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Magnetization of Diesel fuel for Compression Ignition Engine to Enhance Efficiency and Emissions

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Abstract

Due to two major factors, finite oil reserves and stringent emission norms vehicle manufacturer got a huge challenge to research, develop and produce ever cleaner and more fuel-efficient vehicles The last few years have seen a drastic change in emission levels and improvement in exhaust gas treatment techniques. In the following content, there is a comprehensive study based upon the changes in quality of performance of an engine while using magnetized fuel. Among many technologies in use to reduce the emission and subsequently improve the overall performance of the engine, magnetization of fuel (MOF) remains one of the most underdeveloped technologies of all. Magnetization of fuel is linked with altering the stereochemistry of fuel to instill proper combustion of fuel. Under the effect of strong magnetism fuel particles tend to react more with the incoming oxygen which leads to complete burning of fuel. The experiment was conducted on a single cylinder 4-stroke diesel engine under constant speed for variable loads. Fuel was passed through a pipe apparatus that increased the ratio of volume of fuel to number of magnets. Permanent Neodymium magnet grade 52 (N52) were chosen because of their excellent remanence, coercivity and temperature withstanding properties. It has observed an increase of 5% in brake thermal efficiency with 15%-20% reduction in brake specific fuel consumption. The emissions are subsequently reduced with significant reduction of 12% in CO, and 27%-30% in unburnt hydrocarbon (UHC), although nitrogen oxide (NO_x) is found to increase about 20%.

Keywords: magnetic fuel conditioning, emissions, neodymium

INTRODUCTION

Transportation played a vital role in daily life in this modern world. Still, fuel used by most of the vehicles is liquid and fuel has a lot of problems with it. Hydrocarbon liquid fuel leaves deposits of carbon residue that results in a decrement of efficiency by clogging the carburetor, fuel injectors and fuel pipe [1],[2]. Fuel gets atomized when injecting into the combustion chamber and proper combustion does not take place until fuel gets vaporized and blend with air completely. Due to these reasons, emissions of the vehicles have carbon monoxides, unburned hydrocarbons and nitrogen oxides in it. These harmful gases create serious health hazards to the biotic community like breathing and skin diseases and result in smog when released and mix with air. The researchers have a prime focus on re-designing engine and its part for better efficiency and tackling the problem of pollution. There are certain properties of fuels they are ignoring that can help too and one of them is magnetization. Generally, the molecular fuel of internal combustion engine compound of electron and neutron revolve around a stable nucleus. Due to that these molecules already have a magnetic moment and possess positive and negative over them. However, misalignment of these molecules doesn't allow them to actively interlock with oxygen during combustion. This alignment can only be achieved when fuel gets passed through the desired magnetic field [3],[4].

In the influence of magnetic fields of high intensity, hydrocarbons decluster, and these smaller particles possess more surface area, to react with oxygen [5]. There were many experiments occurred which presents the strong evidence of the advantage of magnetization of fuel. As per Van der Wall's observations on weak molecular forces, proper burning of fuel in the combustion chamber is only accomplished when oxygen is strongly bonded to hydrogen. Better combustion shows a reduction in fuel consumption and increases in engine's power output [6],[7]. Hydrocarbons are stable pseudo compound and these highly dense clusters have a hindrance to oxygen. After magnetizing the fuel, the oxygen particles easily penetrate into smaller fuel particles, resulting in improved combustion compared to neat diesel [8].

Hydrocarbon fuels can easily be polarised when a strong external force such as magnetism is applied to it. One benefit of polarity is that it develops dipoles of the magnet which manipulate under large magnetic fields. This results in higher efficiency of fuel as well as a reduction in slime[9]. The observations of Becker, a chemical consultant in oil field suggested that Protoporphyrin (constitute many substances, including oil and blood) respond to the magnetic field and inhibit aggregation of the molecules due to its cage-like structure. This hindrance to oxygen again leads to improper combustion [10]. During the process of magnetization, the outermost electron present in a hydrocarbon structure displaces to a higher energy state. This displacement decreases the number of valence electrons which are responsible for bond formation in fuel compounds. This achieves the state of free association, and a perfectly aligned and directional arrangement of hydrocarbon fuel is observed. This arrangement of hydrogen particles reacts more rapidly to oxygen molecules, giving better combustion and lesser pollutants [11],[12]. According to Ruskin, a molecule's behavior is affected significantly by magnetization i.e due to parallel spin moments it is seen that an ortho-hydrogen responds more quickly towards oxygen molecules. Hydrogen molecules contain a proton and electron which possesses dipole moments. It has two distinct isomeric shape, para, and ortho which relies on the relative introduction of the nucleus spin. In ortho, spin state of the atom is in the opposite direction, while it is same in the case of para. In the typical frame, {at Standard Temperature and Pressure (S.T.P)} hydrogen have a constituency of 25% para and 75% ortho form. There is a variation in equivalence ratio of these ortho & para forms under different temperature conditions. The ortho form, however, possesses more reactiveness towards oxygen molecules due to high instability and parallel spin moments. Researchers have observed the increase in reactivity as well as in total energy of atom upon conversion from para hydrogen to ortho-hydrogen [13]. When a diamagnetic substance (fuel, in this case) comes in the vicinity of magnetic field, it is said to ungroup as a result of forces induced in it. This occurs because of diamagnetic materials having a property to separate the magnetic field in its vicinity, while paramagnetic materials merge them. While this declustering happens, there is a change, i.e., para to ortho form. In the effect of the magnetic field applied, the energy of carbon-carbon and carbon-hydrogen bonds decreases and scatters into refining particles. This expands the linking of these particles to others and also facilitates the access of carbon (methane centered) to the vicinity of exceedingly paramagnetic oxygen [13].In our work, we focused on designing eco-friendly apparatus to magnetized the fuel. Apparatus were designed through different numerical methods discussed below and the flow of fuel through it was analyzed in ANSYS. The fabricated apparatus have thus been experimented on a single cylinder four-stroke compression ignition (C.I) engine. Measurements of fuel flow were performed using an automatic flow control device. Airflow was measured with orifice flow meter. Chrome-alum thermocouples measured engine and exhaust temperatures. The cylinder pressure was measured using a piezoelectric pressure transducer flush mounted in the cylinder head of the engine. The infrared gas analyzer measured exhaust emissions, and all this data were displayed on a computer screen connected to data acquisition using the internal combustion (I.C) enginesoft software. The apparatus is easy to handle and increased the efficiency of the engine as well reduced the emission by a significant amount.

MATERIALS AND METHODS

Material Used

There are a lot of powerful Permanent magnets which are made of special alloys such as ferrites, samarium-cobalt's, alnico (aluminum-nickel-cobalt), ceramics, and neodymium-iron-boron. The permanent magnet chosen for the present investigation is neodymium-iron-boron (NdFeB N52) because these are the strongest type of magnet available commercially with remanence of 1-1.3 T, much higher coercivity (0.875-1.99 MA/m) and an energy product of 200-400 kJ/m^3. The strength of magnets makes the selection of magnets, and these have the characteristic of less variation of magnetic flux with temperature because the system is positioned very close to the burner. To fulfill the requirement of an excellent formability as well as weldability we chose 3003 aluminum alloys. Aluminum is non-magnetic and non-reactive metal with fuel and it is also cost-efficient with respect to stainless steel and iron and provides an option for flexibility in the design. Hence the fixture along with the fuel channel is designed by using it [14], [15].

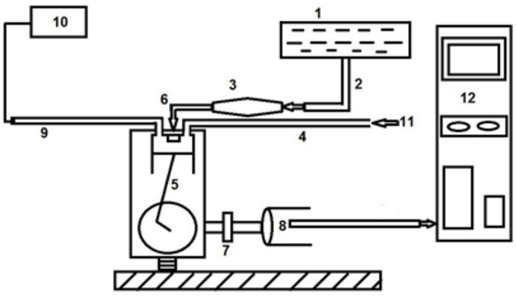
METHODOLOGY

Single cylinder Kirloskar four stroke diesel engine, a naturally aspirated water-cooled engine with a bore of 87.5mm and stroke of 110mm was used for performance and emissions testing. Complete specifications of the engine are given in Table 1.

Table 1. Engine Specifications

Engine	Kirloskar, single cylinder, four-stroke diesel, water Cooled
Bore	87.5 mm
Stroke	110 mm
Power	3.5 kW @ 1500 rpm
Piezo powering unit	Make-cuadra, model AX-409.
Temperature sensor	Type RTD, PT100, and thermocouple, type K
Temperature transmitter	Type two wire, Input RTD PT100, range 0–100 Deg C, output 4–20 mA and type two wire, input thermocouple
Load indicator	Digital, range 0-50 Kg, supply 230VAC
Load sensor	Load cell, strain gauge type, range 0-50 Kg
Fuel flow transmitter	DP transmitter, range 0-500 mm WC
Air flow transmitter	Pressure transmitter, range (-) 250 mm WC

An eddy current water-cooled dynamometer was coupled with the engine output shaft for generating load variations. In-cylinder pressure measurements were done by piezoelectric pressure transducer mounted on the head of the piston and charge encoder for every computer-aided design (C.A.D). National Instruments (N.I) Lab View software acquired the in-cylinder pressure data as a direct function of crank angle and assessed heat release rate and Indicated mean effective pressure (IMEP). Analog data from Resistance temperature detector (RTD) thermocouple was read by NI-USB Data acquisition. The fuel flow was measured using glass burette and the required air flow was measured using orifice air flow meter. The viscosity of diesel was calculated by shear stress Rheometer by fixing the shear rate. Shear stress values were displayed by RHEOPLUS/V3 software. The exhaust gas was analyzed using AVL DIGAS-444 infrared gas analyzer and AVL 437 c smoke meter. The exhaust gases were fed to the gas analyzer directly from the exhaust pipe. The schematic diagram of the experimental set-up is shown in Figure 1.



1)Primary fuel tank 2) Fuel line 3) Magnetic Fuel Conditioner 4) Atmospheric air inlet pipe 5) Engine 6) inlet valve 7) *coupling* 8) Eddy current dynamometer 9) Exhaust pipe 10) Exhaust gas analyzer 11) Air inlet 12) Data acquisition system

Figure 1. Experimental Setup

The experiment was carried out at a constant engine speed of 1500rpm with an injection pressure of 180. Initial load condition starts with no load and an increment of 2kg with a maximum load of 8kg. The magnetic fuel apparatus was installed between the fuel line and inlet valve. The fuel passed through the designed fuel line oriented 90° with the magnet assembly. The procedure was repeated for various loads and performance graphs of fuel consumption, brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) were obtained for neat and magnetized diesel. Meanwhile, pressure transducers gave the reading of IMEP with a change in crank angle which was displayed and plotted on LabVIEW. The exhaust gases were passed from constant volume calorimeter with temperature transducers and change in temperature of the process fluid was noted. Exhaust gas samples of neat diesel and magnetized diesel were then passed through a gas analyzer and the values of Nitrogen Dioxide (NO_X), Carbon Monoxide (CO), Unburnt hydrocarbon (UHC) were studied.

DESIGN AND ANALYSIS

According to different researchers and theories, the placement of magnets be it lateral or radial with an angle compensation of 120 to 180 degree from the horizontal section of pipe produces a continuous magnetic field. Only a part of this magnetic field connects with the fuel mass, so to maintain a circular flow in the range of the magnetic device, electrical assistance is required [16]. Considering this situation, the magnets in the system should be placed in such a way that they form a positive sequence. Also, they must be able to control the increment of magnetic strength that is applied to the fuel. This variation of magnetic field with respect to location is known as magnetic field gradient. Aligning magnets in this way catalyzes the process of changing of the stereochemistry of the fuel particles [17].As

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an effect, there will appear air gap that leads to the growth of the particular magnetic moment, and ionization of passing fuel molecules. Due to all these applied changes, the affinity of fuel's molecule against the other proximity molecules (like oxygen in the air) is increased so abruptly which ensures the fuel's burning process efficiently. As the oxygen is Para magnetically strong this makes it reactive with the hydrocarbon after being treated in a magnetic field. Due to this a comprehensive combustion of the magnetized fuel took place with a notable reduction of the fumes from the exhaust and improved power outcome. As the laminar flow is desired in the apparatus we have come up with a smart solution by modifying the circular shape of the fuel line to elliptical. Later on, this design is verified by ANSYS simulation. It maximizes the magnetized fuel discharge and approximately maintains a laminar flow. Having the described shape also provided a connectedness and continuity to the build. At the molecular level, it guarantees an ideal magnetic treatment of the flow due to the substantial breaking of intermolecular interfaces and polar chains. This geometry was also found beneficial for the previous idea by ensuring the air gap in between the two magnets. A CAD model of the design is shown in Figure 2 with an isometric view of the alignment of pipe with the magnets described in Figure 3.

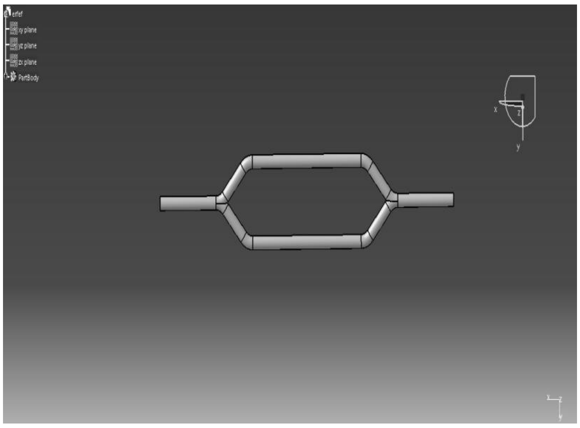

Figure 2 CAD model of pipe design

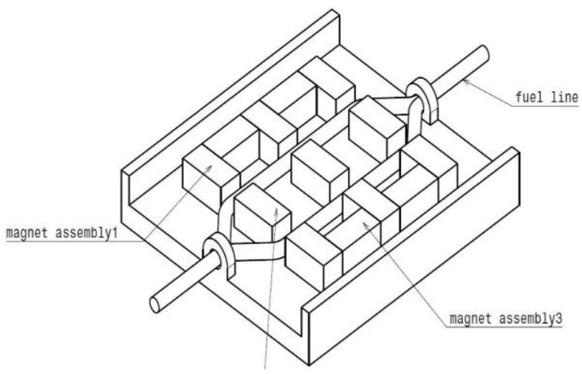

Figure 3 Isometric view of the design

The CAD model was used further for analysis on ANSYS Fluent software. The software has various modules for industrial applications such as flow, turbulence, heat transfer and reactions. After importing geometry from CATIA V5, meshing was kept to 'Fine' level with an extra inflation on the walls. The meshed geometry was then simulated for laminar flow by undergoing 100 iterations. The figure shows the flow of fluid particles during the analysis. After the iterations were studied, the maximum velocity attained by the particles were noted and carried on to propose the characteristic of flow as laminar. Due to the structure of pipe, there are variations in the velocity of flow at various instances as shown in Figure 4.

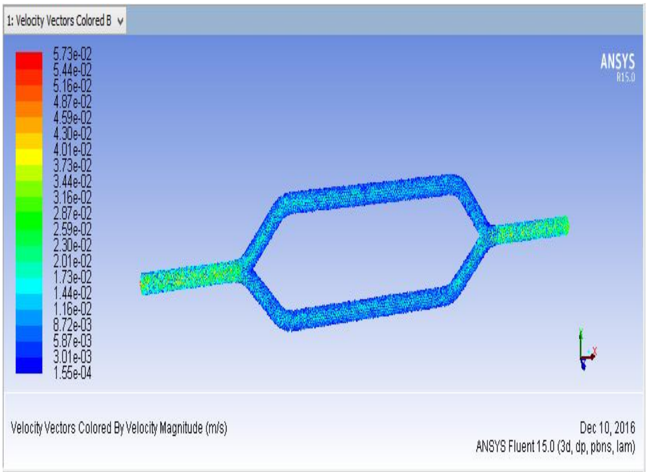

Figure 4 Variation of velocity magnitude

RESULTS AND DISCUSSIONS

The reduction in fuel consumption increases Brake thermal efficiency which is evident from Figure 5. After passing the fuel through magnetic apparatus, there is about 5% increase in brake thermal efficiency.

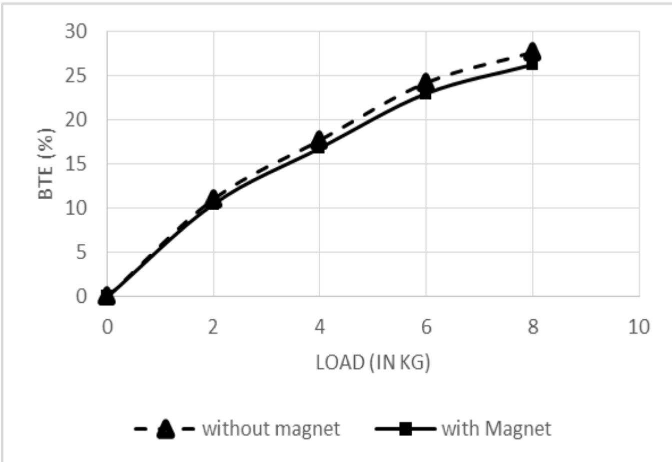

Figure 5. Variation of Brake thermal efficiency with load (with and without MFC)

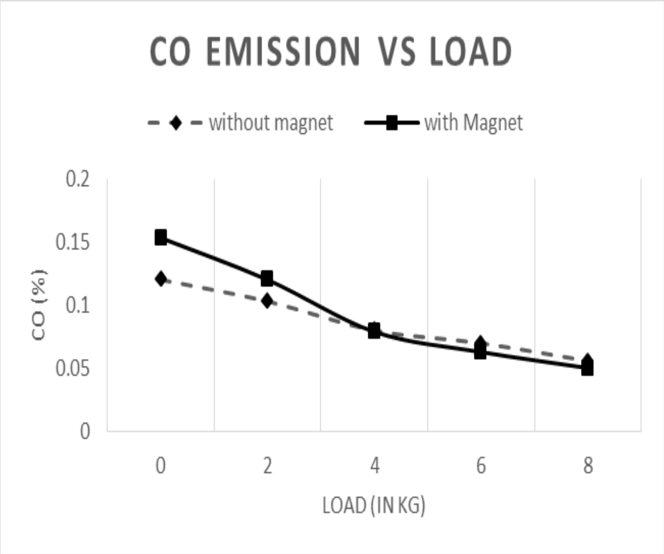

Figure 6. Variation of Carbon Monoxide with load (with and without MFC)

CO emissions are more pronounced at small loads. As load increases, CO emissions decreases. As shown in Figure 6, even at low load conditions there is around 10%-12% reduction in CO using magnetic apparatus.Reduction in fuel consumption is attributed to proper combustion of fuel which is achieved using fuel magnet. As shown in Figure 7 there is about 15%-20% reduction in fuel consumption

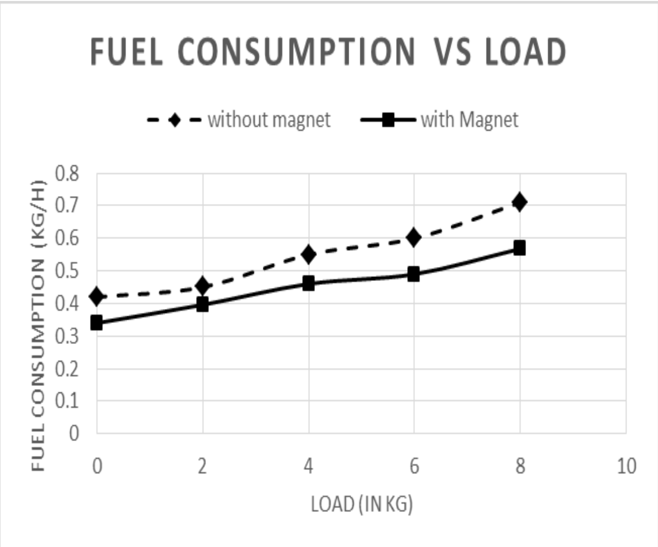

Figure 7 Variation of Fuel consumption with load (with and without MFC)

NO_X is associated with temperature rise in the combustion chamber. Because of proper combustion of fuel, the temperature in the combustion chamber rises in magnetized fuel as shown in Figure 8 and causes around 20% increase in NO_X.

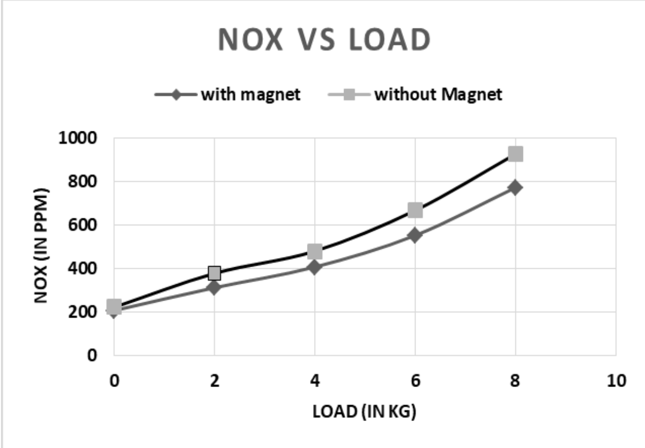

Figure 8 Variation of NOx with load (with and without MFC)

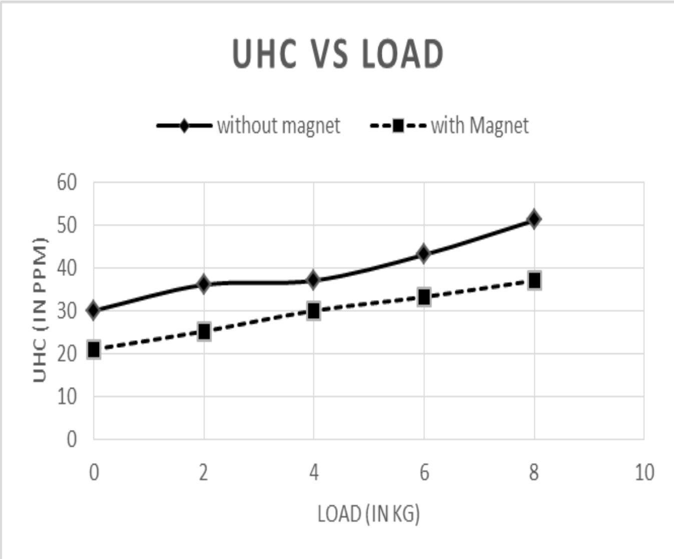

Figure 9 Variation of UHC with load (with and without MFC)

As shown in figure 9, there is around 27%-30% reduction in unburnt hydrocarbon after passing the fuel through magnetic apparatus. This is mostly because of the better reaction of hydrogen with incoming oxygen. Magnetization causes breakdown of hydrocarbon clusters altering the chemical properties of diesel. Owing to smaller particle size where oxygen penetration is more and better atomization the performance of fuel increases drastically. there is 15%-20% reduction in fuel consumption with increasing load due to increasing combustion chamber temperature and faster air movements. Subsequently, an increase in brake thermal efficiency is noted varying between 5%-7%. There is also a decrease in brake specific fuel consumption ranging between 15%-20%. All these observations can be attributed to increasing in evaporation rate and improved oxidation pertaining to a smaller particle size which offers a bigger surface for attraction hence causing more oxidation.

CONCLUSION

Magnetic fuel conditioning gives a pathway to annihilate contaminations like CO_2, CO, before getting discharged into the air and furthermore dispenses with the wax display in fuel before treating. To achieve it fully functioned apparatus was designed successfully using numerical analysis and CATIA. The CFD model of the designed fuel apparatus in ANSYS was able to verify the laminar flow through it which was one of the prime requirement of the apparatus. The apparatus was then connected to the engine in real condition and the experiment did show that there was about 5% increase in Brake Thermal efficiency with about 15%-20% reduction in brake specific fuel consumption. The specific fuel consumption reduced about 20%. There was an overall increase of 20% in NOx with both Unburnt Hydrocarbon and CO decreasing about 30% and 12% respectively. Finally, it can be concluded that there is an overall decrease in emission except for NOx. Fuel consumption and brake specific fuel consumption decreases and brake thermal efficiency increases. The benefits of magnetized fuel are significant since these results show that substitution of the neat diesel fuel with magnetized can be accomplished with little or no detrimental effect. The use of Magnetic Fuel Conditioning apparatus is a financially achievable as it can be installed cheaply and will provide the significant amount of savings. Moreover, it is 100% service free and one-time installation device that will increase the efficiency of the engine as well as saves our mother earth from harmful gases.

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ABBREVIATIONS

C.I	Compression Ignition	R.T.D	Resistance Temperature Detector
I.C	Internal Combustion	B.S.F.C	Brake Specific Fuel Consumption
C.A.D	Computer-Aided Design	B.T.E	Brake Thermal Efficiency
N.I	National Instruments	NO_x	Nitrogen Oxide
S.T.P	Standard Temperature and Pressure	CO	Carbon Monoxide
I.M.E.P	Indicated Mean Effective Pressure	UHC	Unburnt Hydrocarbons

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