

## **THESIS**

Name	E Soon Shen
Student ID	KA13056
Tittle	Formulation and characterization of water-in-diesel emulsion as environmental friendly fuel
Supervisor	Prof Dr Abdurahman Hamid Nour
Evaluation Group	BKC 1

# Faculty of Chemical & Natural Resources Engineering UNIVERSITI MALAYSIA PAHANG

2016

# FORMULATION AND CHARACTERIZATION OF WATER-IN-DIESEL EMULSION AS ENVIRONMENTAL FRIENDLY FUEL

#### E SOON SHEN

# BACHELOR OF CHEMICAL ENGINEERING UNIVERSITI MALAYSIA PAHANG

# FORMULATION AND CHARACTERIZATION OF WATER-IN-DIESEL EMULSION AS ENVIRONMENTAL FRIENDLY FUEL

#### E SOON SHEN

Thesis is submitted in partial fulfilment of the requirements

for the award of the degree of

Bachelor of Chemical Engineering

Faculty of Chemical & Natural Resources Engineering
UNIVERSITI MALAYSIA PAHANG

DECEMBER 2016

#### SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Chemical Engineering.

Signature :

Name of main supervisor : DR ABDURAHMAN HAMID NOUR

Position : PROFESSOR

Date : 15 DECEMBER 2016

#### STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree

Signature :

Name : E SOON SHEN

ID Number : KA13056

Date : 15 DECEMBER 2016

Dedicated to my parents, and my family.

#### **ACKNOWLEDGEMENT**

I would like to express my special appreciation and thanks to my supervisor, Prof. Dr. Abdurahman Hamid Nour. You have been a brilliant mentor for me. I would like to thank you for your never ending support during my tenure as research student under your guidance, for giving insightful comments and suggestions of which without it, my research path would be a difficult one. Your advice on my research has been valuable.

A special thanks to my family. Words cannot express how grateful I am to my mother, father and siblings for the love and support throughout these years. Your prayer for me was what sustained me thus far. I would like express appreciation to my beloved girl-friend who always be my support in the moments when there was no one to answer my queries and for all the sacrifices you have made on my behalf.

I am also indebted to the Ministry of Higher Education and Universiti Malaysia Pahang for funding my study.

I would also like to thank all of my friends who supported me in writing, and motivate me to strive towards my goal. I am sincerely grateful to the staffs of Chemical Engineering and Natural Resources Faculty who helped me in many ways and made my stay in UMP pleasant and unforgettable.

### TABLE OF CONTENTS

SUPERVISOR'S DECLARATION	ii
STUDENT'S DECLARATION	iii
ACKNOWLEDGEMENT	v
ABSTRACT	vi
TABLE OF CONTENTS	vii
LIST OF FIGURES	ix
LIST OF TABLES	xi
LIST OF ABBREVIATIONS	xiii
CHAPTER 1.0 INTRODUCTION	1
1.1 Background of the study	1
1.2 Motivation	2
1.3 Problem Statement	2
1.4 Objectives	2
1.5 Scopes of study	3
CHAPTER 2.0 LITERATURE REVIEW	4
2.1 Overview	4
2.1.1 Gaps	
2.2 Diesel engine	5
2.2.1 Development of diesel engine and its fuel to be environmentally 2.2.2 Introduction of W/D emulsion fuel as environmental friendly fue	el for diesel
engine	
2.3.1 Classification of water-in-diesel emulsion	11 12 12
2.5 Methodologies used in previous W/D emulsion studies	14
2.5.1 Formulation of stable W/D emulsion	15 <b>19</b>
2.134 1	10

3.2 Methods	19
3.2.1 Preparation of W/D emulsion samples	19
3.2.2 Test for emulsion	
3.2.3 Gravitational stability test	
3.2.4 Characterization of W/D emulsion	21
CHAPTER 4.0 RESULT AND DISCUSSION	
4.1 Types of emulsions	23
4.2 Stability test	24
4.3 Microscopic size of water droplets	31
4.3.1 Effect of surfactant types	32
4.3.2 Effect of water concentration	
4.3.3 Effect of surfactant concentration	
4.4 Rheological characterization of W/D emulsion	40
4.4.1 Viscosity behavior for W/D emulsion	40
4.4.2 Effect of types of surfactant on viscosity	40
4.4.3 Effect of water concentration on viscosity	
4.4.4 Effect of surfactant concentration on viscosity	
CHAPTER 5.0 CONCLUSION AND RECOMMENDATION	70
5.1 Conclusion	70
5.2 Recommendation	71
CHAPTER 6.0 REFERENCES	72
CHADTED 7 0 ADDENDICES	77

### LIST OF FIGURES

Figure 2.1: (a) Water-in-oil-emulsion (W/O); (b): Oil-in-water emulsion (O/W)10
Figure 2.2: (a) Oil-in-water-in-oil emulsion (O/W/O); Figure 2.2(b): Water-in-oil-in-water emulsion (W/O/W) (Yahaya Khan et al., 2014)
Figure 3.1: Brookfield DV- III viscometer
Figure 4.1: (a) Triton X-100 emulsion, (b) Span 80 emulsion, (c) NS-16-2 emulsion.
Figure 4.2: (a) Freshly prepared W/D emulsion using Triton X-100 as surfactant, (b) Emulsion started to resolve whereby water rich emulsion and surfactant particles sedimented at the bottom of measuring cylinder, (c) Formation of 3 distinct layers26
Figure 4.3: (a) Most optimum stable W/D emulsion with 1.5% Span 80 surfactant and W/D ratio of 90:10, (b) Unstable W/D emulsion prepared using Span 80 surfactant. 29
Figure 4.4: (a) Stable W/D emulsion with 2.5% NS-16-2 and W/D ratio of 25:75, (b) Unstable W/D emulsion prepared using NS-16-2
Figure 4.5: Photomicrographs of 25:75 W/D ratio and 2.5% of: (a) NS-16-2, (b) Span 80, (c) Triton X-100
Figure 4.6: Photomicrographs of 1.5% Span 80 with W/D ratio of: (a) 10:90, (b) 15:85, (c) 20:80, (d) 25:75
Figure 4.7: Photomicrographs of 20:80 W/D emulsion with: (a) 0.5% NS-16-2, (b) 1.5% NS-16-2, (c) 2.5% NS-16-2
Figure 4.8: Photomicrographs of 10:90 W/D emulsion with: (a) 0.5% Span 80, (b) 1.5% Span 80 and (c) 2.5% Span 80
Figure 4.9: Relation of shear stress and shear rate for W/D emulsions with W/D ratios of: (a) 10:90, (b) 15:85, (c) 20:80 and (d) 27:7542
Figure 4.10: Relation of viscosity and shear rate for W/D emulsions with W/D ratios of: (a) 10:90, (b) 15:85, (c) 20:80 and (d) 27:7547
Figure 4.11: Relation of viscosity and temperature for W/D emulsions with W/D ratios of: (a) 10:90, (b) 15:85, (c) 20:80 and (d) 27:7551
Figure 4.12: Relation of shear stress and shear rate for W/D emulsions with: (a) 0.5% NS-16-2, (b) 1.5% NS-16-2 and (c) 2.5% NS-16-2
Figure 4.13: Relation of viscosity and shear rate for W/D emulsions with: (a) 0.5% NS-16-2, (b) 1.5% NS-16-2 and (c) 2.5% NS-16-257
Figure 4.14: Relation of viscosity temperature for W/D emulsions with: (a) 0.5% NS-16-2, (b) 1.5% NS-16-2 and (c) 2.5% NS-16-259
Figure 4.15: Relation of shear stress and shear rate for NS-16-2 W/D emulsions with W/D ratios of: (a) 10:90, (b) 15:85, (c) 20:80 and (d) 27:7563
Figure 4.16: Relation of viscosity and shear rate for NS-16-2 W/D emulsions with W/D ratios of: (a) 10:90, (b) 15:85, (c) 20:80 and (d) 27:75
Figure 4.17: Relation of viscosity and temperature for NS-16-2 W/D emulsions with W/D ratios of: (a) 10:90, (b) 15:85, (c) 20:80 and (d) 27:7569

Figure 7.1: Emulsions with 0.5% NS-16-2 and W/D ratio of (a) 10:90, (b) 15:85, (c) 20:80 and (d) 25:75 after 1 week
Figure 7.2: Emulsions with 1.5% NS-16-2 and W/D ratio of (a) 10:90, (b) 15:85, (c) 20:80 and (d) 25:75 after 1 week
Figure 7.3: Emulsions with 2.5% NS-16-2 and W/D ratio of (a) 10:90, (b) 15:85, (c) 20:80 and (d) 25:75 after 1 week
Figure 7.4: Emulsions with 0.5% Span 80 and W/D ratio of (a) 10:90, (b) 15:85, (c) 20:80 and (d) 25:75 after 1 week
Figure 7.5: Emulsions with 1.5% Span 80 and W/D ratio of (a) 10:90, (b) 15:85, (c) 20:80 and (d) 25:75 after 1 week
Figure 7.6: Emulsions with 2.5% Span 80 and W/D ratio of (a) 10:90, (b) 15:85, (c) 20:80 and (d) 25:75 after 1 week
Figure 7.7: Emulsions with 0.5% Triton X-100 and W/D ratio of (a) 10:90, (b) 15:85, (c) 20:80 and (d) 25:75 after 1 week
Figure 7.8: Emulsions with 1.5% Triton X-100 and W/D ratio of (a) 10:90, (b) 15:85, (c) 20:80 and (d) 25:75 after 1 week
Figure 7.9: Emulsions with 2.5% Triton X-100 and W/D ratio of (a) 10:90, (b) 15:85, (c) 20:80 and (d) 25:75 after 1 week

## LIST OF TABLES

Table 2.1: Literature matrix of engine performance and exhaust emission for W/D fue
Table 2.2: Measured viscosities and water droplet sizes (Morozumi & Saito, 2010) .10
Table 2.3: Measured interfacial tension between n-hexadecane and water (Morozum & Saito, 2010)
Table 2.4: Comparisons of W/O diesel emulsion properties prepared by a mechanical homogenizer (denoted as W/O emulsion A) and an ultrasonic vibrator (denoted as W/O emulsion B) (Lin & Chen, 2008)
Table 2.5: Chemical characteristics and properties of emulsified fuel and commercia diesel fuel (Armas et al., 2004)
Table 3.1: Formulation of W/D emulsion samples19
Table 4.1: Stability study of emulsions prepared using Triton X-10024
Table 4.2: Stability study of emulsions prepared using Span 802
Table 4.3: Stability study of emulsions prepared using UMP surfactant (NS-16-2)30
Table 4.4: Shear stress and shear rate of W/D emulsion with 10:90 W/D ratio42
Table 4.5: Shear stress and shear rate of W/D emulsion with 15:85 W/D ratio42
Table 4.6: Shear stress and shear rate of W/D emulsion with 20:80 W/D ratio4.
Table 4.7: Shear stress and shear rate of W/D emulsion with 20:80 W/D ratio4.
Table 4.8: Viscosity and shear rate of W/D emulsion with 10:90 W/D ratio4
Table 4.9: Viscosity and shear rate of W/D emulsion with 15:85 W/D ratio4:
Table 4.10: Viscosity and shear rate of W/D emulsion with 20:80 W/D ratio4:
Table 4.11: Viscosity and shear rate of W/D emulsion with 25:75 W/D ratio40
Table 4.12: Viscosity and temperature of W/D emulsion with 10:90 W/D ratio4
Table 4.13: Viscosity and temperature of W/D emulsion with 15:85 W/D ratio43
Table 4.14: Viscosity and temperature of W/D emulsion with 20:80 W/D ratio49
Table 4.15: Viscosity and temperature of W/D emulsion with 25:75 W/D ratio49
Table 4.16: Shear stress and shear rate of 0.5% NS-16-2 W/D emulsion5
Table 4.17: Shear stress and shear rate of 1.5% NS-16-2 W/D emulsion52
Table 4.18: Shear stress and shear rate of 2.5% NS-16-2 W/D emulsion52
Table 4.19: Viscosity and shear rate of 0.5% NS-16-2 W/D emulsion54
Table 4.20: Viscosity and shear rate of 1.5% NS-16-2 W/D emulsion53
Table 4.21: Viscosity and shear rate of 2.5% NS-16-2 W/D emulsion53
Table 4.22: Temperature and viscosity of 0.5% NS-16-2 W/D emulsion5
Table 4.23: Temperature and viscosity of 1.5% NS-16-2 W/D emulsion53
Table 4.24: Temperature and viscosity of 2.5% NS-16-2 W/D emulsion58

Table 4.25: Shear stress and shear rate of NS-16-2 W/D emulsion with 10:90 W/D ratio
Table 4.26: Shear stress and shear rate of NS-16-2 W/D emulsion with 15:85 W/D ratio
Table 4.27: Shear stress and shear rate of NS-16-2 W/D emulsion with 20:80 W/D ratio
Table 4.28: Shear stress and shear rate of NS-16-2 W/D emulsion with 25:75 W/D ratio
Table 4.29: Viscosity and shear rate of NS-16-2 W/D emulsion with 10:90 W/D ratio
Table 4.30: Viscosity and shear rate of NS-16-2 W/D emulsion with 15:85 W/D ratio
Table 4.31: Viscosity and shear rate of NS-16-2 W/D emulsion with 20:80 W/D ratio
Table 4.32: Viscosity and shear rate of NS-16-2 W/D emulsion with 25:75 W/D ratio
Table 4.33: Viscosity and temperature of NS-16-2 W/D emulsion with 10:90 W/D ratio
Table 4.34: Viscosity and temperature of NS-16-2 W/D emulsion with 15:85 W/D ratio
Table 4.35: Viscosity and temperature of NS-16-2 W/D emulsion with 20:80 W/D ratio
Table 4.36: Viscosity and temperature of NS-16-2 W/D emulsion with 25:75 W/D ratio

#### LIST OF ABBREVIATIONS

CMC : Critical micelle concentration

O/W : Oil-in-water

O/W/O : Oil-in-water-in-oil

W/D : Water-in-diesel

W/O : Water-in-oil

W/O/W : Water-in-oil-in-water