Study experimental of flame-spread rate and spread limit distance of bio-solar droplets in microgravity combustion

Laila Fitriana1, Bawono Widyo Gumelarn2, Herman Saputro3, Tutakko Firdani4, Riyadi Muslimi4, Hesti Setyaningrum5, Hengky Aries Ismunandari6, Riffqi Arif Zainudin4, Risdan Aditya Nugroho Ajii7, Revelation Rahmadi7, Valiant L P Sutrisno8, Danar S Wijayanto8, and Husin Bugis9

1Department of Mathematic Education, Universitas Sebelas Maret, Jl. Ir. Sutami 36A, Surakarta, Indonesia
2Department of Mechanical Engineering Education, Universitas Sebelas Maret, Jl. Ahmad Yani No.200, Pabelan, Surakarta, Indonesia

Abstract. The most important issues in spray combustion science are how to understand the mechanism of the combustion of liquid fuel spray, especially in the flame-spread phenomenon. In spray combustion, combustion is the existence of the group is very important in order to obtain the stable combustion. Therefore, the flame spread among fuel droplets affects the occurrence of stable combustion in the spray combustion engine. This study was focused on phenomenon on diesel combustion engines. This research was conducted to study the behavior of flame spread rate of flame spread and limit the distance of bio-diesel liquid droplets. This research method was used experimental research. Microgravity condition was Obtained through the free fall tower with the height of the tower used is 6 m. Observed droplets suspended was placed on SiC fibers with different distance and droplet size 1 mm. This study observed Also the influence of the flame propagation direction of the burning droplet to the next burning droplets that lies in the direction and perpendicular to the direction of the flame propagation. The results showed that the bio-diesel fuel droplet Igniter (I) could burn next droplet (J)at a distance (S/d0) = 8.

1 Introduction

Since the flame spread among fuel droplets plays an important role in the occurrence of stable combustion, some researchers have made efforts to study details of that phenomenon. The investigation into the flame spread phenomenon has been performed in a simplified system of fuel droplet. However, it is difficult to create the droplets size similar to the real sprays. The latest experiment in the suspended-droplet technique by Mikami et al., 2005 could generate droplets size 0.3 to 1.5 mm in normal gravity, whereas in practical combustion processes, fuel droplet sizes are very small (under 50 microns). When the droplet size is very small, the gravitational effect and buoyancy effect influence to the processes around each droplet is negligible, and the flame shape is spheres even though in normal gravity. On the other hand, when the droplets size is larger than those in real sprays is burned in normal gravity, the gravitational effect and buoyancy effect influence to the processes around each droplet. The buoyancy effect destroyed the spherical symmetry of flame shape.

The research in individual droplet behavior, such as droplet ignition, droplet evaporation and combustion has long been recognized as an important component of developing a better understanding of spray combustion processes. The researchers that have performed in individual droplet combustion such as [1-5]. The continuation research on the individual droplet is multiple-droplet combustion, which studies the interactions of arrays or clouds of burning droplets in different spacing to link isolated droplet results to the combustion of spray. The experiment on the multiple-droplet combustion such as: 1) study on two droplet combustion [6-8], study on droplet array combustion [9-12].

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2 Experiment setup

Bio-solar fuel is a mixture of mono-alkyl ester, which is used as an alternative to fuel from diesel engines. Bio-diesel is made from renewable energy sources such as vegetable oils and animal fats [13]. Biodiesel has a higher cetane number than the diesel oil that is about 48 and biodiesel is more easily degraded (biodegradable) and contain aromatic compounds. Bio-solar Droplets are biodiesel-shaped droplets that are suspended or floated.

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*Corresponding author: lailafitrina_fkip@staff.uns.ac.id

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In this study, an investigation of the bio-solar droplet was conducted to determine flame propagation behavior. Considering the droplet size in the real conditions of diesel engines is very small and gravity effect can be neglected. Therefore, in this study was conducted on microgravity tower at ECCL (Energy Conversion Combustion Laboratory) Sebelas Maret University-Indonesia Fig. 1.

![Microgravity tower at ECCL (Energy Conversion Combustion Laboratory) Sebelas Maret University-Indonesia.](image)

In this study droplet arranged arrays on SiC Fiber. in the early stages of the observational study to find out the maximum distance droplet ignition can burn the next droplet. Droplet igniter \((I)\) is a droplet located near the igniter and burned first (Fig.2), in this study using droplet with a diameter of 1 mm. Droplet A is the observed droplet. Flame propagation from droplet I to droplet A will be observed. The main points of observation are the flame spread limit distance \((S/d_0)_{\text{max}}\) and flame spread rate \((V_f)\).

![Droplet arrangement.](image)

### 3 Result and Discussion

#### 3.1 Flame spread limit distance

<table>
<thead>
<tr>
<th>(S/d_0)</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>(burned)</td>
</tr>
<tr>
<td>7</td>
<td>(burned)</td>
</tr>
<tr>
<td>8</td>
<td>(burned)</td>
</tr>
<tr>
<td>9</td>
<td>(cannot burned)</td>
</tr>
<tr>
<td>10</td>
<td>(cannot burned)</td>
</tr>
</tbody>
</table>

![Flame spread limit distance of Bio-Solar droplet.](image)

Figure 3 shows the results of the bio-solar droplets dropped from the microgravity tower. in the figure shows that the experiment for observation of flame droplet propagation behavior of bio-solar successfully done. The success of the experiment of bio-solar droplet propagation behavior seen from the shape of the flame that resembles a sphere. This indicates that the gravitational effect on droplet microgravity combustion does not occur. The results showed that the bio-diesel fuel droplet Igniter \((I)\) could burn next droplet \((A)\)at a distance \((S/d_0) = 8\). Droplets at distances greater than \((S/d_0) = 8\) ((\(S/d_0) = 9,\) and 10) cannot burn.
3.2 Flame spread rate

Figure 4 shows the flame spread rate behavior of the bio-solar droplets. Measurement of frame spread rate is done by observing flame propagation video. The results showed that the flame spread rate ($V_f$) of the next droplet burning flame on the maximum flame spread of distance is 20 m/s.

4 Conclusion

This study was focused on phenomenon on diesel combustion engines. This research was conducted to study the behavior of flame spread rate of flame spread and limit the distance of bio-diesel liquid droplets. The results showed that:

a. The bio-diesel fuel droplet Igniter (I) could burn next droplet (A) at a distance ($S/d_0$) = 8.

b. The flame spread rate ($V_f$) of the next droplet burning flame on the maximum flame spread of distance is 20 m/s.

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