

A review paper on Simulation and modeling of combustion characteristics under high ambient and high injection of biodiesel combustion

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Keywords: Computational Fluid Dynamics (CFD), combustion, ambient, injection

Abstract

Diesel engine performance and emissions is strongly couple with fuel atomization and spray processes, which in turn is strongly influenced by injector flow dynamics. This paper describes simulation of combustion characteristics under high ambient and high injection of biodiesel combustion by using CFD simulation. This study reviews the effect of temperature and pressure on the spray characteristics, as well as fuel-air mixing characteristics. Experiments were performed in a constant volume chamber at specified ambient gas temperature and pressure. This research continues using CFD software. A computational fluid dynamics (CFD) model of an internal engine has been developed using the commercial CFD package ANSYS 14.5. The method of the simulation of real phenomenon of diesel combustion with optical access rapid compression machine is also reviewed and experimental results are presented. Three dimensional models and sub-models are created using Solidworks software before being imported into ANSYS. The increases in ambient pressure inside the chamber resulting in gain of spray area and wider spray angle. Thus predominantly promotes for a better fuel-air mixing.

Introduction

Internal combustion (IC) engines are widely used to convert chemical energy of fuel into mechanical power in many engineering applications, e.g. road and off-road vehicles, locomotives, marine vehicles, airplanes, and in stationary applications such as electric power generation and gas pipelines [1]. One of the sources is the use of a biodiesel combustion system that introduced in the industrial emissions [2-4]. The diesel engine has undergone continues improvements through the developments of engines technologies especially in controlling the combustion process. Although, it is very important to control the ignition process in order to reduce the NO_x and PM levels [5]. CFD results are directly analogous to wind tunnel results obtained in a laboratory. Many studies showed that 20% or less biodiesel blends with petroleum diesel is the optimum blend to gather better effect of emissions reduction and does not require any special adjustments on engine operating conditions and modifications to the engine fuel lines [6]. Biodiesel can be used as a pure fuel or blended with petroleum in any percentage but the standard storage and handling procedures used for biodiesel are the main issue due to the biodiesel fuel specifications. Diesel gives the lowest number of acid value. However, all studies show an increasing rate of acid with long duration of storage time [7]. It is expected that a good fuel should have a low auto-ignition temperature, especially in a diesel engine, since it has no extra mechanism to ignite the fuel in combustion chamber. Cherng-Yuan Lin and Chu-Chiang Chiu [8] has found that the flash point of storage biodiesel is higher for biodiesel storage which has antioxidant.

There were many studies in fuel air premixing that responsible the ignition of diesel spray which linked to the improvement to the exhaust emission [9]. The study on the mixture formation and combustion process was performed in Rapid Compression Machine (RCM) [10]. This paper reviews on Computational Fluid Dynamic (CFD) software used by the researchers to get the simulation result of combustion characteristics. The ignition delay in a diesel engine is generally seen as consisting of two different which is the physical and the chemical ignition delay [11-13].

The physical processes involved such as atomization, penetration, entrainment and vaporization and the chemical processes such as fuel decomposition and accumulation and oxidation [14-16]. However, the main problems associated with diesel engines are the high level of NO_x and particulate emissions. According to Breda Kegl [17], NO_x emissions are significantly affected by injection timing and injection pressure. The aim of the fuel injection process in a diesel engine is the preparation of a fuel-air mixing to achieve a clean and efficient combustion process [18, 19]. The visualization of the formation process of diesel spray and its combustion in the combustion chamber of diesel engine has been recognized as one of the best ways to understand in-cylinder injection performance, spray characteristics and combustion for controlling emissions [20, 21]. Significant reductions in particulate matter (PM) and smoke emissions from DI diesel engines with high pressure injection have been reported [22, 23]. High pressure injection was also expected to result in improvements in exhaust odor.

Experiment Setup and results

A schematic of the machine of RCM is shown in Figure 1 together with outline of the fuel injection system. This machine can generate a high temperature and pressure by a method in which a piston is shot by compressed air and is rammed in to a stopper installed in front of the combustion chamber.

The result can be obtained by using simulation of CFD apart from producing the result by RCM. CFD simulation uses in package of ANSYS 14.5 which comprises various models and sub-models that being drawn using Solidwork software. The general parameters are used in order to run the simulation. The models comprise nozzles, internal chamber, combustion, emission, spray formation, delay period and set of ignition.

The simulation result shown in the form of graphs and images. Figure 2 shows the effect of ambient pressure on ignition delay τ . According to the figure, increasing ambient gas pressure will results in shortens ignition delay because of the better mixing achievable at higher injection pressures. Beside that by increasing the fuel injection pressure, the fuel droplet size becomes finer, the entrainment of the air increases, and the injected spray becomes more uniform. As a result, the ignition delay and combustion periods become shorter, resulting combustion improvement. The ignition delay τ , decreases rapidly with pressure and finally reaches a constant value above a certain pressure [10].

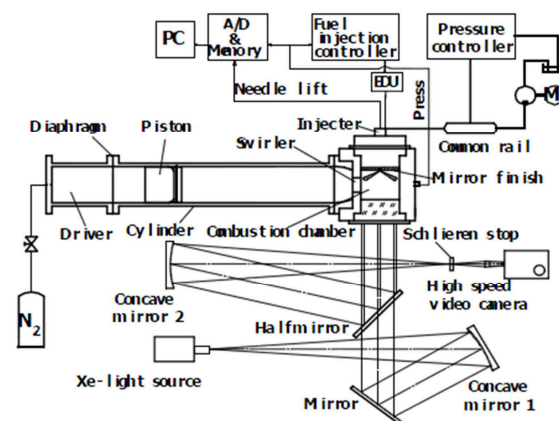


Figure 1. Schematic diagram of experimental set up [10].

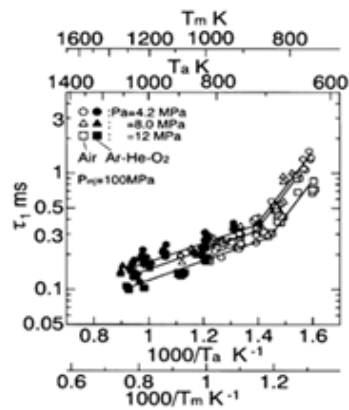


Figure 2. Effect of ambient gas pressure on ignition delay [28]

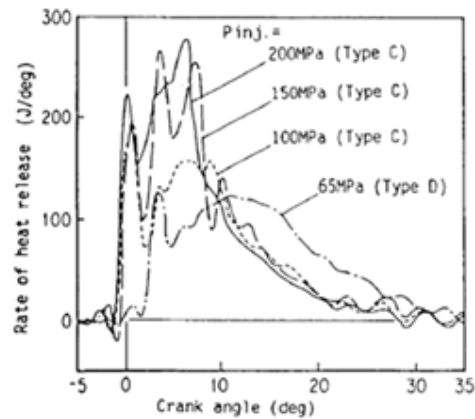


Figure 3. Heat release rate at different injection pressures [26]

Yamaguchi et al. [24] studied the relation between the injection pressure and heat release rate and found that the reduction in heat release results in a lower maximum pressure rise rate. Figure 3 shows the heat release obtained from the injection pressure analysis. The increased injection pressure caused an advance in the ignition timing and an increased peak rate of heat release [25]. At higher injection pressure, the better mixing formation is achievable. The mixture is heated to a considerably high temperature before the beginning of large scale heat release [26, 27]. Most important for a good mixing and utilization of the complete combustion space is an intense interaction of the injected fuel jets with the combustion chamber walls and the in-cylinder flow as well as inner spray interactions [28].

Figure 4 shows the images of the effect of ambient density on mixture formation. At $p_c=100$ kPa, the mixture covers wider area of combustion chamber than the other higher ambient pressure conditions. In this chamber, the condition of $p_c=100$ kPa seems to produce better distribution of the mixture than the cases of $p_c=150$ kPa and 200 kPa. The dark flame is a kind of signal that tells the position where well-mixed mixture is prepared before ignition. Combustion photograph with different injection pressures are compared in figure 5.

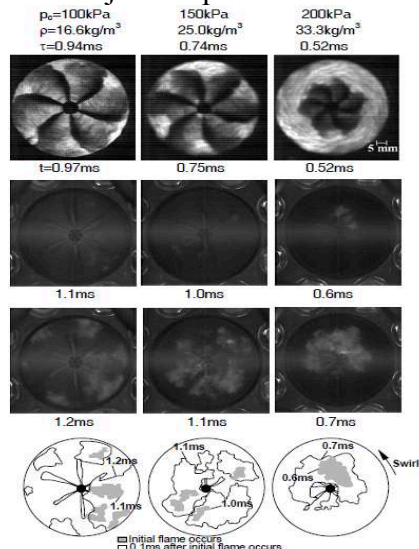


Figure 4. Effect of ambient density on mixture formation and initial flame development [10]

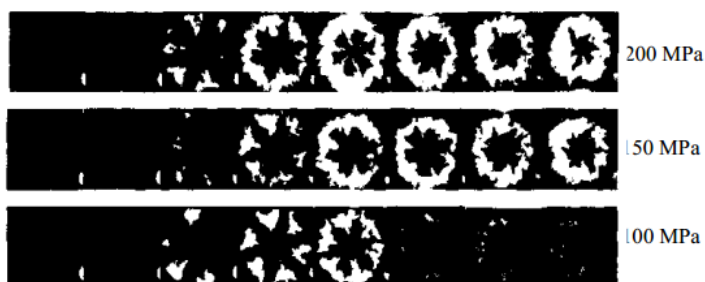


Figure 5. Combustion photographs at different injection pressure [24].

Conclusion

This study revealed the increased injection pressure caused an advance in ignition timing and this is due to the good atomization brought about by the high pressure injection and the short energizing duration for a given injection quantity. The higher injection pressure, higher oxygen content, results in lower smoke and CO emissions and in a slightly higher HC emission. The conditions in the

cylinder during the first part of injection and combustion process influence to great extent the NO_x formation. The result obtained by using the simulation of CFD. The CFD results show that better mixing of formation when using high injection and also shorten the ignition delay.

Acknowledgements

The authors would like to thank the Universiti Tun Hussein Onn Malaysia and Ministry of Higher Education, Malaysia for supporting this research under Fundamental Research Grant Scheme (FRGS) vot. 1054.

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