INVESTIGATING OIL MIXTURE FLOW CHARACTERIZATION

by

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LIST OF ABBREVIATIONS

mm	Milimeter
mL	Mililitre
ppm	Parts per million
rpm	Revolution per minute
RDA	Rotating Disk Apparatus
%DR	Drag Reduction Percentage
HLB	Hydrophile – Lipophile Balance
W/O	Water – in – Oil Emulsion
O/W	Oil – in – Water Emulsion

LIST OF SYMBOLS

ρ	Emulsion density
r	Radius of the disk
μ	Dynamic viscosity of emulsion
ω	Angular velocity
τ_{BS}	Measured torque on the disk
τ_{DRS}	Measured torque with the presence of addictive
E^S	Total surface energy
G^S	Surface free enthalpy
S^S	Surface entropy per unit area of surface
σ	Interfacial tension
R	Drop radius
ρ_l	Droplet density
g	Acceleration of gravity
μ	Viscosity of dispersion medium

PENYIASATAN PENCIRIAN ALIRAN MINYAK CAMPURAN

ABSTRAK

Dalam kajian ini kelikatan tinggi minyak mentah yang mempunyai aliran gelora yang berarus deras mewujudkan rintangan dan juga dikenali sebgai heretan akan mengurangkan mobiliti dan aliran minyak mentah. Oleh itu, lebih kuasa diperlukan untuk mengangkut cecair. Kajian ini adalah untuk menyiasat minyak prestasi campuran apabila agen pengurangan heret diperkenalkan ke dalam sistem. Dalam eksperimen ini, prestasi agen digunakan adalah surfaktan bukan ionik, Triton X - 15 dan Triton X - 114 ditambah ke dalam campuran minyak untuk membentuk emulsi dan sampel diuji menggunakan radas cakera berputar. Parameter yang disiasat adalah kepekatan surfactant, jumlah pecahan kelajuan minyak dan air, putaran dan jenis surfactant yang digunakan bedasarkan kesannya ke hadap emulsi. Nilai tork (aliran kerintangan) diukur berbeza dengan kelajuan putaran sehingga diuji dari 50 rpm hingga 3000 rpm dan kepekatan emulsi pada 600 ppm, 800 ppm dan 1000 ppm. Selain itu, jumlah air yang berbeza: nisbah minyak (50% - 50%, 60% - 40%, 70% - 30%) juga disiasat. Triton X - 114 mempunyai potensi yang tinggi dalam meningkatkan pengangkutan minyak mentah melalui saluran paip sebagai emulsi terbentuk yang mengandungi minyak 40% dan 60% air menunjukkan tork membaca kurang daripada nilai tork yang dikenakan oleh minyak masak tanpa tambahan apa-apa addictives. Pengurangan tork adalah kira-kira 50% lebih rendah daripada minyak masak tanpa sebarang addictives. Ia membuktikan bahawa Triton X - 114 merendahkan ketegangan permukaan cecair oleh itu ia mengurangkan aliran kerintangan. X Triton - 15 amat tidak digalakkan dalam membentuk emulsi untuk pengangkutan kerana ia mengenakan rintangan yang tinggi dalam bentuk emulsi. Ia amat disyorkan untuk kerja-kerja masa depan bahawa kajian perlu dilakukan dalam skop yang lebih besar pada parameter tertentu eksperimen khusus kepada addictives lebih perlu diuji. Selain itu, kajian yang lebih reologi perlu diperluas ke atas kesan suhu, kepekatan dan pecahan isipadu pada prestasi emulsi Selain, ia adalah lebih baik jika pembentukan titisan pada saiz emulsi untuk mempunyai yang lebih baik pemahaman faktor menyumbang kepada kestabilan emulsi.

INVESTIGATING OIL MIXTURE OIL CHARATERIZATION

ABSTRACT

In this research the high viscosity of crude oil exerts high turbulences creates the resistance (drag) and lower the mobility and flow of the crude oil. Thus, more power is needed to transport the fluid. This research is to investigate oil mixture performance when addictives are introduced into the system. In this experiment, the performance the addictives used are non – ionic surfactants, Triton X – 15 and Triton X – 114 are added into the oil mixture to form emulsions and the samples are tested using rotating disk apparatus. The investigate parameters are effect of the concentration of surfactant, volume fraction of oil and water, rotational speed and types of surfactant used to the emulsion. The torque value (flow resistivity) measured varies with the rotational speed up tested from 50 rpm to 3000 rpm and the emulsion concentration at 600 ppm, 800 ppm and 1000 ppm. Besides, different volume of water: oil ratios (50% - 50%, 60% - 40%, 70% - 30%) are also investigated. Triton X – 114 has high potential in enhancing the transportation of crude oil via pipelines as emulsions formed that contains 40% oil and 60% water shows torque reading less than the torque value exerted by the cooking oil without any addition of addictives. The reduction of torque is approximately 50% lower than the cooking oil without any addictives. It is proven that Triton X – 114 lowers the surface tension of the fluid thus it reduces the flow resistivity. The Triton X – 15 is strongly not recommended in forming emulsion for transportation as it exerts high resistance in the form of an emulsion. It is strongly recommended for future work that the study should be done in larger scope on certain experimental parameters specifically on more addictives should be tested. Besides that, the more rheological studies should be expanded on the effect of temperature, concentrations and volume fractions on the performance of emulsion Besides, it is better if the formation of droplets on the emulsion size in order to have a better the understanding of the factors contributes to emulsions stability

CHAPTER 1

INTRODUCTION

1.1 Background of Research

Energy resources consist of nuclear, oil, wind, solar photovoltaic and coal. However, as predicted by Shell International Exploration and Production, the global energy – technology deployment lead by oil up to 2050. Offshore reservoirs shows a significant drop in the production that caused by pressure depletion. The high viscosity of oil limits oil recovery from the reservoir and also it creates a resistance (drag) in transportation of oil via pipelines which consumes high pumping power. The drag increases the difficulties of transporting the oil due to its low mobility and flow ability. Reducing the oil viscosity will be beneficial in order to reduce pumping power to transport oil in pipelines due to the turbulences exerted by the oil itself.

Three stages in oil recovery are primary recovery, secondary recovery and tertiary recovery. In primary process, oil is force out of the reservoir by existing natural pressure generated from the gas present in the oil. When the pressure exerted comes to a point where it does not have enough pressure to pump the oil out of the reservoir, secondary oil recovery comes in. In this stage, water or gas in injected to maintain a pressure in the reservoir that continues to move the oil. Lastly, the tertiary recovery also known as Enhanced Oil Recovery (EOR) is to increase oil recovery by reducing the viscosity of oil and improve flow. Several methods are practiced such as thermal EOR, miscible EOR, chemical EOR and other EOR processes.

In this research, the effect of adding surfactants also known as surface-active-agent, which will exhibits superficial or interfacial activity is investigated. It helps to lower surface tension of liquid, the interfacial tension between two liquids, or between a liquid and a solid. In this research, emulsion is formed by adding surfactants as the emulsifier. Nour et al. (2008) and Anisa et al. (2006) stated that there is no doubt that surfactants will enhance the stability of emulsion by forming protective rigid film surround the droplets.

1.2 Problem Statement

Oil that is pumped out from reservoir is in water-in-oil (W/O) phase. Thus, the continuous phase is the oil and water droplets are dispersed in the oil. When the oil is having difficulties to be transported, the presence of water droplets will cause corrosion in pipelines. This will lead to pipeline damage and loss of oil will occur.

Oil transportation creates many operational difficulties that limit economic growth. Pumping power losses in pipelines during the transportation of oil from oil well to the refinery due to the turbulent flow and high viscosity of oil in pipelines has increases the cost of oil production because more energy is used. Heating the entire pipeline will reduce the drag by maintaining the viscosity of oil as temperature has direct effect to viscosity. However, this method is not practical to be conducted as building power stations along the pipeline will hike up the cost of the transportation. All these consume one thing, none other than money.

1.3 Objectives of Research

The objectives of this present research are:

1. Investigating the effect of using different Hydrophile - Lipophile Balance (HLB) value of surfactants on emulsion formation.

2. Investigating the water content, concentration of surfactant and mixing speed on the viscosity of emulsion.

1.4 Scope of Research

The scopes of this research are:

1. The study of the effect of different surfactant in the emulsion formation.
   Non – ionic surfactants: Triton X – 15 and Triton X – 114.
2. Investigation on the factors that affect the viscosity of emulsions formed
   - Surfactant concentration (600 ppm, 800 ppm and 1000 ppm)
   - Rotational speed (50 – 3000rpm)
   - Oil – water ratio

Table 1.1 Oil –Water Ratio

Sample	Oil Content	Water Content
1	30%	70%
2	40%	60%
3	50%	50%

1.5 Significance of Research

This research is able to reduce viscosity of oil where we will have mobility control of oil thus improvise the conventional EOR way. Moreover, the oil transportation across reservoir and also via pipelines is enhanced. The finding from this research is hoped to increase the oil production. Hence, it helps to boost up Malaysia's economy as the country is one of the main exporters of petroleum where oil wells are located at the offshore of West Malaysia and northern of Sabah and Sarawak. The importance of this research will save cost in transporting oil associated with transportation over considerable distances through underwater pipelines from oil well to refinery by reducing the energy lost and also to prevent the damage of pipelines during the transportation due to corrosion.

1.6 Summary

The high viscosity of oil creates a resistance (drag) lower the mobility and flow of oil. The aim of this research is to form emulsions that will reduce the viscosity of the oil without any heating required hence enhances the transportation of oil. Therefore, different types of surfactants are studied and used to investigate and develop effective surfactants for emulsification process. The emulsions are tested in rotating disk apparatus (RDA) on the effect of emulsion viscosity when different operating conditions such as concentration, oil – water ratio and rotating speed.

CHAPTER 2

LITERATURE REVIEW

This chapter consist of reviews on previous researches that had been conducted to study the properties of emulsion. Firstly, emulsion is introduced followed by the emulsification process. Further explanations of the stability of emulsions and drag reduction and its addictives performance. The concept applied by the Rotating Disk Apparatus (RDA) included in this chapter.

2.1 Emulsions

Schramm (2005) stated that emulsions are colloidal dispersion in which a liquid is dispersed in a continuous phase of different composition. Dispersed phase is referred as internal (disperse) phase and the continuous disperse phase as the external phase. The two types of emulsion are

- Oil-in-water (O/W) for oil droplets dispersed in water
- Water-in-oil (W/O) for water droplets dispersed in oil

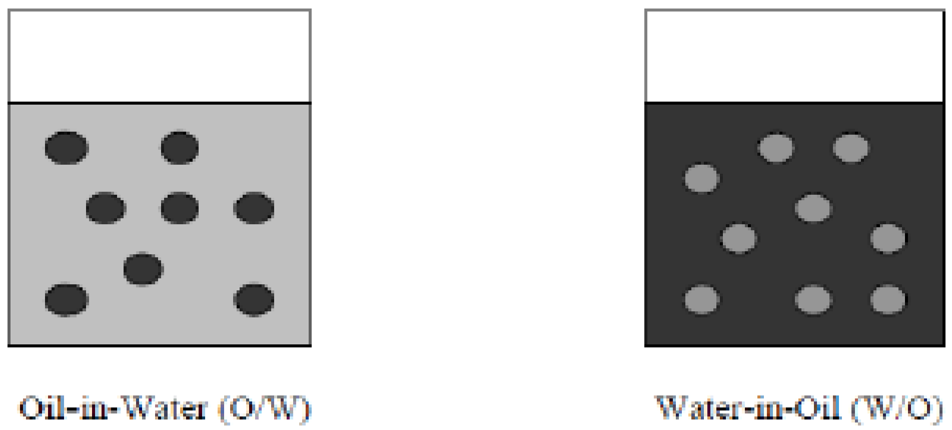

Figure 2.1 Schematic Diagram of O/W and W/O

(**Source:** Schramm, 2005)

2.2 Emulsion Formation

2.2.1 Emulsification Process

Extracted from Physical Chemistry of Foods, the methods of making emulsion are categorized into four methods.

a) Supersaturation: The oil (in gaseous form) is dissolved in a liquid under pressure then the pressure is released in order to form oil bubbles. Hence, the oil is to be ensured soluble in water to obtain a substantial volume of bubbles.

b) Injection: Gas or liquid is injected through small openings into the continuous phase. Thus, forming bubbles or drops and dislodged from the sheet by buoyancy. It is also known as membrane emulsification whereby the membrane is made from porous glass or ceramic material.

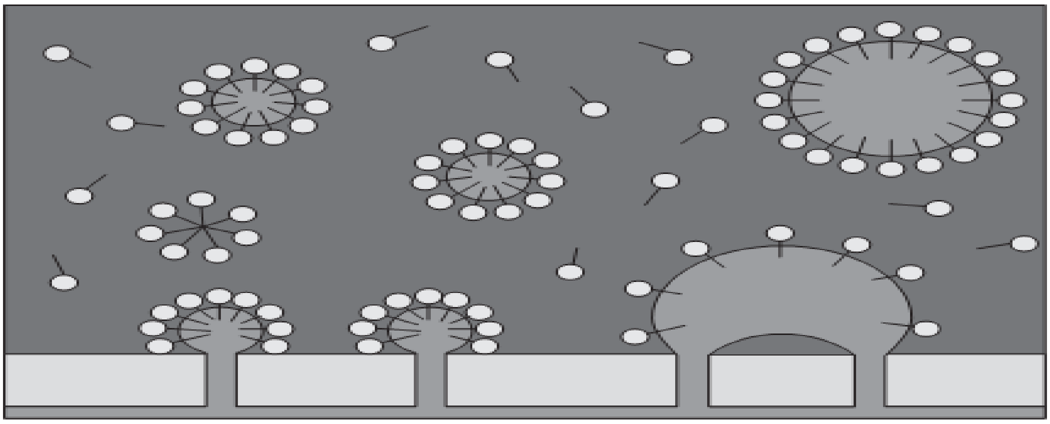

Figure 2.2 Schematic Representation of Membrane Emulsification

(**Source:** Schroder et al., 1998)

c) Agitation: Stirring, beating or homogenising are the mechanical energy transferred from both phases to interfacial region thus forming bubbles or drops. Besides, these particles are to be disrupted into smaller forms will be dispersed in the continuous phase.

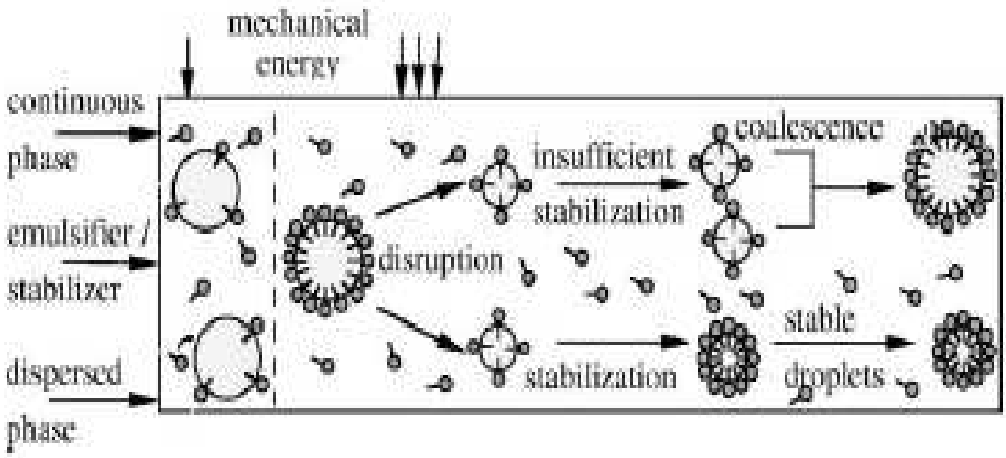

Figure 2.3 Schematic Representation of the Emulsification from Mechanical Process

(**Source:** Aruna S., 2009)

d) Chemical energy: Chemicals are used such as polymers, surfactants or suspended solid to produce emulsions whereby the physiochemical properties such as volume fraction of dispersed phase, particle size distribution, emulsion types and surface layer.

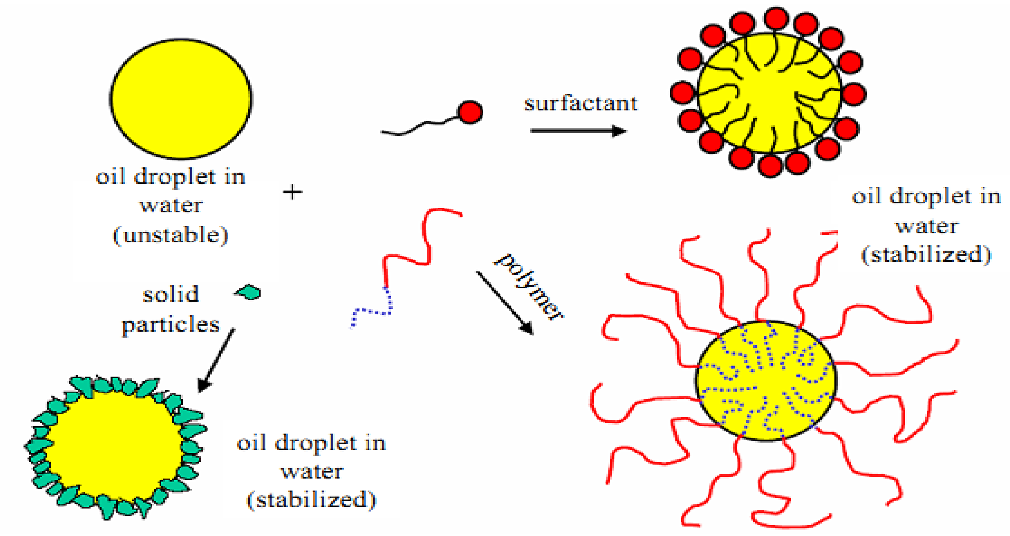

Figure 2.4 Schematic Diagram of Emulsion Formation using Different Emulsifier

However, in this work of studies, both agitation and chemical energy are taken into consideration where surfactants are used as the emulsifier to investigate the emulsions formed. The parameters are volume fraction of oil and water, emulsion types, concentration of surfactant and the rotational speed.

2.2.2 Bancroft Rule

According to Bancroft Rule (1913) that the emulsion is formed based on the solubility of the surfactant whereby the phase in which the surfactant is mainly dissolved will result as the continuous phase of the emulsion.

In this present work, the two surfactants used are non – ionic surfactants with different phase solubility. Triton X -15 is soluble in oil while Triton X -114 is soluble in water. Hence, the emulsion formed using Triton X – 15 is W/O while O/W is formed when Triton X – 114 is used.

2.3 Stability of Emulsion

It is known since 1966, where Becher states the stability of emulsion is greatly depending on the strength and compactness of the interfacial film. The emulsion is a thermodynamically unstable system that made up of at least two immiscible liquid phases where one of the phases is dispersed as globules in the other liquid phase. This is due to the free energy of formation (ΔG_t) is greater than zero resulting in the tendency to break (Taylor, 1998). Therefore, the immiscible phases are stabilized using emulsifying agent.

Adamson, (1997), determination of the change in free energy when a molecule is brought from interior phase to the interface is through the changes in the interaction energies of the molecules involved as the entropy effects.

$G^S = \sigma = E^S - TS^S$ (2.1)

Where, E^S = total surface energy.

G^S = surface free enthalpy

S^S= the surface entropy per unit area of surface.

σ = interfacial tension

The total surface energy is always larger than the interfacial tension. Therefore, it is frequently more informative of the quantities whereby it is easily related to molecular models. Hence, this shows the characterization between interaction energy and the molecules at the interface.

$$\left(\frac{\delta G^S}{\delta T}\right) = \frac{\mathrm{d}\sigma}{\mathrm{dT}} = -\mathrm{S}^{\mathrm{s}} \quad (2.2)$$

- When $\sigma > 0$ ($E^S > TS^S$) it shows a thin, stable interface is formed due to the strong repulsions between the molecules present whereby the repulsion forces is greater than the dispersive forces. Thus, the interfacial region is relatively unfavorable and the interfacial region is thin due to the protrusion of molecule from one phase into another involving large expenditure of energy (Adamson, 1997).
- When $\sigma < 0$ ($E^S < TS^S$) the two liquids are miscible and interfacial region disappears. This lead to a complete dispersion of one phase into another thus forming a stable emulsion.
- When $\sigma = 0$ ($E^S = TS^S$), this shows an unstable interface is formed whereby the liquids are partially miscible. The fluctuations forces will caused a partial dispersion of one phase into another and the interfacial region increases in thickness.

It is very important to identify the stability of emulsion before characteristic and properties of emulsion are investigated. According to Fingas and Fieldhouse (1997), emulsion is categorized in three: stable, unstable and mesostable. Mesostable emulsion is lack of sufficient asphaltenes. The viscosity of oil may be high enough to stabilize water droplets for a period of time but will degrade to form layers of oil and stable emulsion. Unstable emulsion will decompose to water and oil in few hours after mixing. Stable emulsion has significant elasticity and viscosity increased over time. As depicted in Figure 2.5, the mechanism of emulsion destabilizations is explained in details.

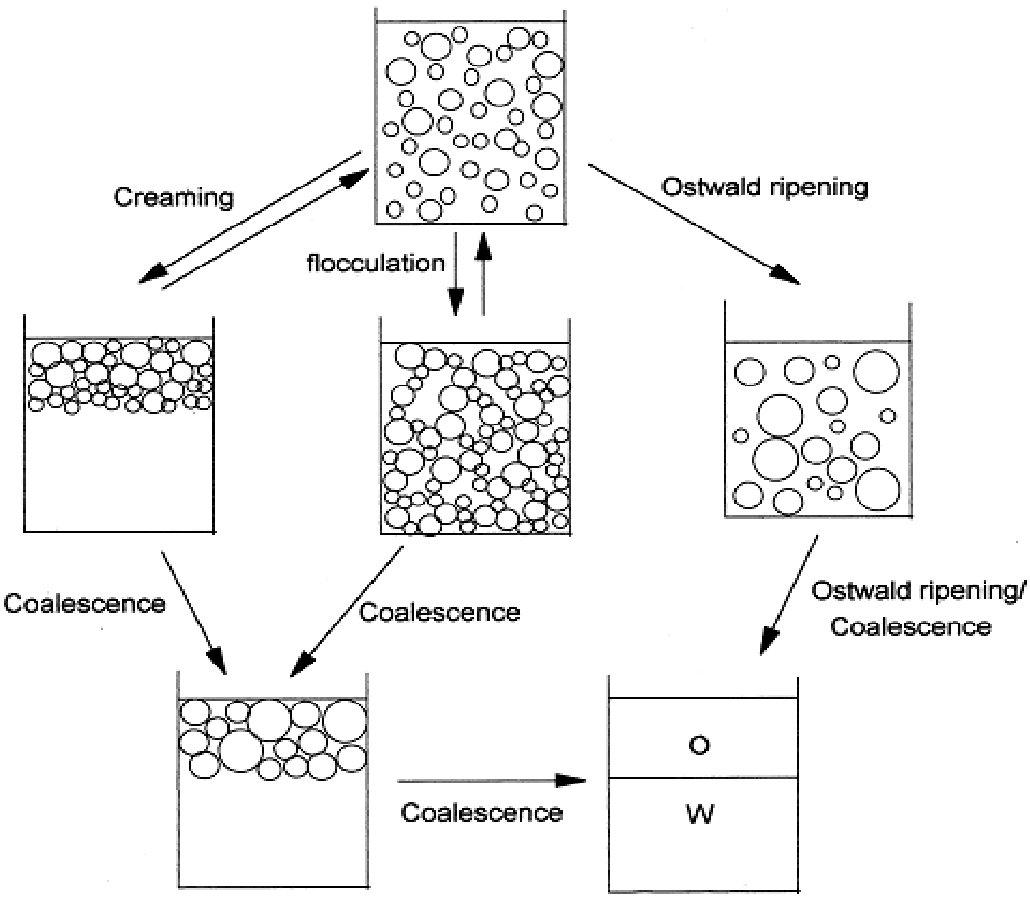

Figure 2.5 Schematic Representation of Emulsion Breakdown Process

(**Source:** Taylor, P., 1998)

2.3.1 Ostwald Ripening

Langevin et al. (2004) explains the Ostwald ripening is actually the drop of growth process occurring when the dispersed phase has a finite solubility into the continuous phase and can migrate between drops and different size. Likewise, Tadros T. (2004) defines Ostwald ripening (disproportionate) occurs there is a clear significant in the solubility of oil whereby the small droplets that has higher solubility than the larger ones has the tendency to dissolve on storage and become deposited on the larger ones.

2.3.2 Sedimentation or Creaming

Creaming occurs when the aggregated droplets rise through the medium but when it sinks to the bottom, it is known as sedimentation. Creaming is depending on the radius of the droplets, the relative density difference of the two phases and the viscosity of the continuous phase. The rate of creaming can be assessed by Stokes' equation (Langevin, 2004).

$$v = \frac{2\,R^2(\rho_l - \rho)g}{9\mu} \tag{2.3}$$

Where, R = drop radius

ρ_l = droplet density

ρ = density of dispersion medium

g = acceleration of gravity

μ = viscosity of dispersion medium