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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.

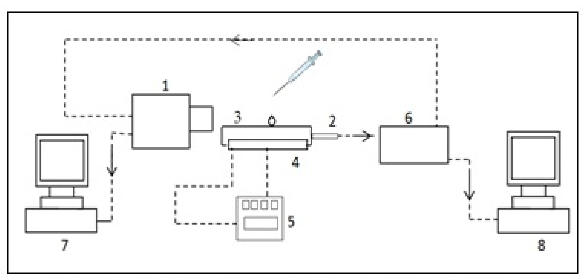
INTRODUCTION

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.



1. High Speed Camera 2. Thermocouple for hot plate 3. Hot plate 4.Ceramic heater 5. Temperature controller for hot plate 6. N.I.Controller 7&8. PC for Data Acquisition and Image processing.

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

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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.

Volume of surfactant	Sample ID	Amount of H_2O (mL)	Volume in mL	
			Diesel	Surfactant
5% from H_2O	WiDE-1	9	90.55	0.45
	WiDE-2	12	87.40	0.60
	WiDE-3	15	84.25	0.75
10% from H_2O	WiDE-4	9	90.10	0.9
	WiDE-5	12	86.80	1.2
	WiDE-6	15	83.50	1.5
15% from H_2O	WiDE-7	9	89.65	1.35
	WiDE-8	12	86.20	1.80
	WiDE-9	15	82.75	2.25

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

$$\% A = 100 \times (x - HLB_B) / (HLB_A - HLB_B)$$

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.

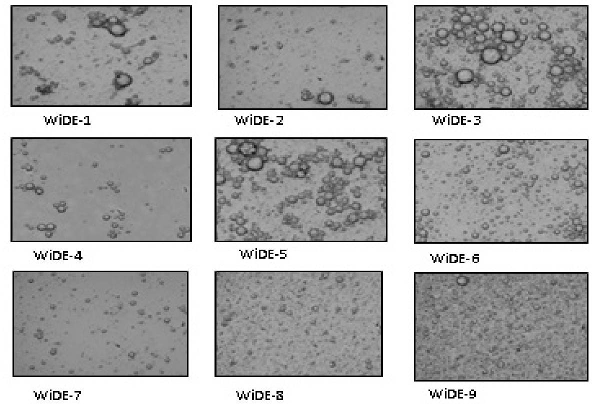

Figure-2. Images of water droplets distribution of WiDE.

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.

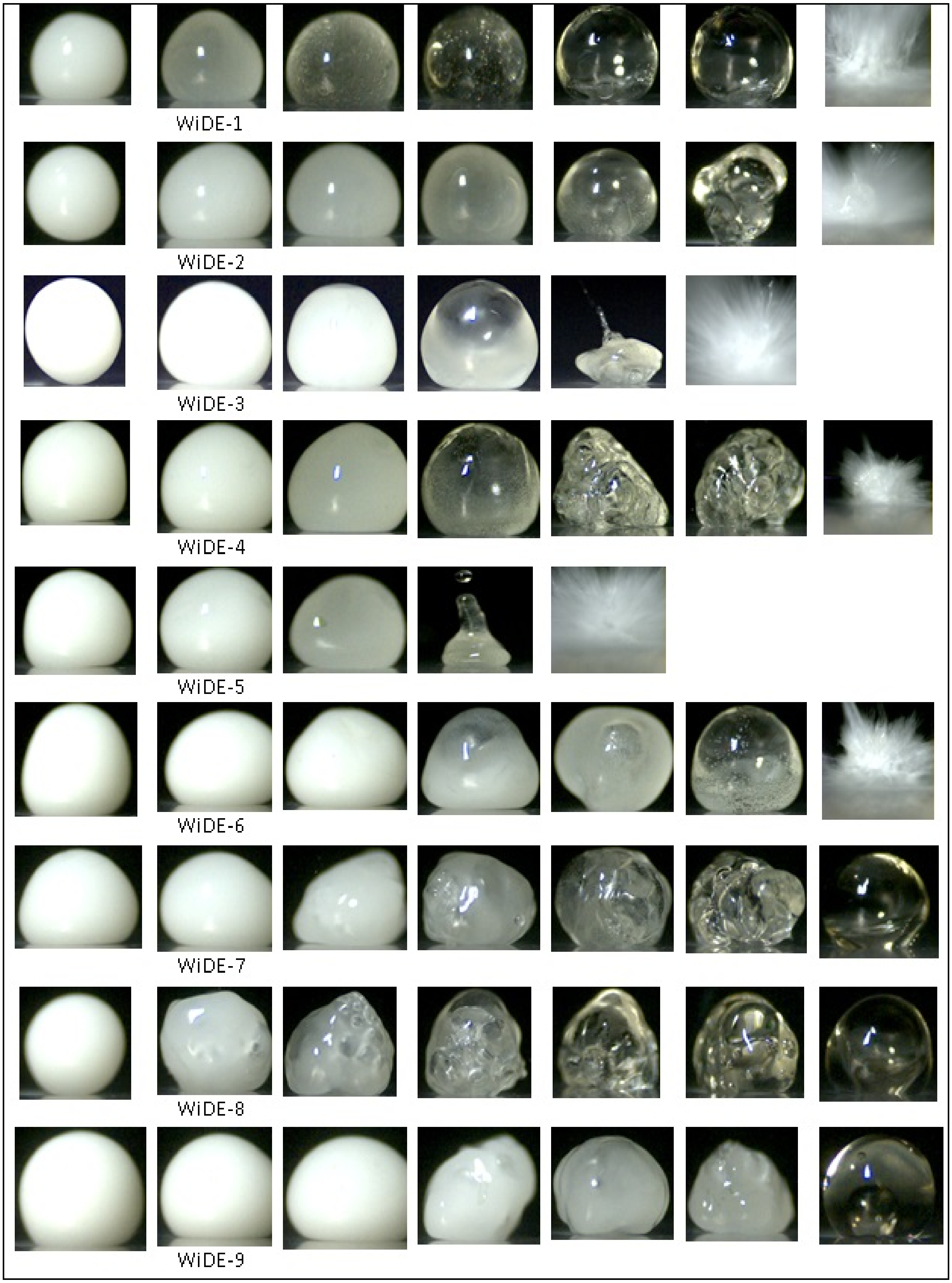

Figure-3. Microexplosion image sequence of WiDE-1 to WiDE-9 for time interval of every 0.5s.

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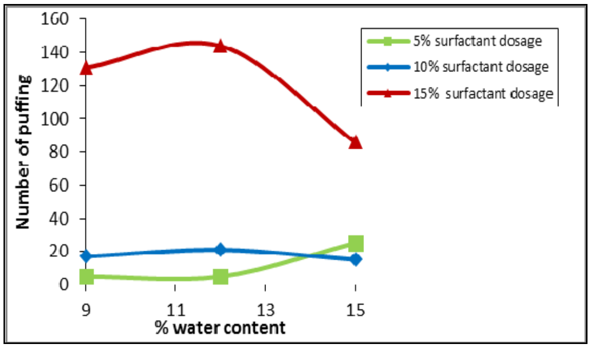

Figure-4. Puffing frequency of emulsions.

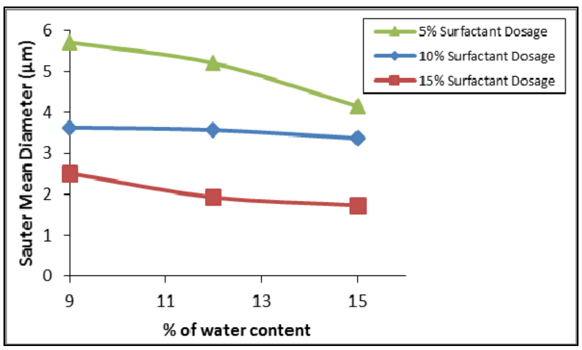

Figure-5. Sauter mean diameter of the dispersed water droplets.

As the droplets gets 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.

Figure-6. Child droplet ejection of WiDE-7 to WiDE-9 due to puffing.

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.

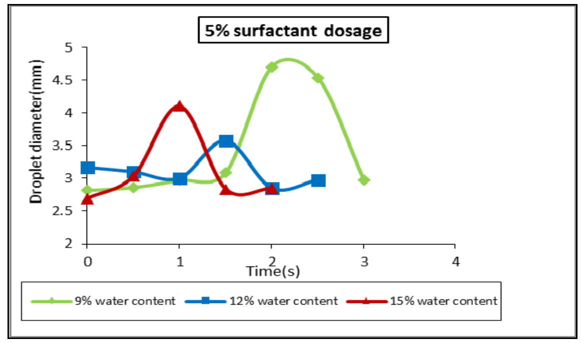

Figure-7. Change in diameter of WiDE-7 droplets.

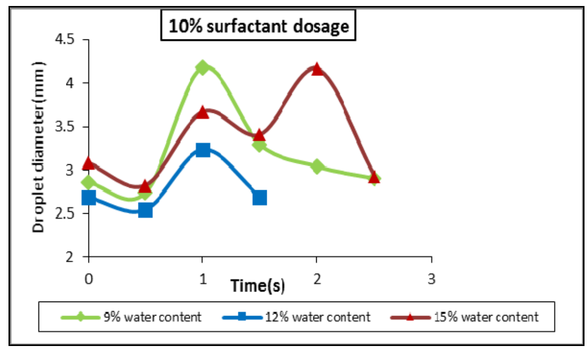

Figure-8. Change in diameter of WiDE-8 droplets.

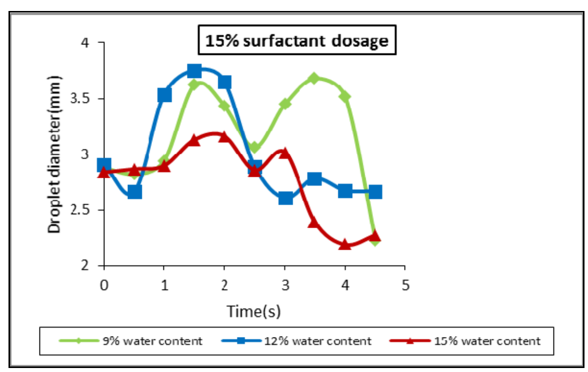

Figure-9. Change in diameter of WiDE-9 droplets.

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.

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