AN EXPERIMENTAL INVESTIGATION OF MICROEXPLOSION IN BIO FUEL EMULSION

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ABSTRACT

Puffing and microexplosion characteristics of water in bio diesel emulsion droplets were investigated. Emulsified fuel droplets were visualized on a hot surface during Leidenfrost effect. The emulsions tested were with 9%, 12% and 15% of water stabilized by 5%, 10% and 15% of surfactant dosages with an HLB value of 6. The results show that the emulsion stabilized with 5% and 10% surfactant dosage undergoes microexplosion phenomenon, whereas emulsion with maximum surfactant dosage did not developed micro explosion. The puffing frequency was found to be increasing as the Sauter mean diameter of the dispersed water droplets in the emulsions decreased.

Keywords: microexplosion, water in diesel emulsion, sauter mean diameter, coalescence.

INTRODUCTION

Compression ignition (CI) engines are more efficient and possess higher torque capacities than spark ignition engines. Importance of alternative fuels has been emphasized than before because the depletion of fossil fuels (diesel) and its adverse impact on the environment. NOx and particulate matter (PM) are one of the important diesel engine exhaust pollutants need to be tackled. Usage of bio fuel in diesel engine helps to reduce PM, CO and total hydrocarbon (THC), adversely it increases the NOx emissions. Alternatively, when water in diesel emulsion (WiDE) is combusted in diesel engine, it enhances the reduction of NOx and PM simultaneously. WiDE contains base fuel and water with different vapour pressure values resulting in a phenomenon called microexplosion during combustion. When such emulsions are sprayed into a high temperature combustion chamber, the volatility difference leads to a violent microexplosion of the emulsified droplets. The presence of water aids to reduce the combustion temperature, therefore NOx is also reduced. The microexplosion phenomena results in the formation of smaller droplets with very high surface-to-volume ratio which result in better mixing with air leading to more complete combustion and lower particulate matter (PM) exhaust.

Examining the evolution of microexplosion concepts can benefit to optimize the bio diesel emulsion formulation so as to achieve the maximum emission reductions. Several researchers have conducted experiments to find out the optimal condition to induce microexplosion effects by suspending single droplets on a thin wire [1-4]. However, little is known about how emulsion composition and droplet size affect the microexplosion process. Analysing a single droplet of WiDE would give a detailed insight of the mechanism and the phenomenon responsible for the development of microexplosion. Previous studies on emulsion droplets have revealed that the microexplosion does not occurs at all the time [2, 5], therefore an in depth visualization investigation on WiDE droplets behaviour would help to identify the influencing parameters on microexplosion frequency. The present study investigates the influence of surfactant dosage, water content, and droplet size of dispersed water on the microexplosion phenomenon of a single WiDE droplet on a hot plate.

EXPERIMENTAL SETUP

The experimental setup is shown in Figure-1. A concave dint of 2.6mm diameter was made on the flat surface of polished aluminium plate over which the WiDE droplet was placed. The heating source used in this experiment is a ceramic heater over which the aluminium plate was placed. At a temperature of 500 °C Leidenfrost effect was attained and this temperature range with a variation of +/- 2 °C was maintained for the entire study by means of a digital temperature controller.

Figure-1. Experimental set up for microexplosion visualization.


It was necessary to maintain the Leidenfrost effect throughout the experiment in order to avoid quick evaporation of emulsion droplet. PHANTOM MIRO M310 high speed camera was used for image capturing. The image acquisition was with a resolution of 510X510 pixels at 2000 frames per second.

A light source comprising of 12 high power LEDs was used for illumination purpose. The real time
temperature of the base plate was monitored by using an 
NI controller. WiDE droplet was created using a syringe 
of 0.8mm orifice diameter and the diameter of the WiDE 
droplet was around 3.0mm.

EMULSION PREPARATION

The emulsions were blended at 1500rpm for 15 
minutes using overhead stirrer. Mixture of commercial 
surfactants Span-80 with an HLB value of 4.3 and an HLB 
of 11 for TWEEN 85 were used as emulsifier. Surfactants 
are necessary to lower the interfacial tension between the 
diesel and water to form a stable emulsion. The base fuel 
used contains 95% diesel and 5% palm oil methyl ester. 
The preparation matrix for the WiDE is shown in Table-1.

Table-1. Preparation matrix of wide.

<table>
<thead>
<tr>
<th>Volume of surfactant</th>
<th>Sample ID</th>
<th>Amount of H2O (mL)</th>
<th>Volume in mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% from H2O</td>
<td>WiDE-1</td>
<td>9</td>
<td>90.55 0.45</td>
</tr>
<tr>
<td></td>
<td>WiDE-2</td>
<td>12</td>
<td>87.60 0.60</td>
</tr>
<tr>
<td></td>
<td>WiDE-3</td>
<td>15</td>
<td>84.25 0.75</td>
</tr>
<tr>
<td>10% from H2O</td>
<td>WiDE-4</td>
<td>9</td>
<td>90.10 0.2</td>
</tr>
<tr>
<td></td>
<td>WiDE-5</td>
<td>12</td>
<td>86.80 1.2</td>
</tr>
<tr>
<td></td>
<td>WiDE-6</td>
<td>15</td>
<td>83.50 1.5</td>
</tr>
<tr>
<td>15% from H2O</td>
<td>WiDE-7</td>
<td>9</td>
<td>89.65 1.35</td>
</tr>
<tr>
<td></td>
<td>WiDE-8</td>
<td>12</td>
<td>86.20 1.80</td>
</tr>
<tr>
<td></td>
<td>WiDE-9</td>
<td>15</td>
<td>82.75 2.25</td>
</tr>
</tbody>
</table>

The Hydrophilic-Lipophilic Balance (HLB) value 
of 6 was used for stabilizing all the emulsions. It was 
obtained by mixing the two surfactants by the following 
equation

\[
\% A = 100 \times \left( \frac{x \times HLB_B}{HLB_A - HLB_B} \right)
\]

Where, HLB_A = HLB value of surfactant A 
HLB_B = HLB value of surfactant B 
x = Required HLB value 
\% A = quantity of surfactant A required 
\% B = quantity of surfactant B required

RESULTS AND DISCUSSION

For the stability observation purpose, the 
prepared emulsions were kept motionless for over a period 
of two weeks at room temperature. The emulsions with 
5% surfactant dosage were unstable within a period of two 
weeks. Emulsions with 10% surfactant dosage was stable 
with sedimentation and with 15% emulsifier dosage the 
WiDE samples were stable without sedimentation.

It is due to the increased dosage of the surfactant 
that can improve the stability if the overall surface of the 
dispersed compound (water) can be completely covered by 
the surfactant molecules.

The water droplet distribution of the emulsions 
was captured using a digital microscope with a 
magnification of 500X and shown in Figure-2. The water 
droplet diameter measurements were made using Motic 
Image plus 2.0 software.

Puffing and Microexplosion behaviour of wide droplets

All the WiDE samples were visualized for 
microexplosion at ambient pressure. The high speed 
camera starts recording the event as soon as the droplet 
touches the hot plate with a pre-trigger option; this 
facilitates the identification of exact starting time during 
post processing of captured images. The sequence of 
microexplosion evolution for every half second is shown 
the Figure-3 for all the tested emulsions.

The phase change for WiDE-1 to WiDE-6 was 
observed to be faster within the time interval of 1.1 and 
1.6s when compared to other emulsion (i.e) WiDE-7 to 
WiDE-9 with time span between 1.8s to 2.9s. This might 
be due to the influence of surfactant dosages, since higher 
concentration would have resulted in high interfacial 
strength between water and diesel droplets. With an 
increase in surfactant concentration, it was observed that 
the waiting time for microexplosion was prolonged as 
reported by earlier studies [6, 7], which is in agreement 
with the present work also.

Micro explosion is due to formation of small 
vapor bubbles [8] which are clearly seen in the case of 
WiDE-1 to WiDE-6 but was not observed in case of 
WiDE-7 to WiDE-9. Puffing is the ejection of the inner 
content of the emulsified droplet without the complete 
shattering of the parent droplet. The puffing rates for the 
emulsions are shown in Figure-4. It is observed that 
the rate of puffing was increasing with increase in surfactant 
concentration also the most stable emulsions had higher 
puffing frequency when compared to other emulsions. The 
Sauter Mean Diameter (SMD) of the emulsion is shown 
in the Figure-5. The SMD was found to be reducing as the 
surfactant dosage is increased.

Among the tested emulsions WiDE-7 to WiDE-9 has 
the smallest water droplets also it has the higher 
puffing rate. Hence, it can be concluded from the tested 
conditions, that the emulsions with higher surfactant and 
smaller droplets size are prone to higher puffing rate 
compared to those with lower surfactant and higher 
droplets size.
Figure-3. Microexplosion image sequence of WiDE-1 to WiDE-9 for time interval of every 0.5s.
As the droplets get heated up, the formation and volume of expansion of vapor bubbles increases the parent droplet volume until it reaches a point and ejects out vapor as puffing. This behavior was observed more frequent with WiDE-7 to WiDE-9, if the puffing is too strong it might result in the disintegration of child droplets as shown in Figure-6.

Also, continuous vapor ejection causes the parent droplet to lose all the water vapor, resulting in reduction of parent droplet volume without any microexplosion leaving only the base fuel to evaporate. The changes in emulsion droplet diameter against time are plotted in the Figure-7 to Figure-9. In case of WiDE with 5% and 10% surfactant dosages the explosive boiling happens in a shorter duration results in the breakup of the parent droplet itself, hence micro exploded.

CONCLUSIONS

In this work, WiDE with different water content and surfactant concentration has been successfully visualized for the microexplosion behaviour. The results of the experiment can be summarized. Emulsions with higher surfactant concentration showed only the progress of phase change and did not develop microexplosion. Most stable emulsion with higher surfactant content had very high puffing frequency compared to other emulsions with 5% and 10% surfactant. Emulsions stabilized with higher surfactant concentration lead to lower SMD values and those emulsions were found to be more stable than the other emulsions.
REFERENCES


