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THE INFLUENCE OF ARGEMONE MEXICANA BIO FUEL ADDED WITH TITANIUM DIOXIDE (TiO_2) NANOPARTICLES ON THE OPERATING BEHAVIOR OF DIRECT INJECTION (DI) COMPRESSION IGNITION ENGINE

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Abstract

Biodiesel is essential for future generation, and this renewable energy will meet energy demand, and the use of biodiesel fuel will spread throughout the world to protect the universe from environmental issues. Raw, non-edible oil from Argemone Mexicana is used for biodiesel production. The fuel produced with eighteen percent biodiesel and eighty two percent diesels by volume, named as B18 is used without any single modification in diesel engines. Blended fuel, B18 is added with Titanium dioxide (TiO_2) nano additives. The addition of TiO_2 as additive of 0.05, 0.07, 0.09, 0.11, 0.13 and 0.15 per cent by volume in B18 biodiesel and referred to as B18T5, B18T7, B18T9, B18T11, B18T13 and B18T15.The diesel engine is tested at a standard injection time of 23°bTDC, injection pressure of 210 bar, compression ratio of 18 and constant speed of 1500 rpm. For varying load conditions from the 0 kg to 16 kg, the performance of engine was recorded as per test standards. The major performance parameters such as brake power (BP), brake mean effective pressure (BMEP), brake thermal efficiency (BTHE) and brake specific fuel consumption (BSFC) were analysed and compared with pure diesel, B00 and B18. Test results shows the increment in BP, BMEP and BTHE of blends in comparison with B00 and B18. BSFC decreased as load increases on the engine. Artificial Neural Network (ANN) is used to validate the experimental work and comparative analysis was performed between the experimental results and ANN results. The experimental results show in good agreement to the ANN results with minimum percentage of error.

Keywords: Argemone Mexicana biodiesel, Performance characteristics, TiO_2 nano particles.

1. Introduction

The world's total energy consumption is increasing on a daily basis. Total energy consumption in the world will increase by 48 per cent from 2012 to 2040 [1]. Population expansion and economic growth are key factors for increasing energy consumption. Total energy consumption is boosted by population growth. Alternative fuel provides the ideal solution to the world's emerging fuel crisis. Alternative fuels are produced from renewable sources of energy. Compared to conventional fuels, renewable energy fuels have many advantages, such as reduced greenhouse gas emissions and pollution. Environmental pollution and lack of availability of resources are the two major issues that could arise as a result of increased fuel demand. To address these challenges, researchers are looking for better properties of fuel. Biodiesel is obtained from a variety of other alternative resources, such as waste cooking oils, animal fats, vegetable oils as well as industrial oil waste. Low-cost feedstock was used to decrease the total cost of biodiesel production. Biodiesel has been produced economically during bulk production. Argemone Mexicana oil is one of the low-cost feed stocks for new energy sources and the cost of production will be reduced by using this feedstock. Nanotechnology is a study of nanoparticles from 1 to 100 nm in size. There are many chemical and physical processes available for the preparation of nanoparticles. Additional to biodiesel blends, TiO_2 nanoparticles play a vital role in improving diesel engine performance.

2. Literature Review

Alternative fuel, known as biodiesel, is a substitute for diesel fuel due to a shortage of fossil fuel supplies. To overcome the shortage of fuel, researchers came up with many alternatives, alcohols are one among of those options. Alcohol offers more promising results compared to other alternatives of gasoline engine [2-6]. Many fuels are tested under combustion engine, researchers are focusing on biodiesel due to lack of petroleum fuel, rising fuel prices and increasing pollution. Renewable energy sources such as biomass, solar, wind, etc. are the prominent alternatives to fulfill the need of energy [1].

Biodiesel has extensive benefits such as easy extraction of animal fats and vegetable oils, easy decomposition, no emission of toxic gases, almost zero sulfur content, good oxygen quality of 10 to 11 per cent by weight, higher cetane content compared to diesel and good lubrication properties [7]. Researchers have experimented with the production of biodiesel using different oils. Research and experimentation have produced successful results with biodiesel. Soybean, coconut and waste oil are shown to yield more than 98 per cent after alkaline esterification [8-10]. Non-edible methyl esters based on jatropha, polanga and karanja oil have been developed and mixed with plane diesel with content less than 10 mg/kg of sulfur. Results after the experiment show that the maximum power increase for 50 per cent of the biodiesel and diesel blend is observed. The specific fuel consumption of the brakes for all mixtures varies with speed [11]. After conducting an experiment with different blends of Lincid Oil Methyl Ester, the results show that biodiesel has improved engine performance and emissions. Engine thermal efficiency improved by increased concentrations of biodiesel in blending and reversing patterns and decreased after a certain concentration of biodiesel [12]. Several studies have been carried out to assess the effect of biofuel on the performance of internal combustion engines [13-23].

Many researchers have performed studies on the blending of biodiesel with nanoparticles as additives to address the drawbacks of biodiesel. The addition of Jatropha methyl ester B15 with aqueous cerium oxide nanoparticles has shown an improvement in BTE by 1.7 percent [24]. Due to the shorter ignition delay and increase in the surface area to the volume ratio the characteristics of the nanoparticles, the fuel weight in the combustion chamber may have been collected in order to have a potential catalytic impact on the volume of the filling unit during combustion. [25]. Experimental results with methyl esters of mustard oil as a fuel additive indicate an improvement in thermal brake efficiency by 5.1 per cent [26]. Pongamia Pinnata added with TiO_2 nanoparticles is used as fuel and the percentage of BTE is 2.38 percent higher than Blends BTE value without nanoparticles [27]. Due to many built-in features, TiO_2, ZnO, CNT, Al_2O_3 and CeO_2 are used as additives in diesel engines, the results show that improved thermal efficiency and reduced the specific fuel consumption of the engine [24-38]. Using an aluminum additive of 30 cc to 50 cc in one litre of diesel, the results show a decrease in BSFC compared to clean diesel due to the moisture content of the fuel [39].

3. Experimentation

3.1. Preparation of blended biodiesel with nano additives

The nanoparticles used in the study are titanium oxide. After reducing the size of nanoparticles using mechanical ball milling process those nanoparticles are mixed with Mexicana biodiesel. Using ultra-sonication technique, blended biodiesel is prepared and combined uniformly using this technique. Blended fuels thermo-chemical properties are shown in Table 1.

Table 1. Properties of blended Mexicana oil.

Test Description	Reference		Mexicana and TiO_2 nanoparticle additives biofuel blends					
	Unit	Limit	B18T5	B18T7	B18T9	B18T11	B18T13	B18T15
Calorific Value	MJ/Kg	34-45	42.09	42.00	49.96	41.90	41.88	41.85
Density	gm/cc	0.800-0.900	0.836	0.837	0.839	0.840	0.841	0.842
Viscosity	mm^2/sec	3-6	2.96	2.99	3.02	3.07	3.10	3.13
Flash Point	ºC	-	99	94	91	89	88	85
Fire Point	ºC	-	103	97.5	95	92	90	89

3.2. Diesel engine testing

The prepared fuel and pure diesel fuel are used in diesel engine with single cylinder and 4 stroke engines. A water-cooling system is used to keep the engine cool. The Rocket Engineering Model VRC-1 engine model is used for engine testing and eddy current dynamometer is attached for engine load variation or to maintain the speed of 1500 rpm. The configuration of the diesel engine used for testing is shown in Fig. 1. The test engine is manufactured by VRC-1 Rocket Engineering System and has 80 mm bore dimensions, Stroke 110 mm, Volume Swept 553 mm, Break Horsepower 5 HP, Compression Ratio 18, High-speed diesel fuel oil, Discharge coefficient 0.65, Water flow transmitter from 0 to 10 litres/min, Air Flow Transmitter from 0 to 250 wc, Piezo Sensor from 0 to 5000 psi, low noise cable.

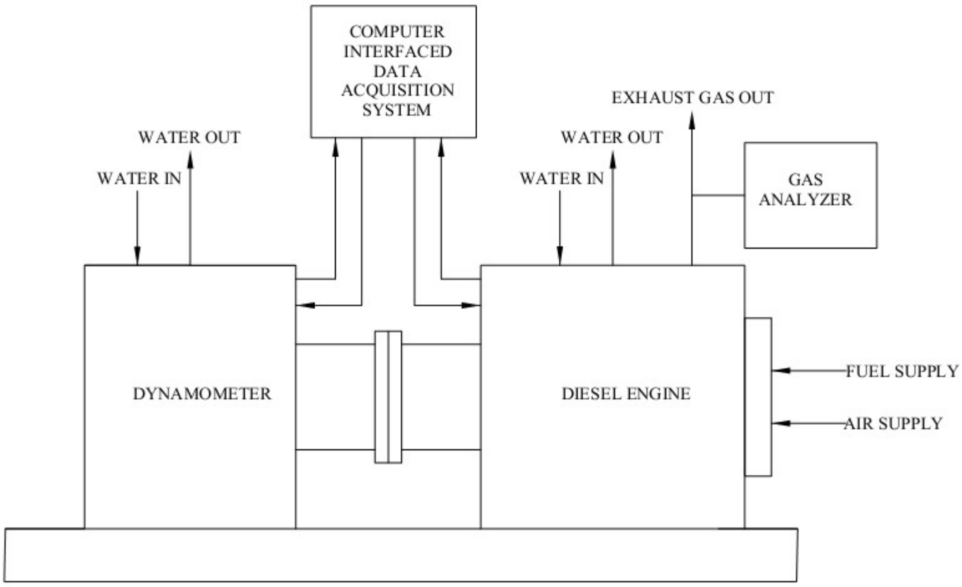

Fig. 1. Schematic diagram of diesel engine set up.

The complete investigation of the diesel engine is carried out in the research laboratory at 32°C of room temperature and 1.01325 bar of atmospheric pressure. Before conducting the experiments, the accuracy of the measuring instruments should be maintained and calibrated and tested within acceptable limits. Each engine test is repeated three times and the uncertainty was reduced on average. After recording the baseline data, tests are carried out using B00, B18, B18T5, B18T7, B18T9, B18T11, B18T13 and B18T15 blends of biodiesel. Engine tests are performed at different loads and performance related parameters are recorded. The sections that followed discussed engine performance parameters such as brake power, brake specific fuel consumption, brake mean effective pressure, and brake thermal efficiency obtained with nano additive biodiesel blends.

Figure 2 shows that the load for all fuels increases the brake power increases. The brake power for B18T5, B18T7, B18T9, B18T11, B18T13 and B18T15 improved their braking energy to 3.96, 4.24, 5.08, 5.45, 5.99 and 5.81 respectively compared to pure diesel. Figure 3 explains the increase in loads for all fuels, the brake means an effective increase in pressure. The mean effective brake pressure for B18T5, B18T7, B18T9, B18T11, B18T13 and B18T15 is 3.49, 3.52, 3.60, 3.64, 3.70 and 3.68, respectively, higher than pure diesel. This may be due to the biodiesel's high viscosity and low volatility, which increases the ignition delay time during the pre-mixed combustion process. The mean effective pressure for all blend is increased by 4 bar at full load, which may be due to better atomization and mixing of fuel air by low viscosity of biodiesel blend, resulting in increased cylinder peak pressure.

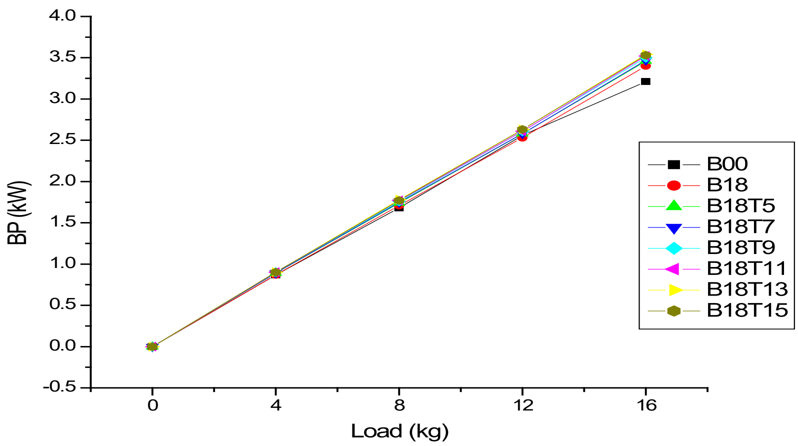

Fig. 2. Brake power of blended fuel at various loads.

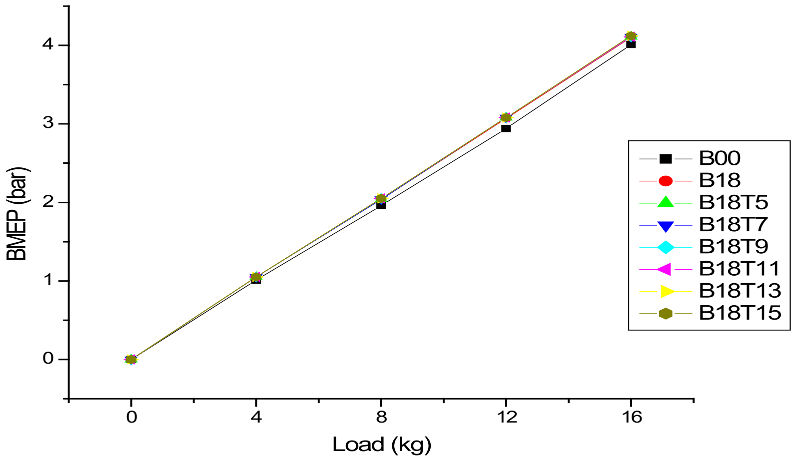

Fig. 3. Brake means effective pressure of blended fuel at various loads.

Figure 4 indicates that the load increases for all fuels, the BTHE increases. As compared to pure diesel, the percentage rises in BTHE for B18T5, B18T7, B18T9, B18T11, B18T13, and B18T15 are 6.92, 9.03, 9.68, 9.15, 9.20 and 9.18. It can be shown that the brake thermal efficiency for diesel is the highest and the lowest for all biodiesel blends. This may be attributed to biodiesel's lower calorific value and higher viscosity as compared to diesel.

Figure 5 explains that the load increases for all fuels, the BSFC reduces. The BSFC of B18T5, B18T7, B18T9, B18T11, B18T13 and B18T15 decreased by 2.35, 2.35, 2.90, 3.91, 2.86 and 3.91 compared to pure diesel. BSFCs have been found to be reduced to raw Mexican biofuel compared to base engine diesel.

The decreasing BSFC with rising load shows that the engine is inefficient at low loads. This may be attributed to insufficient fuel in relation to the amount of air in the combustion chamber. In other words, the combustion has an excessively high air-to-fuel ratio and becomes excessively lean.

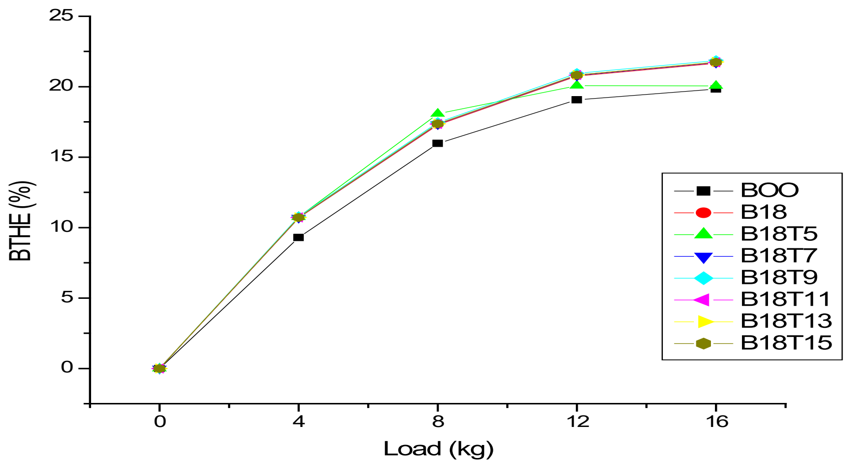

Fig. 4. Brake thermal efficiency of blended fuel at various loads.

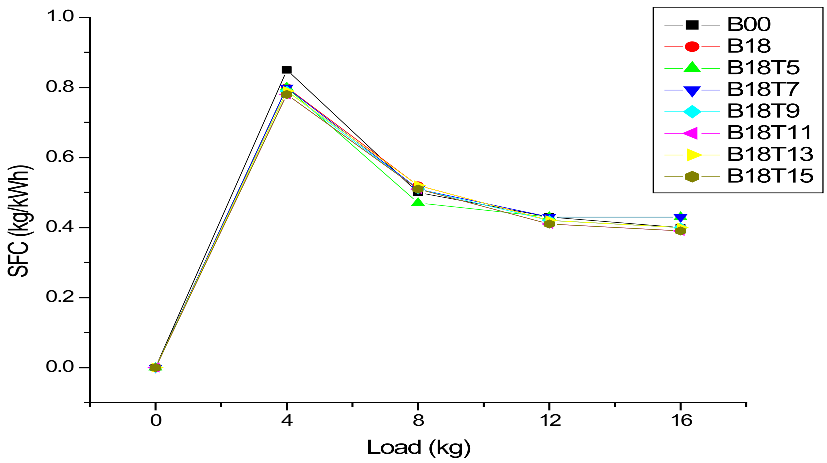

Fig. 5. Specific fuel consumption of blended fuel at various loads.

4. Experimental Validation

BP, BMEP, BTHE, and BSFC obtained with B00, B18, B18T5, B18T7, B18T9, B18T11, B18T13, and B18T15 are found to be influenced by fuel blend and engine loading. The results of the experiments are checked using the ANN method from the MATLAB. Figure 6 shows that the comparison in BP calculated by the ANN method and experimentally, shows small variations in both values. The average error value is 0.0087. Figure 7 shows that the comparison in BMEP calculated by the ANN method and experimentally, shows small variations in both values. The average error value is 0.0037. Figure 8 shows that the comparison in BTHE calculated by the ANN method and experimentally, shows small variations in both values. The average error value is -0.5662.

Figure 9 shows that the comparative graph shows that the comparison in BSFCs, calculated using the ANN method and experimentally, shows small variations in both values. The mean error value is 0.0033.

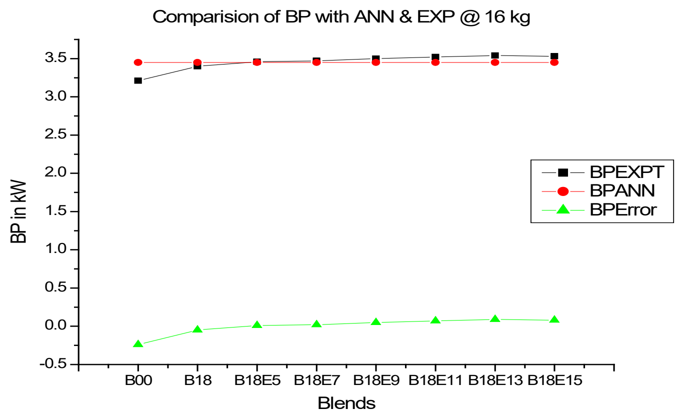

Fig. 6. BP comparison with ANN and experimental.

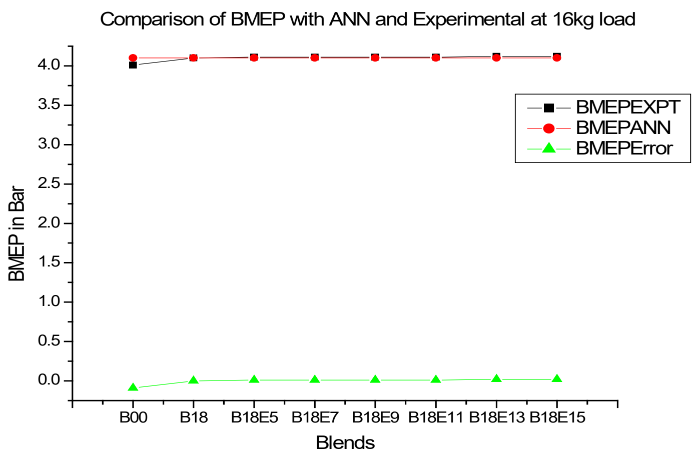

Fig. 7. BMEP comparison with ANN and experimental.

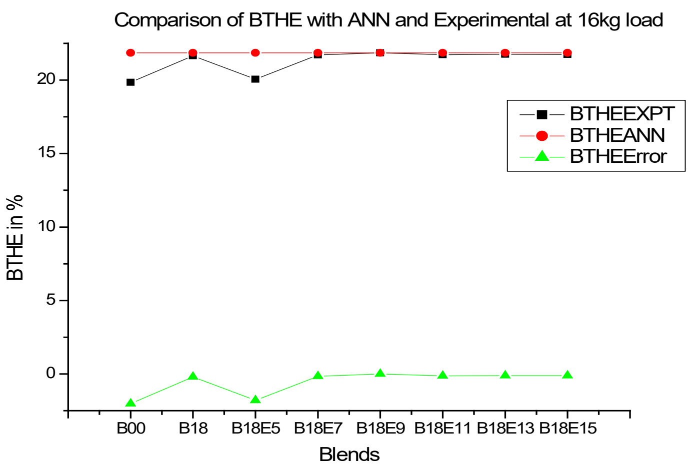

Fig. 8. BTHE comparison with ANN and experimental.

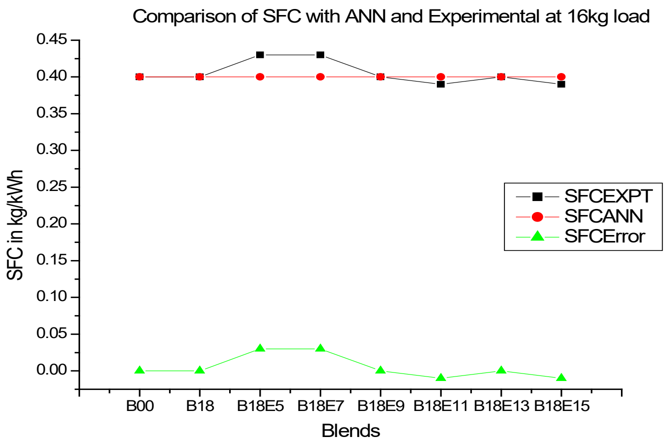

Fig. 9. SFC comparison with ANN and experimental.

4. Conclusions

Biodiesel obtained from Mexicana biofuel is comparable with standard diesel fuel for the performance characteristics. Mexicana biofuel has been chosen based on the amount of petroleum, accessibility, utility and toxicity. The appropriate method of transesterification of Mexicana biodiesel must be selected for use as the primary alternative fuel for large-scale business applications. The diesel engine performed well without changes with Mexicana oil added with nano-TiO_2 blends. The operating characteristics of the engines were investigated experimentally. The inquiries culminated in the following conclusions.

- The BP of all fuels was found close with plane diesel but B18T13 has given more BP than that of diesel fuel in all combinations.
- Biodiesel and its blends have a higher BTHE than diesel. B18T9 shows the greatest difference as compared to other blends because biodiesel requires more oxygen than pure diesel, which promotes full fuel combustion.
- BSFC initially it gets higher, but it reduces with loads for all fuel samples. Among all blends, it was noticed that B18T11 and B18T15 has shown less fuel consumptions than pure diesel as well as any other blends. The rise in fuel consumption by biodiesel and its respective blends were due to its higher density, lower calorific values and simultaneously efficiencies too.

The experimental work is validated using Artificial Neural Networking modelling, and the error found between the experimental and ANN work is close to zero. The results of an artificial neural network modelling are very good, with very low mean errors discovered. The ANN analysis of the experimental data showed a strong correlation between the ANN expected results and the experimental data. As a result, ANN proved to be a valuable method for engine parameter correlation and simulation.

The effect on engine and its parts on account of long-term use of biodiesel, required to be studied. In the field of biodiesel, there is need to search other sources according to cultivation and availability of the biodiesel feedstock. Furthermore, current research on biodiesel fuel claims that since there are so many Argemone

Mexicana plants around, several hundred million gallons of biodiesel could be produced annually using this simple technique.

Nomenclatures

ANN	Artificial Neural Networking
B00	Plane diesel
B18	Blends of Biodiesel (18% Argemone Mexicana + 82% diesel)
B18T5	Titanium oxide as additive in plane diesel at fraction of 0.05%
B18T7	Titanium oxide as additive in plane diesel at fraction of 0.07%
B18T9	Titanium oxide as additive in plane diesel at fraction of 0.09%
B18T11	Titanium oxide as additive in plane diesel at fraction of 0.11%
B18T13	Titanium oxide as additive in plane diesel at fraction of 0.13%
B18T15	Titanium oxide as additive in plane diesel at fraction of 0.15%
BMEP	Brake Mean Effective Pressure
BP	Brake Power
bTDC	Before Top Dead Centre
BTHE	Brake Thermal Efficiency
SFC	Specific Fuel Consumption
TiO_2	Titanium oxide
VCR-1	Variable Compression Ratio-1

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