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Modelling of Engine Performance Fuelled with Second Generation Biodiesel

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Abstract

Increasing interest in diesel engine technology and the continuous demand of finding alternative sustainable fuels as well as reducing emissions has motivated over the years for the development of numerical models, to provide qualitatively predictive tools for the designers. Among the alternative fuels, biodiesel especially second generation biodiesel is considered as a sustainable and the most promising option for diesel engine. In this study an engine combustion model has been developed using computational fluid dynamics (CFD) software, AVL Fire, which can predict the engine performance, and emission characteristics for second generation biodiesel produced from Australian native beauty leaf seed (BLS). This model involves simulation of fuel atomization, burning velocity, combustion duration, and temperature and pressure development in a combustion chamber. The model has been developed for petroleum diesel (normal diesel used in automobiles), 5% BLS biodiesel (B5) and 10% BLS biodiesel (B10) for different injection timings and compression ratios. The simulation results revealed that overall B10 biodiesel provides better performance and efficiency, and significantly reduced engine emissions. On the other hand, the B5 blend provides slightly improved performance and efficiency, and moderately reduced emissions compared to petroleum diesel.
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Keywords: Second generation biodiesel; CFD model development; internal combustion engine performance and emission.

1. Introduction

In recent times there is an extensive focus on developing sustainable energy supply options and reducing the global reliance on non-renewable fossil fuels with finite reserves, as well as reducing the effects energy production has on global warming, largely related to the burning of these fossil fuels. The transport industry relies very heavily

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on the use of oil, and in particular the oil derived fuel diesel, used in a large number of trucks, buses, trains and ships as well as an ever growing number of cars. It is essential that a sustainable alternative fuel source is to be developed to reduce the global dependence on oil, particularly as cheap and reliable oil supplies are reducing. Second generation biodiesel is a significant step forward in the quest to develop a sustainable alternative fuel source [1]. It can be used in unmodified diesel engines; it has been shown to substantially reduce exhaust emissions of carbon monoxide, carbon dioxide, hydrocarbons and particulate matter [2-5], so it is good for the environment. It could have a number of economic benefits through increasing the stability of Australia's fuel market, creating new industries and jobs in both refineries and agriculture, without impacting significantly on food supplies.

The second generation biodiesels are mainly produced from non-edible oils [6, 7], and sometimes produced from waste or recycled oil and animal fats [8-10]. The biodiesel produced from non-edible oil has gained the attention due to the problems associated with food versus fuel, environmental and economic issues related to edible oils [11]. Moreover, non-edible vegetable oils are considered over the edible vegetable oils due to its low feedstock cost [11-13]. Unlike first generation biodiesels, this means they have minimal or no impact on food supply or food prices [6, 7]. The Australian BLS (*Calophyllum inophyllum*) has a high potential for large scale second generation biodiesel production as it can tolerate harsh environmental conditions such as drought, salinity, acidity and a large range of temperature, requires little maintenance, is non-edible, has a large yield of fruit of around 3,000-10,000 seeds/tree/year and has high kernel oil of around 65%. The wild tree lives for up to 200 years, producing fruit twice a year. The BLS is estimated to be able to produce up to 4,000 litres of oil per hectare per year [14, 15].

Modern diesel engines can run on biodiesel and biodiesel blends with no modifications, however the performance, efficiency and emissions can all be optimized by making adjustments within the engine. There are a range of different parameters that can be adjusted to optimize the compression ignition (CI) engine running on biodiesel, including fuel injection timing, injection pressure, air-fuel ratio, crank angle and combustion chamber geometry such as piston, piston ring, cylinder head, inlet and outlet valve. Some recent studies [16-22] have investigated the performance and emission characteristics of biodiesel engines at different engine speeds, loads and biodiesel ratios. These results indicated that the engine performance is sensitively affected by the ratio of biodiesel in the fuel. Nevertheless, there is no shortcut way to determine the optimal biodiesel ratio because the factors (e.g., fuel cost and amount of exhaust emissions) are opposing each other [1]. It is the only way to determine the optimal biodiesel ratio by conducting numerous experiments on a dynamometer subject to the user's requirements. Therefore, creating a computational model for biodiesel engines may be the best solution to the above abridgement because the optimal biodiesel ratio can then be determined by applying computer-aided optimization method to the engine model. However, the main aim of this study is to develop a combustion model to maximize the combustion performance of an automobile engine fuelled with second generation biodiesel produced from BLS. The computational fluid dynamics (CFD) model for the turbulent combustion of biodiesel in an internal combustion engine will allow a range of benefits to be evaluated and be a guide for engine manufacturers, biodiesel producers, biodiesel users and policy makers. Some of these benefits include improving internal combustion engine technology, reducing harmful gas emissions, and increasing fuel efficiency, sustainability and optimum uses of second generation biodiesel as engine fuel.

2. Engine Specifications

The diesel engine is the most efficient of all current types of internal combustion engines, with a higher thermal efficiency and lower specific fuel consumption due to the high compression ratio used. The diesel engine that was used in this study for modelling is a Kubota V3300 that utilizes four cylinders, natural aspiration, indirect injection and compression ignition. The engine's technical specifications include a displacement volume of 3318 cc, a bore of 98 mm and stroke of 110 mm and a compression ratio of 22.6:1. The engine coupled to an eddy-current dynamometer, located at the thermodynamics laboratory of Central Queensland University (Australia) is shown in Fig. 1.

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