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Effect of Di-Tertiary Butyl Peroxide on the performance, combustion and emission characteristics of ethanol blended cotton seed methyl ester fuelled automotive diesel engine

K. Senthil Kumar, R. Thundil Karuppa Raj *

School of Mechanical Engineering, VIT University, Vellore 632014, Tamil Nadu, India

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ABSTRACT

An experimental study is carried out to examine and analyze the influence of Di-Tertiary Butyl Peroxide in bioethanol diesel blends on the performance, combustion and emission characteristics in a single cylinder, 4-stroke, naturally aspirated, automotive diesel engine for variable speed at full load conditions. Esterified cotton seed oil of 5% by volume is emulsified with 95% pure diesel to get the base fuel (BE0) for the experiments. Bioethanol diesel blends are produced from base fuel by adding 5% and 10% pure ethanol on a volumetric basis to obtain BE5 and BE10 respectively. The bioethanol fuels are low in Cetane number and hence Di-Tertiary Butyl Peroxide a Cetane enhancer is added by 0.4% by volume to produce BE5CN0.4% and BE10CN0.4% emulsions respectively. It is found from the experiments carried out, that an inverse trend exists between brake thermal efficiency and percentage of ethanol in base fuel. This is due to the lower calorific value of ethanol and an improvement in brake thermal efficiency is observed with ignition improver added blends. The presence of Cetane improver significantly reduced oxides of nitrogen and unburned hydro carbon emissions for overall engine speed and carbon monoxide emissions for low to medium speed range.

1. Introduction

Many of the recent attempts are encouraging the alternate fuels in diesel engines than gasoline engines because they are more durable, possess high fuel economy resulting from higher volumetric and thermal efficiency and are more suitable for inland transportations, power source for household, commercial and industrial power plants. The need for alternate fuels in internal combustion engines throughout the globe is realized for the past few decades due to exponential decrease in fossil fuel reserves, global warming that leads to stringent emissions norms and moreover the conventional fossil fuels are less economical in nature. Bioethanol is considered as one of the targeted potential alternate fuel for internal combustion engines in many of the developing countries including India. It can be produced in large scale from the grown energy crops, such as corn, maize, sugarcane molasses and agricultural wastes which are largely available [1]. It is found that even though the physical and chemical properties of ethyl alcohol fuel are more suitable and compatible with gasoline engines, majority of the researchers have turned towards diesel engines with a scope to reduce emissions for transport and generator power plant applications. Generally diesel engines are more prone to produce large quantity of oxides of nitrogen and particulate matter [2,3]. Rakopoulos et al. [4] had studied the effect of blending 5% and 10% ethanol by volume to base diesel and analyzed the performance and emission characteristics of ethanol blended diesel fuels to that of base diesel. They concluded that up to 10% of ethanol could be blended in existing diesel engine without much sacrifice in engine power and efficiency. They also reported that NOx emissions remains almost the same, CO reduced and hydrocarbon emissions slightly increased with blending of ethanol to base diesel. Li et al. [5] had studied the performance and emission characteristics of diesel blended with 5%, 10% 15% and 20% of ethanol by volume. They reported an increase in brake specific fuel consumption and brake thermal efficiency with increase in ethanol content in the blended fuel. They also concluded that smoke, NO_X and CO emission gets reduced while total hydrocarbons increased with increase in ethanol in the diesel blends.

It is well known fact that diesel engines are one of the major contributors to the environmental pollutants such as greenhouse gases, NOx and soot particles which are the main sources for photo chemical contamination and acid rains [6,7]. These emissions are subject to stringent environmental legislation and the control of

* Corresponding author.
E-mail address: thundilr@gmail.com (R.T.K. Raj).

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Nomenclature

bTDC	before top dead centre	BTE	brake thermal efficiency
BE0	5% esterified cotton seed oil + 95% diesel - base fuel	CO	carbon monoxide
BE5	base fuel with 5% ethanol	DEBSFC	diesel equivalent brake specific fuel consumption
BE10	base fuel with 10% ethanol	DEBTE	diesel equivalent brake thermal efficiency
BE5CN0.4%	Cetane improver 0.4% added base fuel + 5% ethanol	DTBP	Di-Tertiary Butyl Peroxide
BE10CN0.4%	Cetane improver 0.4% added base fuel + 10% ethanol	HRR	heat release rate
BP	brake power	NOx	oxides of nitrogen
BSFC	brake specific fuel consumption	ppm	parts per million
BT	brake torque	UHC	unburned hydrocarbon

these pollutant emissions cannot be achieved with the help of engine design alone. The pollutant formation can be controlled at combustion phase by altering the properties of fuel injected in the engine cylinder. On the other hand still diesel engines are in place due to their higher combustion efficiency, reliable operation, compliance, low maintenance and cost effective. Moreover the need for alternate source of energy to fossil fuels is the need of the day to meet the ever growing energy demand raised across the globe. In this pursuit, Shahir et al. [8] had analyzed the blending of ethanol to neat diesel in various proportions as an alternative to the existing fossil fuels. The limitation with ethanol-diesel blend is that, it possesses lower Cetane number than neat diesel and thus they are highly unstable. In this regard, they recommended adding biodiesel which could improve the physiochemical properties of the resultant blend making it highly stable, thus increasing the engine efficiency and make the engine suitable for accepting and enhancing the renewable portion namely the ethanol fuel. Ajav et al. [9] had carried out blending of ethanol in a volumetric ratio of 5%, 10%, 15% and 20% to that of neat diesel. They reported that the brake specific fuel consumption increased up to 9% for 20% blending of ethanol to diesel fuel. They also found that the exhaust gas temperature, lubricating oil temperature and emissions of ethanol blended diesel fuel were relatively lesser when compared to engine fuelled with neat diesel. Mofijur et al. [10] had recently critically reviewed the usage of diesel biodiesel blends (binary blends) and ethanol biodiesel diesel blends (ternary blends) as alternative fuel for neat diesel. They reported that both binary and ternary blends could reduce the carbon monoxide and hydrocarbon emissions to a larger extent. They concluded that a combination of 5–10% of ethanol, 20–25% biodiesel could be blended with diesel fuel in reducing the emissions and improving the usage of renewable source of energy for domestic and commercial applications.

The chemical structure of diesel fuel possesses a unique characteristic and improves the self-ignition property under certain standard working conditions. This unique characteristic is defined by an index known as the Cetane number, which is established for the diesel fuel in a standard Cooperative Fuel Research Committee (CFR) engine employing ASTM D 613 standard [11,12].

Diesel engines have a higher Cetane number and it directly influences the thermal efficiency and engine exhaust. With the addition of ethanol, this Cetane number decreases and makes the combustion highly unstable. Thus increasing the cetane number is the most widely accepted alternate for significant reduction of regulated emissions in diesel fuelled engine. Improving the cetane number of diesel fuel can be attained by either limiting aromatic content of the fuel through hydro-treating or by addition of chemical cetane improvers. These chemical cetane improvers promote the rate of initiation to form free radicals. This higher rate of chain initiation leads to improved ignition quality of diesel fuel. Cetane improvers can be derived from alkyl nitrates, peroxides, tetrazoles and thioaldihydes [10]. One of the very promising cetane enhancer is DTBP which does not possess any nitrogen compound in its chemical structure and hence DTBP has potential advantage over alkyl nitrates in reducing NOx emissions.

Ferreira et al. [13] had analyzed the impact of ethanol blending to a mixture of diesel-biodiesel blend in a stationary diesel engine running at 1800 rpm for five different compositions with DTBP as cetane enhancer. The fifth composition had 15% ethanol, 0.4% DTBP and remaining being diesel-biodiesel blends. They reported that the usage of ethanol reduces the NO_X emissions, whereas the CO and HC increase with a slight reduction in engine efficiency. They also observed with the introduction of DTBP the CO and HC emissions had decreased to a significant level. They proved that introduction of ethanol is an effective method of reducing NO_X emissions in case of diesel engines operated with diesel-biodiesel blends. Vallinayagam et al. [14] had investigated the blending of 50% pine oil to neat diesel fuel and performed the performance, combustion and emission characteristics on a single cylinder diesel engine. The experimental studies showed significant reduction in CO and HC whereas NO_X emissions had shown a notable increase. Two ignition promoters Iso-Amyl Nitrate (IAN) and DTBP were added to the biodiesel blend and the NO_X emissions were observed. It was found that the NO_X emissions decrease by 12.8% for IAN and by 19.2% for DTBP cetane enhancers and suggested that DTBP is the pertinent cetane improver for pine biodiesel blends. Recently Imdadul et al. [15] had carried an extensive research work in blending pentanol a long chain hydrocarbon with five carbons to conventional diesel in the presence of Calophyllum inophyllum methyl ester on a variable speed diesel engine. They found that the brake thermal efficiency and brake power greatly improved when pentanol in added to Calophyllum inophyllum biodiesel blends compared to normal Calophyllum inophyllum biodiesel blends. The specific fuel consumption also greatly decreased with increases in percentage of pentanol in the biodiesel. NOx emissions increases by 4.4% on an average over the entire speed range with inclusion of pentanol whereas hydrocarbons, CO and CO_2 emissions has decreased to a great extent. Imdadul et al. [16] had extended their research work by introducing a cetane enhancer 2-ethyl hexyl nitrate [EHN] to the pentanol blended Calophyllum inophyllum biodiesel blends and investigated its influence on the performance, emission and combustion characteristics on a variable speed diesel engine. The thermal stability of the alcohol blended biodiesel blend greatly improved with the introduction of EHN. The brake power increases and specific fuel consumption gets decreased with the addition of EHN to the propanol blended biodiesel.

Labeckas et al. [17] had reported phase separation when ethanol of 5%, 10% and 15% ethanol by volume is blended with conventional diesel. Hence they made use of rapeseed methyl ester a biodiesel by 5% is blended to the above mixture to overcome the phase separation issues on a variable speed naturally aspirated diesel engine. They studied the influence of air-fuel ratio (λ) in the range of 5.5, 3.0 and 1.5 on a variable speed diesel engine. They