Design and Numerical Analysis of CI Engine Combustion Chamber

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Abstract: The world is facing the problem of energy so it is necessary to seek for alternative sources rather than petrol and diesel so mostly we have a choice of biodiesel in that algae oil is one of the best fuel. it has the property that to easily miscible in diesel. Algae biofuel containing very good lubrication property so it reduces the wear and tear losses in fuel injection system, cheap etc. So in this paper we are going to compare the pressure, temperature, reduction of pollutants for neat diesel with 5%algae blend,10% blend,15%blend at different cam anges using numerical analysis.

KEYWORDS: Alternative sources, biodiesel, algae, pollutants, fuel injection system

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ENGINE:An engine or motor is a machine designed to convert one form of energy into mechanical energy.

Types of Engine:

We can broadly classify engines into two categories those are Internal Combustion Engine and External Combustion Engine.

- Internal Combustion Engine: Fuel combustion takes place inside the engine system.

Example: Motorcycle, Car, Bus (fuel burns inside the engine system)

- External Combustion Engine: Fuel combustion takes place outside the engine system.

Classification based on ignition:

- Spark ignition

It's also called as SI engine means here the combustion is initiated by giving the spark to the combustion chamber

- **Compressive ignition**

It's also called as CI engine, here the combustion process is initiated by the compressing the fuel

Stages of Combustion in CI engine:

1. Ignition Delay Period
2. Period of Uncontrolled Combustion
3. Period of Controlled Combustion
4. After Burning

Stages of Combustion in CI engine:

There are four different stages of combustion in CI engine where proper combustion of air and fuel takes place as follows:

Ignition Delay Period

Period of Uncontrolled Combustion

Period of Controlled Combustion

After Burning

1. Ignition Delay Period

At this first stage of combustion in the CI engine, the fuel from the injection system sprayed in the combustion chamber in the form of a jet. Due to atomization and vaporization, this fuel disintegrates at the core which is surrounded by a spray of air and fuel particles. In this vaporization process, the fuel gets heat from the compressed and hot surrounding air. It causes some pressure drop in the cylinder. You can see this pressure drop (curve AB) in the above figure. After completion of the vaporization process, the preflame reaction of the mixture in the combustion chamber starts. During the preflame reaction, pressure into the cylinder starts increasing with the release of energy at a slow rate. This preflame reaction starts slowly and then speeds up until the ignition of the fuel takes place. You can see this process at point C on the diagram. This time interval between the starting of the fuel injection and the beginning of the combustion is called the delay period. This delay period can further be divided into two parts – Physical delay and chemical delay. The period between the time of injection of the fuel and its achievement of self-ignition temperature during vaporization is called physical delay. When physical delay completes, the time interval up to the fuel ignites and the flame of the combustion appears is called chemical delay.Preflame reaction we discussed above is taking place during the chemical delay. Due to the complex process of combustion is a CI engine, it's difficult to separate these two delay periods. If this delay period performs longer than usual, then we can here knocking in CI engine.

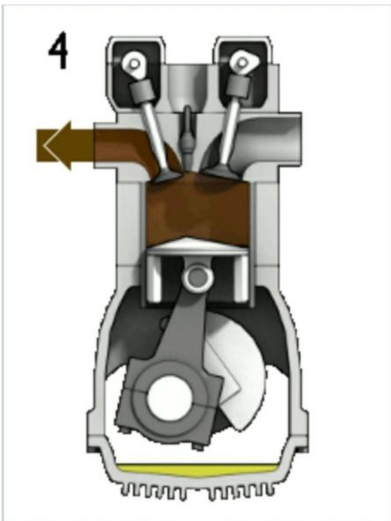
2. Period of Uncontrolled Combustion

This is the second stage of combustion in the CI engine. After the above-mentioned delay period is over, the air and fuel mixture will auto-ignite as they have achieved their self-ignition temperature. The mixture of air and fuel in CI engines is heterogeneous unlike homogeneous in the SI engines. Due to this heterogeneous mixture, flames appear at more than one location where the concentration of the mixture is high. When the flame formed the mixture in the other low concentration starts burning by the propagation of flames or due to auto-ignition, because of the process of heat transfer. The accumulated fuel during the delay is now started burning at an extremely rapid rate. It causes a rise in in-cylinder pressure and temperature. So, the higher the delay period, the higher would be the rate of pressure rise. During this stage, you can't control the amount of fuel burning, that's why this period is called a period of uncontrolled combustion. This period is represented by the curve CD in the above figure.

3. Period of Controlled Combustion

When the accumulated fuel during the delay period completely burned in the period uncontrolled combustion, the temperature and pressure of the mixture in the cylinder are so high that new injected fuel from the nozzle will burn rapidly due to the presence of sufficient oxygen in the combustion chamber. That's the reason we can control the rise of pressure into the cylinder by controlling the fuel injection rate. Therefore, this period of combustion is called a period of controlled combustion.

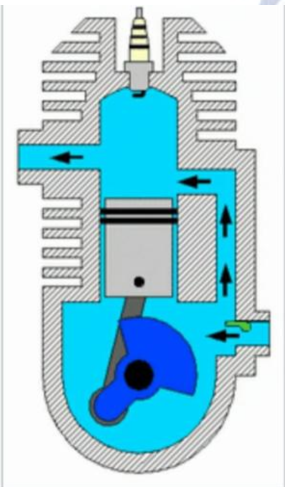
4. After Burning



This is the last stage out of the four stages of combustion in CI engine. Naturally, the combustion process is completed at the point when the maximum pressure is obtained in the combustion chamber at point E as shown in the figure. Practically, the burning of the fuel in the combustion chamber remains to continue during the expansion stroke. The main reason behind it is the association of dissociated gases and unburnt fuel. Therefore, this last phase of combustion is called After Burning. These are the four different stages of combustion in CI engine

Classification based on the no.of strokes:

- **Two stroke engine:**



As the name implies, the system only requires two piston movements in order to generate power. The main differentiating factor that allows the two stroke engine to function with only two piston movements is that the exhaust and intake of the gas occurs simultaneously,[6] as seen in Figure 3. The piston itself is utilized as the valve of the system, along with the crankshaft, to direct the flow of the gases. In addition, due to its frequent contact with moving components, the fuel is mixed with oil to add lubrication, allowing smoother strokes. Overall two-stroke engine contains two processes:

The air-fuel mixture is added and the piston moves upwards (compression). The inlet port is opened up due to the position of the piston and the air-fuel mixture enters the holding chamber. A spark plug ignites the compressed fuel and begins the power stroke. The heated gas exerts high pressure on the piston, the piston moves downward (expansion), waste heat is exhausted.

Four stroke engine:

While there are many kinds of internal combustion engines the four-stroke piston engine (Figure 2) is one of the most common. It is used in various automobiles (that specifically use gasoline as fuel) like cars, trucks, and some motorbikes. A four stroke engine delivers one power stroke for every two cycles of the piston. There is an animation to the right, of a four-stroke engine, and further explanation of the process below. Fuel is injected into the chamber. The fuel catches fire (this happens differently in a diesel engine than a gasoline engine).This fire pushes the piston which is the useful motion. The waste chemicals, by volume (or mass) this is mostly water vapour and carbon dioxide. There can be pollutants as well like carbon monoxide from incomplete combustion.

LITERATURE REVIEW:

- S.Bari,S.N.Hossain,I.Saad

It is undoubtedly proven that alternative fuels are going to play an important role to mitigate the energy crisis and harmful pollutions to the environment. This is the thriving force for the researcher to search for different alternative fuels. In recent years, it is found that HVFs (both biodiesel and vegetable-oil-based fuels) are one of the best options for CI engines. These fuels have better environment friendly properties as well as can be used in the existing CI engine with minimum modifications. However, the performances of the engine running on HVFs are not at par with diesel. The main reasons of these are the higher viscosity, density and heavier molecules present in the fuels. As a result, researchers have used various techniques such as blending HVFs with lighter fuel, preheating the fuel or air, changing the injection pressure and timing to improve the performance of diesel engine running on HVFs. The main objective of these techniques is to improve the properties of the HVFs closer to diesel fuel

- K.A.Abed,M.S.Gad,A.k.EI Morsi,M.M.Sayed

A single cylinder diesel engine was run using different source of biodiesel such as Jatropha, palm, algae and waste cooking oil biodiesel blends B10 and B20. Exhaust emissions were examined at different engine loads of 1, 2, 3 and 4 kW and a constant engine speed of 1500 rpm. Exhaust emissions such as CO, CO2, NOx, HC and smoke emissions were examined and compared with diesel fuel. The following conclusions could be summarized as:

1. CO, HC and smoke emissions were lower for the tested four biodiesel types (Jatropha, algae and palm and waste cooking oil) mixtures B10 and B20 as compared to diesel fuel.
2. CO2 emissions from biodiesel blends B10 and B20 produced from waste cooking oil were higher compared to diesel fuel and the other biodiesel fuel.
3. NOX emissions; from biodiesel mixtures, B10 and B20 increased compared with diesel fuel for the examined biodiesel blends.

- Manish saraswati,department of mechanical engineering ABES engineering college Ghadiabad,India.

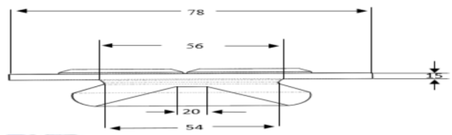
The world is facing the problem of energy so it is necessary to seek for alternative sources rather than petrol and diesel so mostly we have a choice of biodiesel in that algae oil is one of the best fuel. it has the property that to easily miscible in diesel. Algae biofuel containing very good lubrication property so it reduces the wear and tear losses in fuel injection system.

- S.karthikeyan,M.periysamy,A.prathima

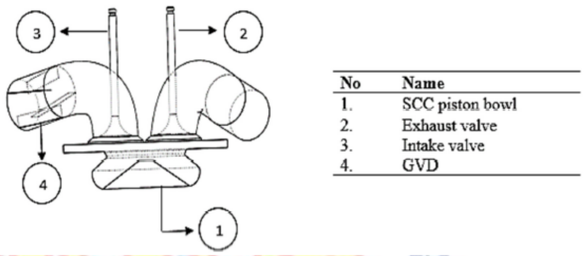
racemosa algae oil biodiesel with Bi2O3 nano additives and its diesel blends have thepotential for the use of a substitute fuel for a diesel engine with any engine modification. Bi2O3blending reduces viscosity and improves volatility of the blend, which leads to improved atomization, vaporization and air–fuel mixing formation.

METHODOLOGY

Basic Steps to Perform CFD Analysis



Schematic to import into IC engine Module



The CAD model Considered for Volume decomposition to Perform CFD

I. **Pre-processing: CAD Modelling:**Creation of CAD Model by using CAD modelling tools for creating the geometry of the part/assembly of which you want to perform FEA.CAD model may be 2D or 3d.

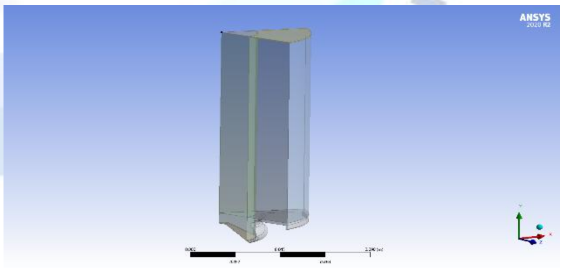
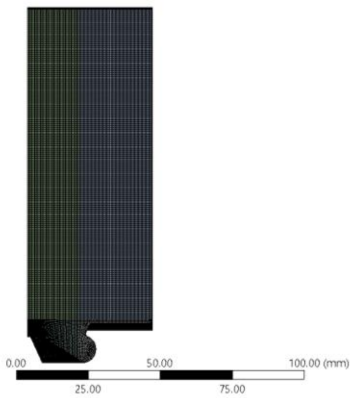


Figure 10 Sector Cylinder and Piston Considered For Simulation.

Meshing: Meshing is a critical operation in CFD. In this operation, the CAD geometry is discretized into large numbers of small Element and nodes. The arrangement of nodes and element in space in a proper manner is called mesh.The analysis accuracy and duration depends on the mesh size and orientations. With the increase . mesh size (increasing no. of element), the CFD analysis speed decrease but the accuracy increases.



Meshing Done For Sector Combustion Model.

Type of Solver:Choose the solver for the problem from Pressure Based and density based solver.

Physical model: Choose the required physical model for the problem i.e. laminar, turbulent, energy, multi-phase,etc.

Material Property: Choose the Material property of flowing fluid.

Fuel Samples	Density (g/cm^3)	Initial Boiling Point (^0C)	Flash Point (^0C)	Calorific Value (MJ/kg)
Neat Diesel	0.831	314	61	42.4

Boundary Condition: Define the desired boundary condition for the problem i.e. temperature, velocity, mass flow rate, heat flux etc.

SOLUTION

Solution Method : Choose the Solution method to solve the problem i.e. First order, second order

Solution Initialization: Initialized the solution to get the initial solution for the problem.

Run Solution: Run the solution by giving no of iteration for solution to converge.

II. **Post Processing:**For viewing and interpretation of Result. The result can be viewed in various formats: graph, value,
animation etc.

Chapter 4

Results and Discussions:

The current Chapter deals with the Results generated for CFD simulation of IC engine done for Diesel and Bio diesel Models.

Case 1 Neat Diesel

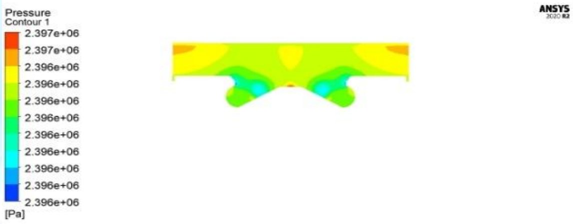
Results and Discussions

The current Chapter deals with the Results generated for CFD simulation of IC engine done for Diesel and Bio diesel Models.

Case 1 Neat Diesel

Crank Angle@720^0

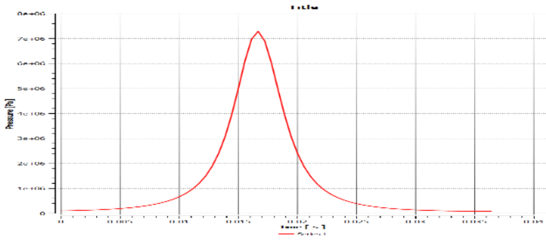
Crank Angle@735^0



Crank Angle@750^0

Pressure Profile Obtained for Diesel

The above Pictures Represent Pressure generated after Combustion with diesel in the engine mass flow of the diesel started injecting from the injector at 720^0 crank angle the combustion process started mixing diesel with Compressed air where the Pressure generated at 720^0 is 69.09 Bar and Gradually Start Decreasing upto 830^0



M

Plot 1 Time Vs Pressure with Diesel Fuel.

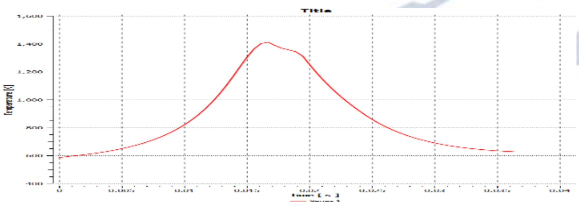
Crank Angle@720^0

Crank Angle@735^0

Crank Angle@750^0

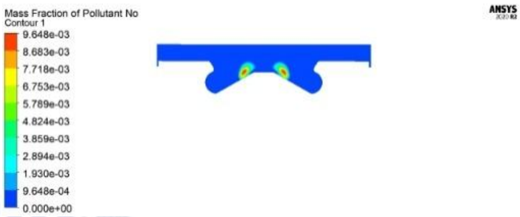
Temperature Profile Obtained for diesel at different Crank angles.

The above figures represents the Temperature contour obtained inside the cylinder and piston bowl geometry The fuel injection started at the crank angle 720^0 at the time of injection 1904 K is the Maximum temperature the temperature gradually increases up to 735^0 and starts decreasing at 750^0 Crank angle the maximum combustion temperature recorded is 2776 K.

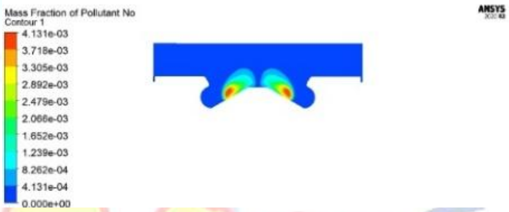


Plot 2 Time Vs Avg Temperature with Diesel Fuel.

Crank Angle@720^0



Crank Angle@735^0



Crank Angle@750^0

Pollutant Profile Obtained for diesel at different Crank angles.

CONCLUSION:

The average compute time for one simulation without advanced species transport and kinetics was around 5 weeks given license limitations and turbulence modeling. The requirement of convergence and extended solution stability between timesteps increases overall compute time beyond 5 weeks. In the future, to reduce 92 costs, more accurate chemical kinetics will need be employed using CFD software such as Ansys Fluent. Because the user can alter the code and add sub models, the addition of more advanced injected spray and breakup models such as the one proposed by Turner et al. [66] is possible. The computational resources needed are considerable and such simulations require high performance cluster computers to keep compute times reasonable. The parallel licensing and load control software fees would be reduced or eliminated using open source software. Streamlining and optimization of solver code is also possible so that computational speed can be maintained on cheaper hardware.

It is observed that the developed model is good for predicting the behaviour of compressed ignition engine. It is observed that By blending the Bio fuel algae at 10 15 and 20% the Peak pressure Observed in the Combustion chamber is high in the diesel at 70 Bar when compared with bio fuel The Mass Fraction of pollutants is reduced when diesel is mixed with algae.

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