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Technical note

In-situ spectroscopic monitoring of Jatropha oil combustion properties

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ABSTRACT

In-situ monitoring of chemical species emitted from the combustion of Jatropha oil in a practical *Semawar* burner were performed by means of several spectroscopic diagnostics. A practical burner commonly used in Indonesia having a built-in preheating system, called *semawar*, used for illumination purposes with the combustion of Jatropha oil. Non-intrusive two-dimensional (2-D) distributions of flame temperature were obtained using a thermal video camera. The experimental results showed the flame temperatures to range from 500 to 1400 °C. Chemical species generated from within the combustion zone were also determined in the Ultraviolet–visible (Uv–Vis) range from the spontaneous emission spectra of the flame. Spatial distribution of NO, C_2 and OH were identified from the spectra. The 2-D distribution emission intensity visualized and recorded for NO, C_2 and OH revealed high temperatures close to the root of the flame that rapidly dispersed radially outwards to provide very high temperatures over much larger volume at downstream locations. The radial stretch of the reaction zone is important for improved performance of the burner with light emission form a much wider zone. In addition, in-situ monitoring of CO_2 emission of Jatropha oil was performed by using infrared (IR) spectroscopy. The presence of CO, H_2O and NO were also investigated in this research. Moreover, 2D distribution of CO_2 emission intensity was also visualized using an IR camera.

1. Introduction

Fossil fuels are overwhelmingly in charge of energy sources in many combustion processes such as transportation, internal combustion engines, electrical utilities, and other uses. The facts about fossil fuel as a non-renewable resource and environmental issues generated from their combustion process have increased a concern to seek for reliable fuel alternatives. Vegetable oils have been considered among the most promising candidates and being known as biofuel due to renewability and carbon zero-balance. Unfortunately, the disadvantages of the vegetable oils include that they are also food crops, which means that the fuel from vegetable oils is considered as a food competitor. Jatropha oil does not have this disadvantage since Jatropha is not a food crop; in fact it is toxic to both human being and animals.

In the recent years, the Jatropha oil has widely been considered attractive since it is considered as a potential alternative biodiesel replacing fossil fuel by blending it with diesel or straight use. From this point of view, therefore, it is important to acquire the useful information on their combustion and emission characteristics. Some researchers have examined the combustion properties of Jatropha oil as a fuel [1–4]. However, the spectroscopic monitoring of combustion properties of Jatropha oil has not yet been reported. Therefore, in this study, the combustion properties of Jatropha oil were investigated by means of some selected spectroscopic diagnostics.

Some of the characteristics of Jatropha oil as compared to Diesel oil are as given in Table 1 [3]. The net calorific value and the cetane number of Jatropha oil are almost similar to that of diesel oils. The flash point of Jatropha oil is much higher than diesel so that this property offers an advantage for safe transportation of this fuel. However, the disadvantages include low volatility and low vapor pressure to provide leaner conditions under identical thermal operating conditions. Higher density means reduced fuel dispersion to provide finer mist of vapors. SO_x emission of Jatropha oil is considered low due to low chemically bound fuel nitrogen in this oil. Presence of oxygen in Jatropha oil improves combustion and emission characteristics but reduces the fuel calorific value. Jatropha oil has almost 90% calorific value than that of diesel, see Table 1. Even the low amounts of nitrogen content in the Jatropha oil induces the formation of fuel NO_x emission [1], as Nitrogen (N) content is available as shown in Table 2. The main problem of

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Table 1
Chemical properties of Jatropha Oil as Compared to Diesel Oil.

Characteristics/Oil	Jatropha oil	Diesel oil
Viscosity (mm^2/s)	55	3–7.5
Net calorific value (kJ/kg)	38.85	43.8
Cetane number	45	50
Flash point (°C)	240	93
Density at 20 °C	920	836

Table 2
Carbon, hydrogen and nitrogen contents of Jatropha and diesel oils.

Contents	Jatropha oil	Diesel oil
C (%)	75.92	87.08
H (%)	14.755	13.69
N (%)	0.10	0.16

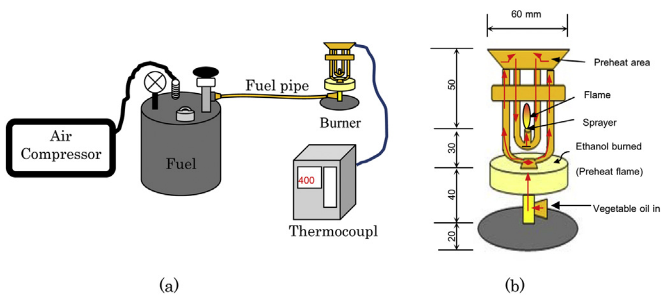

Fig. 1. Schematic illustration of (a) the combustion system and (b) the *semawar* burner.

Jatropha oil, as compared with other vegetable oils, is high viscosity of this fuel. However, this can be addressed using a preheating system or via fuel blending to decrease the viscosity prior to combustion.

2. Experimental

Fig. 1 shows a schematic illustration of the combustion system used in this research [5]. A conventional stove used in Indonesia, so-called *semawar* stove, is adopted as the burner system. The burner has a preheating system which is required for the combustion of straight vegetable oil (SVO). Preheating is effective to reduce the viscosity of Jatropha oil with the high temperatures achieved during the combustion of this oil. In practice it is closer to ignition temperature of the oil to provide efficient atomization and ignition of the vaporized fuel-air mixture. In operation, the outside part of the burner is initially heated using ethanol fuel until it reaches a temperature that is commensurable with flash point temperature of Jatropha oil fuel. This procedure results in good ignition of the oil from the formation of fine fuel droplets in the form of mist and vapors with the actual fuel spray located inside the unit. The Jatropha fuel oil is stocked in the fuel tank. The fuel oil is fed to the burner through a fuel pipe using pressurized air that is supplied from a compressor. Temperature of the preheated fuel is monitored using a thermocouple.

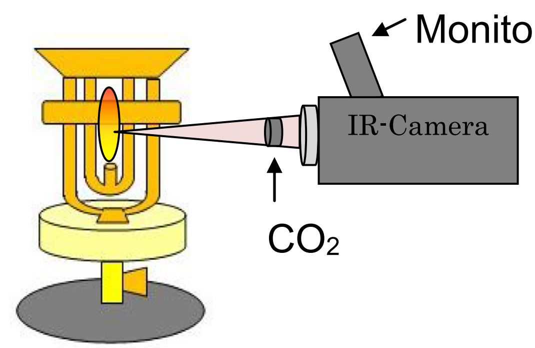

Fig. 3. The schematic diagram of CO_2 visualization using IR-Camera.

Fig. 2 shows a schematic diagram of the measurement system assembled for this study. To investigate the 2-D temperature characteristics from the combustion of Jatropha oil, a thermal video camera was used to determine the thermal distribution from within the flame. This samples the gray body emission at two different wavelengths and calculates the temperature images based on a narrow band two-color method. A total of 100 images were recorded by the thermal video camera located at a distance of 50.0 cm from the flame. The frame rate and the shutter speed were 120 fps and 1/15 ms, respectively. Uv–Vis emission spectra over a wavelength 236 ± 15 nm were recorded using an intensifier–spectrometer combination to measure the NO spectra from the combustion of Jatropha oil. The exposure time was 1 s, the gain used was 0 and the pulse width was set to 500 ms. In addition, 2-D spectroscopic imaging of Uv–Vis light emission from NO molecule (236 nm), C_2 radical (515 nm) and OH radical (310 nm) was performed using a CCD camera. The wavelength was selected for imaging through the optical band-pass filter. The exposure time was 1 s for NO, 1 ms for C_2 and 0.5 ms for OH. The intensifier gain was set to 30 for NO and 0 each for C_2 and OH.

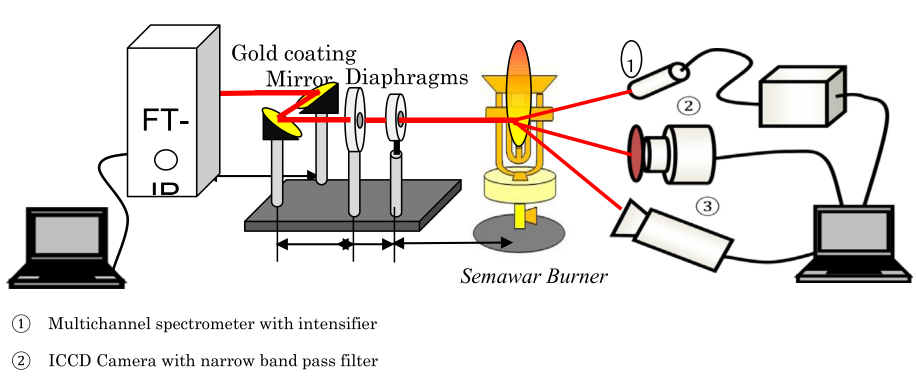

Fig. 2. Schematic diagram of measurement system.