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Implementation of Fusel Oil as an Octane Enhancer with Commercial Gasoline to Operate Gasoline Engine

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ABSTRACT

The rise of energy demand and ecological contaminations encourage the utilization of alcohol bases on substitutes fuels in spark ignition (SI) engine. The fusel oil is a byproduct acquired from fermentation process with higher alcohol content. It has high-octane and less exhaust emissions; therefore, it takes significant place between the substitutes fuels. During this study, the impact of utilizing mixtures of pure gasoline & fusel oil on engine exhaust emissions & performance has been evaluated after water extraction from fusel oil. A single-cylinder, four-stroke SI engine has been utilized in these tests. The examinations execute at different speeds. The experiment fuels mixed with fusel oil at proportions of 5%, 10%, 20%, and 30%. At each speed, the engine's performance & emissions measurement have been conducted. During the experimentations, it has been noticed that the torque (T) and specified fuel consumption (SFC) rises as the quantity of fusel oil risen in the mixture. Carbon monoxide (CO) and carbon dioxide (CO_2) emissions are decreased as the quantity of fusel oil is raised in mixtures.

1. INTRODUCTION

Ecological pollution, speedy reduction of not able to be renewed, fossil fuels, charge have caused rising the need to use substitute fuel to (SI) engines [1]. So, biofuels manufactured of stuff can be gained, which have higher thermal efficiency and lower emissions of exhaust [2, 3]. Alcohol-based as alternative fuels presently widely considered. Fusel oil is a long series alcohol category sub-product of alcohol produced through the distillation process [4]. Its smell is bad and its color is dark brown. It has the same properties of alcohol fuel as higher (RON=106), (MON= 103), and also has high oxygen contented about 30.23%, also solo ebullition point, but fusel oil has a high-water content of about 3-20% [5]. These properties indicated that fusel oil can be utilized as substitute fuel and as additive to gasoline for (SI) sparkle ignition Engines [6].

Several studies have investigated fusel oil-gasoline mixture impact on the act of SI engine and emissions [7, 8]. Alper Calam showed that fusel oil may be used in SI engine as substitute fuel because of its (physical & chemical) characteristic Increasing blends effects on the torque of engine and fuel consumption, they were discussed with many researches [2]. Also, Calam and Icingur [5] used another fuel blend (10, 20, 30%) to operate spark-ignition engine at different speeds under higher load conditions. The results revealed that the BSFC improved in all test conditions at a maximum value of about 7.7% with F 30, after the proportion of. the fusel oil increased in the mixture; engine torque decreased. Furthermore, in wholly fusel oil-blends, NOx emissions decreased compared to untainted gasoline for the reason that the reduction in engine exhaust temperature [9]. Calam et al. studied single-cylinder gasoline (SI engine), they used another fusel oil mixing percentage (0%, 5%, 10%, 20%, 30% & 50%) with diverse load with stable speed of 3500 rpm. In this study, the fusel oil introduced as a renewable fuel for SI engine because of its physico-chemical properties. The result showed an increase in BSFC and torque with a reduction in NOx [5]. Another study investigated fusel oil at adding ratio of (0%, 50% and 100%) to gasoline. The results of the study were collected at speed of 2500 rpm, 4 load level of (25%, 50%, 75% & 100%), when fusel oil content increased the (IMEP) and heating value decreased because of water in fusel oil. Moreover, NOx decreased with (31%) for F100 [10]. Suleyman & Bulent definite that by adding of fusel oil in to pure gasoline engine torque and (SFC) increased. Further when fusel oil quantity increased in mixture. NOx, CO_2 and UHC emission reduced [10]. Also solmaz [11] claimed that the torque was decreased commonly into (6%) and (2%) at using of (F100). & (F50) fuel with addition of fusel oil, while BSFC increased [12]. A study presented by Calam et al. showed significant effect of fusel oil and gasoline blend percentage of 5%, 10%, 20% & 30% on (SI) mot execution and its emissions. Also, Omar [13] presented a study showed the effect of water extraction from fusel oil on heating value and engine execution. The test steered on (SI) motor below (4500 rpm) motors speed by using diverse mixing fraction of (gasoline & fusel oil), G100, FBWE10, FBWE20, FAWE10 and FAWE20), engine execution and heating value were improved.

The results shown that by increasing percentage of fusel oil in mixture, significant increasing in octane number of blended fuels is obtained. The aim of this study is to indicate the most suitable utilization for fusel fuel in SI engine that achieve the best engine efficiency at maximum pollution protection.

Different ratios of fusel oil and commercial gasoline have been implemented in this study to indicate a better additive ratio.

2. INVESTIGATIONAL ARRANGEMENT

2.1 Experiment fuel

In this study, engine test was conducted with fusel oil & gasoline mixtures after water removal form fusel oil. Fusel oil provided of Eskişehir sugar factory, that making ethyl alcohol (99.5%) purity. Pure gasoline fuels have been acquired of native petrol stations in Iraq and indicated as commercial fuel. Pure gasoline (F0%), (pure gasoline & fusel oil mixtures) applied in the experimentations, and the mixtures are show in Table 1.

Table 1. Structure of fuel mixtures

Sample	Structure
(F0%)	Pure Gasoline
(F5%)	(5%) Fusel Oil + (95%) Pure Gasoline
(F10%)	(10%) Fusel Oil + (90%) Pure Gasoline
(F20%)	(20%) Fusel Oil + (80%) Pure Gasoline
(F30%)	(30%) Fusel Oil + (70%) Pure Gasoline
(FS)	Enhance Gasoline

2.2 Water extraction

Water contented of fusel oil is higher that nearly 3-20% which led to decrease its heating value, and that led to an adversarial effect on the efficiency of composition, and performance of engine. Fusel oils heating value was 30 MJ/kg, its fewer than for pure gasoline that about 44.598 MJ/kg [14]. In this experiment (H_2O) contented for fusel oil removed by utilizing center fugue in laboratory of north oil company in Iraq/Kirkuk. After water extraction the heating rate of fusel oil becomes 33.8 MJ/kg.

2.3 Engine test

Figure 1 presents the engine test rig used in this study for testing prepared fuel samples. Single cylinder SI engine with the specifications listed in Table 2 has been used to conducted the fuel tests. Engine load arrangement comprises of a hydraulic dynamo meter fixed on a usual experiment basis. The extreme vigor of the hydraulics dynamo meter is (7.5) kW on (7000) rpm. That relates conception accord to the current average and grade of water into its sheath. The quantity of H_2O stock requisite to hydraulic dynamo meter extent is specified as a lower than (5) (L/min) in (1bar). Cell of electric burden kind (S) by a full burden ability of (15) N.m is attuned over with command measure [15].

Table 2. Engine characteristics

Factors	Specifications
(Displacement)	(172) Cm
(Bore) × (cycle)	(67) mm × (49) mm
Arrangement	four cycles, sparkle - ignition, solo cylinder
Connect shaft length	(85) mm
Fuel	Gasoline
Compression percentage	(8.5:1)

Figure 1. Engine test rig

3. OUTCOMES AND DEBATE

The current outcomes of experiment (physical & chemical) feature (heating value, research octane number , thickness and viscidness), outcomes of investigational experiments of engine execution (BP, BSFC and BTE).The research done by utilizing pure Gasoline fuel (F0) and (gasoline & fusel oil) mixture (F5%, F10%, F20%, F30%) & enhanced gasoline (FS) in a solo -cylinder, four- cycle flicker engine Robin (EH 17) working in speeds range of (1500 - 2700) rpm by an increase (300 rpm) & (100%) choke valve open (WOT).The engine operational settings were kept similar in nearly all experimentations as environs temperatures of ambient and air pressure & wetness.

3.1 Test fuel quality investigation

The properties for the fuel utilized for process of inner burning engines the utmost significant factors in relations of competence and superiority of burning [16-19]. Chemical & physical future scaled and debated in such paper comprised (heating value, octane number, thickness and viscidity). The stuffs calculated to seven fuel tested samples (Fusel oil F, pure gasoline F0, F5, F10, F20, F30, FS). The physical and chemical properties have been examined in laboratory of north oil company in Kirkuk.

3.1.1 Heating value

Heating rate is quantity of ability which one kilo gram from fuel produces after its totally burned. That scaled by (MJ/kg) unity by utilized oxygen bombs calorimeter. Figure 2 shows the experiment effects. The figure show that the heating rate for fusel oil **(**F**)** after H_2O extraction equal (33.8MJ/kg), while for pure gasoline F0 equal to (44.598 MJ/kg), so heating rate for enhancing gasoline equal to (43.781 MJ/kg) and the heating value of F5 equal to (44.173 MJ/kg), and F10 was (43.625 MJ/kg), and F20 was (42.125 MJ/kg), and F30 was (41.307 MJ/kg). The outcomes of the research tested fuels

shown that heating rate was suggestively decreased by 0.9%, 2.2%, 3.1% and 5.1% for F5, F10, F20 and F30 respectively with adding fusel oil to pure gasoline due to the low heating rate of fusel oil.

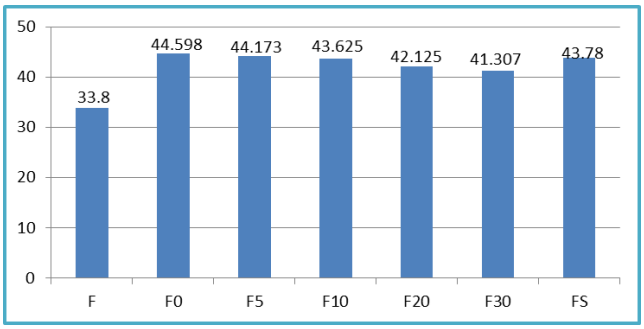

Figure 2. Heating value (MJ/kg).

3.1.2 Research octane number (RON)

Research octane number (RON) is a measurement of the fuel opposition to hit of (SI) sparkle flicker engines. The aloft octane (RON) for gasoline is the better capability of the gasoline to fight natural flicker through compression & previously sparkle ignition [20, 21]. Advanced compression attends high temperature & high pressure which may be completed inside the cylinder of engine & interprets in high engine energy. Figure 3 shown the outcomes for inspection of the (RON) for tested fuels (F, F0, F5, F10, F20, F30, FS). Fusel oil has high octane number (106) before water extraction, therefore (RON) for tested fuel increase. (RON) of fuel (F0) was (86), and it increased when the fusel oil added. By adding F5 the octane number RON be (95.4), also by adding (F10) fuel, (RON) increased to (96.7), the octane number RON for fuel (F20) be (96), and (F30) be (97.1), also the octane number of enhanced fuel (FS) was (93.4).

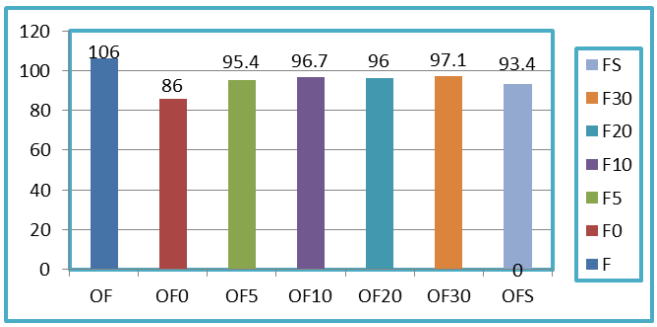

Figure 3. Research octane number (RON)

3.1.3 Density

Density is the proportion among cluster and bulk of fuel, it is a fuel physical feature which marks fuel frugality for engine through acting procedure of equivalent burning and aloft density rises ability of density for a fuel [22-27]. In addition, high density products high viscosity, that in order grants bad burning and impact on engine execution & emission [28]. Figure 4 shown fuel density for (F, F0, F5, F10, F20, F30, FS) found to be (867, 762, 769, 782, 789, 794, 774 kg/m³) respectively. The tested fuel densities were scaled at 20°C by utilizing (Digital Density Gage).

3.1.4 Viscosity

Viscidity is a measurement of interior rubbing or fuel fight to flowing, viscosity is a quite significant quality for fuel, and it impact procedure treatment of fuel structure tools [29-32]. The Kinematic viscidity of tested fuels were measured according (38°C) by utilizing a viscometer. Figure 5 shown the outcomes of viscidity of test fuels (F, F0, F5, F10, F20, F30, FS) that were (2.896,0.467, 0.514, 0.521, 0.594,0.732, 0.468) mm²/sec respectively. The viscosity of fusel oil (F) is high compared with pure gasoline, there for viscosity of pure gasoline increased with the addition of fusel oil.

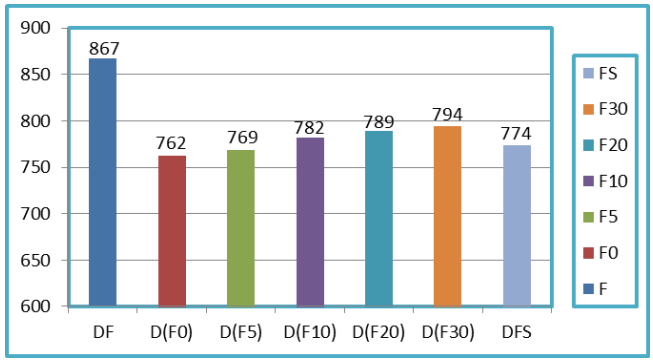

Figure 4. Density for tested fuel (kg/m³)

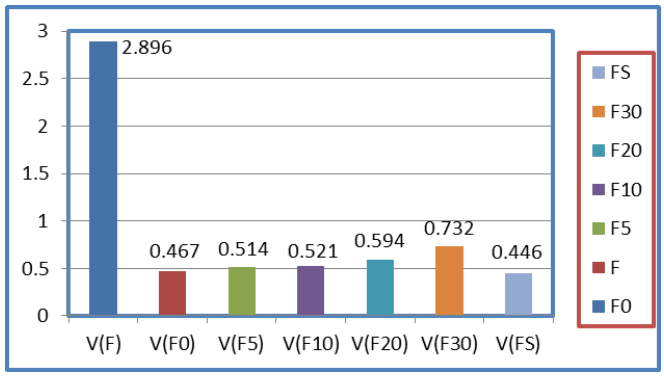

Figure 5. Viscosity K (cm²/s)

3.2 Engine performance

3.2.1 Brake power (BP) & Brake Torque (BT)

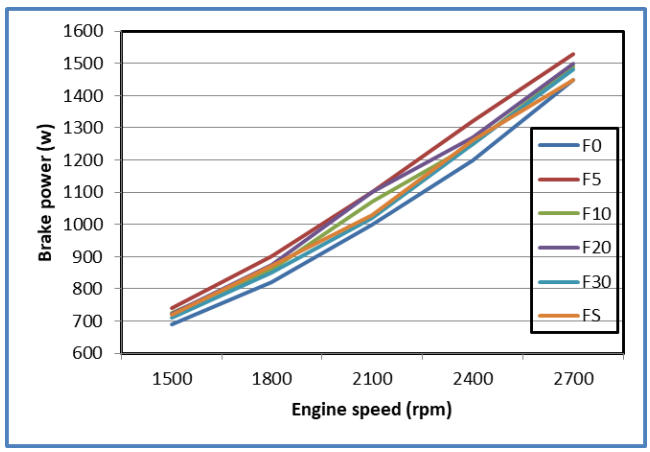

Figure 6. Brake power against engine speed

The engine brake power mastery studied based brake torque of engine per speed. Engine torque increase by adding fusel oil and increasing engine speed. At compared (fusel oil &

gasoline) mixtures of (F5, F10, F20, F30) with pure gasoline (F0), the engine torque showed a little increase. The reason of engine torque increasing at the increasing of amount of fusel oil, considered to higher oxygen consist of the fusel oil which led better combustion. Figure 6 shown brake power for tentative engine trials with utilized tested fuels (F5, F10, F20, F30) and comparing between the outcomes of a tentative trials and pure gasoline & enhanced gasoline at the similar working conditions of the engine. Brake power is increased when speed of the engine raised [33-36]. Brake power for pure gasoline. (F0) is lower from that of enhanced gasoline and it increased by adding of fusel oil at all engine speeds. The best enhancement of a brake power completed in speed (2700 rpm) by (F5).

3.2.2 Brake Specific Fuel Consumption (BSFC)

The difference in the BSFC for engine using the investigated fuel samples at increasing speed and fully open choke (WOT) shows in Figure 7. The relation of BSFC for all tested fuels that utilized in tentative engine trials in fading speeds was high. While engine labor in lower speed an influence of weakened burning & refrigerating is robust that lead up to aloft scale of BSFC to all tested fuel. By increasing the speed of engine, BSFC reductions for lowest led to a slow enhancement in burning process, so rising the total energy operation BSFC initiates rise slowly when the speed of engine rises for totally tried fuels. Figure 7 shown the lower BSFC accomplished for F5 in most speeds of engine compare to F0. This enhancement in BSFC because of the raise into energy of density [37], and fusel oils high octane number.

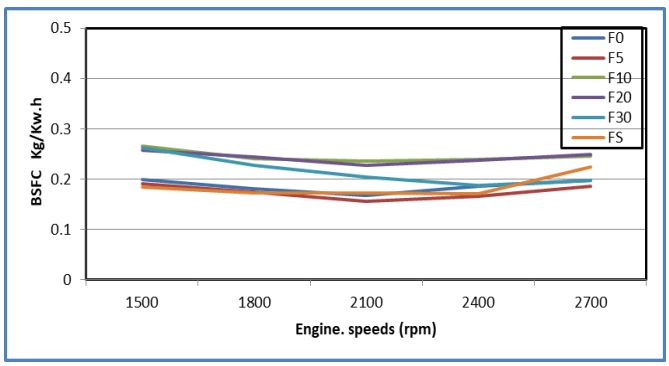

Figure 7. (BSFC) at all engine speed

3.2.3 Brake Thermal Efficiency (BTE)

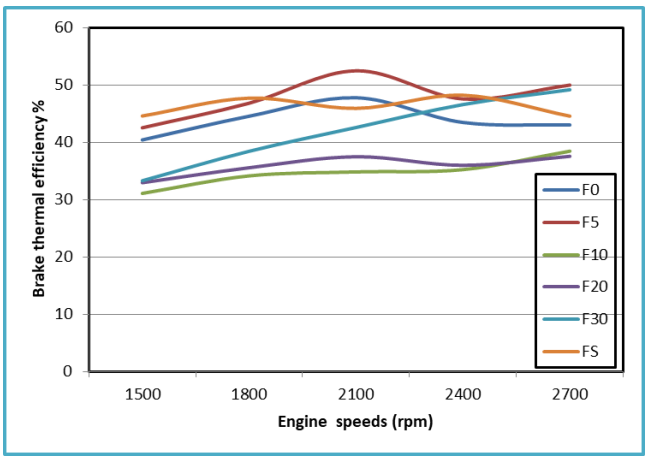

Figure 8. BTE at all engine speeds

The (BTE) is proportion of a brake power formed from engine to overall thermal energy of a fuel [38, 39]. BTE is a measurement of estimation for engine process utilizing tested fuels [35, 40]. Mono of recital factors utilized for consider ability of engine's for transform warmth energy of the fuel for mechanical energy that superior assessment of engine execution of fuel consuming of diverse utilized fuels in tentative trials [41, 42]. Figure 8 shows that (BTE changes at all tested fuels. With introducing fusel fuel with gasoline at 5% the BTE enhanced to a value higher than that of pure gasoline at low and medium speeds with comparable values at high speeds. That rises with utilization of fusel oil at 5% addition ratio at most speeds compared with pure gasoline fuel (F0) due to the noticeable improvement in octane number compared to the slight reduction in the heating value. This increasing in brake thermal efficiency is on account of high octane number for fusel oil, and its high oxygen contains [43].

3.3 Exhaust emissions

3.3.1 Carbon Monoxide CO

Figure 9 shows the variations of CO emissions at different speeds. CO emission focus reckon the procedure of engine & air/ fuel) percentage. The emissions happen because of imperfect combustion while thither not sufficient time to burning, and because of scanty oxygen such is requisite to complete burning of affluent (air to fuel) mixes into cylinder. Fusel oils oxygen contain is high, so the addition of it recovers the burning and decreases (CO) emissions planes. BY compared with F0, CO emission was noticed to be decreased when a quantity of fusel increased in mixture. Although the emission of CO fluctuated with increasing engine speed, at most engine speeds, emissions of (CO) were decreased with introducing fusel oil with gasoline. These effects are in compact with other researches [44-46].

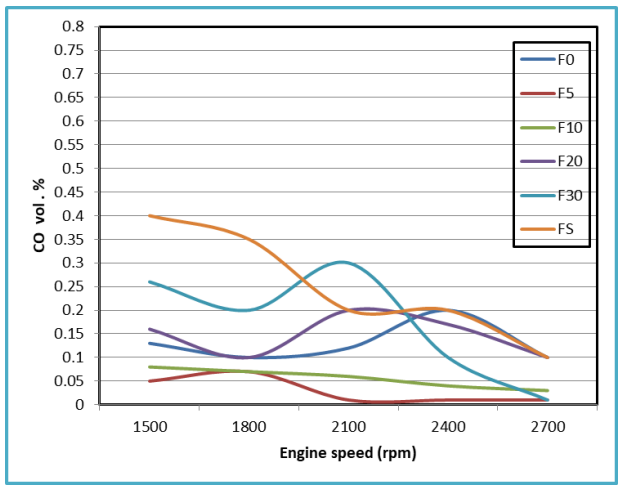

Figure 9. CO Emissions for tested fuel

3.3.2 Carbon Dioxide (CO_2)

The leading objective is to mend fuels frugality & decrease (CO_2) emissions by respect to statute as bazaar ways. Fusel oil and gasoline blends let engines worked in advanced compression percentages. The transformation percentage may be improved in actual uses overall (CO_2) relief may increase [47]. Figure 10 shows (CO_2) emissions for tested fuel (fusel oil & gasoline mixtures), gasoline (F0) in diverse engine speeds. Because of high viscidity and higher oxygen contented for fusel oil, (CO_2) relief were raised with increased

percentage of fusel oil in the blend with most speeds of engine, except in high engine speed (2700) (CO_2) emissions were decreased. Oxygen contented function in recover engine combustion, there for (CO_2) grade increased and had clearly happened in alcoholic fuels [48].

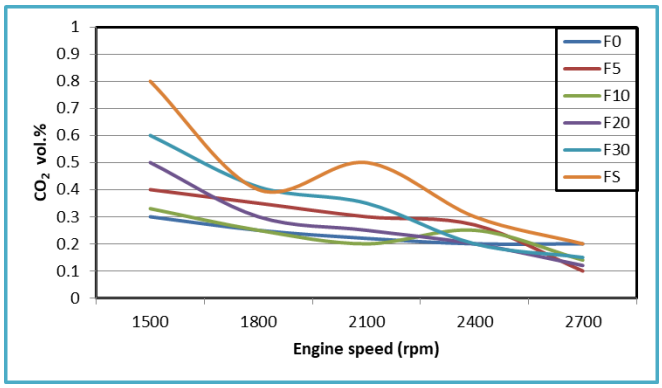

Figure 10. CO_2 Emissions for tested fuels

4. CONCLUSION

With this investigation, experimental research of an influence a different percentage of (fusel oil & gasoline) blends were utilized as fuel for (SI) a spark-ignition engines, with different ranging for speeds of engine that was from (1500 - 2700) (rpm) with raise of (300) (rpm), check sluice opening 100% (WOT) below different operation conditions, a pure gasoline fuel and tested blends properties (octane number , heating rate, density and viscidity), and engine execution (BP), (BSFC), (BTE), and engine exhaust emissions, were analyzed . Based on this work, the most important conclusion summarized as following:

1. Fusel oil addition to pure gasoline increased octane number & viscidity of tested fuels compare with a pure gasoline.

2. Because of higher hidden heat for evaporation of (fusel oil & gasoline) mixtures, by comparing with pure gasoline (F5%, F10%, F20%, F30%) mixtures improved engine torque.

3. The heating rate for fusel oil was (30MJ/kg), next water removal it raised to (33.8 MJ/kg), it was lower of pure gasoline that (44.598 MJ/kg), so lead to decrease heating value of tested fuel and an increasing in (SFC) by an increasing amount of (fusel oil) into mixtures, except fuel (F5) decrease BSFC at most speeds compared to the pure gasoline (F0).

4. (BP) and (BTE) were raised with addition of (fusel oil) compared to a pure gasoline fuels.

5. Higher oxygen content & high viscosity for (fusel oil) lead to reduction (CO) emissions, increased (CO_2) emissions.

6. Generally, higher oxygen contented & higher octane number for fusel oil headed improve engine performance & a combustion with high (air to fuel ratio) percentage led into whole burning for fuel blend.

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NOMENCLATURE

BP	Brake power
BTE	Brake thermal efficiency
BT	Brake torque
BSFC	Brake specific fuel consumption
CO	Carbon monoxide
CO_2	Carbon dioxide
FAWE	Fusel oil after water extraction
FBWE	Fusel oil before water extraction
SI	Spark Ignition