FORMULATION, CHARACTERIZATION, AND OPTIMATION OF EMULSION FUEL

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ABSTRACT

This research presents formulation, characterization, and optimization study of emulsion fuel. Different types of surfactants, ratios of surfactants, and water/oil ratios were used. Types of surfactants used were Span-80, Triton X-100, and SDDS. The ratios used for each surfactant was 1.0%, 1.5%, and 2.0%. The ratios of water/oil used were 20/80, 30/70, and 40/60. The samples were prepared by dissolving surfactant in the oil, followed by addition of water. The samples were agitated using three-bladed propeller to disperse the water in the emulsion. Two types of tests were done to the samples; the first is stability test, and the second is viscometer test. Stability test was done with the duration of five to six days, and data of shear rate, shear stress, torque, and viscosity were recorded via viscosity test. Viscosity test was done for 30°C, 50°C, and 70°C with rpm of 20, 30, 50, and 30. Results from observation and viscometer test suggest that Span-80 with 2% surfactant and 20/80 water ratio is the most stable emulsion. Results from this work may be useful for further development of emulsion fuel.

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LIST OF ABBREVIATIONS

SDDS	Sodium Dodecyl Sulfate
Span 80	Sodium Monooleate
Srfctnt	Surfactant
Triton X-100	Octyl phenol ethoxylate
W/O	Water to oil ratio

1 INTRODUCTION

1.1 Motivation of study

As the source of fuel become scarcer, it is vital to look for alternatives to fossil fuel. Researchers, who are looking at the problem in development aspect, are looking for a new type of fuel which is more environmental friendly than the current fuel. Meanwhile, entrepreneurs are more interested in fuel which is more economical while at the same time provide equal or better efficiency than the current fuel.

The current diesel fuel contains no percentage of water. Generally, water in diesel is unfavorable as it can cause engine damage and corrosion in the system. However, using conventional diesel fuel which is 100% fuel emits NOx which is harmful for environment. An initiative to the decreasing fossil fuel is by using emulsion fuel. Emulsion fuel not only helps to lessen our use on fossil fuel, emulsion fuel is known to have a better efficiency and emit less NOx than conventional diesel fuel.

Emulsion fuel is water and oil emulsion, with water in the dispersed phase and oil as the continuous phase. Unlike normal emulsion, emulsion in emulsion fuel is at sub-micron level. Generally, emulsion fuel contain about 10-20% of water, and use surfactant known as emulsifier to keep the emulsion stable. An unstable emulsion will cause the dispersed phase and continuous phase to be separated, creating two layers of immiscible liquid. Emulsion fuel is different from conventional fuel in the aspect that emulsion fuel gives a cleaner burning than that of conventional fuel.

According to Ecofuel (2011), the mechanism of diesel fuel combustion is as follow: when diesel is to be combusted, it is sprayed into the combustion chamber. The fuel droplets will be atomized into smaller sizes in varying degree. Combustion takes place at the surface area of the droplets, and this left the larger droplets with portions that do not burn completely. The unburned carbons will be accumulated at the inner surface of the combustion chamber, which will reduce the efficiency of the chamber in the long run, or it will escape through the exhaust as particulate matter. These unburned carbons reduce the efficiency of the fuel and emits harmful gases to the environment.

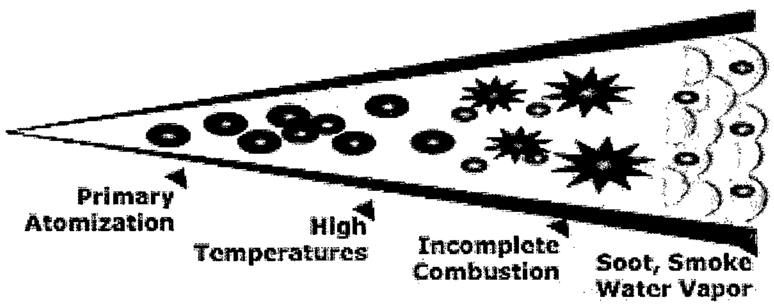

Figure 1.1: Conventional diesel combustion (Retrieved from Ecofuel s.a.r (2011)

Emulsion diesel fuel is different from conventional diesel in terms that they have a second atomization when water droplets in emulsion experience high temperature change and turn into vapor. The transformation to steam further atomized diesel droplets around the steam molecule, bringing the fuel droplets to even smaller sizes. As smaller droplets have bigger surface area over volume ratio, the combustion of emulsion diesel fuel is much more complete than conventional diesel, increasing the fuel efficiency. Complete combustion combined with amount of fuel burned during combustion significantly decrease the amount of toxic gas released to the atmosphere.

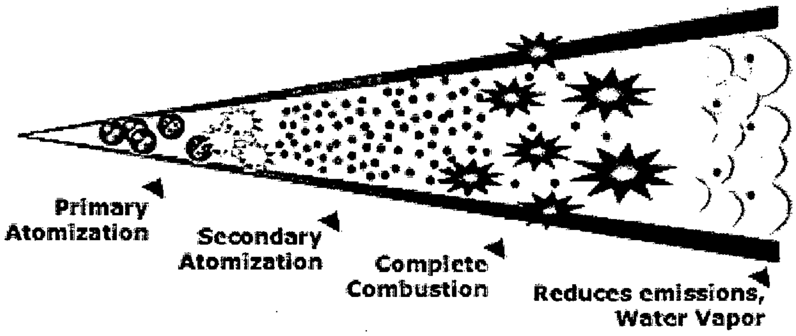

Figure 1.2: Emulsion diesel fuel combustion (Retrieved from Ecofuel s.a.r (2011)

1.2 Problem statement:

Conventional fuel does not burn completely, which release NOx and other harmful gases to the atmosphere. The reserve of fossil fuel is decreasing with globalization. Toxic release and supply of fossil fuel has become a worldwide problem.

1.3 Objectives:

There are three objectives of we are aiming to accomplish in this research. The first objective is to formulate an emulsion fuel that is very stable and have a significant amount of water as the dispersed phase. The second objective is to find the best optimization in terms types of emulsifier and the amount of it, the best RPM to achieve stabilization, and the percentage of water/oil emulsion itself. The last objective is to devise a technique to break the dispersed phase (water) to an even smaller size to rid the emulsion fuel of the milky color.

1.4 *Scope of study:*

In this research, we are focusing on diesel fuel. We are using three kinds of surfactant, which is Triton X-100, Span 80, and Sodium Dodecyl Sulphate (SDDS). We are going to use different percentage of each emulsifier for our emulsion stability study. Furthermore, in this research we are also going to use different ration of water/oil emulsion which are 20/80, 30/70, and 40/60. For propeller speed, we are going to use propeller speed in the range of 2000 rpm. Our emulsion is prepared at temperature between 30-50°C.

We are going to study the effect of amount of water separated, shear rate, shear stress, surface tension, interfacial tension, viscocity, pour point, cloud point, and flash point over emulsion stability.

1.5 *Main contribution of work*

There are several significances in conducting this study. On is to find an alternative to fossil fuel. Having an alternative to fossil fuel is crucial as fossil fuel is depleting fast with the rate of globalization around the world. It is also vital as gases emitted from fossil fuel combustion are one of the major air pollutants. This is especially true in cities and developing countries. Emulsion fuel is also more environmental friendly compared to conventional diesel fuel, so by using emulsion fuel, less damage is done to nature. . A better, cheaper, and safer alternative may be the stepping stone to change public perception regarding environmental issue and the cost required to implement it. As environmental issue has become a concern to many developed countries, emulsion fuel has become a hot topic among researchers and businessman alike, giving a big opportunity in the research of emulsion fuel. As mentioned before, fossil fuel resources are running dry. Thus, advancement in oil industry technology, such as this, is needed to ensure a better management of our now limited sources of crude oil.

2 LITERATURE REVIEW

2.1 Emulsion

Emulsion is defined as a mixture of two or more immiscible liquids in dispersed and continuous phase. To understand more about dispersed and continuous phase, let say we have two types of liquid, A and B. Dispersed phase means that the droplets of a liquid (liquid A) is scattered or dispersed in medium of another liquid (liquid B) while continuous phase is a liquid in the disperse system (liquid B) in which the droplets of another liquid (liquid A) is scattered. Continuous phase is also known as dispersion medium.

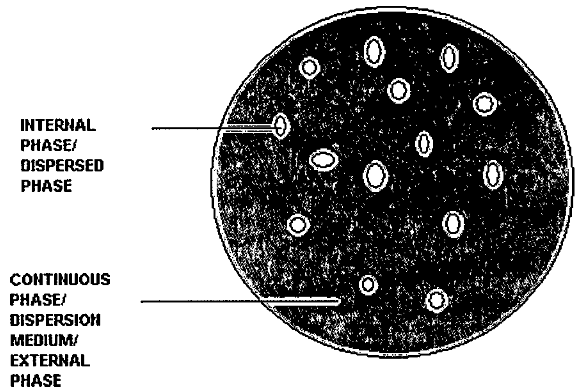

Figure 2.1: Dispersed and continuous phase. From Ali, Babuta, & Ahuja (2008).

2.2 Emulsion fuel

Emulsion fuel is a new type of fuel where water and oil coexist as emulsion, with water in the dispersed phase and oil as the continuous phase. The most preferable emulsion fuel is an emulsion where the water droplets are in sub-micron level, as smaller droplets mean a greater stability of the emulsion. Emulsion fuel uses a surfactant called 'emulsifier to retain the emulsion stability and keep the dispersed droplets from coagulating. Emulsion fuel is different from conventional fuel in the aspect that emulsion fuel gives a cleaner burning than that of conventional fuel.

According to Ecofuel (2011), the mechanism of diesel fuel combustion is as follow: when diesel is to be combusted and sprayed into the combustion chamber, the water droplets will implode into smaller sizes, and in turns the water droplets will cause the fuel droplets to break down into smaller sizes. Combustion takes place at the surface area of fuel droplets, and this will cause the larger fuel droplets with portions left unburned. The unburned carbons in the fuel droplets will accumulate at the inner surface of the combustion chamber, and reduce the efficiency of the chamber in the long run. Some of the carbons will escape through the exhaust as particulate matter as harmful gases to the environment.

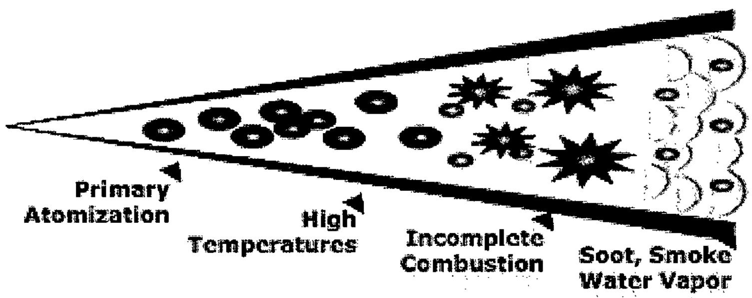

Figure 2.2: Conventional diesel combustion (Retrieved from Ecofuel s.a.r (2011)

Emulsion diesel fuel has second atomization. This happens when water droplets in emulsion experience high temperature change and turn into vapor. The transformation of water droplets to steam will further atomized diesel droplets around the steam molecule, bringing the fuel droplets to even smaller sizes. As smaller droplets have bigger surface area over volume ratio, the combustion of emulsion diesel fuel is much more complete than conventional diesel, increasing the fuel efficiency. As emulsion diesel fuel contains a portion of water, it gives a cleaner burning than conventional diesel, and this will significantly decrease the amount of harmful gas released to the atmosphere.

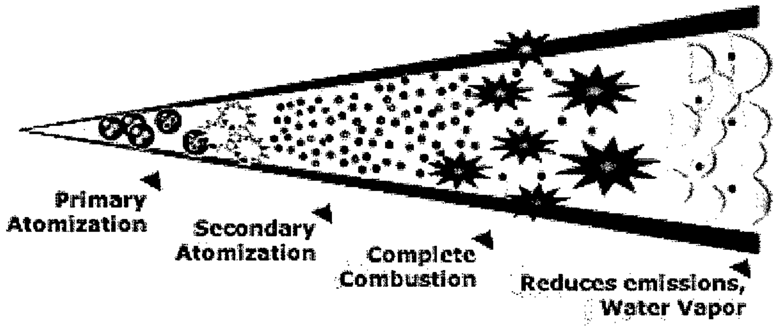

Figure 2.3: Emulsion diesel fuel combustion (Retrieved from Ecofuel s.a.r (2011)

According to Hiroki (n.a), the characteristics of a good and stable emulsion fuel is as follow:

1. The diameters of water droplets in the emulsion should be uniform and smaller than 10μm.
2. There should be no separate layer of water and oil in the emulsion fuel after the preparation process till the emulsion fuel is fed to the combustion chamber.
3. The emulsion should not be affected by temperature change and flow rate when combusted in the gas chamber.

4. There should be no indication of corrosion happening in the combustion chamber caused by the emulsion fuel.
5. The emulsifier used to maintain the stability of emulsion should be minimized as possible.
6. The cost to produce the emulsion fuel should be economical.

2.3 Emulsion stability

A stable emulsion is defined as emulsion in which the water persists for 5 days or longer (Fingas, M., Fieldhouse, B., Mullin, 1994, as cited in Lee, 1999). The characteristics of a stable water-in-oil emulsion are small water droplets (1 to 10 μm), high water content (50% to 90%), high viscosity, and higher density than the original oil (Brandvik and Daling, 1991; Fingas et al., 1994, as cited in Lee, 1999). Asphaltene and waxes, which can be found in crude oil, as well as resins and sea particulates, also contribute to water-in-oil emulsion's stability (Lee, 1999).

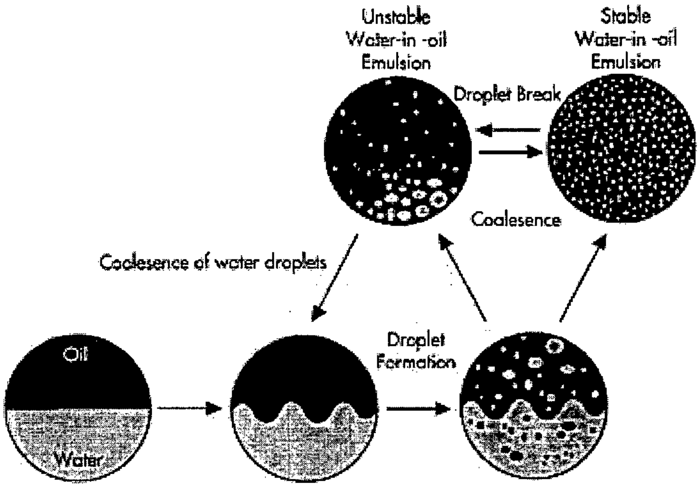

Figure 2.4: Formation of water in oil emulsions. Modified from Lewis and Walker (1993), as cited in Lee (1999)

2.4 *Emulsion instability*

There are three types of emulsion instability: flocculation, sedimentation, and creaming. The first type, flocculation, is a process when microscopic particles (dispersed phase) coagulate to form larger particles in the form of 'flocs' or 'flakes', suspended in the continuous phase. The second instability of emulsion is sedimentation, a process where particles large enough to be affected by gravity settled to the bottom of a fluid. Centrifugal force can be used for sedimentation if the particles are too small to be influenced by gravity. The last type of instability is creaming, which is the opposite of sedimentation. Where sedimentation causes particles to settle down at the bottom of fluid, creaming is a process where particles congregate at the top of the liquid, still retaining their separation from other particles. Creaming depends on relative densities of the two immiscible liquid, the size of particles, and viscosity of the continuous liquid.

fines and mud solids deposited near the wellbore during production and drilling (Venkitaraman et al., 1994).

2.6 Ultrasound in emulsion fuel technology

Hielsher Ultrasonics GmbH is one of company that uses ultrasonic cavitations to produce nano-particles in emulsion fuel technology. According to Hielscher (2005), ultrasonic cavitation initiates implosion in the dispersed zone, resulting in the formation of liquid nano-droplets in the continuous phase. Emulsifier is used to stabilize the newly formed droplets so the droplets will not coalesce and form a separate layer from the continuous phase. However, the emulsifier used has to be efficient enough so that the amount is used is proportional to the distribution of the droplets after being hit by ultrasonic cavitation.

According to a study conducted by Behrend and Schubert (2000) as cited from Hiescher website (2011), there is a correlation between particle size and emulsion stability. From the study, they concluded that the smaller the particle size, the more stable is the emulsion in question. The study also shows the correlation between energy density and droplet size.

2.7 Reduction in NO_x emissions

As cited from Hiesher website (2011), a summary of NO_x reduction is concluded from a research done by Canfield (1999):

- Unstabilized emulsion

  Water added : 10 to 80%

  NO_x reduction : 4 to 60%

- Stabilized emulsion

  Water added : 25 to 50%

  NO_x reduction : 22 to 83%

3 MATERIALS AND METHOD

3.1 Introduction

In this research, we are going to study the formulation, characterization, and optimization of emulsion fuel. We are using three kinds of emulsifier which are Span 80, Triton X-100, and SDDS, with each emulsifier to emulsion ratio from 1.0-2.0%. We are using three ratios of water/oil emulsion which are 20/80, 30/70, and 40/60.

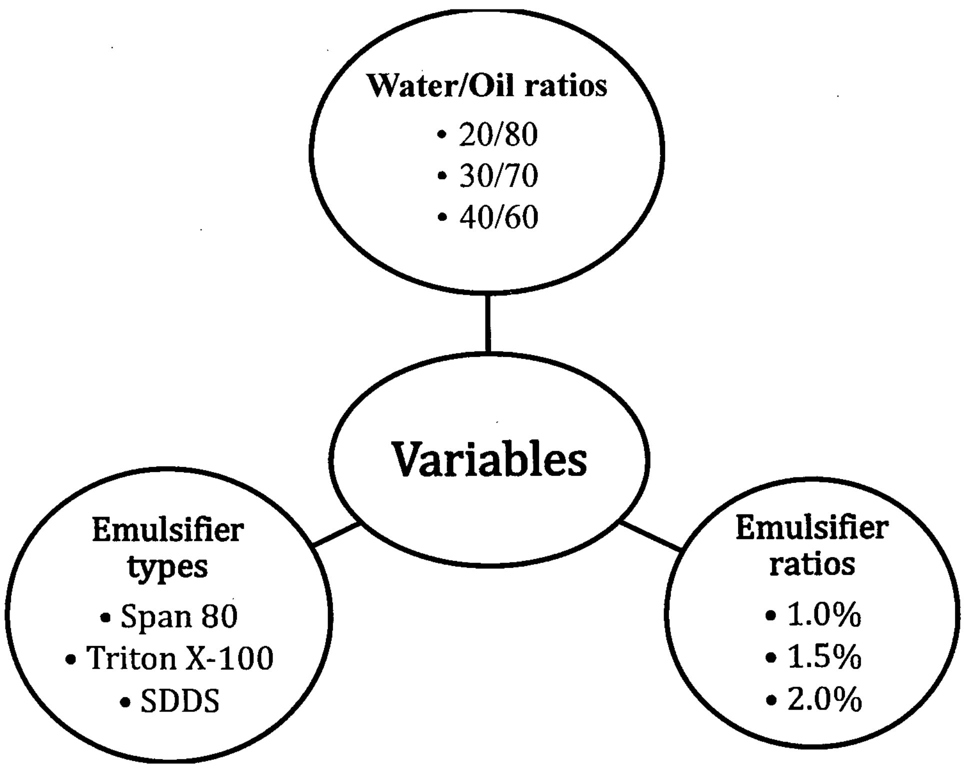

Figure 3.1: List of variables in the research.

3.2 Procedure

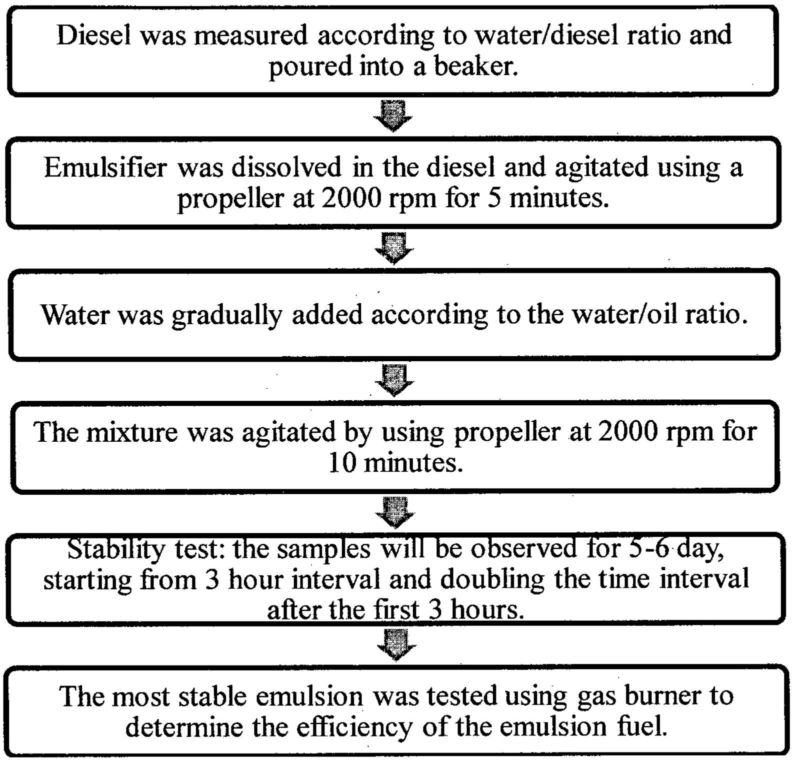

Figure 3.2: Procedures on preparing emulsion fuel. Adapted from A.N. Ilia Anisa et al., (2011)

4 RESULT AND DISCUSSION

4.1 Result

Sample 1.1.2, which is Span 80 with 30/70 water/oil ratio with 1% surfactant give encouraging result. Below is the result on stability test and viscometer.

Viscometer test:

TEMP	30°C	**SPINDLE**	18	
RPM	20	30	50	80
TORQUE (%)	10.5	13.9	19.1	27.4
VISC (mPas)	15.6	13.8	11.5	10.3
S.STR(N/m^2)	0.41	0.55	0.76	1.08
S.RATE (1/sec)	26.4	39.6	66	106
TEMP	50°C	**SPINDLE**	18	
RPM	20	30	50	80
TORQUE (%)	7.2	10.2	14.4	20.7
VISC	11.2	10.3	8.64	7.80
S.STR	0.3	0.40	0.57	0.83
S.RATE	26.4	39.6	66	106
TEMP	70°C	**SPINDLE**	18	
RPM	20	30	50	80
TORQUE (%)	6.8	8.2	11.2	15.8
VISC	10.0	8.2	6.78	5.92
S.STR	0.26	0.32	0.45	0.63
S.RATE	26.4	39.6	66	106

Table 4.1: Viscometer test for Sample 1.1.2

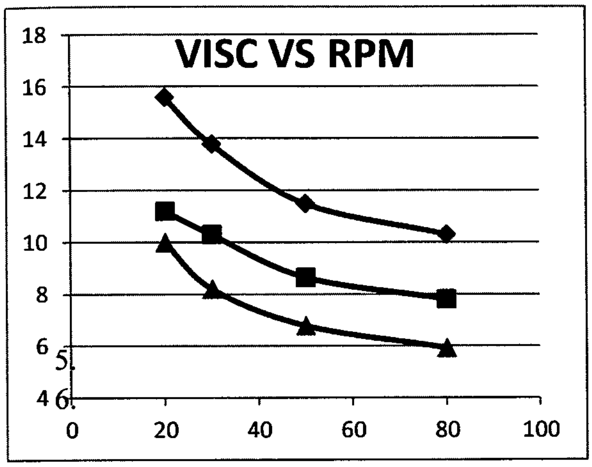

Figure 4.2: Viscosity vs. RPM for Sample 1.1.3

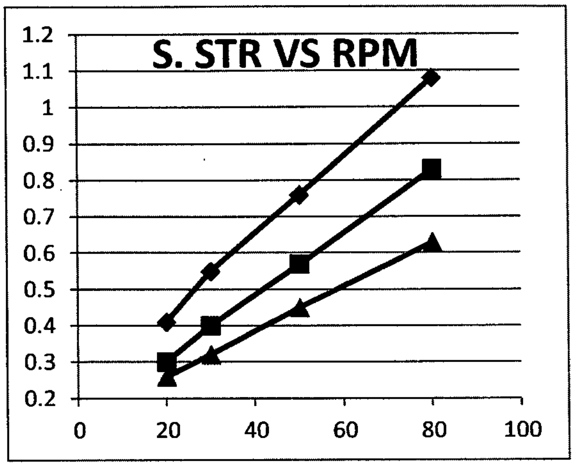

Figure 4.1: Shear strentgh vs. RPM for sample 1.1.3

Legend: 30°C
50°C
70°C

Stability Test:

Date	Time (hr)	Bottom (mL) (Milky white)	Middle (mL) (Milky brown)	Oil (mL)	Total (mL)
1st day 6/3/13	0	Milky white mixture			198
	3	178	16	-	194
	6	167	27	-	194
2nd day 7/3/13	24	152	42	-	194
3rd day 8/3/13	48	146	44	4	194
6th day 11/3/13	120	132	56	6	194

Table 4.2: Stability test for Sample 1.1.3

Sample 3.2.1, which is Triton X-100 with 20/80 water/oil ration with 1% surfactant, also give encouraging result, though not as stable as Sample 1.1.3. The data on viscometer and stability test is as below.

Viscometer test:

TEMP	30°C	**SPINDLE**	18	
RPM	20	30	50	80
TORQUE (%)	2.5	3.6	4.8	5.2
VISC (mPas)	4.05	3.6	2.94	2.40
S.STR(N/m²)	0.10	0.14	0.19	0.25
S.RATE (1/sec)	26.4	39.6	66	106
TEMP	50°C	**SPINDLE**	18	
RPM	20	30	50	80
TORQUE (%)	1.5	3.4	3.7	4.7
VISC	2.25	2.20	2.22	1.71
S.STR	0.06	0.09	0.13	0.19
S.RATE	26.4	39.6	66	106
TEMP	70°C	**SPINDLE**	18	
RPM	20	30	50	80
TORQUE (%)	2.0	3.5	4.7	6.8
VISC	3.60	3.5	2.88	2.66
S.STR	0.09	0.14	0.19	0.28
S.RATE	26.4	39.6	66	106

Table 4.3: Viscometer test for Sample 3.2.1

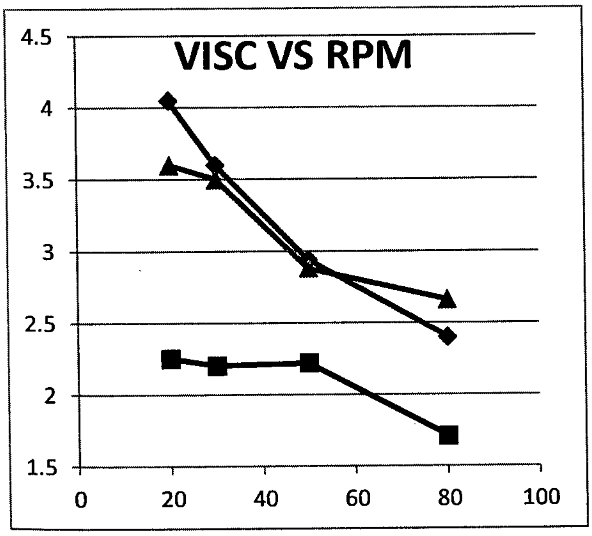

Figure 4.3: Viscosity vs. RPM for Sample 3.2.1

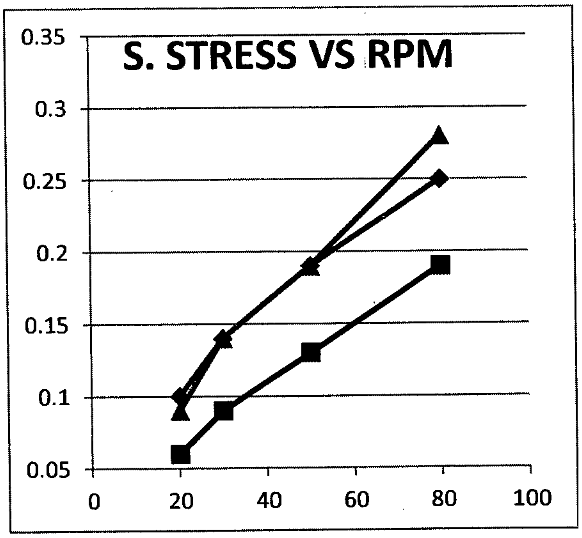

Figure 4.4: Shear strength vs. RPM for Sample 3.2.1

Legend: —◆— 30°C
—■— 50°C
—▲— 70°C

Stability test:

Date	Time (hr)	Bottom (mL) (Pale white)	Middle_1 (mL) (Milky white)	Middle_2 (mL) (Bubble)	Top (mL) (Dilute yellow)	Oil (mL)	Total (mL)
1st day 18/3/13	0	Dilute yellow mixture					198
	3	41	1	42	114	-	198
	6	41	1	32	122	2	198
2nd day 19/3/13	12	41	3	28	118	9	199
3rd day 20/3/13	24	41	3	20	128	6	200
5th day 21/3/13	48	42	2	20	128	7	199

Table 4.4: Stability test for Sample 3.2.1

Below is the summary of oil separation for each sample tested at the end of their stability test.

Sample	Srfctnt	Srfctnt (%)	W/O	Duration (days)	Oil	
					mL	%
1.1.1	Span 80	1	20/80	6	4	2.50
1.1.2	Span 80	1	30/70	6	4	2.86
1.1.3	Span 80	1	40/60	6	6	5.00
1.2.1	Span 80	1.5	20/80	6	3	1.88
1.2.2	Span 80	1.5	30/70	6	4	2.86
1.2.3	Span 80	1.5	40/60	6	5	4.17
1.3.1	Span 80	2	20/80	6	5	3.13
1.3.2	Span 80	2	30/70	6	4	2.86
1.3.3	Span 80	2	40/60	6	4	3.33
3.1.1	Triton X-100	1	20/80	5	-	0
3.1.2	Triton X-100	1	30/70	5	3	2.14
3.1.3	Triton X-100	1	40/60	5	9	7.50
3.2.1	Triton X-100	1.5	20/80	5	7	4.38
3.2.2	Triton X-100	1.5	30/70	5	6	4.29