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# Comprehensive Analysis of Vegetable and Microalga Oil-Based Biodiesel for Diesel Engine Application

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***Abstract* - In this study, the use of low percentages of biodiesel blends from different feedstock's was investigated because it leads to little level performance decrease, with biodiesel advantages on reducing pollutant emissions according to ULSD when used in diesel engines only with a small amount of carbon residue in the combustion chamber. There are two fuels i.e. VOB10 (10% vegetable oil biodiesel + 90% ULSD (in vol.) and MOB10 (10% microalgae oil biodiesel + 90% ULSD (in vol.) are considered as the fuel for combustion in a diesel engine.**

**A comparative study having finite element analysis considering the cold flow and combustion simulation has been carried out. A CFD analysis has been carried out using Ansys as simulation tool.**

***Index Terms* - Biofuel, modelling, vegetable oil, diesel engine**

## I.INTRODUCTION

Webster's Dictionary provides a useful starting point for a definition of combustion as "rapid oxidation generating heat, or both light and heat; also, slow oxidation accompanied by relatively little heat and no light." For our purposes, we will restrict the definition to include only the rapid oxidation portion, since most practical combustion devices belong in this realm.

This definition emphasizes the intrinsic importance of chemical reactions to combustion. It also emphasizes why combustion is so very important: combustion transforms energy stored in chemical bonds to heat that can be utilized in a variety of ways. Throughout this book, we illustrate the many practical applications of combustion.

Environmental pollution and the energy crisis are affecting life at a global level. Limited reservoirs of fossil fuel and emission due to the combustion of these fossil fuels are affecting the balance of our mother nature. Phenomena like global warming, climate change, and increase in Greenhouse Gases (GHG's) are among such unbalances. The automobile sector is among those sectors which heavily rely on these fossil fuels for energy requirement.

Biodiesel Production

The transport sector currently accounts for over 30% of the total primary energy consumption in the European Union (EU) and is 98% dependent on fossil fuels. The EU is a net crude oil importer, with an increasing oil dependency ratio (over 80% in 2007, Eurostat). One of the most important energy targets for the EU is thus the reduction of oil use and dependency. A recent EU Directive (2009/28/EC) establishes a 20% target share of renewable energy in primary energy consumption by 2020, with a 10% share of energy from renewable sources for transport. In turn, another EU Directive (2003/96/EC) allows the Member States to have exemptions from or reductions in excise duties so as to promote biofuels and, consequently, there is a growing interest in biofuels in Europe. In this context, biodiesel constitutes a renewable fuel that is almost compatible with commercial diesel engines and has clear environmental benefits relative to diesel fuel.

Therefore, it is of major importance to study alternative non-edible waste feedstocks for the sustainable production of second-generation biodiesel.

## II-LITERATURE REVIEW

In the study presented by Selman Aydın et. al. (2020), the use of low percentages of biodiesel blends from different feedstock's was investigated because it leads to little level performance decrease, with biodiesel advantages on reducing pollutant emissions according to ULSD when used in diesel engines only with a small amount of carbon residue in the combustion chamber. Therefore, firstly, biodiesel fuels were obtained from unique resources of animal, vegetable and microalgae oils by transesterification method. Then these biodiesel fuels were blended with ULSD by 10% and were named as here AOB10, VOB10 and MOB10, respectively. Afterword, these biodiesel blends were compared with ULSD by testing the combustion, performance and emission in a diesel engine generator under 3.52 kW, 6.98 kW and 10.37 kW loads with constant speed of 1500 rpm. According to the results, for all engine operating loads although the BSFC values of blends were higher compared to the ULSD, all blends gave almost identical results. In addition, blends had identical values of CGP, CHR, HRR, knock density and AGT compared to ULSD operation in engine. In the cases of usages of all blends; smoke opacity, HC and CO emissions considerably decreased, while NOx and CO2 slightly increased in all loads when compared to ULSD.

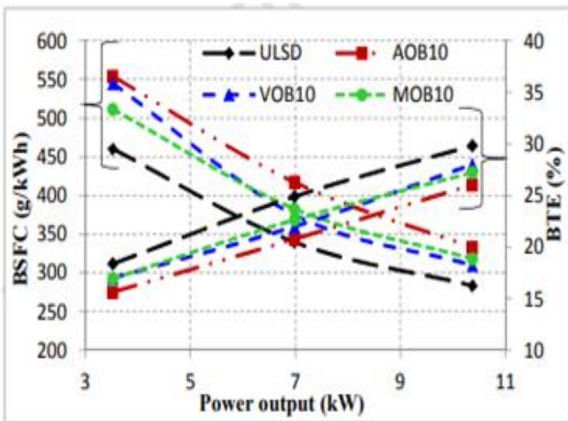



Figure 2.1 Changing of BSFC and BTE curves with power output.

The effect of utilizing AOB10, VOB10 and MOB10 fuels in a diesel engine coupled with an electrical generator on performance, emission and combustion has been investigated. This research was conducted at loads of 3.52 kW, 6.98 kW and 10.37 kW equivalent to those of just about 20 percent, 40 percent and 60 percent the full power of the generator, respectively.

The article given by Shivanshu Dixit et. al. (2020) is about CFD based combustion analysis of biodiesel fuel using ANSYS Fluent and matched with the combustion of diesel fuel. Parameters like the temperature of combustion at various blend ratios of B0-B100 varies from 2100 K to 1100 K are recorded through contour plots. Results are compared with diesel fuel, and an appropriate blend ratio is given for biodiesel for having for maximum efficiency and the least emission in applications.

In this article, it was reported theoretical combustion analysis and CFD simulation of biodiesel fuel using ANSYS Fluent and are compared with diesel combustion. The various blend ratios of B0, B15, B20, B50, B90, and B100 are studied using temperature contour plots. Results in comparison with diesel fuel are made, and an appropriate blend ratio is given for biodiesel for having maximum utility is studied.

## III- RESEARCH METHODOLOGY

Simulation in ANSYS IC engine

The IC engine system is located in the analysis system toolbox of the workbench in ANSYS. The first step is to run ANSYS and then launch “IC Engine”. Then the properties parameters and controls are required to be defined for this analysis. Eight steps need to be completed to successfully run a simulation and to get a result for analysis.

The steps are geometry, meshing, ICE solver setup, setup boundary conditions, monitor setup, solution initialization, run calculation and post-processing. Development of the combustion chamber geometry is very important and a fundamental part of the simulation. If the geometry is developed accurately, then there is a great possibility to obtain a more realistic predictive solution.

Geometry

Figure 3.2 shows the 3D geometry of the combustion chamber in isometric and cross-sectional views. CFD deals only with the fluid region and generates the mesh or grid in this region for numerical simulation. The number of iterations depends on the number of mesh and complexity of the shape of the geometry.

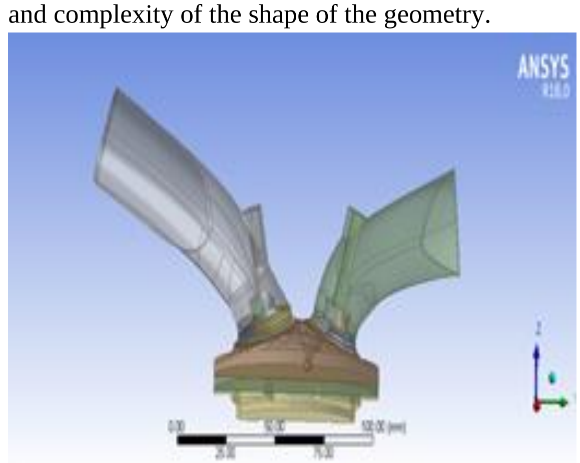



Figure 3.2 Engine Geometry for Cold Flow Analysis

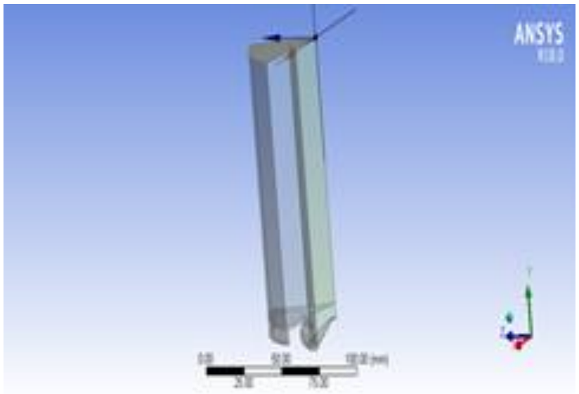



Figure 3.3 Engine Section Geometry for Combustion Analysis

Meshing:

The project in ANSYS should be updated after every action that had been done on it. This is the end step for the physical model. The IC engine solver setup is the beginning step for the numerical simulation process. In this stage, every step should be taken very carefully and precisely.

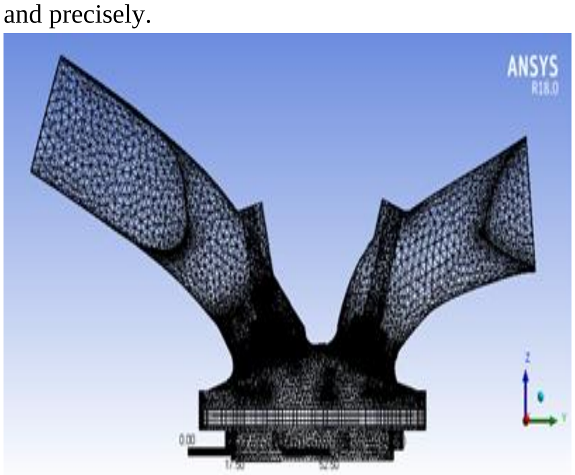



Figure 3.4 Meshed Geometry for Cold Flow Analysis

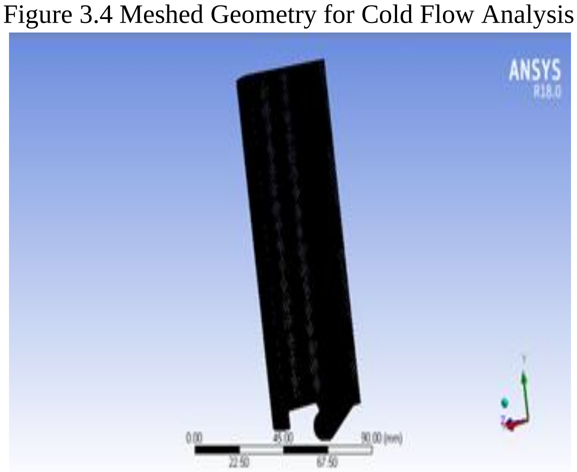



Figure 3.5 Meshed Geometry of Engine Section for Combustion Analysis

The Engine Inputs considered for the study are as:
Engine Speed (rev/min): 1800
Crank Radius (mm): 55
Piston Pin Offset/Wrench (mm): 0
Connecting Rod Length (mm): 165
Compression ratio: 22.5

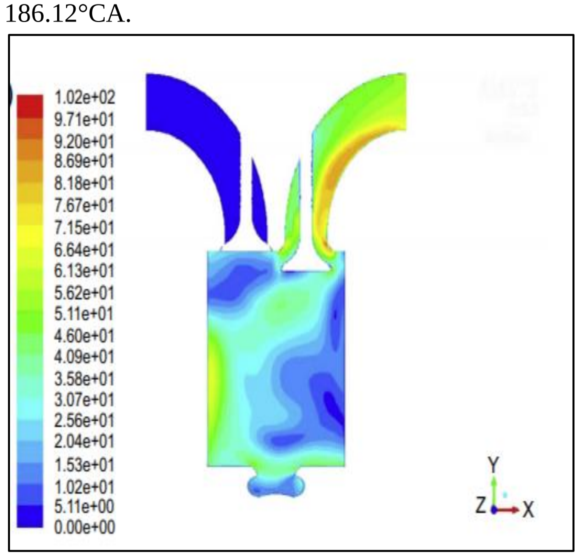
## IV-RESULT ANALYSIS

The study has been divided in two parts. In first part the cold flow simulation of the diesel engine has been carried out while in the second part the engine sector combustion simulation for both of the fuel has been carried out. The results obtained are as:

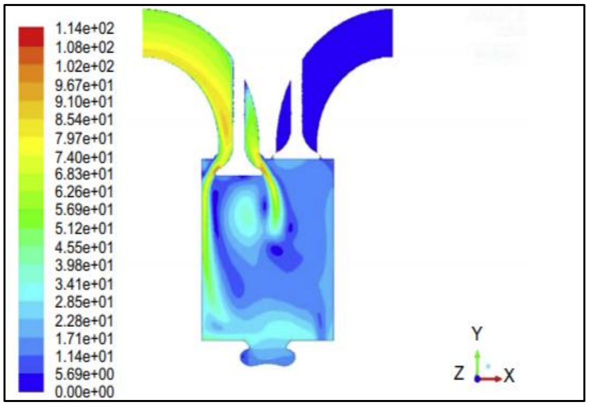
Cold Flow Simulation

In this numerical study, ANSYS IC engine application was used for CFD analysis which is considered as one of the efficient tools to describe the complex phenomena of the flow system of the engine. Initially, the properties of the engine specification required to be specified where the engine parameters and controls need to be defined for the analysis. There is a high possibility of obtaining a more realistic predictive

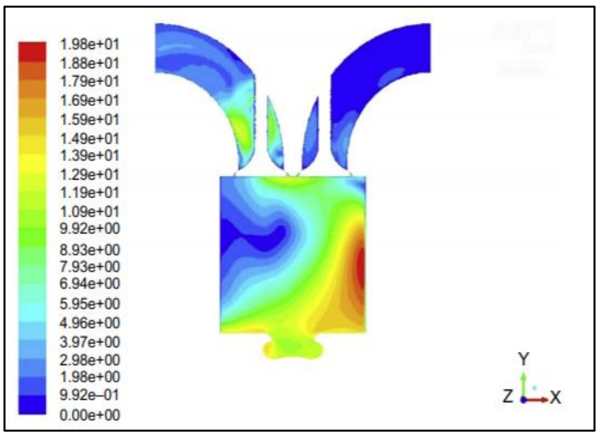
Figure 4.1 shows the velocity profile of the intake air inside the cylinder for different CA. In this simulation, both of the valves are closed at 213°CA (crank Angle). In this case, the higher velocity was found near the cylinder head compared to the top dead center (TDC). At 182.12°CA, the piston reached almost the bottom dead center (BDC) and initiated to move upward at 186.12°CA.




(a)



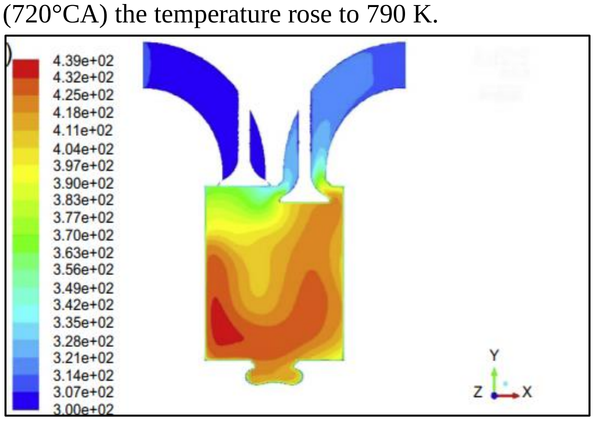

(b)



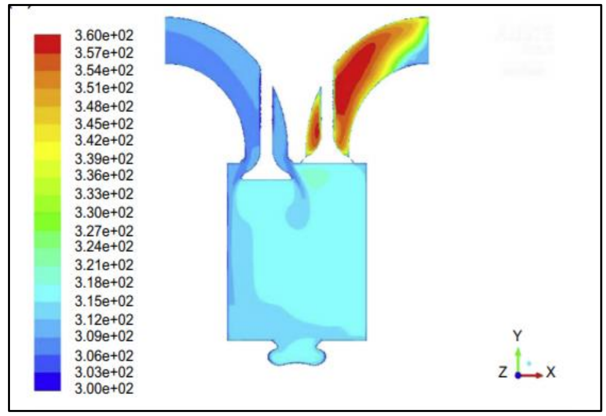

(c)

Figure 4.1 (a) Velocity distribution (m/s) inside the combustion chamber at 182°CA (b) at 184CA (c) at 212°CA when the engine running at 1800 rpm.

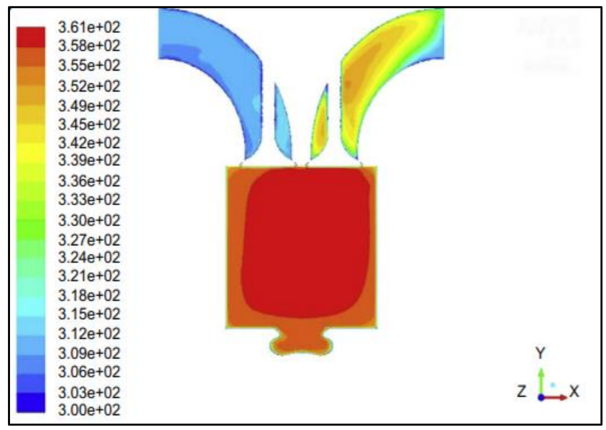
Fig. 4.2 illustrates the in-cylinder static temperature (K) for 182°, 184°, and 212°CA. It can be seen from the figure that the temperature profile is not uniform throughout the cylinder volume. It varies with the velocity vortex and total static pressure inside the cylinder. At the end of the compression stroke (720°CA) the temperature rose to 790 K.




(a)




(b)




(c)

Figure 4.2 (a) Static temperature distribution (m/s) inside the combustion chamber at 182°CA (b) at 184CA (c) at 212°CA when the engine running at 1800 rpm.

Table 4.1 shows the Engine variable consideration for both the fluid simulation. It has been observed that the engine variables are considered same for the analysis. It's necessary for evaluating the performance of both the fuel.

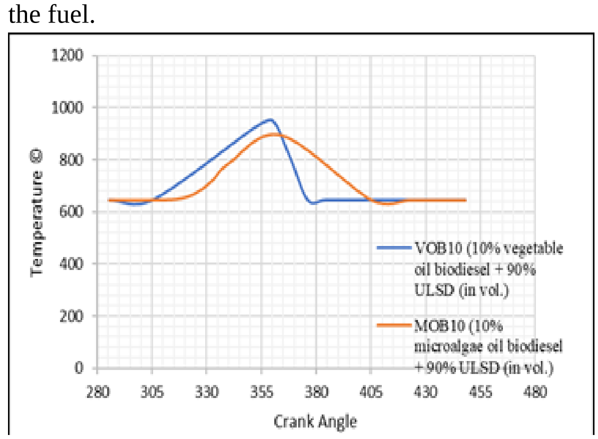



Figure 4.3 Temperature Distribution inside the cylinder at different crank angle for both the fuel

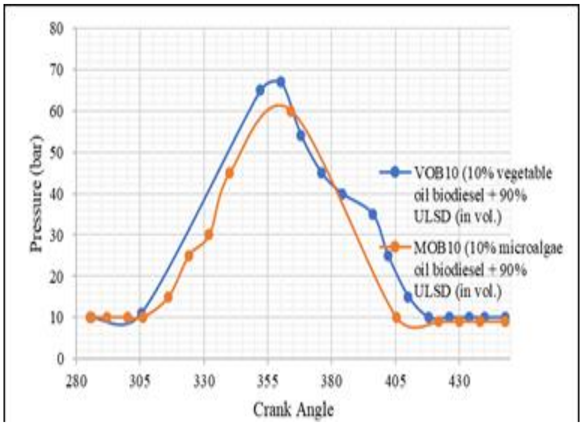



Figure 4.4 Pressure Distribution inside the cylinder at different crank angle for both the fuel

## V-CONCLUSION

The effect of utilizing VOB10 and MOB10 fuels in a diesel engine on performance and combustion has been investigated. After having a cold flow simulation, a combustion simulation has been carried out. The following observations can be made after the study:

- The cold flow analysis deals with the formation of the air-fuel mixture without reaction as well as the development of static pressure and temperature at a different CA in the transient engine cycle. At this stage, the simulation computes the conditions of the end of the compression stroke and provides information for proper combustion and flame propagation.
- It can be seen from the figure that the temperature profile is not uniform throughout the cylinder volume. It varies with the velocity vortex and total static pressure inside the cylinder.

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