Engineering Science and Technology, an International Journal xxx (2018) xxx–xxx

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Contents lists available at ScienceDirect

Engineering Science and Technology, an International Journal

journal homepage: www.elsevier.com/locate/jestch

Full Length Article

Investigation on performance and emission characteristics of EGR coupled semi adiabatic diesel engine fuelled by DEE blended rubber seed biodiesel

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ARTICLE INFO

Article history:
Received 17 November 2017
Revised 16 February 2018
Accepted 19 February 2018
Available online xxxx

Keywords:
Yittria- stabilized zirconia
Exhaust gas recirculation
Rubber seed oil-biodiesel
Diethyl ether additive
Start of injection timing
Diesel engine

ABSTRACT

The test case was semi adiabatic diesel engine (SADE) produced by thermal barrier 8 YSZ (Yttria Stabilized Zirconia) ceramic coated cylinder head and liner with bond coat NiCrAl as an intermediate layer and coupled with an EGR (exhaust gas recirculation) of 10% constant rate. The test fuels injected directly into the combustion chamber are diesel and blend A15B85 by vol. (Additive Diethyl Ether 15% + Rubber seed based Biodiesel 85%). Throughout the experimentation, a constant compression ratio 18:1, fuel injection pressure 190 bar and speed 1800 rpm. Load from 0% to 100% and start of injection (SOI) timing from 30^0 BTDC to 35^0 BTDC were varied to investigate performance, in-cylinder pressure and emission parameters of SADE and ordinary diesel engine (ODE) fuelled by test fuels. It was found that advancement of SOI timing improved all the investigated parameters except NOx emissions. Compared to ODE with diesel at any specific SOI timing, the test case with blend found to be favourable. The optimum results of SADE were 7% enhancement of BTE with the reduction in BSEC by 5.5%, particulates by 48.5%, NOx by 19.5% and exhaust gas temperature by 18.5% found with the blend at 33^0 BTDC with higher load compared to ODE with neat diesel at 30^0 BTDC. The optimum configuration of ODE found to be diesel fuel at 34^0 BTDC with higher load.

Introduction

The objective of the current study is to present a better viable solution to an ordinary diesel engine fuelled by fossil diesel. Even though many technological advancements to improve diesel engine efficiency and emissions were made, still much remains to investigate. The chief hurdles of the ordinary diesel engine at normal operating conditions are low efficiency (only about 29–30%) and higher exhaust emissions like particulate matter, CO, unburnt HC, CO2 etc. The various reports published in recent years on fossil fuels showed a rapid decline in its reserves and strongly suggests for alternatives. Hence, in the current study an attempt is made to address all the above problems through a slight modification (Thermal Barrier Coating) to core engine components along with 100% renewable fuel (blend of rubber seed based biodiesel and diethyl ether additive) operation. Also, an attempt is made to find out the optimum engine operating configuration for the blend A15B85.

The acute problems faced by the world regarding conventional/fossil-based energy were the rapid decline in proved reserves and the damage to the atmosphere by fossil pollutants emitted from internal combustion engines that currently reached a wholly insupportable conclusion and needs sustainable addressing through technological advancements besides adopting alternative energy strategy. Significant research progress [1] regarding biodiesel acknowledged it as environmentally friendly fuel and potential alternative and also found that the properties of biodiesel were directly related to the type of source feedstock. Review of different studies [2,3] regarding biodiesel as alternative fuel in compression ignition engine found that brake thermal efficiency (BTE), CO, HC and Smoke were reduced significantly whereas brake specific fuel consumption (BSFC) and NOx emissions increased. It was found [4] that CI engine fuelled by a blend of diesel and low percentage biodiesel showed improvement in BTE, ignition delay, smoke, CO and HC compared to diesel fuel. The presence of toxic compounds in the oil sources like Jatropha, Karanja and Rubber seed makes them unfit for human consumption (non-edible) and hence can be

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Peer review under responsibility of Karabuk University.

https://doi.org/10.1016/j.jestch.2018.02.010
2215-0986/

Nomenclature

SADE	Semi Adiabatic Diesel Engine	NiCrAl	Nickel-Chromium-Aluminium
ODE	Ordinary Diesel Engine	TBC	Thermal Barrier Coated
DEE	Diethyl Ether	BTE	Brake Thermal Efficiency
SOI	Start of Injection	BSEC	Brake Specific Energy Consumption
A15B85	(Additive diethyl ether 15% + Biodiesel 85% by vol.)	EGT	Exhaust Gas Temperature
EGR	Exhaust Gas Recirculation	BTDC	Before Top Dead Center
YSZ	Yttria Stabilized Zirconia	NOx	Nitrogen Oxides

considered [5] as alternative fuels in compression ignition engine so that no effect on food security. The biodiesel produced from rubber seed oil blended with DEE fuelled to diesel engine showed higher peak pressures along with higher BTE. The oil extracted from rubber seed have multiple uses in chemicals, pharmaceutical, and consumer industries. The study [6] done on biodiesel produced from rubber seed oil confirmed that all the properties like viscosity, flash point, iodine value, ester content and higher heating value were within the standards of ASTM D6751 and EN 14214. The combustion, performance and emissions parameters of a single cylinder diesel engine significantly improved with rubber seed oil in crude as well as methyl ester forms and besides with ethanol injection at different rates [7]. The blends of Diethyl ether-Biodiesel-Diesel tested [8] with PCCI-DI engine showed enhancement in BTE by 13% and reduction in Smoke, HC and NOx emissions. The DEE injection at inlet port with rubber seed oil as fuel to diesel engine showed significant improvement in BTE, combustion characteristics, smoke and other investigated parameters except for NOx [9]. The technology adopted [10] to enrich the oxygen content in the combustion chamber of a diesel engine showed significant improvement in BTE, BSFC and other emissions except for NOx which suggested for appropriate addressing. 100% Calophyllum inophyllum methyl ester as a fuel to a regular CI engine done at different injection timings and EGR rates found [11] that 10% EGR rate was optimal as it greatly reduced NOx emissions without any penalty on efficiency. Also, with the advancement of injection timing (IT) the BTE, BSFC, EGT and all other emissions improved significantly except NOx. Investigation [12] of a thermal barrier coated diesel engine with NiCrAl as lining layer fuelled by biodiesel produced from residual of cottonseed shows a partial increase in power, engine noise and NOx and a reduction in BSFC. Study [13] on EGR assisted CRDI (common rail direct injection) diesel engine fuelled by honge biodiesel at advanced injection timing showed an enhancement in BTE, peak pressure and heat release rate while the reduction in ignition delay, smoke and NOx. Investigation [14] done on EGR assisted thermal barrier coated (TBC) diesel engine fuelled by mahua oil methyl ester showed significant improvement in BTE, particulates, HC and NOx. Also, the optimal EGR rate found to be 10%. The low heat rejection engine made via different thermal barrier coating (TBC) materials and bond coats fuelled by biodiesels and crude vegetable oils showed improvement in BTE, BSFC, and emissions and also recommended for more investigations on LHR with novel modifications to explore its full potentiality [15]. The Low heat rejection engine developed [16] via Nickel alloy (superni) along with 3 mm air gap insulation fuelled by blends of crude jatropha and alcohols (ethanol and methanol) showed significant improvement in all the investigated parameters except formaldehyde and acetaldehyde emissions. At normal operating conditions, the LHR (semi adiabatic) diesel engine fuelled by Cottonseed, Neem and Kernel oil methyl esters showed a decrease in BTE and increase in BSFC and NOx for all the methyl esters [17]. The performance and emission characteristics of a partially stabilized zirconia (PSZ) coated diesel engine significantly improved with the blend of biodiesel and Cetane number enhancing additive [18]. The Rubber tree (Hevea brasiliensis) belongs to the family of euphorbiaceous. The rubber seed contains oil between 40% and 50% and the oil composition depends upon the area of source feedstock. The oil was non-edible [19]. In the current study, the general mechanical press technique was used to extract the crude oil from rubber seed. The crude rubber seed oil that has very high viscosity cannot be used directly as a fuel in CI engine because of a decrease in BTE with an increase in BSFC and NOx emissions. Hence the general chemical *trans*-esterification process was adopted to convert the crude rubber seed oil into fatty acid methyl ester (FAME) or biodiesel.

The available literature regarding TBC (Thermal barrier coatings) on vital diesel engine components like a piston, cylinder head and cylinder liner was only satisfactory and needs more investigation to explore it fully. Also, very few literature was available on exhaust gas recirculation (EGR) assistance to TBC diesel engine fuelled by 100% renewable fuel (rubber seed based biodiesel and DEE additive). Hence, an investigation was successfully done to full fill this gap. The additive diethyl ether (DEE) was blended at an optimal rate with rubber seed biodiesel to enhance its combustion, performance and emission characteristics as confirmed by literature. The novelty of the paper is an investigation of performance and emission characteristics of an EGR coupled TBC (8 YSZ) diesel engine fuelled by 100% renewable fuel blend at different SOI timing and loads.

2. Materials and method

2.1. Test fuels

The test fuels used in this investigation were diesel and blend A15B85 by vol. (Additive diethyl ether 15% + Rubber seed based biodiesel 85%). Due to its properties like high cetane number, excellent renewability and reasonable energy density the oxygenated additive Diethyl ether (DEE) was blended with rubber seed oil-based biodiesel at the optimal rate of 15% by vol. as it improves performance, combustion and emission characteristics of biodiesel. The significant properties of fuels are given in Table 1.

2.2. Making of semi adiabatic diesel Engine(SADE)

The optimum thickness of thermal barrier coatings on diesel engine components must be a maximum of 0.5 mm (500 μm). The application of bond coat NiCrAl (Ni 22%, Cr 11% and Al 67%) between the ceramic top coat and the substrate is to form a slow-growing protective oxide layer besides providing adhesion and also a better physical and chemical bond between the ceramic top coat and substrate [20,21]. The bond coat may also serve as a compliant layer (at high temperatures) which partially accommodates thermal stresses and offers better component life. The significant properties of 8 YSZ ceramic [22] were given in Table 2.

Please cite this article in press as: K. Vamsi Krishna et al., Investigation on performance and emission characteristics of EGR coupled semi adiabatic diesel engine fuelled by DEE blended rubber seed biodiesel, Eng. Sci. Tech., Int. J. (2018), https://doi.org/10.1016/j.jestch.2018.02.010