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Evaluation of endurance characteristics for a modified diesel engine runs on jatropha biodiesel

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HIGHLIGHTS

- Modification of engine parameters of diesel engine to suit B40.
- Combined effect of modification and B40 on wear after 512 h engine operation.
- Lower carbon deposits on engine components for B40 fuelled modified engine.
- Lower wear for piston and cylinder for B40.
- Modified engine can be successfully operated with B40.

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ABSTRACT

There is an imperative need to ensure biodiesel's long-term sustainability to fulfil the quest for renewable fuel resources. The technical problems which are correlated with the use of higher blends of fatty acids methyl esters in diesel engine need to be taken into account in order to avail the environmental and social advantages of biodiesel. The present 512 h long term endurance test performed with B40 (40% jatropha biodiesel + 60% diesel) fuelled modified engine has investigated the fundamental premise on the basis of the technical criteria of durability. Special focus has been given on certain phenomena that affect the engine utility life like lubricating oil dilution, deposits formation and oxidative stability. Experimental results indicated that modified engine can be successfully operated with B40.

1. Introduction

In many countries utilization of biodiesel as a partial substitute to diesel has been approved by the concern authorities due to its environmental and social advantages [1]. Many studies have been conducted with pure biodiesel and its blend which shows promising result for short duration experiments [2–5]. Though encouraging performance in short term operations, biodiesel contribute to several operating issues such as carbon deposition, engine oil dilution and its degradation, injector coking, fuel filter plugging and wear related concern, especially corrosive wear in long term tests [6,7]. It is commonly accepted that the formation of deposits around the injector may alter injection pattern and fuel flow rate inside combustion chamber which leads to deteriorations in overall system performance. The process of deposit formation is mainly influenced by fuel contaminants, reactive combustion products, soot and volatilized lubricating oil [8]. Agarwal et al. [9] have conducted 512 h long-term engine operations with B20 LOME (Linseed oil methyl ester). Lower carbon deposits were reported for B20 in comparison to that of diesel. Ku et al. [10] have reported that application of B5 resulted in less carbon deposit than that of diesel in a 500 h durability operation. In a recent study, Dhar and Agarwal [11] have reported higher carbon deposition for B20 karanja biodiesel in 250 h of engine operation. Liaquat et al. [12] have conducted 250 h long endurance test in a single-cylinder CI engine with B20 jatropha biodiesel and compared the results with diesel. Authors with the help of SEM (scanning electron microscopy) and EDX (energy dispersive X-ray spectroscopy) demonstrated that operation of engine with B20 resulted in higher carbon deposition. Further, nozzle holes were either covered or partially obstructed by the deposits for B20 operated engine. Ramadhas et al. [13] have conducted experiment on a four stroke direct injection single cylinder diesel engine fuelled with rubber seed oil and reported that the deposits on cylinder head were higher than that of diesel. Wander et al. [14] have also reported higher carbon deposition for SME

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Nomenclature

Abbreviations

AAS	atomic absorption spectroscopy
BD	biodiesel
BDC	bottom dead center
BSU	Bosch smoke unit
bTDC	before top dead center
BTE	brake thermal efficiency
BXX	XX% biodiesel in the blend
CA	crank angle
CO	carbon monoxide
CR	compression ratio
HC	hydrocarbon
ID	injection delay
IP	injection pressure
IT	injection timing
OMDC	modified condition
ORGC	original condition
SFC	specific fuel consumption
TDC	top dead center
ZDDP	zinc dialkyldithiophosphate
MDC	mid-stroke

(Soybean oil methyl ester) and CME (castor oil methyl esters) in a mono cylinder CI engine. While, another research has reported same level of carbon deposits on fuel injectors for both tested fuels; biodiesel (waste cooking oil) and diesel in a 7500 km field test in winter conditions [15]. Pehan et al. [16] also reported that carbon deposits in the combustion chambers of rapeseed biodiesel and diesel fuelled engines were similar. Similar finding was also reported by Dorado et al. [17] who have experimented with waste olive biodiesel in a direct-injection Perkins engine running in the range of 8–15 kW and 1800–2100 rpm. In another paper it was shown that carbon deposits particularly in combustion chamber is independent of the fuel used [16].

Wear measurement during long term endurance is typically divided into two parts. The first part consists of those components of engine where fuel itself provides necessary lubrication between mating parts to reduce friction and wear. In this case, inherent characteristics of fuel play dominating role for longer life of the components and smoother operation of engine. Wander et al. [14] have conducted 1000 h endurance test with SME 100, CME 100 and diesel separately and demonstrated higher wear of pressure valve seating. This is due to greater use of these components. Some corrosion marks were visible for SME 100. Other components were corroded and wear with normal rate. Pehan et al. [16] have used rapeseed oil biodiesel (B100) in a bus diesel engine for 500,000 km. The test results revealed no difference in pump plunger surface after the test. Surface measurement analysis exhibited little difference at skirt, however, significant differences were found at plunger head for biodiesel operated engine. Further, the impact of biodiesel on discharge coefficient was minimal. In another experiment conducted on Bosch fuel injection systems with ethanol–biodiesel–diesel blend and diesel, it was shown that both fuels produced a similar effect on the durability on the injection pump components and injector nozzle [18]. Celik and Aydin [19] have performed 200 h endurance tests on two similar engines fuelled with B100 and diesel to access the effects of biodiesel on the fuel injection system. It was demonstrated with the help of scanning electron microscopy (SEM) and energy-dispersive X-ray (EDX) analysis that significant structural changes occurred on the surfaces of the injector nozzle and pump piston for BD fuelled engine.

The parts which are lubricated mainly by lubricating oil fall in the second group. An overview of existing scenario indicates similar wear condition of lubrication regardless of fuel used. However, considering engine oil dilution and combustion characteristics, the effectiveness of lubricating oil becomes a function of used fuel. The life and performance of lubricating oil is significantly affected by the engine oil dilution, and addition of different impurities such as wear debris, carbonaceous materials and impurities entering along with intake air [20]. There is a consistent evidence of engine oil dilution for all fuels [14,21]. However, the intensity of dilution increased significantly with application of more viscous and less volatile fuels like biodiesel. Biodiesel upon injection into combustion chamber produces larger spray droplet than the diesel due to higher density, viscosity and surface tension, which in turn increases the spray length [22] and may impinge on cylinder wall [23]. Some of the impinging droplets may enter into the crankcase. Further, due to lower volatility biodiesel remains in the crankcase oil [24] causing increased lubricating oil dilution. Agarwal et al. [25] have reported degradation of lubricating oil with the use of biodiesel. It is commonly believed that the biodiesel if present in lubricating oil oxidizes and may leads to degradation of lube oil. It was shown that even presence of 5% biodiesel can cause oxidation and increased wear [26]. In this regard, Fang et al. [27] have reported that dilution with fresh biodiesel actually decreased wear. However, presence of oxidized biodiesel in lube oil severally affects its lubricating performance due to complex reaction between ZDDP and oxidized products. Further, increased in acidity is also reported in literatures [28]. In addition to this, presence of glycerine and water play significant role in assessing wear [29].

Okamoto et al. [30] have sown that operating DPF fitted engine with 10–20% rapeseed methyl ester (RME) employed with 10W-30 engine oil result in dilution of engine oil due to poor evaporation and accumulation of biodiesel leading to increased wear of piston top rings and cylinder liners. Further, drop in oil pressure was also observed which reduced the oil change interval to about a half of the diesel operated engine. Additional test with B10 employed with 15W-40 engine oil revealed increased total acid number (TAN) and lead elution. Agarwal et al. [9] have conducted 512 h endurance test and demonstrated with the help of AAS that utilization of B20 (LOME) resulted in lesser amount of metallic debris including Fe, Cu, Zn, Mg, Cr, Pb and Co. In another 512 h endurance experiments, two similar engines were fuelled with diesel and 20% blend of LOME. It was reported that operation with B20 LOME resulted in almost 30% lower wear than that of diesel [31]. Pandey and Nandgaonkar [32] conducted 100 h long term endurance tests on a Military 780 hp, CIDI engine operated with karanja oil methyl ester (KOME) and diesel fuel respectively. The results reveled with the help of atomic absorption spectroscopy that the wear of metals were approximately 30% lower for KOME fuelled engine due to inherent lubricity and higher viscosity of KOME. In another experiment the engine wear was measured when a military 585 kW CIDI engine was run for 100 h with diesel, Karanja oil biodiesel and JP-8 respectively. The wear was found to be lower for biodiesel [33]. A long-term 500 h full load durability operation with blended biodiesel (2% and 5%) by standard engine test has been evaluated. It was reported that tribological performance of the B5 biodiesel in terms of key components wear was slightly better than that of diesel [10]. Sinha and Agarwal [34] have conducted