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STUDY OF THE MACROSTRUCTURAL CHARACTERISTICS OF SOYBEAN VEGETABLE OIL SPRAY OBTAINED FROM A DIESEL NOZZLE

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Abstract. *The combustion process in a Diesel engine is very complex, and its detailed mechanisms are not well understood and requires a basic understanding of the processes of mixture formation, because the diesel combustion is strongly controlled by a fuel spray injected into the combustion chamber. Natural vegetable oil like soybean oil is a potential substitute for regular fuel for Diesel engines. Compared to other biogen fuels like soybean methyl ester, pure soybean oil is neutral towards groundwater and it needs considerably less energy and additives for production. Different physical properties of soybean oil compared to Diesel fuel are the reason why conventional Diesel engines can hardly be used satisfactorily with soybean oil without being modified. Due to poor spray atomization of vegetable oil, an increased fuel entrainment in the lubricating oil, carbonization in the combustion chamber and deposits at injectors and valves are further drawbacks of injection systems designed for conventional diesel fuel. There are few works that study the effects of the spray's characteristic of vegetable oils as fuel for Diesel engines. The aim of this study were investigated photographically a comparative study of spray angle and spray tip penetration of Diesel fuel and soybean oil in a pressurized vessel.*

Keywords: *Combustion, Diesel engine, spray characteristic, vegetable oil, spray tip penetration, spray angle.*

1. INTRODUCTION

Today, most combustion engines draw their thermal energy from combustion from fossil fuels. The reserves of fuels are limited, and the world market and political conflicts have direct effects on the price of fuel. Some of the advantages of using vegetable oil are to be a completely renewable fuel, which assists in reducing emissions, because the oil of the germination cycle of reabsorbs the carbon emitted into the atmosphere by the exhaust gases and sulfur, characteristic in Diesel fuel, is practically negligible in its composition. The drawback in relation to Diesel fuel is the physical-chemical properties which cause a poor spray within the cylinder, generating an incomplete combustion results in carbon deposits and increased fuel consumption. Use prioritizes meet the small farmer, who does not have access to electricity and need to travel to large urban and commercial centers or to be able to supply their equipment. So with the possibility to get their fuel through own manufacturing or together with other farmers in small cooperatives, generates economy and development of the countryside.

Understanding of the disintegration process and spray characteristics is of importance in the design of a high quality Diesel engine, because the diesel combustion is strongly controlled by a fuel spray injected into the combustion chamber. It is commonly known that concentration of smoke, unburned hydrocarbon and nitric oxide in the exhaust gas depend to a great extent upon the form, the size distribution and the aerodynamic motion of the fuel spray. However, diesel combustion processes are very complex and their detailed mechanisms are not well understood. The primary factor which controls the diesel combustion is the mixture formation. The mixture formation is controlled by the characteristics of the injection system, the nature of air swirl and turbulence in the cylinder, and spray characterization.

The fuel injected from the nozzle into the combustion chamber of the Diesel engine disintegrates into numerous drops of different sizes and concentrations in the spray. The motion of the spray tip and break-up length gives clue as to the understanding of the disintegrating process of the fuel jet. Spray angle and drop size distribution are the results of this disintegrating process. These four parameters of the spray are related to each other in the disintegrating process and affect, the mixture formation through aerodynamic and thermodynamic processes in the combustion chamber of the Diesel engine.

In this work, the comparative behavior of soybean sprays obtained by injection through a Diesel engine nozzle into a high pressure vessel is studied using the photographic observations for the spray tip penetration and spray cone angle. The objective of this work is to study the fundamental knowledge for the characteristics of a Diesel fuel and soybean oil spray. Figure 1 shows the parameters that will be studied.

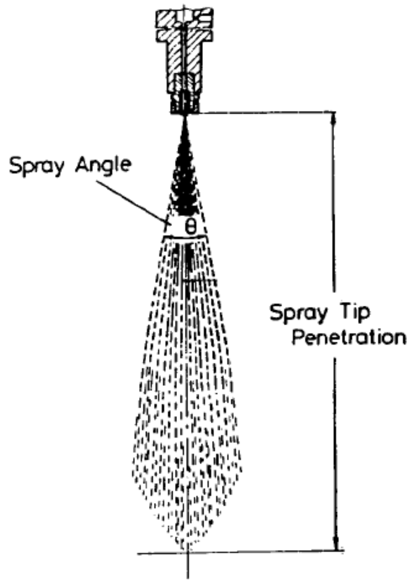

Figure 1. Parameters of spray

2. EXPERIMENTAL APPARATUS AND PROCEDURES

3. Experimental apparatus

The experimental apparatus consisted of the pressure vessel, the fuel injection system, injection nozzle and high speed photographic camera.

The spray visualization system consisted of a high speed camera (Phanton V411) with one led lamp as a light source. The frame rate and shutter speed of the high speed camera were set to 8.000 fps (frames per second) and 1/4.000s, respectively. The resolution of the spray images was set to 400x800. The input signals to the high speed camera and a test injector were synchronized by image-based auto-trigger function. Figure 2 presents the spray visualization system, while Figure 3 shows a picture of the fuel injection system.

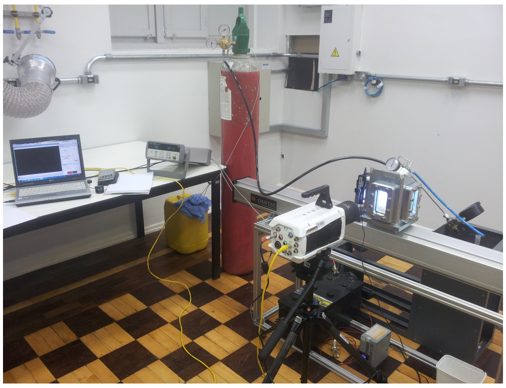

Figure 2. Spray visualization system

Table 1. Specification of experimental apparatus.

Visualization system with high speed camera	
Light source	Led lamp
Frame rate	8.000 fps
Shutter speed	1/4.000
Resolution	400 x 800

Table 2. Experimental conditions.

Injection system	Manual
Fuel	Diesel, Soybean oil
Nozzle type	Sac
Number of nozzle number	4
L/D ratio	3,6
Injection pressure	18 MPa
Ambient temperature	25°C
Ambient pressure	2,5 MPa

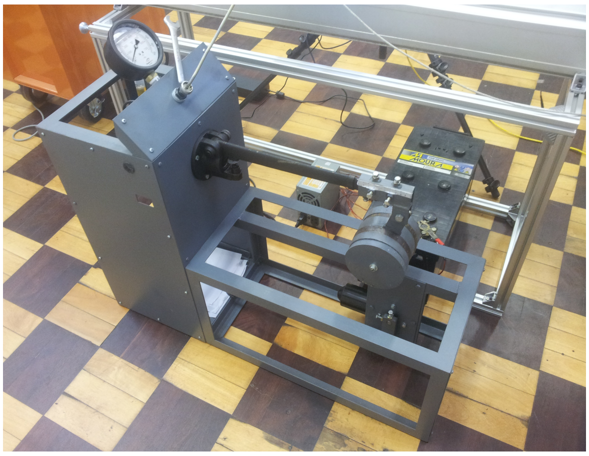

Figure 3. Fuel injection system

4. Experimental procedures

In the experiments, the residual gas and fuels in the high pressure chamber were exhausted through the suction chamber after every injection. Soybean oil and diesel oil were used as test fuels. The detailed specifications of the test fuels are listed in Table 3.

Table 3. Properties of Diesel fuel and soybean oil.

Fuel property	Diesel fuel	Soybean oil
Viscosity at 40°C (mm^2/s)	2,814	30,354
Density at 20°C (kg/m^3)	839,5	919,3
Surface tension at 20°C (kg/s^2)	0,02824	0,03272

Spray tip penetration was measured with the aid of photographic techniques. The liquid injection system allowed for a test liquid to be injected continuously into the spray chamber in such a way that the liquid injection pressure was kept constant during a given injection period. The injection system was designed to provide a injection pressure level of 18 MPa.

The images collected by the high speed camera were obtained through the Phantom Camera Control 2.3 software, that allows one to make the collection of data penetration, angle and speed manually from direct measurements in the images. For the study, each test, corresponding to the two fuels, was replicated 3 times. The averaged results are presented here.

5. RESULTS AND DISCUSSION

The results for tip penetration, tip velocity and cone angle of the sprays of the two fluids are compared in Figures 4, 5 and 6, respectively.

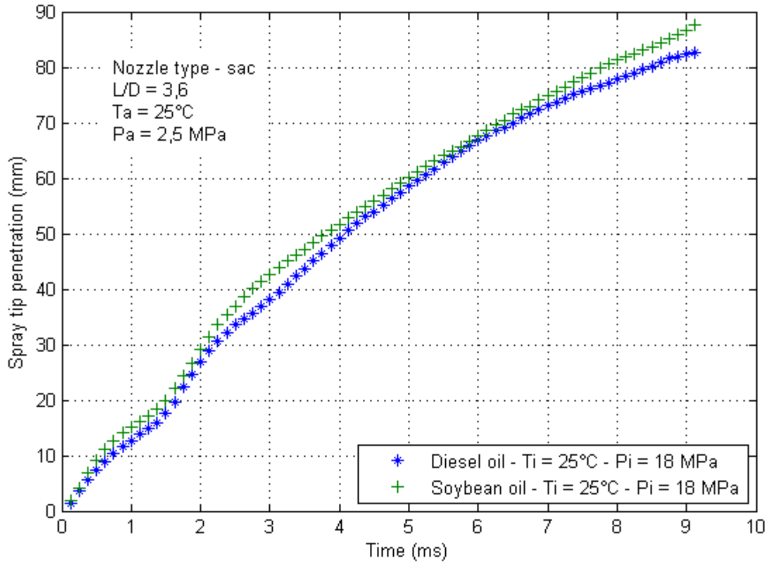

Figure 4. Spray tip penetration

The comparison of the results for the spray tip penetration shows that the sprays formation follow a similar pattern, with a slightly higher velocity being reached in the soybean oil sprays.

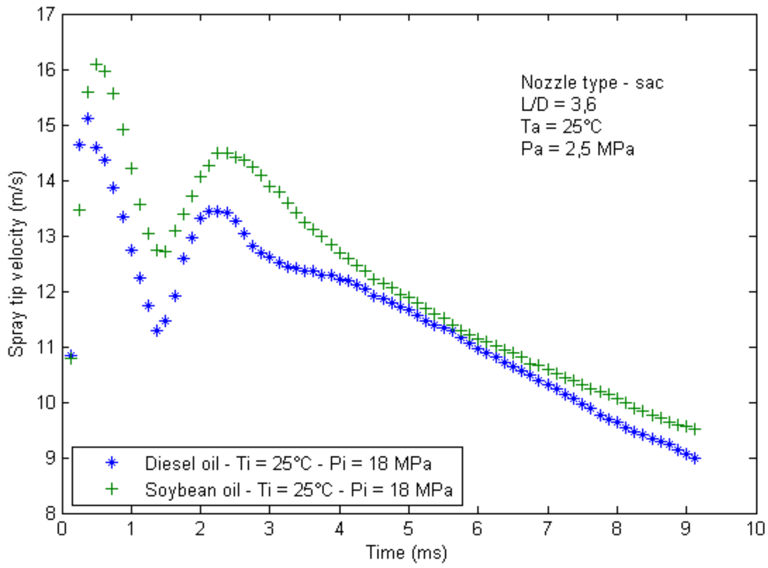

Figure 5. Spray tip velocity

Also in Figure 5, it is observed that the speed of the soybean oil spray tip is higher (16 m/s) than that measured for spray of diesel fuel (15 m/s). This is due to the difference of the physical-chemical characteristics of the two fuels. It is also possible to notice the occurrence of two velocity peaks, one in the time interval between 0 and 1.5 ms and the other in the time interval between 1.6 ms and 3 ms. The same oscillation can also be seen in the graphic penetration and occurs due to characteristic of the fuel injection system used.

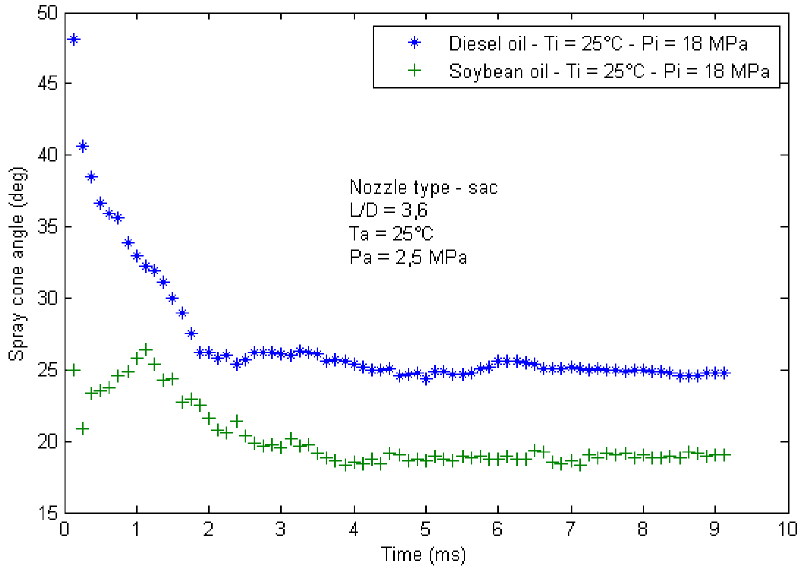

Figure 6. Spray cone angle

Figure 6 shows the comparison of the evolution of the angle of the spray cone formed. It can be seen that the droplets of the diesel spray move farer of the main axis, yielding a cone angle of 25 degrees, larger than the 18 degrees cone angle of the soybean oil spray. Since this is a transient study of the spray, the measurements collected in the time interval between 0 and 2 ms vary in the proximity of the gun output. The reason for this variation can also be related to the change in injection rate shown in Figure 5.

For a better understanding of the process, Figure 7 shows the evolution of the vegetable soybean oil spray during the test. Figure 8 shows a detail of the spray in the time interval between 0 and 3ms.

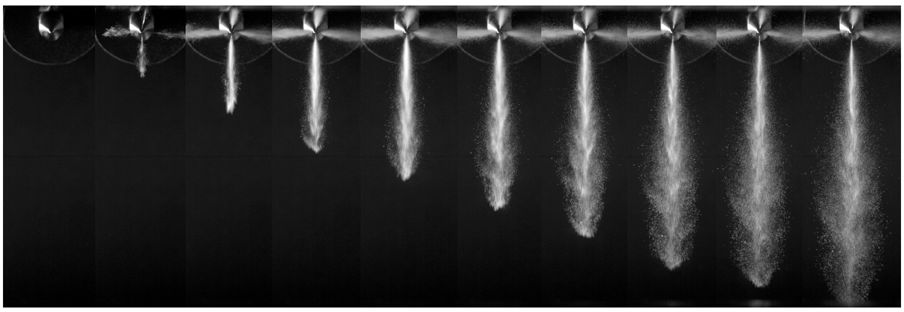

Figure 7. Photograph of soybean oil spray tip penetration (0 to 9ms).

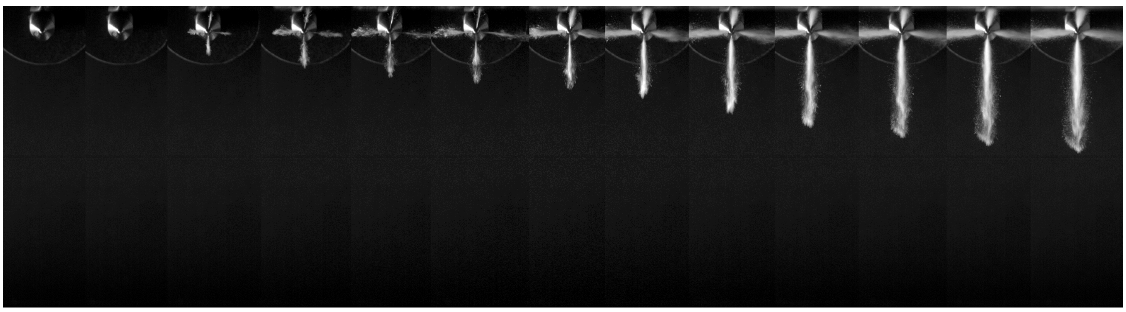

Figure 8. Photograph of soybean oil spray tip penetration (0 to 3ms).

Regarding the evolution of the diesel oil spray, Figure 9 shows the development during the test. Figure 10 shows the detail of the evolution of the spray in the time interval between 0 and 3ms.

Figures 7 and 9 allow for the observation of the good spray propagation of the diesel oil. The spray pattern of soybean oil results in narrower and longer cones in the comparison with the diesel oil sprays. This effect is due to the higher viscosity of soybean oil.

Poor nebulization of the soybean oil at 25°C, which is caused by the higher surface tension, is also involved in the constricting of the spray cones.

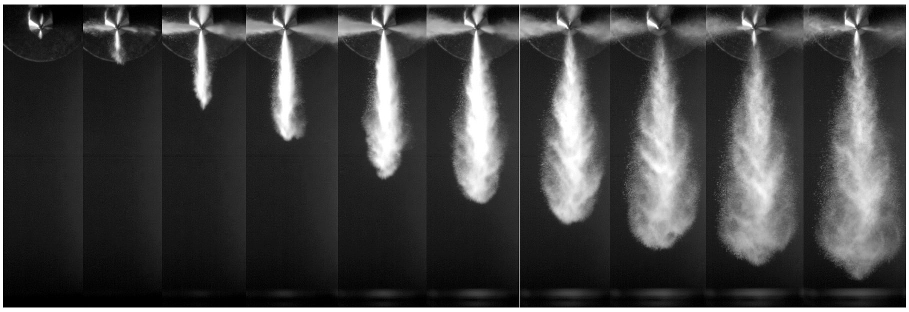

Figure 9. Photograph of diesel oil spray tip penetration (0 to 9ms).

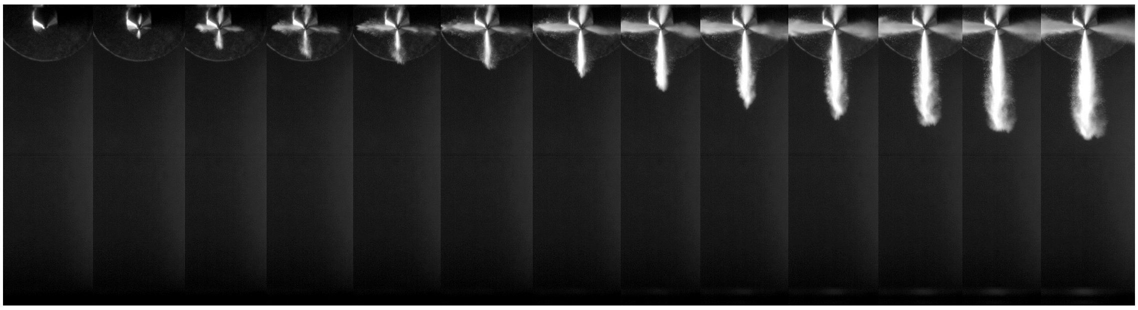

Figure 10. Photograph of diesel oil spray tip penetration (0 to 3ms).

6. CONCLUSIONS

Soybean oil is a potential substitute for regular fuel for diesel engines. Different physical properties of soybean oil compared to Diesel fuel are higher viscosity and surface tension. These characteristics lead to increased fuel entrainment into the lubricating oil, resulting in carbonization in the combustion chamber and deposits on injector and valves due to insufficient atomization and carburation. A poor vaporization, non-uniform spray pattern and constricting of the spray cones of soy bean oil was observed. The spray propagation of cold soy bean oil showed constricted and longer spray cones.

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