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Numerical modelling of biodiesel blends in a diesel engine

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Abstract

Biodiesel is a biofuel which has similar properties to diesel and can readily be used in a diesel engine with minimal modifications. Promising results have been determined using mixtures of biodiesel and diesel with the reduction of soot and emissions of a diesel engine. Experimental analysis of diesel engines can be expensive and therefore Computation Fluid Dynamics programs are used to analyses the combustion process. The AVL Fire ESED program is currently being employed to investigate the effects of biodiesel on the diesel engines soot, emissions and power generation from a Cummins ISBE220 engine. Investigation is performed on pre and post injection-rate shapes on the combustion process establishing the results correlate accurately with researched data. A pre injection was determined to increase maximum power, reduce combustion generated noise, increase early in cylinder temperature and reduce fuel consumption due to the increase in power. A post injection was verified to reduce soot emissions while increasing NO_x emissions marginally. The investigation of the injection-rate shape established the soot- NO_x trade-off which was also found in the research. The models developed were agreeable with biodiesel data with percentage error in indicated power ranging from 1.62-8.85%. The models suggested that biodiesel assists in reducing NO_x and soot emissions. The soot- NO_x trade-off was further investigated determining the theory that then by reducing the combustion temperature in the combustion chamber the NO_x emissions can be reduced while increasing soot emissions. By increasing the temperature in the combustion chamber the opposite effect was found to occur.

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Keywords: Biodiesel; CFD; multiple injection, injection-rate shape; NO_x emission; soot.

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1. Introduction

Biofuels are renewable fuels sources which are manufactured by various crops and waste oils. Alcoholic fuels such as ethanol and methanol are quite stable however have restricted use in compression ignition engines due to the low cetane number and low lubricative properties required. Capacities of up to 20% of ethanol-diesel blends have been analysed with promising results in reduction of CO_2 and NOx emissions [1]. Other methods of injecting such as fumigation and duel injection can increase this capacity. Additional fuels such as biodiesel are manufactured from waste oils and various crops. Biodiesel has high oxidation properties and when exposed to air for long periods of time can deteriorate. Biodiesel possesses similar properties to petroleum diesel fuels and therefore 100% biodiesel blends can be utilized in a compression ignition engine, also with promising results [2].

Commercialisation of biofuels would allow engine manufacturers to meet emission requirements set by the government. Energy production would be cleaner, reducing global warming and climate change. The economy would be assisted with several new areas for profit gain, however more research needs to be conducted on the benefits of renewable fuels in an ignition combustion engine

The ignition combustion engine is a complex piece of machinery with massive cost associated to experimental analysis of renewable fuels. Theoretical simulations are required to be developed in place of experimental analysis to reduce cost. Computational fluid dynamics (CFD) programs such as AVL Fire are capable of modelling the injection, combustion and emissions of various fuels and mixtures in a combustion ignition engine. The simulations can provide a reduction in cost with comparable accuracy to experimental investigations [3].

The aim of this paper is to numerically investigate the combustion of biodiesel blends in a diesel engine in the Biofuel Engine Research Facility (BERF) of the Queensland University of Technology. The simulation will be compared with the experimental results of pure diesel fuel and biodiesel-diesel fuel blends on a Cummins ISBe220 engine. Various engine parameters have been determined from data to develop an accurate numerical model.

2. Methodology

The software chosen to model the Cummins ISBe 220 engine is AVL Fire ESED. ESED is a CFD simulation tool which is used to perform and analyse the injection and combustion process of a diesel engine. ESED employs mathematical models to simulate fluid flow, mass flow, mass transfer, heat transfer and chemical reactions which are performed inside the combustion chamber of the engine.

Each mathematical model is derived over a particular small volume (cell) using the Finite Volume Method. The geometry is simplified by ignoring details like intake ports and valves, which reduces the effort of mesh development. If the combustion chamber is centric and rotationally symmetric and if fuel flow is equal across all holes of the injector, a segment of the geometry for one injected spray may be used, significantly reducing computational time while maintaining an accurate solution. Along with continuity and energy equations, other equations are also used to model the spray, evaporation, combustion and emissions of the engine.

2.1. Engine General Data

The general data section allows the user to input general parameters relevant to the specific engine being analysed. Parameters are separated into two tabs, general engine parameters which contains input fields for engine name, type of engine, number of cylinders, bore, and compression ratio. Piston movement specification is related to the data of piston movement which includes stroke, connecting rod length, etc. All data is taken directly from the Cummins ISBe220 engine being modelled and will not change with the comparison of different fuels. The following data in Table 1 was inserted.

Table 1. General Engine Data

General engine parameters		**Piston movement specification**	
Engine Layout	Inline	Piston displacement function	Selected
Number of Cylinders	6	Crank radius (m)	0.06
Bore (m)	0.102	Connecting rod length (m)	0.22
Compression Ratio	17.3	Piston pin offset (m)	0