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Experimental Investigation of Mixture Formation and Flame Development using The Basics Technique of Schlieren Optical Visualization Principle

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ABSTRACT

The Schlieren technique remains to be one of the most powerful technique to visualize the flow and it is relatively easy to implement, high and variable sensitivity, low cost and its used conventional of light. This technique allows us to see the invisible of the optical inhomogeneities in transparent media like air, water and glass that otherwise cause only ghostly distortions of our normal vision. This research investigates the mixture formation and flame development of biodiesel fuel using the Schlieren optical visualization principle. This method can capture spray evaporation, spray interference, mixture formation and flame pattern clearly with real images. During the experiment, the camera lens was used with telephoto lenses (Nikon 70-300mm f/4-5.6G) in order to capture a large amount of light especially the low flame intensity during the initial flame development. The flame development was captured with color images from a color digital video camera. This method can capture the flow of fluids of varying density, such as spray evaporation, spray interference and mixture formation clearly with real images. The result shows that the mechanism of fuel-air mixing and a better comprehension of combustible mixture that can give valuable information to improve and optimize the combustion process.

Introduction

The Schlieren photography technique is a visualization that used to capture the flow. The Schlieren technique remains to be one of the most powerful technique to visualize the flow and it is relatively easy to implement, high and variable sensitivity, low cost and its used conventional of light. Schlieren imaging system has been used since early 1800's to visualize fluxions optical density [1-2]. Schlieren optical visualization technique system [1] is the unique technique because it produce a neutral image easily-interpretable image of refractive-index-gradient fields [3]. The Schlieren technique remains to be one of the most powerful technique to visualize the flow and it is relatively easy to implement, high and variable sensitivity, low cost and its used conventional of light. Schlieren technique also based on the light reflection and in this technique the light reflect by using concave mirror. It is more sensitive than its companion the shadowgraph, and better suited to the qualitative visualization than its cousin the interferometer [1-3]. The Schlieren optical system delivers the ability to view the phase of the object that cannot be seen normally by a human eye [4]. Most of the Schlieren technique is utilizing the toopler technique as the benchmark for the most Schlieren systems.

However, the traditional instrument of Schlieren have a limitation in the field of view by the cost for the lagers diameter of Schlieren mirror also got the high quality optics. The method of slain optical visualization mostly using high-speed camera to be observed or visualized the Schlieren object. In the middle of the 19th century is the first high-speed photographic record, it's been about ten years after the successful photography produce were established [5]. Other camera also can be used to visualize the Schlieren object, but it's depend on the object that observed. If the object only in a slow motion compact camera or digital single lens reflect camera (DSLR) also can be used.

Optical principle

Schlieren technique the major apparatus includes two concave mirrors, LED light, knife edge and camera. The setup of Schlieren is in Z-type Schlieren formation. The principle of Schlieren technique is that of introducing an LED as a source and projected with a concave mirror passing through the mirror. Here, the straight and equal intensity of light is produced by the LED light source [6,7]. Then, the parallel light of LED light created by a concave mirror was reflected by the mirror surface. A ring edge was used as a Schlieren stop and was set at the focal point of another concave mirror. At the last the reflected light will become to the camera sensor and the image will be recorded.

Already mention above many types of digital cameras made by Nikon, Canon, Olympus, Panasonics, Sony and others. By the way, a DSLR camera is the best choice and it is easily yielding images of gather than 10 megapixel resolution in full color [8]. However a few DSLR camera still have their own limitation,

The used in the schlieren technique in flame and spray penetration studies is primarily intended to quantify the burning rates. It also can be used to observe the flame surface structure [9]. By using this method, it's the evaporation of spray can be seen clearly [7]. But not least need to mention here this method was difficult to perform because to put and choose some equipment need try and error approach.

Light source, Knife-edge and Camera setting

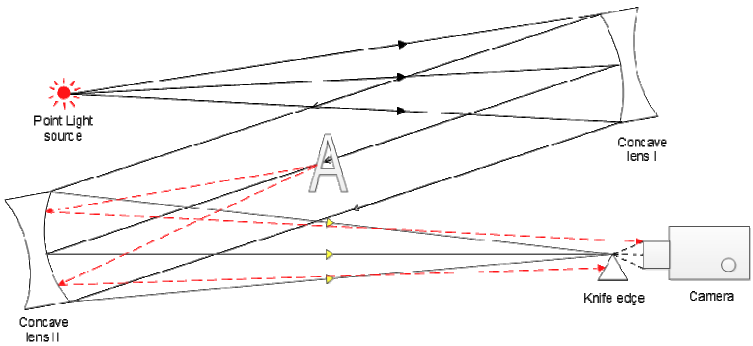


Figure 1: Z-type Schlieren system with a point light source

The basic Schlieren system apparatus includes a light source, hear the discussion bout light source will be discussed a little bit. As shown figure 1 the beam from the light source from a point source is collimated by a concave lens. If an added object in test area, it will bend the ray of light away from the original paths. However the second mirror will be focusing the ray from the corresponding point of the camera. As seen in figure 1 the ray reflected in upward and downward, but can be seen that the downward ray are blocked by knife-edge but the upward ray of light straight through without any interference and it's coming straight into the camera lens[1-3]. By the way the upward deflected ray will show the brightest point at the camera while the downward ray that hits with the knife edge will be shown the dark image. So that chose the correct light source and knife edge will be given the better Schlieren image.

Three basic Knife-edge that's always used in Schlieren technique is circular, vertical and horizontal. Using the difference will be produced different image quality. However, each type of knife-edge have their own function depend on what type of image wants to show in the camera. To get the best image camera setting is one the most important setting that will find out before run the experiment. Exposure is the making of an image on a digital sensor by using light. Three variables that making the exposure is Aperture, Shutter speed and ISO. Changing any one of this will affect the image exposure.

Result and discussion

This experiment will use palm oil in different type will apply. There are comparison between three (3) types of biodiesel. In this part, the effects of flame development and spray penetration for different type of biodiesel will be shown.

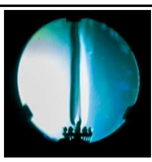
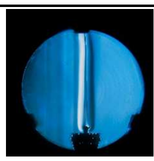
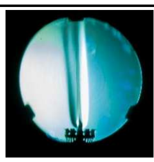
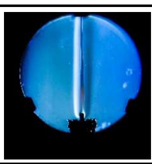
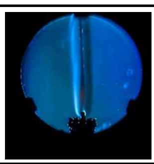
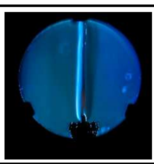
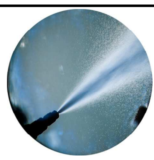
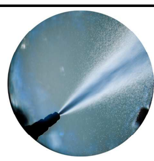
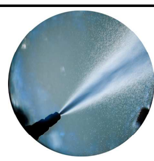
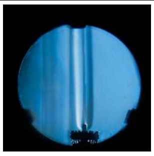
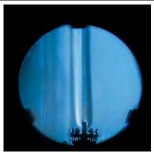
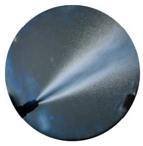
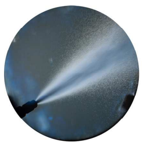
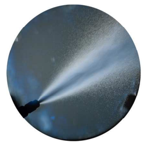
	Flame			Spray		
Fuel	B5	B10	B15	B5	B10	B15
Biodiesel (WCO)						
Biodiesel (CPO)						
Biodiesel (SVO)						

Figure 2: Schlieren image for flame and spray

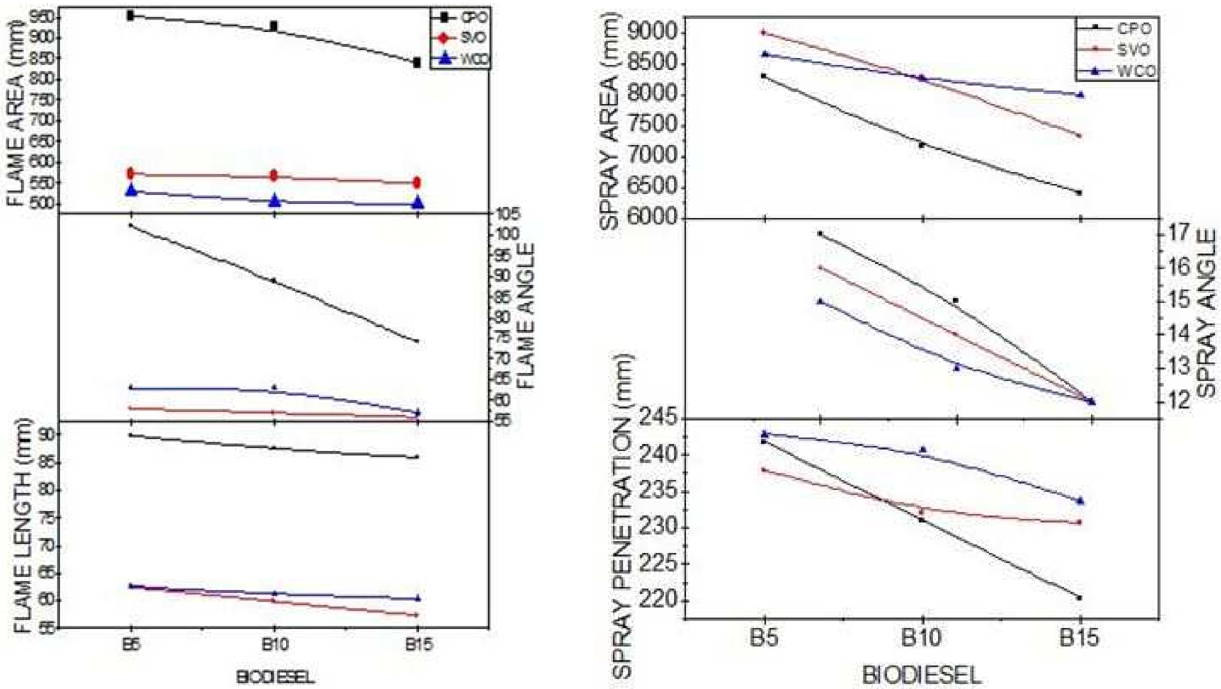


Figure 3: Graph for spray and flame patern

Figure 2 shown the schlieren image for different biodiesel fuel. Can be seen that the image clearly shown the flame development. Figure 3 shows the CPO and SVO the effect of flame area same with WCO where more biodiesel add in pure diesel will be decreasing the flame area. CPO is showing the greater flame area compare than WCO and SVO for the compression the flame area for SVO and WCO, show SVO have greater flame are than WCO [10]. Same as flame CPO have a greater flame angle than other type of biodiesel. The greater blending ratio of biodiesel will be decreasing the flame angle. CPO has a greater flame compare than other it also has bigger flame longest. Same as flame area and flame angle B5 is have the higher value and the value is decreased until B15 for all types of biodiesel. Overall for all types of biodiesel have a different flame development.

As seen in Figure 3, the penetration length is decreasing with the equivalent ratio of different blending ratio content. It can be observed that B5 biodiesel containing smaller biodiesel, but it produces longer flame penetration compared to the one that have a greater blending ratio. The spray angle for B5 and B10 are not much different and it decreased uniformly, but for B15 all the biodiesel has a same angle. The spray penetration for CPO are decreased uniformly from B5 until B15. From the image observation the spray angle, spray penetration and spray area are decreased uniformly for CPO.

Conclusion

This sturdy constructed Schlieren photography system with a digital camera to investigate the detailed behavior of flame and spray pattern. Aligning the optics of a Schlieren configuration requires some skills, but once acquainted with the technique, clear visualizations can be obtained in a short time. The Schlieren technique is ideally suited for the visualization both of the spray and flame development. It is clear that Schlieren optical visualization techniques are perfectly suitable for the study of the spray and flame development. This optical technique can be measure reflect the actual flow and it can be directly translated. The optical techniques used in this thesis allow a two dimensional, or integrated two dimensional measurement, which results in a clearly recognizable image and thus facilitates the interpretation.

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