EMISSION PERFORMANCE OF CERAMIC HOT SURFACE IGNITION ENGINE(CHSIE) WITH DIESEL-ETHANOL-AGRO WASTE BLENDED FUELS

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Abstract

An experimental investigation is conducted for increasing brake thermal efficiency, reducing brake specific fuel consumption and emissions using biofuel on four stroke Ceramic Hot Surface Ignition Engine (CHSIE). A partially stabilized zirconium ceramic heater is fitted in the cylinder head and the top of the engine block is grinding to reduce 50% of the clearance volume of the engine cylinder. The relevant parameters such as brake thermal efficiency, brake specific fuel consumption and Carbon Monoxide (CO), Hydro Carbon (HC), Nitrogen Oxide (NOx), and smoke density emissions are evaluated for the fuel blends. The ratio of tested fuel blends of diesel-ethanol-agro waste(D-E-C) are D80E15C5, D65E30C5, and D50E45C5. The n-butanol additive is added as an ignition improver. The CHSIE is operated with each fuel blend of different power output at constant engine speed of 1500rpm. The brake thermal efficiency is increased for the fuel blends of D80E15C5 to D50E45C5 by 2.9% at maximum engine power. The CO, HC, NOx, and Smoke density emissions are low levels for the fuel blend D50E45C5 and the reduced values are 0.11%, 3.1ppm, 14ppm, and 4HSU respectively, from the fuel blend D80E15C5.

Key words: emissions, ignition improver, fuel blends, ceramic, grinding.

1. Introduction

It is apparent from the increasing usage of C.I engines, that ethanol is an alternative fuel to diesel combustion [1]. The replacing diesel fuel fully by ethanol is more difficult, but particularly emerged with biofuel is best fuel blends [2]. Ethanol is an alternative renewable fuel produced from different agricultural products like sugarcane. The diesel-ethanol-agro waste emulsion technique is applicable to produced fuel blends of modified CHSIE. It offers a reduction of Carbon Monoxide (CO), Hydro Carbon (HC), Nitrogen Oxide (NOx), and smoke density emissions. The economics have also become much more favourable in the production of agriproduct [3]. The addition of ethanol to diesel fuel gives physical-chemical changes in fuel properties, particularly in cetane number, viscosity and heating value [4]. Many techniques involving diesel-ethanol-agro waste fuel blends operation in CHSIE has developed to make Compression Ignition (C.I) engine technology compatible with the properties of ethanol-based fuels. The fuel properties like cetane number, heating value, aromatics fractions, kinematics viscosity and changes distillation temperatures are changes [4] for diesel-ethanol-agro waste fuel blends.

An n-butanol additive is making the fuel blends homogenous and stable, and act as an ignition improver. That can enhance cetane number of the fuel blends and making burning effects on the physicochemical properties related to ignition and combustion of the fuel blends. Ethanol and agro waste - diesel mixer a promising oxygenated fuel blend. Ethanol with additive such as cetane improver can sharply reduce particulates. At the early stage, poor fuel economy and low ignitability are the main barriers to apply ethanol fuel on diesel engines. Since late 1990s, ethanol blended diesel fuel has been used on heavy-duty and light-duty diesel engines in order to modify their emission characteristics. A higher percentage of bioethanol blends causes different in NOx across the entire load range, except at low load conditions [5]. As alternate fuels, ethanol and agro waste stand out because of the feasibility of producing them in bulk from plentifully available raw materials.

Thermal barrier test is conducted by heating the entire coated surface uniformly and by keeping the ceramic heater surface temperature constant till the stabilization in the range of 3000C to 5000C. The temperature drop achieved is in the range of 460C to 1270C depending upon the coating thickness [6]. The highest reduction percentages in CO emissions are achieved by 42%, 30% and 8% of the D90E10, D70C20E10 and D80C20 fuels, respectively [7]. The Hot Surface Temperatures (HST) varied from 623 to 723 K, Cylinder air Pressure (CP) varied from 20 to 40 bar and fuel injection pressures varied from 100 to 400 bar [8]. Zirconia ceramics as high toughness materials for cutting tool, metal forming applications, mechanically superior ceramics called Partially Stabilized Zirconia (PSZ), solid electrolytes, have been fabricated using the martensitic nature of the tetragonal to monoclinic phase transition [9]. The present study provides significant results relating to the effect of the expansion to compression ratio on the short stroke engine, and the feasibility of applying ethanol blended fuel to a short stroke engine [10]. Biodiesel from citrus sinensis oil (10e15%), anhydrous ethanol (5%) and diesel ternary fuel mixtures meet expectations of European Commission (EC) Renewable Energy Directive (RED) for 2020[11].

2. Experimental setup

A Ceramic Hot Surface Ignition Engine (CHSIE) is selected for the experiment. The specifications of the Ceramic Hot Surface Ignition Engine (CHSIE) is given in tab. 1. A partially stabilized zirconium ceramic heater is fitted in the cylinder head and connected by 12-volt Direct Current (D.C) battery to heating inside part of the cylinder, and the top of engine block is grinding to reduce 50% of clearance volume of the engine cylinder. The Ceramic Hot Surface Ignition Engine (CHSIE) is shown in fig. 1. The partially stablished zirconium ceramic heater is shown in fig. 2. The engine block grinding is shown in fig. 3, and after grinding the engine block is shown in fig. 4. The engine clearance volume is reduced to 50% of total clearance volume, by which the fuel blends are completely combusting and reduce the emissions. The relevant parameters such as brake thermal efficiency, brake specific fuel consumption and emissions are calculated for the fuel blends. The ratio of tested fuel blends of diesel-ethanol-agro waste are D80E15C5(Diesel-80% Ethanol-15% and Waste Coconutoil-5%), D65E30C5(Diesel-65% Ethanol-30% and Waste Coconutoil-5%) and D50E45C5(Diesel-50% Ethanol-45% Waste Coconutoil-5%) and the results are compared to each other. The properties of fuels are given in tab. 2 and the specifications of partially stabilized zirconium ceramic heater is shown in tab. 3.

The engine is run on no-load condition at the constant speed of 1500rpm by adjusting the screw provided with the fuel injector pump. The engine is run to gain uniform speed after which it is gradually loaded. The experiments are conducted at six power levels. For each load condition, the engine is run for at least 10 minutes after which data is collected. The experiment is repeated four times and the average value is taken. The observations made during the test for the determination of various engine parameters Brake thermal efficiency, Break specific fuel consumption and exhaust emissions.

fig. 1. Ceramic Hot Surface Ignition Engine (CHSIE)

fig. 2. Partially Stabilized Zirconium Ceramic Heater (PSZCH)

fig. 3. Engine block grinding

fig. 4 After grinding the engine block

tab. 1. Specifications of the Ceramic Hot Surface Ignition Engine

SI.NO	DESCRIPTION	VALUE
1.	Engine Type	4 Stroke Forced air and oil cooled C.I engine
2.	No of Cylinder	One
3.	Bore Diameter	86 mm
4.	Stroke Length	77 mm
5.	Engine Displacement	446 cc
6.	Compression Ratio	25:1
7.	Max. Engine power	6.62 kW
8.	Max. Torque	23 N. m
9.	Attachment	12-volt D.C current PSZCH

tab. 2. Properties of fuels

PROPERTIES	DIESEL	ETHANOL	WASTE COCONUT OIL
Chemical formula	$C_{12}H_{23}$	C_2H_5OH	$C_4H_8NNAO_2$
Calorific value (kJ/kg)	42500	26400	38100
Carbonate (Wt%)	86	52.2	78
Hydrogen (Wt%)	14	13	12
Oxygen, (Wt%)	0	34.8	11
Viscosity (cSt) at 40˚C	3.11	1.2	4.1
Flash point (˚C)	78	13.5	115.5
Boiling point (˚C)	180-330	78	95-99
Auto ignition temperature (˚C)	230	366	171
Cetane number	45	9	56
Density (Kg/m^3) at 20˚C	837	788	886.2
Surface tension (N/m) at 20˚C	0.023	0.015	0.034

tab. 3 Specifications of partially stabilized zirconium ceramic heater

Material	PSZ
Youngs Modulus (KPa)	200
Mohr's hardness	8
Water absorption (%)	0
Boiling point(°C)	4300
Melting point (°C)	2750

3. Result and discussion

3.1. Brake thermal efficiency

The blended fuels are evaluated on the basis of both engine performance and its emissions. The effects of ethanol addition to diesel fuel with waste coconut oil on different performance and emission parameters like brake thermal efficiency, brake specific fuel consumption, Carbon Monoxide(CO), Hydro Carbon(HC), Nitrogen Oxide(NOx) and smoke density emissions are evaluated. fig. 5. indicates the various of brake thermal efficiency of the engine with various ratio of fuel blends at different brake power in the range of 1 to 6 kW. From the results, it is observed that with an increase of brake power, the brake thermal efficiency for each fuel increases and the maximum thermal efficiency 32.6% is obtained at 5kw engine power for the fuel blends D50E45C5. This is due to the oxygen content of ethanol enhances the combustion efficiency and decreases the heat losses in the cylinder by lower flame temperature. The vaporization of the fuel continues in the compression stroke as the latent heat of vaporization is more with ethanol blended fuel.

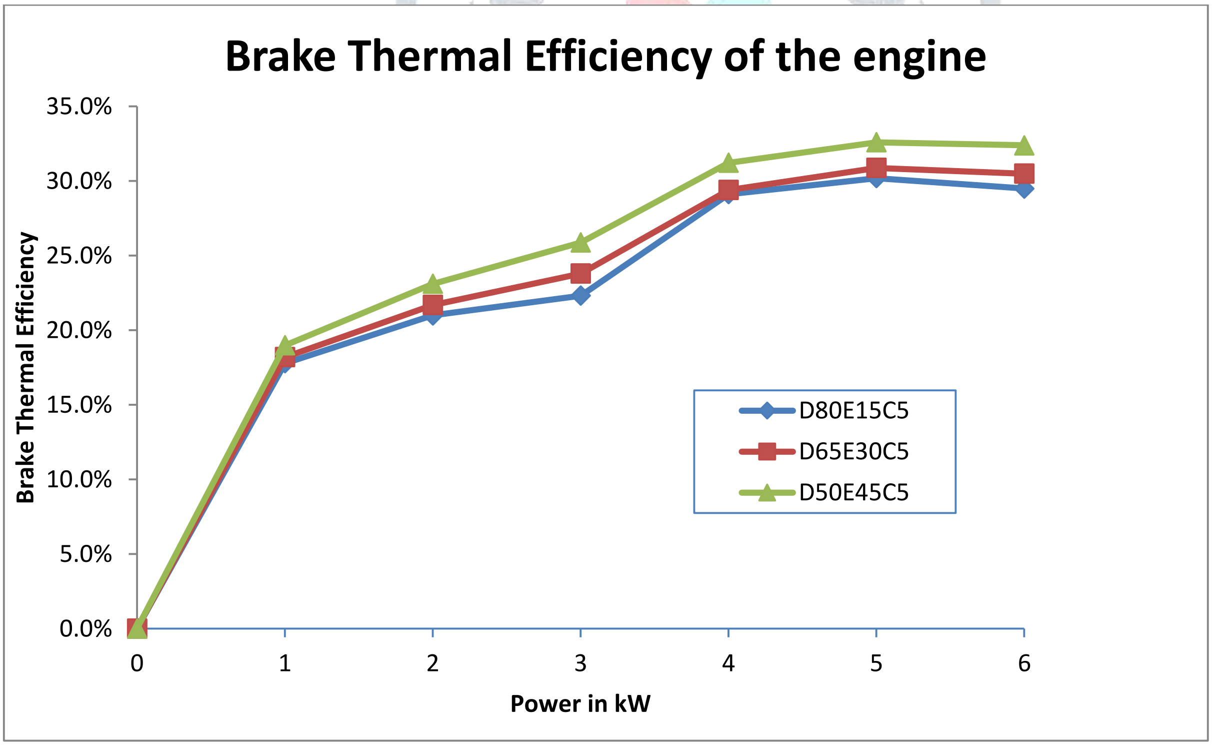

fig. 5. Brake thermal efficiency

3.2. Brake specific fuel consumption

The variations of brake specific fuel consumption of the engine with brake power is shown in fig. 6. it is observed that with increase of brake power, the brake specific fuel consumption for each blended fuel also increased. The fuel blend D50E45C5 gives 232g/kWhr lesser brake specific fuel consumption. The reason behind this is that ethanol blends burn more efficiently due to presence of oxygen in their molecular structure compared to other fuels. The differences in brake specific fuel consumption is a reflection of the differences in fuel density and calorific values.

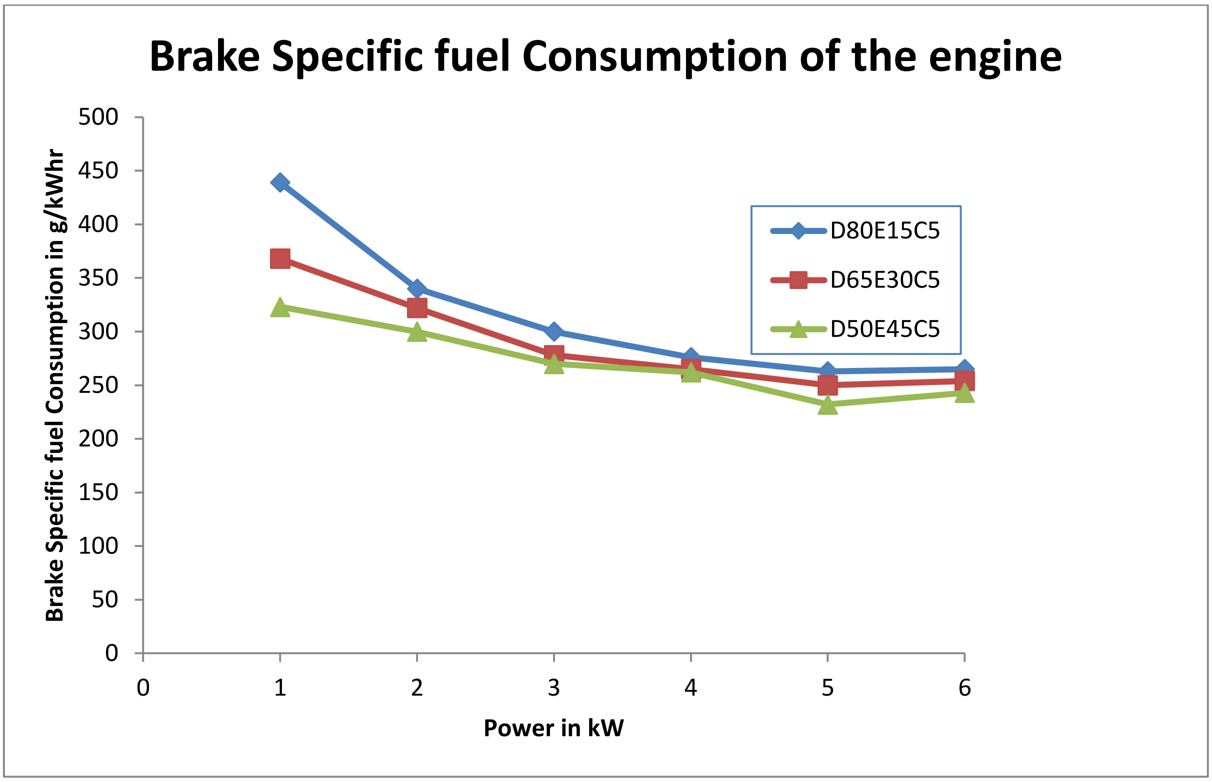

fig. 6. Brake specific fuel consumption

3.3. CO emission

The fig. 7. shows the reductions of CO emission after half load for D50E45C5 fuel blend. This is due to the more complete combustion. The phenomenon or trend is due to that ethanol contains oxygen element in it. When the engine above its half load, the temperature in the cylinder is high, which made the chemical reaction of fuel with oxygen be easier and the combustion is thoroughly completed.

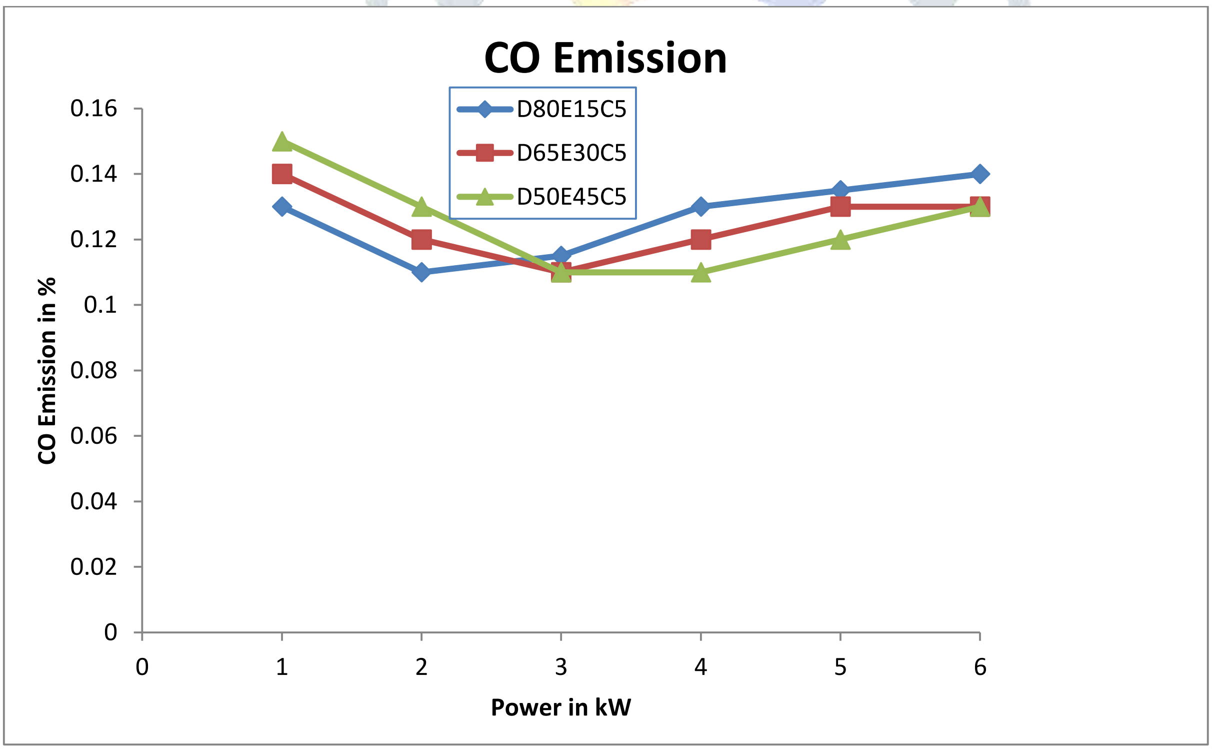

fig. 7. CO emission

3.4. HC emission

The fig. 8. shows the HC emission for various ratios of blended fuels. The minimum value of 24.8ppm gives by the fuel blends D50E45C5. This is due to the high temperature in the zirconium ceramic heater engine cylinder to make the fuel be easier to react with oxygen when the engine runs on the top load and high speed.

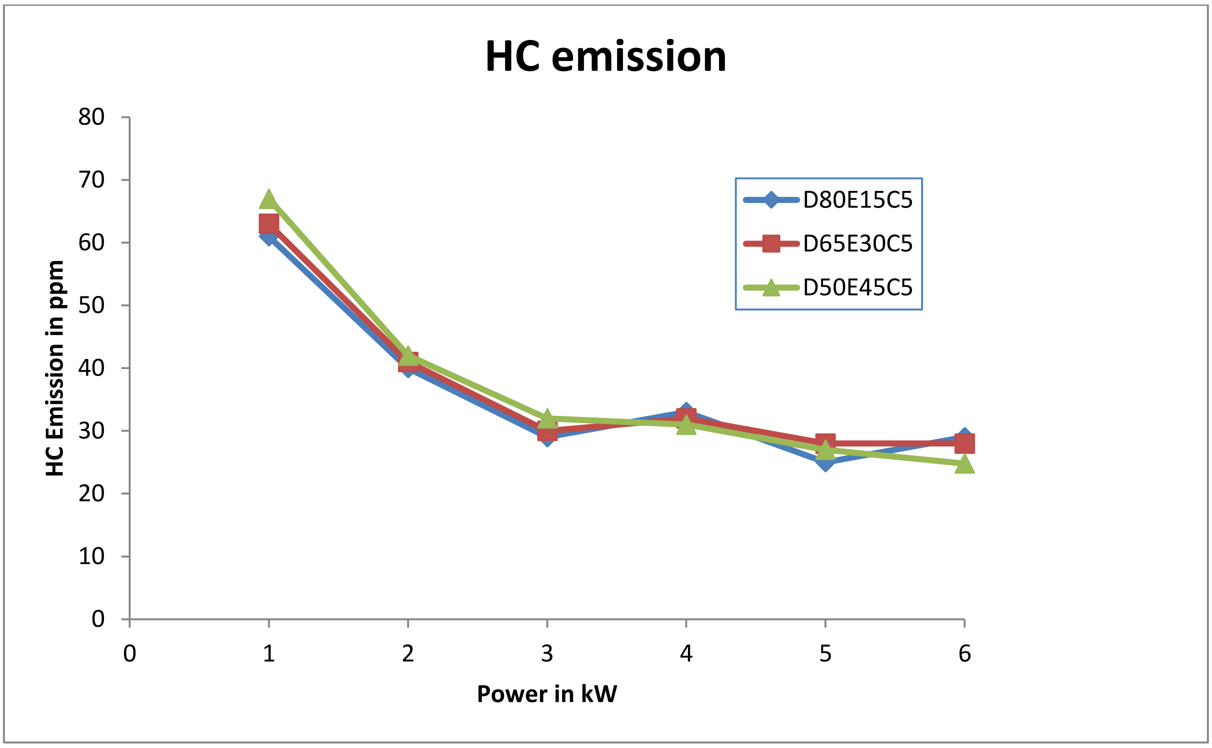

fig. 8. HC emission

3.5. NOx emission

The variation of NOx present in the exhaust gas with brake power is graphically represented in fig. 9. The amount of NOx formed, mostly depends on the combustion temperature, the oxygen concentration and residence time for the reaction to take place. The NOx emission is 103ppm for the D50E45C5 fuel blend. This is due to higher latent heat and the burning mixture likely to be closer to stoichiometric by the help of zirconium ceramic heater.

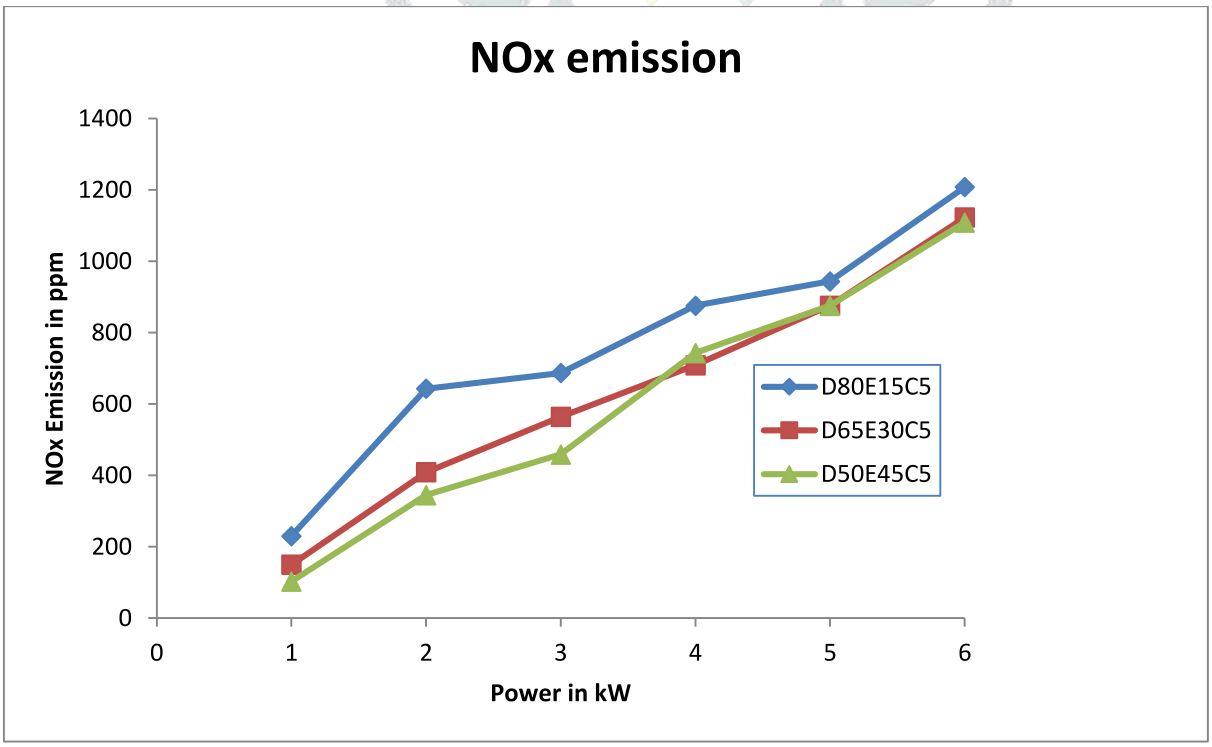

fig. 9. NOx emission

3.6. Smoke density

The fig. 10. shows the smoke density of the all fuel blends. The reduction of smoke emissions is attributed to the better combustion in the fuel blend D50E45C5 This is due to higher prevailing operating temperatures. Premixed combustion in the case of biodiesel with higher cetane number is the reason for lower exhaust gas temperature.

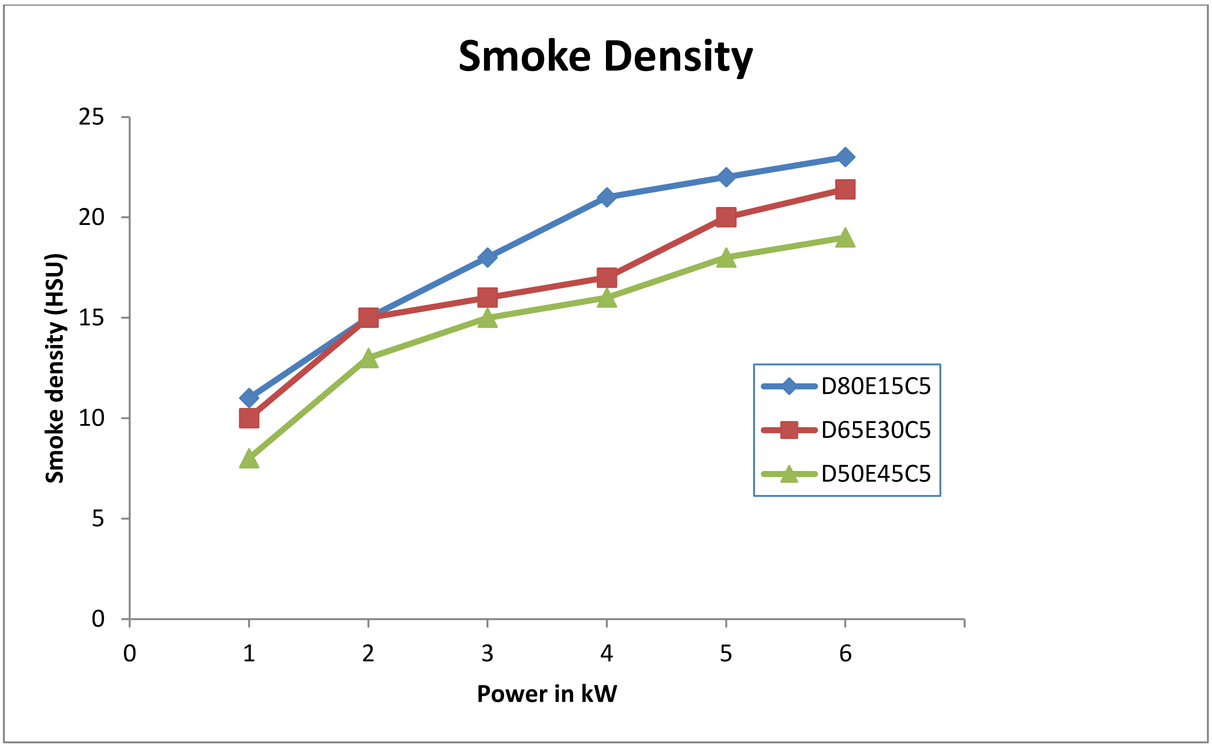

fig. 10. Smoke density

4. Conclusion

An experimental investigation was conducted in the partially stabilized zirconia (PSZ) attached with 50% of engine clearance volume reduced Ceramic Hot Surface Ignition Engine (CHSIE). The tested fuel blends were D80E15C5, D65E30C5 and D50E45C5 and added 2.5ml of n-butanol ignition improver. The Experiment showed that the n-butanol is a good additive for mixing the fuel blends. The maximum thermal efficiency 32.6% was obtained at 5kw engine power for the fuel blend D50E45C5. The brake specific fuel consumption is maximum by 439g/Kwhr for the fuel blend D80E15C5 at low engine power and minimum by 232g/Kwhr for D65E30C5 fuel blend at high engine power. The CO, HC, NOx and Smoke density emissions were low level for the fuel blend D50E45C5 and the re\duces values were 0.11%, 3.1ppm, 14ppm and 4HSU respectively, from the fuel blend D80E15C5.

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