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Bio fuels for compression ignition engine: A review on engine performance, emission and life cycle analysis

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ABSTRACT

As an alternative fuel for compression ignition engines, biofuels are in principal renewable and carbon unbiased. However, their use raises technical, economical and environmental issues. A complete technical review on the use of biofuel (pure oil/blend with diesel/blend with diesel in the presence of additives) in CI engines based on performance and emission comparisons with diesel fuel is carried out in this work. It is observed that biofuel seems to be a good option to substantially reduce environmental emissions. Although the majority of biofuels can be used in CI engine without any modifications, change in operating parameters (injection timing, injection pressure & compression ratio) is advisable for improvement in engine performance. Moreover, short run studies show that biofuels have great potential to replace conventional diesel fuel, the review suggests that biofuels produce a various problem when used for extended period of times. Especially, in this study particular attention is focused on the long run test (life cycle analysis) of CI engine fuelled with biofuels. The study suggests that use of biofuels produces various tribological issues on key components of CI engine. In the literature the tribological studies were discussed with atomic absorption spectroscopy, surface roughness analysis, wear analysis, close microscopic image analysis etc. of the CI engine components.

Contents

Abbreviation: AC, air cooled; B10, 10% biodiesel mix with diesel; B20, 20% biodiesel mix with diesel; B25, 25% biodiesel mix with diesel; B50, 50% biodiesel mix with diesel; B80, 80% biodiesel mix with diesel; B100, pure or 100% biodiesel; B20A4, 20% bio-diesel and 4% DEE mix with diesel; BP, break power; BSFC, break specific fuel consumption; BTDC, before top dead center; BTE, break thermal efficiency; CA, crank angle; CIDI, compression ignition direct injection; CO, carbon monoxide; CO_2, carbon dioxide; CR, compression ratio; DEE, Di-ethyl ether; DI, direct injection; DME, Di-methyl ether; E10, 10% ethanol mix with diesel; EGT, exhaust gas temperature; NOx, nitrogen oxide; PM, particulate matter; TDC, top dead center

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1. Introduction

The world's budget rest on the use of fossil fuel equivalent of approximate 94.67 million barrels of oil every day [1]. The consumption rate is equal to an annual burning of what environment takes around one million years to store as fossil deposits. The world at current is challenged with the twin crises of fossil fuel reduction and environmental degradation. Unselective extraction and excessive consumption of fossil fuels have led to decreasing in underground-based carbon capitals. The hunt for an alternative fuel, which assures a pleasant correlation with sustainable growth, energy conservation, management, efficiency, and ecological protection, has become extremely marked in the present framework. It is interesting to note that, more than 6.5 million diesel engines are existing in the Indian farming area for numerous activities. It is difficult to find a substitute for diesel engines and hence alternative fuels are being expeditiously required. As far as the application in agricultural areas of an emerging country like India is concerned, such internal combustion engines must preferably utilize alternative fuels of bio-origin, which are nearby existing. This permits the replacement of diesel fuel by plant oils, and for a short-range fuel as a mixture. Alternative fuels are usually mentioned as cleaner fuels in contrast with petrol or else diesel fuels. While using a different fuel, it is very vital to balance equilibrium among several conflicting constraints involving not only the performance and emission characteristics of the engine, but also the complete life of the system [2].

Amongst all the experiments done for the alternative fuels, it is observed that biodiesel, produced from renewable and often domestic sources, represents a more sustainable source of energy and will, therefore, play an increasingly significant role in providing the energy requirements for transportation. The majority of studies have shown that PM, CO2, unburned hydrocarbons and CO emissions for biodiesel are significantly reduced, compared with diesel. Also, experiments show that the use of bio-diesel favors to reduce carbon deposit and wear of the key engine parts, compared with diesel [2].

Although the combustion-related properties of plant oils are nearly diesel like, it is observed that the pure plant oils or their mixtures with diesel pose many long-standing problems in compression ignition engines, e.g., poor atomization characteristics, ring-sticking, injector-choking, injector deposits, injector pump disappointment, and lubricating oil thinning by crankcase polymerization. Such difficulties do not rise with short-range engine operations. Occasionally, the engine fails terribly, while operated on pure vegetable oils continuously for an extended period. The properties of plant oils such as high viscosity, low volatility, and polyunsaturated character are accountable for these difficulties. The deposits on the piston top are black, dense and hard, and at the edge, they seal the clearance in the top dead centre point so that they will polish the bore at every stroke. The main problem with using plant oil in engine operation is the deposits in the upper piston ring channel and on the piston ring. The piston ring becomes trapped in the channel thus weakening and lessening the engine performance, as the combustion becomes unpredictable. Additional problem is that the plant oil and gases leakage through clearance into the engine crankcase as the stabbing ring fails to seal adequately. As an outcome, it contaminates the lubrication oil, which leads to harsh, rubber-like covering on the engine parts and the walls of the case, the fuel pump, camshaft, and pushrods. The coverings on these parts can origin for trouble or even failure.

With above-mentioned reasons, it is essential to analyse life cycle of CI engine when fuelled with biofuels. According to ISO 14040.2 life cycle analysis is basically a systematic set of procedures for examining the engine conditions and durability throughout its life cycle when fuelled with alternative fuels or its blend with diesel. Although the life cycle analysis is costly and time-consuming, its results are far better to compare to short-term experiments.

The focus of the present study is to provide through a review on the use of biofuels – mainly biodiesel and other oxygenated fuels such as methanol, ethanol, diethyl ether etc – and its blends with conventional diesel fuel. The other objective is to review the status of the studies on life cycle analysis of the CI engine fuelled with biofuels or its blend with diesel. Previous reviews in this direction include Ramadhas et al. [3], Battacharyya and Reddy [4], Kowalewicz and Wojtyniak [5] and Hossain and Devies [6], however limited to performance and emission of engine or comparisons of properties of different biofuels and detailed discussion on life cycle analysis of engine (wear analysis) is literally absent.

2. Comparisons of physicochemical properties of biofuels

Numerous biofuels have been tried in CI engine till date. Properties of few such biofuels are shown in Table 1. Note that the biofuels are categorized as plant oils (see Sr. No 2 to 5 in Table 1) termed as "biodiesel" and other oxygenated fuels (see Sr. No 6–9 in Table 1) termed as "additives" hereafter. It is observed that the density and calorific value of all the biofuels are lower as

Table 1
Comparison of various physicochemical properties of bio fuels.

Sr No.	Fuel	Properties						
		Density (gm/cc) at 40 °C	Kinematic viscosity (mm^2/s)	Flash point (°C)	Calorific values	Oxygen content	Cetane No.	Ref
1	Diesel	0.830	1.3–4.1	57	42000	0	45	[8]
2	Jatropha bio diesel	0.855	1.9–6.1	100–170	34220	11	53	[7]
3	Karanjia bio diesel	0.797	7.0	97.8	37120	12	51	[9]
4	Neem bio diesel	0.61	5.96	110	38150	10	48	[10]
5	Linseed bio diesel	0.880	3.32	196	37251	–	45	[11]
6	Diethyl ether	0.704	0.23	35	26589	21	> 125	[7]
7	Dimethyl ether	0.67	1.84	41	28882	34	> 55	[12]
8	Ethanol	0.789	0.7893	74.4	26900	34.8	54	[13]
9	Methanol	0.792	0.5990	64.9	20000	49.9	50	[13]