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Study of Combustion Modeling In CI Engine with Biodiesel as an Alternative Fuel: A Review.

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ABSTRACT
In recent years several researchers has been made to use vegetable oil, animal fats as a source of renewable energy known as biodiesel that can be used as fuel in CI engines. Vegetable oils are the most promising alternative fuels for CI engines as they are renewable, biodegradable, non toxic, environmental friendly , lower emission profile compared to diesel fuel and most of the situation where conventional petroleum diesel is used. The Computational Fluid dynamics (CFD) code FLUENT is used to model complex combustion phenomenon in compression ignition (CI) engine. The CFD modeling can be the reliable tool for modeling combustion of internal combustion engine.

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I. INTRODUCTION

During last decade India has maintained a high growth rate in accepting the improved technological challenges in global scenario. The energy demand is expected to grow at 4.8%. The demand of diesel is projected to grow from 39.81 million metric tons in 2001 – 02 to 52.32 million metric tons in 2006 – 07 at 5.5% per annum. Also due to gradual depletion of the world petroleum reserve, rising petroleum prices, increasing threat to the environment from exhaust emission and global warming have generated an intense international interest in developing alternative non petroleum fuels. The desire to have suitable replacement, alternative or an entirely different source of fuel from the presently existing fossil fuel has being very imperative. Till today researches are still being carried out all over the world on a suitable alternative. In recent years, biodiesel is seen as a promising alternative to conventional diesel due to its desirable attributes such as biodegradable, renewable, sustainable and carbon neutral. It can directly replace petroleum diesel and be used in diesel engine without the requirement of any major modifications, reducing the country's dependence on imported oil. Biodiesel produced from either vegetable oil or animal fats consists of long chain mono-alkyl esters derived through transesterification process. Diesel sprays can be studied by carrying out controlled experiments or deriving mathematical models or sub-models that isolate the relevant sub-processes. Several numerical models have been developed using combinations of sub-models to describe the performance of the overall system. Multidimensional CFD-codes solve the full set of differential equations for species, mass, energy, and momentum conservation on a relatively fine numerical mesh and also include sub models to account for the effects of turbulence.

II. EXPERIMENTAL

2.1. Performance Analysis

Fuel crisis and environmental concerns have renewed the interest of scientific community to look for alternative fuels of bio origin such as vegetable oils. Some non-edible vegetable oils such as jatropha oil, mahua oil, karanja oil, etc. are potentially effective as a diesel substitute and have reasonable energy content. Biodiesel is an alternative to petroleum-based diesel fuel and is made from renewable resources such as vegetable oils, animal fats, or algae. It is an oxygenated, sulfur-free, biodegradable, non-toxic, and environmentally friendly fuel. Umakant V. Kongre , et al (2010) has performed Experiments on a fully instrumented, single cylinder, four stroke, direct injection, at constant speed of 1500 rpm. The cylinder pressure data were averaged over 5 consecutive cycles for the same load condition. Pressure was recorded with Crank angle sensor resolution 1degree, speed 5500 rpm has TDC pulse and Piezo sensor Range 5000 PSI. For digital load measurement strain gauge sensor, range 0-50 Kg with eddy current dynamometer is used. Dipak Patil et al (2001) in this Performance tests were conducted on stationary cylinders, diesel engine, by using Karanja Biodiesel and its various blends with diesel from no load to full load condition. The tests were conducted also conducted with conventional diesel fuel for comparison; Biodiesel is blended with diesel in proportion like 20%, 30%, and 40%. These blends are termed as KBD20 (20% Karanja Biodiesel + 80% diesel), KBD40 (30% Karanja Biodiesel + 70% diesel), KBD60 (40%Karanja Biodiesel + 60% diesel). Devershi Mourya et al (2012) has prepared a C program to apply the combustion model for the prediction of combustion emissions.

Program takes the inputs of: Blend of the fuel to be used (*B* and *D*), Number of Carbon, Hydrogen, Oxygen and Nitrogen atoms in Biodiesel (*a*, *b*, *c*) and Diesel (α, β, χ, δ), Stoichiometric air-fuel ratio (*as*), equivalence ratio (*Ø*) as in equation (1).Combustion temperature (*Tcomb*), gibbs free energy for particular product in the dissociation. Another C program is prepared for calculating the values of x_1 , x_2 ,x_7 ,x_8,x_9 ,and x_{10} which takes x_3, x_4, x_5 and x_6 as the inputs. Hoon Kiat Ng et al (2012) in this the test engine running at a fixed engine speed of 2000 rev/min and load of 0.5 kW. The use of low engine speed and load conditions is strategic here to represent typical urban driving characteristics. The experimental data is recorded at fully warm, steady state engine conditions. For all simulations, the initial temperature and pressure are maintained at 313 K and 1 bar, respectively. Wall temperature measurement is not available from the test-bed studies. Therefore, the wall temperature in the simulation cases is fixed as 313 K, which is identical to the initial in-cylinder mixture temperature. Due to the simplicity in the treatment of wall boundary condition, no wall heat transfer effect and soot deposition is considered in the current study. Jonathon P. et al (2007) uses five biodiesel samples prepared from feed stocks of soybean oil, rapeseed oil, coconut oil, palm oil, and beef lard. Methanol was used as the alcohol in the transesterification process, forming methyl esters. The viscosities of the biodiesel, Density, Surface tension were measured by respected instruments. Ming Jia et al (2011) in this the engine simulated from a Ford four cylinder , high-speed direct injection (HSDI) diesel engine with a displacement of 0.5 liters/cylinder. A major modification to the original engine is decreasing the compression ratio from 18.2 to 16.0 in order to realize PCCI combustion. A new piston with an open crater- type combustion bowl and a six-hole nozzle with narrow spray included angle (120) were used in this study to give better mixture preparation. Shaik Magbul Hussain, et al in the present study was on a Kirloskar AV-1, single cylinder direct injection diesel engine. Diesel was injected with a nozzle of hole size of 0.15mm; Biogas was injected by a Biogas injector. Simultaneous provision is also provided for biogas induction through inlet manifold, this is to compare the effect of injection verses induction.

The engine was coupled to a DC dynamometer and all the experiments were carried out a constant speed of 1400 rpm. Crank-angle-resolved in-cylinder pressure and the diesel injection pressure were measured. A computer interfaced Piezoelectric sensor, of Range 145 bar was used to note the in cylinder pressure. Pressure signals were obtained at one-degree crank angle intervals using a digital data acquisition system. The average pressure data from 100 consecutive cycles were used for calculating combustion parameters. Special software was used to obtain combustion parameters. The special software stores the data of pressures and volumes corresponding to a particular crank angle location for plotting the P-V and P-θ curves. The Software also provides the facility of analyzing the combustion data such as the Rate of Heat-Release; peak pressures and stores it separately for analysis in the computer system. The experiments were carried out first by injecting biogas at a pressure of 60bar, and then it was repeated for the same operating conditions by induction into the manifold at atmospheric pressure, while the diesel was directly injected into the cylinder in both the cases at a pressure of 160 bar. Biogas flow rate was controlled by a mass flow controller. The airflow rate was measured using a laminar flow element. The engine speed was maintained constant by controlling the Biogas gas mass flow rate. Engine exhausts emissions were measured using an advanced AVL five-gas analyzer, which is a non-dispersive infrared gas analyzer. The sample to be evaluated is passed through a cold trap to condense the water vapors, which influences the functioning of the infrared analyzer. The exhaust gas analyzer is calibrated periodically using standard calibration gas. The hydrocarbons and NOx are measured in terms of parts per million (ppm) as hexane equivalent and carbon monoxide emissions are measured in terms of percentage volume. Standard Bosch smoke measuring instrument is used to measure the exhaust smoke emission from the engine.

Tarek M. Belal, et al (2013) uses a multi-zone direct-injection (DI) diesel combustion model implemented for full cycle simulation of a turbocharged diesel engine. T. Mirunalini et al has performed the test on a 4 stroke single cylinder, air-cooled, DI diesel engine running at a maximum load of 4.4 KW at a constant speed of 1500rpm coupled with an electrical generator. The NOx emission is measured using Kane May make NOx analyzer. Unburnt hydrocarbons (UBHC) and carbon monoxide (CO) emission is measured using MRU exhaust gas analyzer while Smoke is measured using difference in weight method respectively. The tests were conducted in the following phases. In the first phase, tests were carried out in base line operation (pure diesel was used as fuel). In the second phase, Jatropha oil was blended with diesel at different proportions and used as fuel and the emission characteristics were studied. S. Naga Sarada et al in this study a single cylinder direct injection type, 4 stroke, water cooled vertical diesel engine developing 3.5 kW at 1500 rpm is coupled with rope brake dynamometer for experimentation purpose. The dynamometer consists of a pulley coupled to the engine. A thick rope is wound around the pulley. One end of the pulley is connected to lead screw that can be rotated by wheel mounted on it and other end is connected to a spring balance. Load can be applied by rotating the wheel. As the rope is tightened around the pulley, engine is loaded and the spring balance shows the load in kg. Control panel consists of engine speed indicator which indicates the speed of engine in RPM.

The different physical properties of cotton seed oil, procured for the purpose of experimentation were determined in the laboratory. Specific gravity and gross calorific values are determined with hydrometer and Bomb calorimeter respectively. Experiments were conducted with diesel and cotton seed oil under naturally aspirated conditions with increased injection pressures from 180 bar to 240 bar (in steps of 15 bar). R. Lokanadham1 et al (2013) in this the analytical experimental procedure was carried out using a four stroke Kirloskar diesel engine; characterized biodiesel Pongama oil, conventional diesel fuel. The properties that determine the performance of biodiesel in a stationary diesel engine includes; mass flow rate, torque, input power, brake power, brake mean effective pressure, specific fuel consumption, break thermal efficiency and the relationship between pressure and time.

III. METHODOLOGY

Based on CFD

C.S. Sharma, T.N.C. Anand and R.V. Ravikrishna has made the best use of the strengths of KIVA-3V and AVL FIRE as elucidated in the previous section, the following methodology has been developed for the analysis of in-cylinder processes in a diesel engine: **a.** Utilise the CAD data of the engine geometry to create a mesh for fluid flow simulation using the advanced meshing tools of AVL FIRE. Simulate suction stroke using AVL FIRE, which is suitable for the modeling of intake system involving complex geometries. **b.** Map the CFD solution from the mesh in AVL FIRE to the mesh in KIVA-3V at the end of suction stroke, i.e., at intake valve closure. **c.** Perform the computations for compression, combustion and expansion using the modified KIVA-3V (i.e., with the Shell ignition and the Characteristic-time combustion models incorporated into the standard source code). John Agudelo et al (2009) in this the Kelvin-Helmholtz Rayleigh-Taylor (KH-RT) model was selected to represent spray breakup. This model, alongside the Taylor analogy breakup (TAB) model, is one of the most used models in Lagrangian spray simulation. This approach follows the droplets paths in space, although the continuous phase (gas) is not solved. It should be noted that the KH-RT model was originally applied for hydrocarbon fuels. However, it is a physically based model, which means it can be extended to other fuels provided the physical properties are well defined. Helgi Fridriksson et al (2011) in this study, an investigation was made on a heavy duty diesel engine using both conventional diesel combustion mode and a partially premixed combustion (PPC) mode. A segment mesh was built up and modeled using the commercial CFD code AVL FIRE, where only the closed volume cycle, between IVC and EVO, was modeled. Both combustion modes were validated using experimental data, before a number of heat flux boundary conditions were applied. These conditions were used to evaluate the engine response in terms of engine performance and emission levels for the different percentage of heat rejection.

Paulius Rapalis et al (2013) in this study Various ICE working process mathematical simulation software packages based on Multi-zone models are widely used in research and design works ("AVL FIRE", "GT power" ,"KIVA", "Ricardo VECTIS", "Open Foam"). Multi-zone models are based on partial differential mass, chemical equilibrium, momentum and energy conservation equations solved by numerical methods in free liquid domain. For solving of multi zone model with PC combustion chamber is divided into a number of discrete finite volumes (number of volumes is unlimited). And time is discretized into a series of small time intervals called steps. T. Lucchini et al (2007) uses Open-source, freely available CFD Toolbox, licensed under the GNU General Public Licence .Written in a highly efficient C++ object-oriented programming language. Easy customisation, extensions and modifications by the user. Domain decomposition parallelism is fundamental and integrated at a low level so that solvers can generally be developed without the need for any 'parallel-specific' coding. OpenFOAM includes a wide range of solvers, model libraries, meshing and post-processing tools to make it attractive as research platform for fundamental studies. Hoon Kiat Ng et al (2012) in this a finite volume based commercial CFD software, FLUENT 6.3.26 which operated under the Windows XP 64-bit operating system was used for this simulation study.

Prior to the running of the numerical simulation, GAMBIT 2.3.16 was employed for the mesh generation of in-cylinder fluid volume of the combustion chamber. B. Jayashankara et al (2009) in this a single cylinder DI diesel engine having a toroidal combustion chamber with two directed intake ports whose outlet is tangential to the wall of the cylinder and two exhaust ports has been used. The pre-processor GAMBIT is used to create the entire computational domain of the engine including intake and exhaust ports and commercial computational fluid dynamics code STAR-CD is used for the solution of governing equations and post processing the results. Renganathan Manimaran et al (2012) several applications have proven the reliability of using multi-dimensional CFD tools to assist in diesel engine research, design and development. CFD tools are extensively used to reveal details about invisible in-cylinder processes of diesel combustion so that guidance can be provided to improve engine designs in terms of emissions reduction and fuel economy.

Innovative combustion concepts can be evaluated numerically prior to experimental tests to reduce the number of investigated parameters. In this present work, reacting flow simulations were performed in a single cylinder direct injection diesel engine with an improved version of the ECFM-3Z (extended coherent flame model – 3 Zones) model using ES-ICE and STAR-CD codes. Combustion and emission characteristics are studied in a sector of engine cylinder, which eliminates the tedious experimental task with conservation in resources and time. Shaik Magbul Hussain et al (2012) In the present study, Biogas-Diesel dual fuel combustion CFD analysis is carried out using FLUENT software to study the effect of Biogas substitution on turbulent kinetic energy, Turbulent Dissipation Rate, Combustion flame velocity, and NOx formation for five compression ratios. For Turbulence analysis, RNG $\kappa-\varepsilon$ model is used, which is further modified for the dual fuel analysis. Meshing of the combustion chamber is carried out using GAMBIT, by tetrahedral element using cooper tool.

IV. CONCLUSION

The overall analysis has shown that biodiesel has potential as an alternative fuel in conventional internal combustion engines as the maximum brake mean effective pressure (BMEP) obtained with the biodiesel was slightly higher than that obtained with the diesel fuel, with the difference being just slight under maximum power. While biodiesel increase the maximum engine power, it reduces the brake specific fuel consumption. Changes of maximum cylinder pressure have occurred at the same magnitude for both fuels for the same engine speeds. The overall analysis has shown that biodiesel has potential as an alternative fuel in conventional internal combustion engines. The CFD modeling can be the reliable tool for modeling combustion of internal combustion engine.

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