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Experimental study on the effect of cetane improver with turpentine oil on CI engine characteristics

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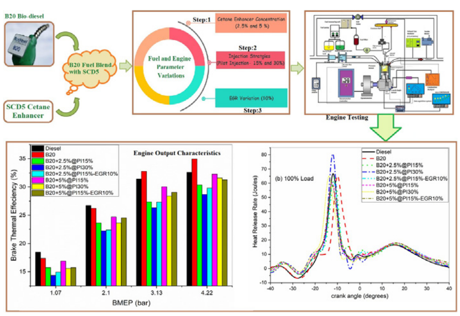
GRAPHICAL ABSTRACT



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ABSTRACT

The Turpentine oil has getting wider attention in recent times due to many significant benefits. In this present study, 20% Turpentine oil has been blended with 80% diesel fuel by volume. A novel cetane improver called SC5D has been doped with 20% biofuel at 2.5% and 5% concentrations. All the properties of all the blends are evaluated and it has been identified that the 5% of cetane improver has increases the fuel density. All the fuel samples have been tested in a single cylinder CRDI diesel engine under different pilot injection rate of 15% and 30% at 600 bar injection pressure. For the higher NOx emission condition, the 10% EGR has also been applied. The experimental study revealed that the addition of cetane improver with biofuel blends has shown comparable performance behaviours at all concentrations. Furthermore, the unburned hydrocarbon and smoke emissions are remarkably lower for biofuel blends at both the injection rate with cetane improver addition. Significant reductions has been noticed by 10% EGR addition for PI15% rate at 2.5% and 5% concentrations without much defect in other emissions. All the combustion behaviours have shown comparable behaviours with cetane improver addition and 10% EGR implementation with biofuel blends. Therefore, it can be concluded that the novel cetane improver could be used as additive with Turpentine oil in diesel engine applications.

Abbreviations: CI, Compression Ignition; BTE, Brake Thermal Efficiency; CRDI, Common Rail Direct Injection; BSFC, Brake Specific Fuel Consumption; BSEC, Brake Specific Energy Consumption; CO, Carbon monoxide; EGR, Exhaust Gas Recirculation; CHRR, Cumulative Heat Release Rate; HC, Hydrocarbons; ECU, Electronic Control Unit; HRR, Heat Release Rate; MFB, Mass fraction burnt; NOx, Oxides of nitrogen; TPO, Turpentine Oil; BP, Brake power; PM, Particulate Matter; PI, Pilot injection; B20, 80% of diesel + 20% of TPO; IP, Indicated pressure; CD, Combustion delay; ID, Ignition delay

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1. Introduction

Today even with so much development in the area of renewable energy, still most of the automotive sectors are dependent on fossil fuels. With the ever-increasing population of the world, the utilization of energy in transportation has multiplied in the past three decades, and it is relied upon to be multiplied in the following thirty years [1]. This dependency is only increasing while the source is becoming scarcer. The problem is not just the scarcity even the emissions produced by the fossil fuels upon combustion like oxides of carbon and nitrogen are toxic, harmful and responsible for major climatic anomalies [2]. Biofuels are the renewable fuels which can be utilized in a certain quantity with petroleum products so that the harmful emissions could be greatly reduced [3]. In recent times, the direct production of renewable biofuels from various parts of the plants, waste resources and from other biological resources seem to be more attractive than the esterified biodiesel from different form of edible and non-edible oils [4]. Many renewable biofuels like lemon peel oil, lemon gross oil, pine oil, orange peel oil have low viscosity, inherent oxygen content and low flash point and comparable heating value compared to diesel fuel [5]. However, the calorific values of these kinds of biofuels are extremely lower than diesel which makes them unsuitable for complete replacement of diesel fuel [6]. Significant feasibility studies of these light viscous biofuels have been evident that all these biofuels showed remarkable improvement in diesel engine behaviours [7]. Ashok et al. [8] have made an comparative analysis on two biofuel blends in diesel engine performance characteristics. They have pointed out that the both the biofuels have produced much improved performance with remarkable benefits in engine emissions. However, this biofuels could not control the oxides of nitrogen emission (NOx) due to longer delay period that has enhanced by their poor ignition quality.

Among the available biofuel, Turpentine oil is one of the renewable biofuel and it has been widely used as solvent in medical applications. This biofuel would be prepared from pine trees through steam distillation process and pyrolysis process. It had been used as fuel in many thermal systems in the early 1700s around the globe. Anand et al. [9] have reported that the Turpentine oil has better miscible property in diesel and this quality had not witnessed in other biofuels. Physically it looks yellow, obscure, dull, foul, water-immiscible fluid. Artificially, turpentine is inflammable, volatile and ignitable; and possesses 40% by weight of alpha-pinene. It is composed of 52–64% gamma–pinene alongside beta-pinene and other isometric terpenes [10]. There are considerable research works that have been carried on the turpentine as alternate fuels in CI engine applications. Anand et al. [11] have examined the suitability of Turpentine oil as fuel in a diesel engine as fuel through 50% volume addition with diesel. They have stated that the diesel engine fuelled with 30% Turpentine oil–70% diesel has increased the power output and heat release rate and the results are reversed by concentration of biofuel in the blend. Interestingly, all the Turpentine oil blends have shown remarkable reductions in carbon monoxide (CO), unburned hydrocarbon (UBHC) and smoke emissions. The reasons for this behaviour are due to the significant reduction in heating value of the blend. Karthikeyan and Mahalakshmi [12] used the Turpentine oil as fuel in dual fuel mode in a specially designed diesel engine. They have pointed out that the diesel engine performance was in better form upto 75% loading condition and afterwards, the results are not within satisfied limit. The experimental study has revealed that around 75% of diesel fuel replacement is quite achievable with minor modifications. Dubey and Gupta [13] used a blend of turpentine and Jathropa biodiesel to completely replace diesel in a CI diesel engine without any alterations. All the performance characteristics at different blend ratios showed improvement; also, emissions like NOx and CO were reduced at 50% blend ratio (BT50). This was mainly because of lesser burning time and increased ignition delay. Moreover, during full load it was observed that HC and smoke emissions reduced by 4.56% and 29.16% respectively, while CO_2 emission is increased by 10.5%. In another investigation, the 40% of pure Turpentine oil has been blend with diesel for diesel engine operation and results are revealed that brake thermal efficiency was better than diesel fuel by 2.5% without deteriorating emission behaviours [14].

From the above discussed technical literature, it was clearly evident that the Turpentine oil was suitable for partial replacement of diesel fuel due to its lower cetane number. Therefore, in many research works, the NOx emission was remarkably higher during biofuel blends operation. The autoigntion ability of Turpentine oil can be improved by the addition of suitable cetane improvers in a small quantity. Many cetane improvers' additives have been used by the researchers like alkyl-nitrates, 2-eth-ylhexyl nitrate (EHN) in recent times for the improvement auto ignition quality of diesel and other biofuels [15]. Imdadul et al. [16] investigated performance and emission of n-butanol and diesel blends with 2- EHN as cetane improver. Reduced NOx emissions and increased BTE were observed by adding EHN to the blend, this was because of the free radicals in the combustion chamber that are provided by EHN, they speed up the oxidation process, reducing the ignition delay hence improved combustion. Mustafa [17] investigated the performance and emission characteristics for biodiesel fuelled, zirconia coated diesel engine mixed with cetane enhancing additive Di-*tert*-butyl peroxide (DTBP). The biodiesel used was prepared from palm oil and the additive was added 1% by volume. Significant reduction in NOx and CO levels was noted for the sample with additive because of large oxygen content of bio diesel and reduced ignition delay due to high cetane number of the additive. Very recently, Karthikeyan [18] evaluated the impact of Progallol cetane enhancer with Morginga Oleifera oil biodiesel. The study revealed that the brake thermal efficiency has improved upto 28.1% with reduction in brake specific fuel consumption (BSFC) at all concentrations. Rajkumar et al. [19] worked on experimental investigation of polymer based additive called SC5D that is mixed in different proportions with B15 (15% of Mamey Sapote oil + 85% of diesel) bio diesel in a variable compression ration CI engine. It has been noted that the BTE of B15 blend has been increased by 4.16% during 3 ml SC5D cetane improver addition. Furthermore, the CO, HC and smoke emissions are decreased by 10%, 16% and 11.12% respectively at same operating conditions.

From the in-depth cited technical literatures, it has been noticed that the Turpentine could be a viable alternative fuel for diesel engine applications. All the previous studies have resulted in much improved performance when the Turpentine oil has been used upto 30% and after that the reverse results are witnessed. This is mainly because of lower cetane number of Turpentine oil which prevents them to use it for higher concentration with diesel fuel. Furthermore, many cetane improvers have been used by the researchers recently with diesel or biodiesel or any biofuel at small fractions and these have shown much better performance in a diesel engine without major modifications. Notably, only one technical study on SC5D diesel additive biodiesel blend is available and there is no other technical literature on SC5D cetane improver additive with any other low viscous biofuel. In particular, no technical reports on fuel injection variation for Turpentine oil blend with cetane improver. Therefore, in this present study, an impact of SC5D cetane improver additive with 20% Turpentine oil–80% diesel at 2.5% and 5% concentrations on common rail direct injection diesel engine characteristics. All the biofuel blends have been tested at two different pilot injection rates under variable loading conditions. The experimental results are compared to conventional diesel fuel. During experimental works, the NOx emission has been continuously monitored and 10% exhaust gas recirculation is applied for which the fuel sample produced higher NOx emission.

2. Material and methods

This chapter focuses on the production of Turpentine oil and biofuels blends preparation methods. In this work, the newly obtained cetane improver SC5D has been used as additive with 20% of