUSSION

Conventional catalytic converter and 0.5gm, 1gm of nano magnetic fluid coated catalytic converter tested under full load of the engine. In the present section, based on the emission data, HC, CO, smoke and NOx are plotted against brake power. The magnetic fluid nanoparticles effectively reduce CO, HC and NOx emissions.

A. *Hydrocarbon emission*

HC mainly cause due to incomplete combustion because of lean mixture, presence of lubricating oil in fuel or combustion chamber wall, improper ignition timing, defective ignition component, defective catalytic converter, defective air injection component and low cylinder compression. From the graph, it is shown that how emission rates decreasing by using catalytic converter and it reduces further when it is coated with the magnetic fluid. At diesel fueled catalytic converter it gives emission 128 ppm, when using the conventional catalytic converter it reduced up to 28 ppm and when it is coated with nano magnetic fluid of 0.5gm and 1gm, it reduced to 20 and 12 ppm.

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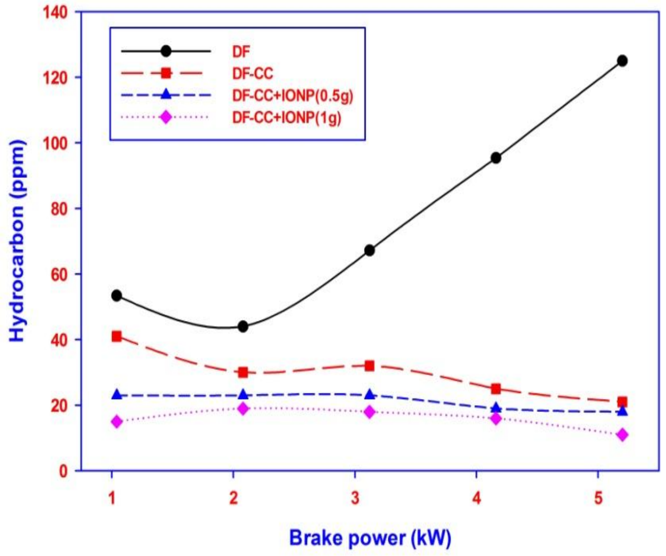

Fig. 12. Brake power against Hydrocarbon emission.

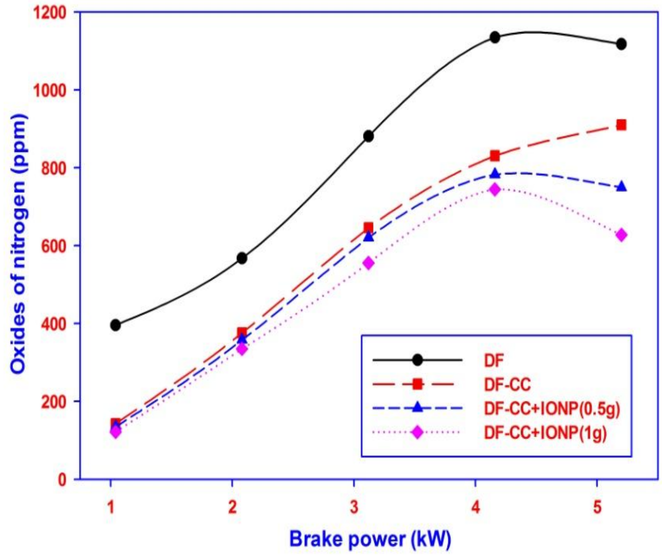

Fig. 14. Brake power against Oxides of nitrogen emission.

B. Carbon monoxide

Emission of CO is caused due to rich mixture, dry air filter that restrict air flow, fault in oxygen sensor, engine coolant temperature and defective catalytic converter too. In this work, nano magnetic fluid coated catalytic converter is compared with the conventional catalytic converter. The CO emission was reduced about 97%, 98% and 98.5% for conventional, 0.5g and 1g nano magnetic fluid coated catalytic converter respectively.

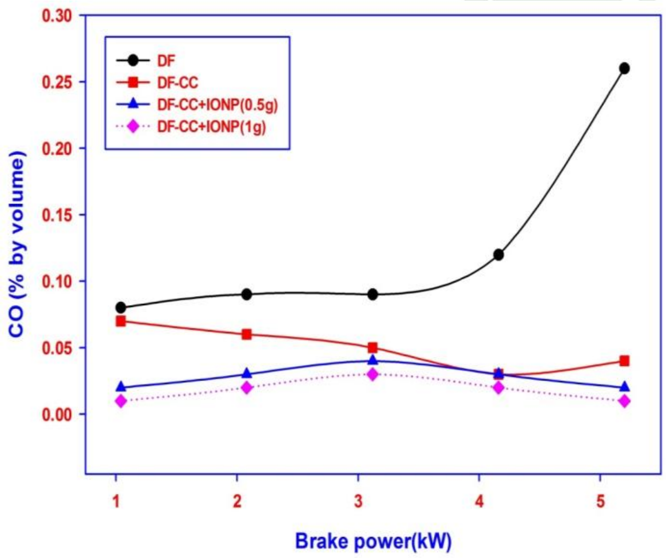

Fig. 13. Brake power against CO emission.

C. Nitrogen oxide

NO_x are emitted due to engine overheating and defective catalytic converter. At diesel fueled, the NO_X is about 1120 ppm and while using the conventional catalytic converter it reduces up to 910 ppm. When the nano magnetic fluid coating is applied of 0.5 gm then emission reduced up to 740 ppm and on further increasing the quantity it reduce up to 600 ppm.

D. Smoke capacity

The smoke emitted from diesel engines, indicates poor and incomplete combustion of the diesel fuel. There are causes: incorrect timing, over fueling, incorrect valve clearance, incorrect air / fuel ratio, low cylinder compression and cool operating temperatures. From the experiment, the smoke density for diesel engine is about 78 HSU whereas in case of the conventional catalytic converter has a smoke density about 22 HSU, which much lower than the engine without catalytic converter. The smoke density of the catalytic converter with nano magnetic fluid coating of 0.5g and 1g is about 21 HSU and 20 HSU respectively.

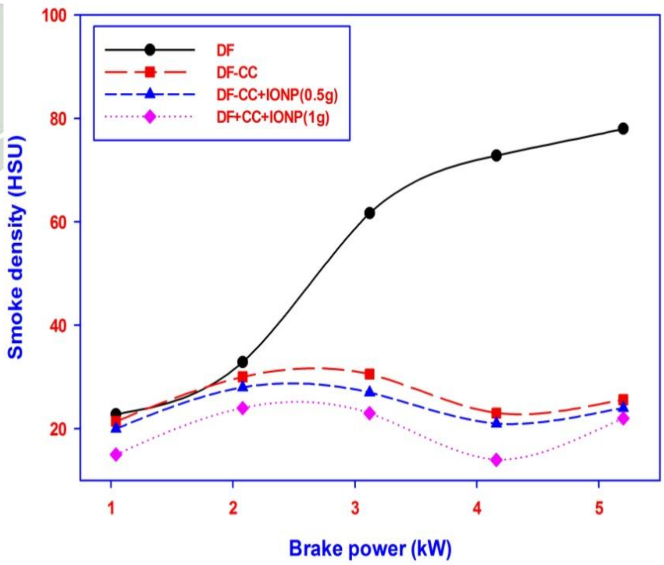

Fig. 15. Brake power against Smoke density.

CONCLUSION

This paper's aim is to investigate the diesel engine emissions by using a nano magnetic fluid coated conventional catalytic converter and by experimental aspect various conclusions are drawn. In this paper, also discuss about how the nano magnetic fluid coated catalytic converter is better than conventional catalytic converter at both aspect 1. Cheaper in cost 2. The emission control rate is far better.

- HC emission is reduced from 20ppm to 12ppm when coated with the nano magnetic fluid
- CO emission reduced by the conventional catalytic converter is 97% and it further increased to 98% and 98.5% for 0.5 and 1g of nano magnetic particles coated respectively.
- NOX emission was 910 ppm, when using the conventional catalytic converter and it reduces to 740ppm and 600ppm for the nano magnetic fluid coated with 0.5g and 1g respectively.
- Smoke density of diesel engine without catalytic converter is 78 HSU and at the conventional catalytic converter is 22HSU. When it is coated with the 0.5 and 1 g of nano magnetic particles, it reduces smoke density around 21HSU and 12HSU.

Finally, when catalytic converter is coated with nano magnetic fluid, it gives more efficiency to reduce the emissions in diesel fuel engine.

References

[1] C. Syed Aalam, C.G. Saravanan, M. Kannan, Experimental investigations on a CRDI system assisted diesel engine fuelled with aluminium oxide nanoparticles blended biodiesel, Alexandria Engineering Journal (2015) 54, 351–358.

[2] G. Marland and R. M. Rotty, Carbon Dioxide Emissions From Fossil Fuels: A Procedure For Estimation And Results For 1951-1981, DOE/NBB-0036 TR-003, Carbon Dioxide Research Division, Office of Energy Research, U. S. Department of Energy, Oak Ridge, TN, 1983.

[3] Merget R, Rosner G 2001 Evaluation of the health risk of platinum group metals emitted from automotive catalytic converters. The Science of Total Environment 270, 2001, pp 165–173.

[4] Jan Kaspar, Paolo Fornasiero, Neal Hickey, Automotive catalytic converters: Current status and some perspective, catalysis today 77, 2003, pp 419-449.

[5] C. Syed Aalam, C.G. Saravanan, B. Prem Anand, "Influence of Iron (II, III) Oxide Nanoparticles Fuel Additive on Exhaust Emissions and Combustion Characteristics of CRDI System Assisted Diesel Engine" International Journal of Advanced Engineering Research and Science, Vol-2, Issue-3, March- 2015.

[6] Heck RM, Gulati S, Farrauto RJ. The application of monoliths for gas phase catalytic reactions. Chem Eng J 2001;82:149-56.

[7] Nijhuis TA, Beers AEW, Vergunst T, Hoek I, Kapteijn F, Moulijn JA. Preparation of monolithic catalysts. Catal Rev 2001;43 (4): 345-80.

[8] Dubien, C. Schweich, D. Mabilon, G. Martin, B. Prigent, M. 1998. Three-way catalytic converter modelling: fast- and slow oxidizing hydrocarbons, inhibiting species, and steam-reforming reaction, Chemical Engineering Science 53 (3): 471–481.

[9] Kruse A. Frennet J.M. Bastin (Eds.), Catalysis and Automotive Pollution Control, vol. IV, Elsevier, Amsterdam, 1998, pp. 507-511.

[10] Jia, L. Shen, M. Wang, J.; Wang, J. Chu, X.; Gu, W. Durability of three-way and close-coupled catalysts for Euro IV regulation, Journal of Rare Earths 26 (6), 2008, pp 827–830.

[11] Balenovic, M.; Edwards, J.; Backx, T. Vehicle application of model-based catalyst control, Control Engineering Practice 14 (3), 2006, pp 223–233.

[12] Poulopoulos S G and Philippopoulos C J, MTBE, Methane, ethylene and regulated exhaust emissions from vehicles with deactivated catalytic converters. Atmospheric Environment 38, 2006, pp 4495–4500.