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Optimisation of operating parameters of DI-CI engine fueled with second generation Bio-fuel and development of ANN based prediction model

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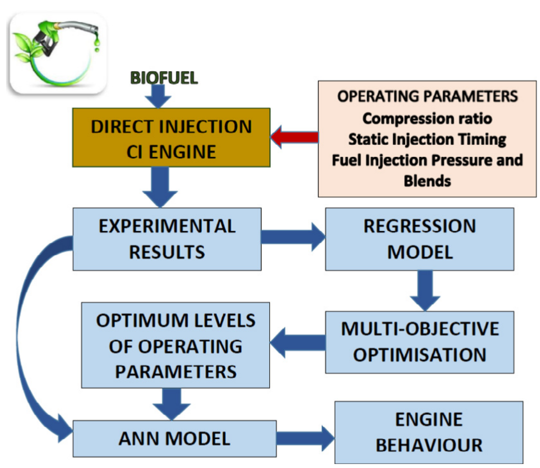
HIGHLIGHTS

- Engine output at different compression ratio, injection timing/pressure, blends.
- Blends of Biodiesel and Diesel used are B0, B20, B40, B60, B80, and pure Biodiesel.
- Multi-objective optimisation conducted based on Genetic Algorithm.
- Optimal values of compression ratio, injection timing/pressure, blends are found.
- ANN model is developed to predict the performance and emissions.

GRAPHICAL ABSTRACT



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ABSTRACT

Honne oil methyl ester which is derived from non-edible Honneoil was blended with petroleum diesel fuel and tested on the DI-CI engine. The experiments were conducted at different levels of operating parameters, viz. compression ratio, static injection timing, fuel injection pressure, load and blend. This study aims to determine optimal combination of engine operating parameters with objective of attaining better performance and lower emission. The multi-objective optimisation based on Genetic algorithm is performed which lead to multi pareto optimal solution.

The performance parameters were BSEC, BTE and EGT. The emittants were CO_2, CO, HC, NO_X and smoke. The regression models for performance parameters and emittants as a function of the operating parameters are developed using Minitab. These models were used as a fitness function for optimisation.

ANN model based on multi-layer perception was developed to predict the performance and emissions using the experimental data. Four different transfer functions were tried to develop the model and one which yields lowest mean absolute percentage error and highest prediction accuracy is chosen. Preprocessing of data is done by normalizing input data and logarithmic transformation of target data. Levenberg-Marqardt back propagation training algorithm trainlm is used with feed forward multi layer neural network.

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Nomenclature

HnOME	Honne oil methyl esters
B20	20% HnOME and 80% mineral diesel by volume
BTE	brake thermal efficiency
BSFC	brake specific fuel consumption
HSU	hartridge smoke unit
EGT	exhaust gas temperature
BSEC	brake specific energy consumption
GA	genetic algorithm
MAPE	mean absolute percentage error
CR	compression ratio
MSE	mean square error
HC	unburned hydrocarbon
CO	carbon monoxide
CO_2	carbon dioxide
NO_X	oxides of nitrogen
CI	compression ignition
VCR	variable compression ratio
DI	direct injection
ANN	artificial neural network
SIT	static injection timing
FIP	fuel injection pressure
bTDC	before top dead center

1. Introduction

Diesel engines are widely used in automobiles and power generation sectors owing to their better fuel efficiency and performance. Growing world population in addition to increasing energy consumption, dependence on foreign fuel and global warming offers a prospect for the use of biodiesel [1,2] in Diesel engines as an alternative fuel derived from regionally available oil feed stock. In order to avoid greenhouse gas release, Kyoto Protocol was endorsed by European Union [3] along with emphasizing the need of possible technological innovations in 2002, unfortunately which is not yet accomplished [4]. The amount of Carbon Dioxide in the environment has already exceeded the allowable limits 10 years earlier than the forecast [5].

By 2030, the fuel consumption and also the harmful emission of automobile vehicles are forecasted of reaching eightieth times higher than the amount of 2007 [6]. Moreover, automobile vehicles are largely relying on petroleum based fuels such as gasoline and diesel. Hence as an alternative to these fossil fuels, exploration of a renewable fuel which can retain its properties for a longer term is utmost necessary [7,8]. So, Biodiesel has been becoming a center of attraction worldwide and rising as another alternative to traditional fuel. Bio-diesel can be used in engine by blending it with conventional Diesel in specific proportion without making any major hardware modification of engine. It can be produced from various crops and its advantages over fossil fuels are non-toxic, eco-friendly, sulfur-free and renewable in nature. Its thermos physical properties and fuel rating are comparable to conventional fuel with abundant oxygen [6]. However, some of its properties like higher density and viscosity cause issues like injector choking, cylinder liner deposits, piston ring sticking [7]. Overall, it delivers comparable power output and thermal efficiency. Presently 95% of world biodiesel is extracted from edible oils that is easily obtainable on an enormous level from the agricultural sector. Biofuel created from edible oil sources such sunflower, Soybean, Peanut, Palm, Cotton seed, Linseed, Sesame, Corn etc., is termed first generation biodiesel [3]. But due to consumption of edible oil for domestic use, it is not appropriate source or feedstock for the producing biofuels [7,9]. So use of non-edible oils for making biofuel would be a better substitute which reduces dependence on the edible oil. Therefore, a lot of effort is needed to be focused on using non-edible oil seeds like Jatropha, Karanja, Calophyllum inophyllum, etc., for developing potential feedstock for biodiesel [10]. The bio fuel technologies report [10] established that 1st generation bio diesels based on edible oils are inadequate in their ability to contribute for economic growth, global warming alleviation and as an alternative to conventional diesel. As a result, there's a requirement to cultivate technologies for extracting biodiesel from feed stocks of non-edible oil to avoid limitations of 1st generation biodiesels. The biodiesels extracted from non-edible oil sources are classified under second generation bio diesels [10]. Solely few non-edible oils extracts are used by researchers on IC engines. Thus, there's wide opportunity of research in the area of using non-edible oil based biofuels. The current potential for non-edible oils are Calophyllum inophyllum (Honne), Karanja, Jetropha, Rubberseed, rapeseed.

In the present work, the non-edible Honne oil which is derived from Honne seeds is transesterified with Methyl alcohol and converted into biodiesel. So, it is called as Honne oil methyl ester (HnOME). The HnOME was tested on the DI-CI VCR engine of Kirloskar make. It has the provision to change compression ratio in the range of 12–18. The experiments were conducted on the engine at predetermined levels of operating parameters, viz. compression ratio (CR), static injection timing (SIT), and fuel injection pressure (FIP). The blends of HnOME and conventional Diesel fuel used as a fuel wereB20, B40, B60 and B80. Blend B20 means mixture of 20% HnOME and 80% Diesel by volume. Also, pure HnOME and Diesel was used to run the engine. Experiments were conducted by loading through dynamometer over a span of 0–12 kgin steps of 3 kg. The CR was varied from 15 to 18 in steps of 1. The FIP was varied over a range of 180–240 bar with increment of 30 bar. The SIT was changed over a span of 19–27° bTDC with increment of 4°. Experiments are conducted by varying one parameter at a time and keeping two other engine parameters unchanged. The one of the primary objective of the experimentation is to acknowledge the various effect of the above mentioned operating parameters and blends on the performance and exhaust emission of the engine. The authors already [40–43] presented the effect of these operating parameters on the exhaust emission and performance. The performance parameters considered were brake specific energy consumption (BSEC), brake thermal efficiency (BTE) and exhaust gas temperature (EGT). The emittants considered were carbon dioxide (CO_2), carbon monoxide (CO), unburnt hydrocarbon (HC), nitric oxides (NO_X) and smoke intensity which was measured in Hartridge smoke unit (HSU). Then the optimal levels of the operating parameters and HnOME blends were determined corresponding to better performance and lower emissions.

Several researchers [11–19] investigated the emission characteristics and performance of engine using various types of Biodiesels by changing speed, load, compression ratio, fuel injection pressure, static injection timing and blend ratios. There results showed that with increase in concentration of biodiesel in the blend, increases both BSFC and NOx emission, whereas emissions of CO, HC, smoke reduces.

The dual objectives of attaining lower exhaust emissions and better engine performance are both conflicting in nature. As