Comparison of Injection Characteristics and Droplet Distribution on Crude Palm Oil and Diesel Using CFD

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***Abstract*— CPO (Crude Palm Oil) is a potential renewable fuel as a substitute for fossil fuels used in internal combustion engines. An important parameter that affects the combustion of an engine with an injection system is the characteristics of the fuel spray. This research was conducted using Computational Fluid Dynamics (CFD) software to model the atomization process that occurs when CPO and diesel fuel are injected with a pressurized atomizer. The modeling shows the characteristics of the spray which include the shape of the spray and the droplet diameter distribution. These characteristics are presented with spray images, droplet diameter distribution graphs, and velocity distribution graphs. Simulations show that at temperatures above 75°C and 100°C, CPO spray produces droplet shapes and distributions that are almost the same as diesel spray. On the other hand, diesel injection spray produces a lower droplet size. The highest droplet size distribution is at 12-16 microns.**

Keywords*— renewable fuel, CFD, crude palm oil, droplet, solar.

I. INTRODUCTION

Inventories of fossil fuels that are dwindling and non-renewable encourage businesses to look for alternative fuels in anticipation of future fuel problems. Crude coconut oil or often called CPO (Crude Palm Oil) is one of the potential alternative fuels [1] especially for diesel motor fuel, so further research needs to be done. Indonesia is the largest producer of CPO in the world and has the potential to meet Indonesia's fuel needs [2].

The results of the study indicate that some vegetable oils have considerable potential both as fuel substitutes [3], and as fuel extenders for diesel motors [4]. One of the advantages of this energy source is that it is renewable. In the research of vegetable oil as an alternative fuel, CPO has potential as an alternative fuel for diesel motors [5]. The physical and chemical properties of CPO which are close to those of diesel fuel are very possible to produce combustion similar to that of diesel. The most prominent differences in properties between CPO and diesel are surface tension and viscosity [6]. The use of CPO as fuel has been carried out using B100 fuel (100% biodiesel from CPO) [7]. The results show that the use of B100 produces slightly lower power, torque and thermal efficiency compared to B20 fuel (20% biodiesel). This factor is due to its higher viscosity and density. High viscosity makes the process of atomization and mixing of air and fuel less than perfect [8]. The viscosity and surface tension of CPO can be reduced by increasing the temperature [9]. Another method is to mix it with diesel fuel [10]. A blend of 30% CPO produces the best performance and emissions [11].

The atomization process itself occurs because of the interaction with the air or gas that is around it. With the interaction with the surrounding air, friction will occur which causes the droplets to break up [12]. The viscosity and surface tension of the fluid will resist the breakdown process. By increasing the temperature, the viscosity and surface tension of CPO will decrease so that the ligaments or droplets will break more easily so that the resulting droplets are smaller and this indicates that the atomization process is going well [13].

The fuel used in a diesel motor must be able to flow easily through the pump and injection system so that spraying and atomizing the fuel is easy when it is injected into the combustion chamber. In addition, the characteristics of the spray (droplet distribution) produced must also be good so that it can produce optimal combustion [14]. The high viscosity of the fuel causes the fuel mixture to be less homogeneous and reduces the efficiency and heat generated in combustion [9]. In addition, the high viscosity of biofuels also triggers carbon deposits on the injectors, valves and combustion chambers [14].

Thus the problem that arises from these conditions is how the characteristics of the CPO spray in order to produce a homogeneous mixture of fuel and air. One of the parameters of a good spray is the size of the resulting droplet. The smaller and more homogeneous the droplets produced, the better the quality of the spray. From these problems, in this study numerical modeling was carried out with the help of CFD (Computational Fluid Dynamic) software to determine the characteristics of the CPO spray, especially the resulting droplet distribution. The use of CFD is considered an efficient tool in analyzing the processes that occur in the internal combustion engine [15]. In this study, CFD is used to find out more details about the characteristics of the spray that cannot be displayed in the experimental method, for example, the droplet distribution, droplet size and spray conditions at certain intervals. This research was conducted with the aim of obtaining modeling results, namely the characteristics of CPO and diesel sprays with varying temperatures.

II. METHODS

The research method used in solving the problem is to use a computational method using CFD Software, namely Fluent. The type of analysis in this study is 3-dimensional and unsteady. The turbulence viscous used is the k-epsilon model and the discrete phase model. In the process of solving equations, Fluent can simulate a discrete phase flowing with the continuous phase. The discrete phase in this case can be in the form of inert particles, bubbles or droplets dispersed in a continuous phase. The discrete phase is CPO in the form of droplet particles and the software will calculate the particle trajectory, inertial force, hydrodynamic drag, gravitational force, both in steady and unsteady conditions. The type of atomizer designed in this model is a pressurized atomizer. The initial condition setting that has been done in the simulation is with an injection pressure of 60 atm.

The materials injected are CPO and diesel oil with their properties presented in table 1.

TABLE 1 CHARACTERISTICS OF FUEL USED

Fuel	Density (kg/m^3)	Viscosity (cps)	Surface Tension (dyne/cm)
Solar 30°C	875	5.6	66
CPO 30°C	935	157	133
CPO 50°C	922	20.3	78
CPO 75°C	912	9.6	80
CPO 100°C	900	5.8	66

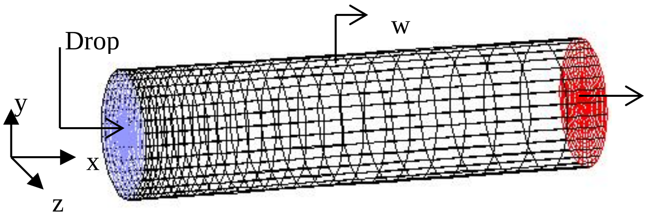

Fig. 1. Geometric models, mesh, and boundary conditions

III. RESULTS AND DISCUSSION

The results of modeling and calculations from numerical simulations in the form of spray images are shown in Figure 2.

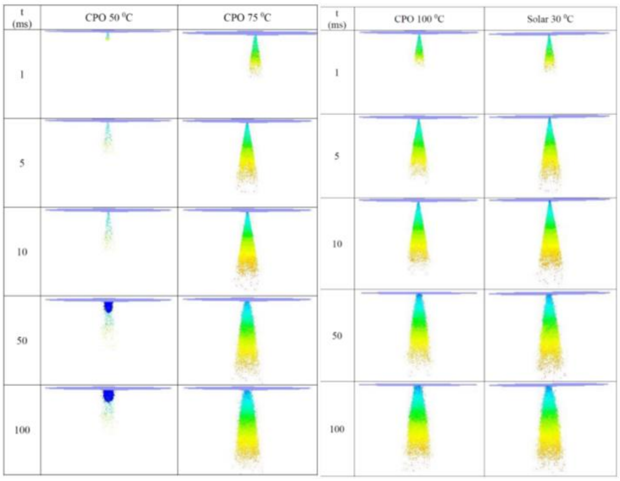

Fig. 2. Spray simulation results CPO 30°C, 50°C, 75°C, 100°C, and solar 30°C.

Figure 2 shows the results of the spray simulation. Injection using 30°C CPO cannot produce droplets so that the simulated image cannot be displayed. This is because the viscosity is still too large (157 cps) so that injections carried out using an injector with a diameter of 0.25 mm and a pressure of 60 atm cannot be carried out. By increasing the temperature to 50°C, the viscosity of CPO has decreased to 20.3 cps. From the injection carried out with 50°C CPO was able to produce droplets, but from Figure 2 it can be seen that the injection is still difficult to do. On injection with an interval of time (t) up to 10 ms, very few droplets are produced. The high viscosity makes it difficult for CPO to come out of the atomizer.

The injection carried out at a temperature of 75°C showed that the injection was carried out to produce a good spray. At an interval of 1 ms the number of droplets produced is already large. This means that the atomization process can take place in a very short time. For injections carried out at 100°C CPO can produce a spray image that is not much different from injections made with 75°C CPO. From the spray image the simulation results can be compared and it can be seen that between injections made using diesel oil has a spray shape that is very similar to injections using CPO 75°C and 100°C. This is due to differences in properties, especially viscosity and small surface tension.

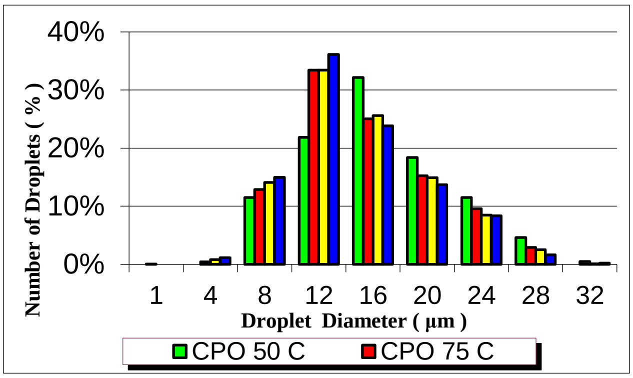

Fig. 3. Droplet Size Distribution

Figure 3 shows that the higher the CPO temperature, the more the droplet distribution shifts to the left. That is, the lower the viscosity and surface tension of CPO, the smaller the droplet size produced. The lower the viscosity and surface tension of a fluid, the easier it is for the atomization process to occur. Ligaments and droplets will breakup more easily when they are disturbed, either due to friction with the surrounding gas or due to unstable pressure when the droplets have high velocity.

Figure 4 shows that the longer the path taken by the droplet, the smaller its size. When the fuel (liquid) comes out of the atomizer, ligaments are formed. These ligaments have fluctuating velocity and pressure, causing them to become unstable. In addition, the friction with the surrounding gas also adds to the instability of the droplet. If the ligaments are no longer able to withstand this instability then these ligaments will then break down into droplets. If this droplet still has a high speed, then the droplet can still be broken up again into smaller droplets and eventually disappear due to a phase change into vapor. With this condition, the farther away from the injection center, the smaller the droplet even disappears. The higher the viscosity and surface tension, the ligaments or droplets will be more stable and require greater force to break them.

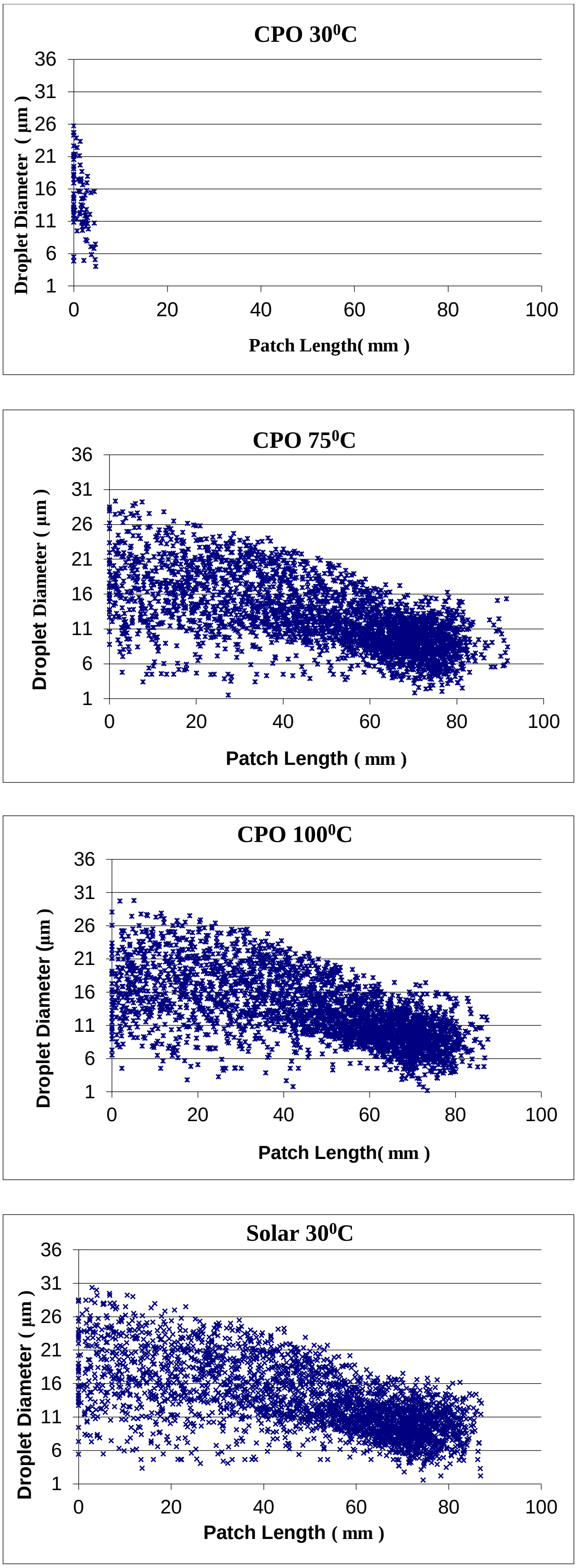

Fig. 4. Distribution of droplet diameter to path length

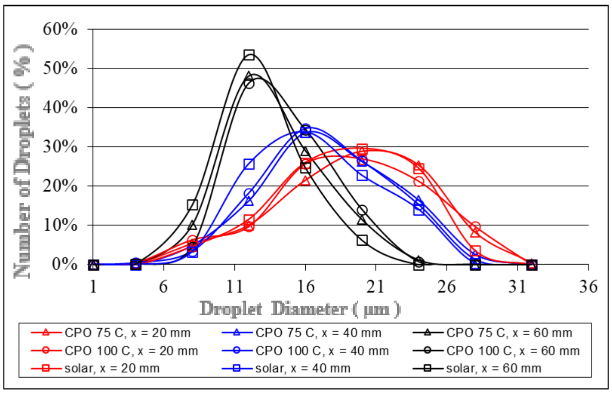

Fig. 5. Diameter distribution by path length

Figure 5 is a comparison of the droplet size distribution produced by injection of CPO 75°C, CPO 100°C and diesel 30°C. The graph shows that in general, injections made using diesel fuel have a higher percentage of small droplets. This event shows that more solar droplets breakup than others.

IV. CONCLUSION

Assuming that there are no droplets that experience evaporation, it can be concluded:

1. With the higher temperature of CPO, the viscosity and surface tension will decrease, causing the spray characteristics produced to be better

2. Judging from the form of spray produced, injections carried out with CPO at 75°C and 100°C were able to produce sprays that were almost the same as solar fuel at 30°C.

3. Judging from the droplet size distribution, diesel injection produces more droplets with smaller sizes than CPO injection.

Suggestions that can be given based on the results of this study are: it is necessary to add additives in CPO to facilitate the atomization process and the combustion process so that the resulting droplets are smaller, more homogeneous and accelerate the combustion reaction.

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