

2015 3<sup>rd</sup> International Conference on Adaptive  
and Intelligent Agroindustry (ICAIA)

ICAIA 2015

August 3<sup>rd</sup> - 4<sup>th</sup>, 2015

IPB International Convention Center  
Bogor, Indonesia

ISBN : 978-1-4673-7405-7

IEEE Catalog Number : CFP15C67-ART



## TABLE OF CONTENTS

<b>Innovative Agroindustrial and Business System Engineering</b>	
The Feasibility Study of Establishment of Biodiesel And Paving Block Industry From Spent Bleaching Earth	I-1
Febriani Purba, Ani Suryani and Sukardi	
Green Supply Chain Management Innovation Diffusion in Crumb Rubber Factories: Designing Strategies towards Implementation	I-7
Tri Susanto, Marimin Marimin and Suprihatin	
Mobile Business Analytics System for Service Level Analysis of Customer Relationship Decision	I-13
Taufik Djatna and Yudhistira Chandra Bayu	
Exploring an Innovative Approach to Address Non-Tariff Barriers Experienced by Small to Medium Enterprises in Downstream Coffee Production in Indonesia	I-19
Andar Hermawan, Yandra Arkeman, Titi Candra Sunarti	
An Analysis of Innovation Network Performance on the Palm Oil Industry in North Sumatera	I-26
Danang Krisna Yudha, Aji Hermawan and Machfud	
Exploring the Internationalization Process Model of an Indonesian Product – Case study : Fruit Chips SME's	I-33
Dickie Sulistya Apriliyanto, Hartrisari Hardjomidjojo, Titi C Sunarti	
Innovation Management in Indonesian Palm Oil Industry	I-39
Karim Abdullah, Aji Hermawan and Yandra Arkeman	
Technology Innovation Adoption to Improve the Performance of Dairy Small-Medium Enterprises (SME): Case study in Pangalengan-Bandung Regency, West Java, Indonesia	I-45
Nuni Novitasari, Titi Candra Sunarti and Nastiti Siwi Indrasti	
Managing Innovation through Knowledge Sharing in An Indonesia Coconut SME	I-54
Muchammad Kodiyat P, Machfud, Nastiti S Indrasti	
Increasing Added Value of Banana by Producing Synbiotic Banana "Sale" Using Innovation & Technology Strategy Approach	I-60
Eka Ruriani	
An AHP Application for Selecting A Business Innovation Strategy of Chocolate SMEs in East Java	I-65
Yani Kartika Pertiwi, M. Syamsul Maarif and Machfud	
Understanding local food consumers and their motivations: A case study in Padang city	I-71
Poppy Arsil	
Spatial Model Design for Competitive Improvement of Small Medium Scales Enterprises (Case Study: Bogor Area)	I-77
Hartrisari Hardjomidjojo, Harry Imantho and Armaiki Yusmur	
System Analysis and Design for Selecting Chitin and Chitosan Industry Location by Using Comparative Performance Index Method	I-82
Dena Sismaraini, Nastiti S. Indrasti and Taufik Djatna	
Arduino-Based Temperature Monitoring Device for Cold Chain Transportation	I-90

- Delmar Zakaria Firdaus and Endang Warsiki  
Development of Downstream Cocoa Industry: Exploring the Role of Government and Small and Medium Industry in Partnership I-95  
Farda Eka Kusumawardana, Yandra Arkeman, Titi C Sunarti  
The Role of Communication in the Technology Transfer Process I-101  
Anindita Dibyono, Sukardi, Machfud  
The Center for Pulp and Paper Appraising its Productivity in Generating Industry-Applicable Research: A Good Practice Illustration I-108  
Ahmad Rudh Firdausi, Anas M Fauzi, Machfud

### **Frontier Approaches in Process and Bioprocess Engineering**

- Identification of Flavor Compounds In Cemcem (*Spondiazpinata* (L.F) Kurz) Leaf Extra II-1  
Luh Putu Wrsiati, Ni Made Wartini and Ni Putu Eny Sulistyadewi  
Synthesis and characterization of nanosilica from boiler ash with co-precipitation method II-5  
Wahyu K. Setiawan, Nastiti S. Indrasti, and Suprihatin  
The Comparison Of Media on the Microalgae *Nannochloropsis* sp. Culture II-10  
Anak Agung Made Dewi Anggreni, I Wayan Arnata and I B Wayan Gunam  
Identification of Media and Indicator Liquid as A Recorder Smart Label II-14  
Endang Warsiki and Riris Octaviasari  
The Effects of Palm Oil MES Surfactant and Inorganic Salt Concentration on Interfacial Tension Values II-19  
Rista Fitria, Ani Suryani, Mira Rivai and Ari Imam  
Effect of Nano Zinc Oxide On Characteristic Bionanocomposite II-25  
Siti Agustina, Nastiti Siswi Indrasti, Suprihatin and Nurul Taufiq Rohman  
The Effects of Molar Ratio Between 80% Glycerol And Palm Oil Acid on the Synthesis Process of Ester Glycerol II-31  
Mira Rivai, Erliza Hambali, Giovanni Nurpratiwi Putri, Ani Suryani, Pudji Permadi, Bonar T.H Marbun and Ari Imam Sutanto  
Selecting Part of Natural Fiber EFB which has Best Mechanical Strength through Tensile Test Analysis for Composite Reinforced Material II-37  
Farkhan, Yohanes Aris Purwanto, Erliza Hambali and Wawan Hermawan  
Identification of phenol red as *Staphylococcus aureus* indicator label II-44  
Melati Pratama, Endang Warsiki and Liesbetini Hartoto  
Enhancing Ethanol Tolerant of *Escherichia coli* Recombinant by Glutamate Addition under Aerobic Conditions II-48  
Indra Kurniawan Saputra, Prayoga Suryadarma and Ari Permana Putra  
In Vitro Potentifal of Antibacterial Marine Microalgae Extract *Chaetocerosgracilis* Toward *Staphylococcus epidermidis* Bacteria II-53  
Ardhi Novrialdi Ginting, Liesbetini Haditjaroko and Iriani Setyaningsih  
The Potential Applications of Modified Nagara Bean Flour through Fermentation for Innovation of High Protein Analog Rice II-59

Susi, Lya Agustina and Chondro Wibowo	
Studies on the Characteristics of Pasayu (Pasta of Waste-Cassava) Fortification as a New Product Development	II-64
Marleen Sunyoto, Roni Kastaman, Tati Nurmala and Dedi Muhtadi	
Optical And Particle Size Properties Of <i>Sargassum</i> Sp Chlorophyll As Dye-Sensitized Solar Cell (DSSC)	II-72
Makkulawu Andi Ridwan and Erliza Noor	
Alkaline Pre-Treatment of <i>Gelidium latifolium</i> and <i>Caulerpa racemosa</i> for Bioethanol Production	II-76
Dwi Setyaningsih, Neli Muna, Elisabeth Yan Vivi Aryanti and Anastasya Hidayat	
<b>New Trends in Industrial Environmental Engineering &amp; Management</b>	
Use of Biofilter to Improve Quality of Polluted River Water for Drinking Water Supply	III-1
Suprihatin, Muhammad Romli and Mohamad Yani	
An Empirical Investigation of the Barriers to Green Practices in Yogyakarta Leather Tanning SMEs	III-8
Dwi Ningsih, Ono Suparno, Suprihatin and Noel Lindsay	
Preliminary Study For CO <sub>2</sub> Monitoring System	III-15
Farhan Syakir, Rindra Wiska, Irvi Firqotul Aini, Wisnu Jatmiko and Ari Wibisono	
Designing a Collaboration Form to Overcome Innovation Resistance in Waste Management Practices in Lampung Tapioca Industry	III-22
Nur Aini Adinda, Suprihatin, Nastiti Siswi Indrasti	
Pollution Reducing Opportunities for a Natural Rubber Processing Industry: A Case Study	III-29
Syarifa Arum Kusumastuti, Suprihatin and Nastiti Siswi Indrasti	
Effects of Palm-Dea Non-Ionic Surfactant as an Additive in Buprofezin Insecticide on the Efficacy of it in Controlling Brown Planthopper Rice Pest	III-35
Fifin Nisya, Rahmini, Mira Rivai, Nobel Cristian Siregar, Ari Imam Sutanto and Ainun Nurkania	
<b>Intelligent Information &amp; Communication Technology for Adaptive Agroindustry of the Future</b>	
Design of Web-Based Information System With Green House Gas Analysis for Palm Oil Biodiesel Agroindustry	IV-1
Yandra Arkeman, Hafizd Adityo Utomo and Dhani S. Wibawa	
Sequential Patterns for Hotspots Occurrence Based Weather Data using Clospan algorithm	IV-8
Tria Agustina and Imas S. Sitanggang	
How to Deal with Diversity in Cultivation Practices using Scenario Generation Techniques: Lessons from the Asian rice LCI Initiative	IV-13
Kiyotada Hayashi, Yandra Arkeman, Elmer Bautista, Marlia Mohd Hanafiah, Jong Sik Lee, Masanori Saito, Dhani Satria, Koichi Shobatake, Suprihatin, Tien Tran Minh and Van Vu	
Development of Life Cycle Inventories for Palm Oil in North Sumatra: Modelling Site-Specific Activities and Conditions	IV-16

Vita D Lelyana, Erwinsyah and Kiyotada Hayashi	
Sequential Pattern Mining on Hotspot Data using PrefixSpan Algorithm	IV-20
Nida Zakiya Nurulhaq and Imas S. Sitanggang	
An Intelligent Optimization Model Analysis and Design of Bio-filtration in Raw Water Quality Improvement	IV-24
Ramiza Lauda and Taufik Djatna	
Development Of People Food Consumption Patterns Information System Based On Webmobile Application.	IV-30
Fadly Maulana Shiddieq, Roni Kastaman and Irfan Ardiansah	
Association Rules Mining on Forest Fires Data using FP-Growth and ECLAT Algorithm	IV-37
Nuke Arincy and Imas S. Sitanggang	
Development Of Expert System For Selecting Tomato ( <i>Solanum lycopersicon L.</i> ) Varieties	IV-41
Erlin Cahya Rizki Amanda, Kudang Boro Seminar, Muhamad Syukur and Noguchi Ryoza	
Developing Life Cycle Inventories for Rice Production Systems in Philippines: How to Establish Site-specific Data within the General Framework	IV-47
Elmer Bautista, Kiyotada Hayashi and Masanori Saito	
Construction of Site-specific Life Cycle Inventories for Rice Production Systems in Vietnam	IV-50
Tran Minh Tien, Bui Hai An, Vu ThiKhanh Van and Kiyotada Hayashi	
Study on Life Cycle Benefit Assessment as a tool for promoting the solution of Environmental Problems	IV-53
Tetsuo Nishi	
Real Time Monitoring Glycerol Esterification Process with Mid IR Sensors using Support Vector Machine Classification	IV-57
Iwan Aang Soenandi, Taufik Djatna, Irzaman Husein and Ani Suryani	
Extraction of Multi-Dimensional Research Knowledge Model from Scientific Articles for Technology Monitoring	IV-63
Arif R. Hakim and Taufik Djatna	
Performance of Artificial Lighting Using Genetics Algorithms	IV-69
Limbran Sampebatu	
The Application of Fuzzy-Neuro Approach for ERP System Selection: Case Study on an Agro-industrial Enterprise	IV-74
Joko Ratono, Kudang Boro Seminar, Yandra Arkeman and Arif Imam Suroso	

# The Effects of Palm Oil MES Surfactant and Inorganic Salt Concentration on Interfacial Tension Values

Rista Fitria, Eliza Hambali, Ani Suryani, Pudji Permadi, Mira Rivai, Ari Imam

*Laboratory of Surfactant and Bioenergy Research Center*

*Faculty of Agricultural Technology, Bogor Agricultural University*

*Program Study of Petroleum Engineering, Bandung Institute of Technology*

*E-mail: risfit.92@gmail.com, erliza.h@gmail.com, anisuryani.sbrcipb@gmail.com,*

*pudji@tm.itb.ac.id, me\_rarivai@yahoo.com, ari\_imam@yahoo.com*

**Abstract**— The application of methyl ester sulfonic (MES) surfactant for enhanced oil recovery (EOR) was based on its ability to reduce interfacial tension in crude oil-water system that reached  $10^{-3}$  dyne/cm. Performance of methyl ester sulfonic (MES) surfactant from palm oil can be identified with the spinning drop IFT method. The objectives of this research were to determine MES surfactant performance with the addition of inorganic salt in different conditions. The dispersing media used in this research were demineralized water and formation water. The spinning drop IFT method was conducted using spinning drop tensiometer TX500D tested in 40, 50 and 60°C. Results showed that reduction of IFT values was affected by MES surfactant and inorganic salt concentration in the demineralized water and formation water as dispersion medium. Methyl Ester Sulfonic surfactant could react better at salinity ranges of 5000-25000 ppm.

reservoir temperature, pH interval 6-8, having III phase (middle phase) or phase II (-), and oil recovery increment between 15-20% of original oil in place (OOIP) [1]. A surfactant with ultralow interfacial tension ( $<10^{-2}$  dyne/cm) was predicted to be able to increase oil recovery by about 10-20% [2].

A surfactant that needs to be developed for enhanced oil recovery (EOR) requirement is methyl ester sulfonic (MES) surfactant of palm oil. It was known from an analysis that MES had IFT values of  $7.7 \times 10^{-3}$  dyne/cm and was stable in reservoir temperature of up to 80°C. This finding approved that MES was suitable for use in sandstone fields in Indonesia and was resistant to reservoir temperature.

Methyl ester sulfonic is an anionic surfactant that developed as petroleum sulfonic substitution. MES has good dispersion characteristic, good detergency, especially in hard water, excellent biodegradability and it does not contain phosphate, ester fat-acid  $C_{14}$ ,  $C_{16}$  and  $C_{18}$  gave the best detergency. Compared to petroleum sulfonic, MES surfactant shows some advantages. In lower concentration, MES has equal detergency level, better ability to maintain enzyme activities, better tolerance to calcium, and lower salt content [3].

Surfactant injection in a water-oil system makes surfactant dispersed in oil and water. This is then followed by the formation of emulsion in water. As the result of capillary effect and high interfacial tension between oil and water, oil droplets trapped in pore throats cannot be produced by using water injection only. The addition of surfactant is expected to lower the interfacial tension between water and oil allowing a decrease in capillary pressure of oil and rocks. High capillary pressure results in low recovery factor. Low capillary pressure is needed to recover most remaining oil which is trapped after waterflooding. Lowered interfacial tension makes oil concentrated in rock surface [4]. In the end, surfactant binds the oil so that the oil can be produced. The effect of IFT values on oil recovery is modelled by capillary a desaturation curve, where residual oil saturation is correlated with capillary number function. Capillary number ( $N_c$ ) is

## I. INTRODUCTION

The application of surfactant for enhance oil recovery (EOR) needs particular requirements including ultralow interfacial tension ( $\leq 10^{-3}$  dyne/cm), compatibility with formation water and stability in

Manuscript received April 27, 2015. Thanks to SBRC LPPM IPB for all facilities, so this research could be done.

Fitria, Rista was with Department of Agroindustrial Technology, Bogor Agricultural University, Bogor, Indonesia. She is now with Surfactant and Bioenergy Research Center, Bogor, Indonesia (corresponding author, phone: +62 856-9594-4901; e-mail: risfit.92@gmail.com).

Hambali, Erliza, is with Departemen Agroindustrial Technology, Bogor Agricultural University, Bogor, Indonesia (e-mail: erliza.h@gmail.com).

Suryani, Ani, is with Department of Agroindustrial Technology, Bogor Agricultural University, Bogor, Indonesia (e-mail: Anisuryani.sbrcipb@gmail.com).

Permadi, Pudji is with Program Study of Petroleum Engineering, Bandung Institute of Technology, Bandung, Indonesia. He is now with Surfactant and Bioenergy Research Center, Bogor, Indonesia (e-mail: pudji@tm.itb.ac.id)

Rivai, Mira is with Surfactant and Bioenergy Research Center, Bogor, Indonesia (e-mail: me\_rarivai@yahoo.com).

Imam, Ari is with Surfactant and Bioenergy Research Center, Bogor, Indonesia (e-mail: ari\_imam@yahoo.com).

defined as viscosity ratio and capillary force. Generally, capillary number is calculated by using the following equation.

$$Nc = \frac{v\mu}{\sigma \cos \theta}$$

where:

V = effective flow rate (cm/s)

$\mu$  = viscosity of pusher solution (cp)

$\sigma$  = interfacial tension (dyne/cm)

$\theta$  = wetting angle

Surfactant and salt concentration in solution is the has great effect on the obtainment of minimum IFT values. IFT values get lower as surfactant concentration increases. IFT reaches its minimum value as the critical surfactant concentration. Higher surfactant concentration than its critical point will lead to increased IFT values [5]. In this study, two types of water with extreme difference in salinity levels (demineralized water and formation water) were used. Formation water was used as electrolyte solution. Electrolytes in surfactant system decrease surfactant-water interaction. Lipophilic groups of ionic surfactant will half-bind or full-bind with electrolytes, so each molecule will bind with the right molecule. Negative charge of active lipophilic group will have a positive interaction with positive charge of salt molecules such as  $\text{Na}^+$  molecule in  $\text{NaCl}$  solution when anionic surfactant is used [6,7]. It is different from demineralized water which has no salt or electrolyte in it, so surfactant-water interaction will be bigger than surfactant-oil interaction.

## II. METHODS

*The study was done in two stages. In the first stage, formulation of basic material was done and in the second stage interfacial tensions were tested.*

### A. Basic Material Formulation

#### 1. Formulation of demineralized water with different surfactant concentration

MES was formulated with demineralized water. Total weight of formulation result was 25 gram for one formulation. Two samples were made for each formulation. Total weight of formulation result for trial procedure was 25 gram. MES surfactant was added in the concentrations of 0.1, 0.3, 0.5, 0.7, 1.0, 1.5, and 2.0%. The example of surfactant weight calculation was shown below:

$$0.3\% \times 25 \text{ gram} = 0.075 \text{ gram}$$

Formation water was then added in to the formulation until the mixture weighed 25 gram. The formulation was stirred for an hour by using a magnetic stirrer in room temperature (27 °C). Then, density test and IFT value test were done.

#### 2. Formulation of MES surfactant and demineralized water with different inorganic salt concentration.

In this stage, formulation of demineralized water and 0.3% MES surfactant was done. The value of 0.3% MES surfactant was used based on the optimum surfactant concentration found in the previous study at SBRC. Inorganic salt was added within the concentrations of 0, 1, 3, 4, 5, 6, 7, 8, 9, and 10%. Total weight of formulation result was 25 gram for one formulation and two samples were made for each salt concentration. Formula 1 was the formulation of demineralized water with inorganic salt of 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10%. The example of salt weight calculation was shown below:

$$1\% \times 25 \text{ gram} = 0.25 \text{ gram}$$

Demineralized water was then added in to the formulation until the mixture weighed 25 gram. The formulation was stirred for 15 minutes until it was well blended by using a magnetic stirrer in room temperature (27°C). MES surfactant was weighed (0.075 g) and put in a different tube. Formula 1 was then added into the tube containing MES surfactant until the weight of the mixture reached 25 grams.

In this study, a case study in an oil field which had salt concentration that fitted with performance of MES surfactant according to IFT test result of demineralized water. Same treatments were done to formation water.

### B. Interfacial Tension (IFT) Value Test

Interfacial tension was measured by spinning drop method. The following steps were the procedures of spinning drop interfacial method. The device and the LED button were turned on. The spinning drop device was heated before the temperature was set at 40 °C (fitted to test condition). Once the temperature was stable, surfactant which was prepared in certain concentrations was added into a glass tube. Then, crude oil was added. Air bubble was not allowed in the glass tube. Then, the glass tube was put in the spinning drop device with glass tube surface facing outside. Spinning speed was set to be stable at 6000 rpm. Drop radius was read when the device temperature reached 40°C. The reading was repeated until the value of drop radius was constant. The test was repeated for the temperatures of 50 and 60°C.

When the fluid drop had a cylindrical form, cylinder radius (r), difference of drop density ( $\Delta\rho$ ) and drop spinning speed ( $\omega$ ) were measured. Spinning Drop

Tensiometer could measure interfacial tension (IFT) up to  $10^{-6}$  mN/m. Finally, interfacial tension ( $\gamma$ ) was calculated by using the following equation [8].

$$\gamma = \frac{1}{4} r^3 \Delta \rho r \omega^2$$

where:

r : radius

$\gamma$  : interfacial tension

$\Delta \rho$  : difference of drop density

$\omega$  : spinning speed

### III. RESULTS AND DISCUSSION

Optimum surfactant concentration for demineralized water formula as dispersion medium was 0.7% of MES surfactant, but it did not meet the ultralow interfacial tension (Figure 1). IFT values for demineralized water as dispersion medium at 40, 50, and 60°C were  $6.75 \times 10^0$ ,  $1.12 \times 10^1$ , and  $8.31 \times 10^0$  dyne/cm, respectively.

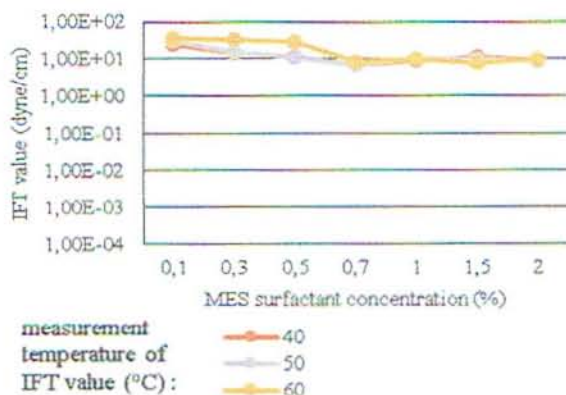


Fig. 1. Effect of interaction of MES surfactant concentration and measurement temperature on IFT values of surfactant solution with demineralized water as dispersion medium.

Next formulation step was optimal salinity by adding NaCl to demineralized water then 0.3% MES surfactant was added. According to previous research by SBRC IPB, surfactant that would be added was 0.3%. Salt addition caused IFT value decreased and then would increased again along with salt concentration increment at various temperatures, 40°C, 50°C, and 60°C.

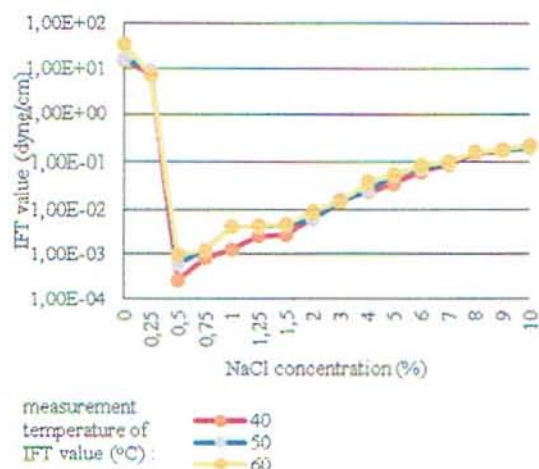


Fig. 2. Effects of Interaction of salt (NaCl) concentration and measurement temperature on IFT value of 0.3% MES surfactant solution with demineralized water as dispersion medium.

It was shown in Figure 2 that demineralized water formula with NaCl and 0.3% SMES addition had minimum IFT value when salt concentration was 0.5% or 5000 ppm. The IFT value required by oil industry was  $\leq 10^{-3}$  dyne/cm. Results (Figure 2) showed that optimum salt concentration for MES surfactant was 5000 to 25000 ppm or 0.5 to 2.5%. Therefore, for a field case study, fluid X which had salt concentration of 5795 ppm which was within the optimum range, was used. As for reservoir which has salt concentration higher than 5000-25000 ppm, the surfactant could not be used.

The IFT values for formation water as dispersion medium with 0.3% palm oil surfactant addition were found to be within the ultralow interfacial tension. The IFT values at 40, 50, and 60°C were  $4.40 \times 10^{-3}$ ,  $1.68 \times 10^{-3}$ , and  $1.10 \times 10^{-3}$  dyne/cm, respectively. These IFT values were shown in Figure 3.

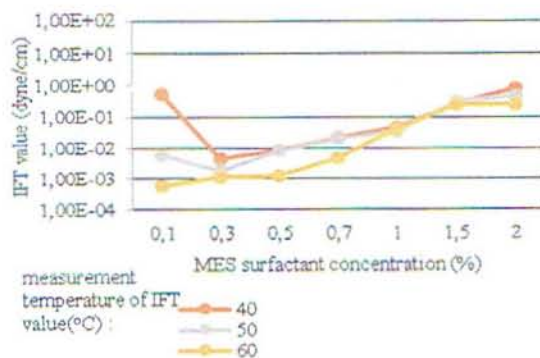


Fig. 3. Effects of interaction of MES surfactant concentration and measurement temperature on IFT values of surfactant solution with formation water as dispersion medium.

In surfactant addition formula, differences in IFT values of surfactant solution dispersed in demineralized



water medium and surfactant solution dispersed in formation water medium were caused by differences in water salinity levels. Formation water salinity reached 5795 ppm (Table 1) while that of demineralized was 0 ppm. When salinity condition was optimum, minimum value of IFT could occur and the emulsion formed could reach phase III. IFT decreased as surfactant concentration increased. However, this IFT value would reach its minimum value at a certain surfactant concentration known as the critical concentration. Increasing surfactant concentration above this critical point would not further lower but rather increase IFT value [5]. This interaction is seen in Figure 1 and Figure 3.

Results of IFT test gave a different description of oil respond in demineralized water and formation water media. When the test was done, in demineralized water medium, the oil used had a round shape. Meanwhile, the oil taken from a sandstone field used in formation water medium was longitudinally twisted indicating that the oil was not well blended although surfactant was added. This might be cause by the fact that there was no salt in it.

Inter-headgroup repulsion occurring in a surfactant molecule is one of the factors most affecting self assembly of surfactant molecules in micelle formation. In anionic surfactant solution, repulsion occurs because surfactant head groups have the same charge. As this repulsion will obstruct surfactant molecules to aggregate, it has to be decreased [9]. Repulsion of surfactant solution occurs because ionic power of the solution is weak. Salt addition, like in the form of formation water used as a dispersion medium, can be done to increase the ionic power of solution. Salt ions give a screen out effect which decreases inter-headgroup repulsion. This leads to a decrease in micelle formation free energy so that surfactant molecules are easier to unite and the micelles formed tend to have bigger size [10].

The inclination of micelle growth is affected by the type and concentration of salt added [11]. As the concentration of salt added gets higher, the screen out effect resulted is also higher leading to an expansive micelle growth forming a flexible cylinder shape (worm like) as seen in the response of oil to formation water dispersion medium [12]. In MES solution, with the existence of NaCl, micelle growth is attributed to the screen out effect resulted from the release of  $\text{Na}^+$  ion from NaCl. This ion neutralizes charges of sulfonate groups in the headgroup of MES molecules so that inter-headgroup repulsion caused by similar charges can be minimized. Expanded micelle formation with an increased salt concentration is shown in next formula in Figure 2 and 4.

The mechanism of a decrease in interfacial tension of oil and water is as follows. Organic surfactant has a hydrocarbon basic group (R) which is bonded to  $\text{SO}_3^-$ , an inorganic compound (sulfonate group), to form  $\text{R-SO}_3\text{H}$ . In water, this type of surfactant is ionized into  $\text{SO}_3^-$  and  $\text{H}^+$ . When an  $\text{R-SO}_3^-$  molecule has a contact with a nonpolar compound (oil), the R-group will form an adhesion force (surfactant-oil) while to surfactant molecule, a cohesion force among  $\text{R-SO}_3^-$  molecules will work. The effect of this adhesion force reduces the resultant value of the cohesion force of the oil which will, in turn, reduce the interfacial tension of oil and water [13]. If IFT could be decreased to  $10^{-3}$  dyne/cm, oil fraction inside rock pores could be better mobilized [14].

In this study, in formation water with 0,3% surfactant and NaCl addition, the IFT values were found to increase with an increase in the concentration of NaCl added.

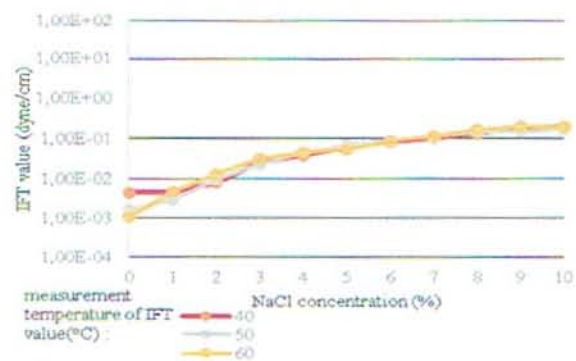


Fig. 4. Effects of NaCl concentration and measurement temperatures on IFT values of 0.3% MES surfactant in formation water dispersion medium.

It was found in this study that the addition of NaCl to demineralized water and formation water resulted in increased IFT values. In water formation dispersion medium samples, the lowest IFT value was found in formulation without NaCl addition. This was supported by the finding that formation water reached its optimum salinity of 5795 ppm with MES surfactant inclusion of 0.3%. Higher concentration of NaCl added resulted in higher IFT values.

Results of this study also showed that salt addition in an optimum optimum concentration decreased IFT values. MES surfactant used in this study had an optimum salt concentration of 5000-25000 ppm. If salt concentration in the solution was above 5000 ppm, IFT values of the solution would start to increase as shown in Figure 2 and 4. This could happen because disodium carboxy sulfonic was formed when salt in the solution was over the optimum salt limit of the surfactant itself. Salt existence in a solution containing

MES would make MES lose its lost its facial active property as MES would get involved in a reaction to form disodium carboxy sulfonate (di-salt). Anionic surfactant (MES) which was originally bonded to a Na molecule would bind to more Na ions from salt (NaCl) so that there would be one molecule containing two Na ions [15,16]. This resulted in a decreased surfactant performance and higher IFT values. The reaction mechanism of disodium carboxy sulfonate formation is depicted in Figure 5..

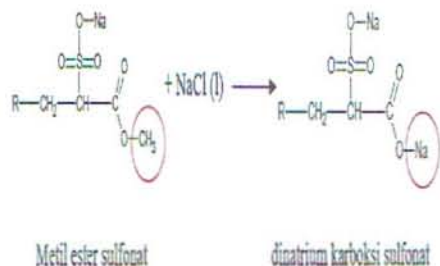


Fig. 5. Reaction mechanism of disodium carboxy sulfonate formation

With similar salt concentration and MES surfactant concentration (0.3%), IFT values of samples of demineralized water dispersion medium were lower than those of formation water. The lowest IFT value was obtained at salt concentration of 0.5% or 5000 ppm which was closed to salt concentration in formation water. Results of the test done at three temperatures with salt addition of 5000-7500 ppm in demineralized water dispersion medium showed that the IFT values were  $2.64 \times 10^{-4} - 1.3 \times 10^{-3}$  dyne/cm. These values were lower than those obtained from formation water ( $1.10 \times 10^{-3} - 4.40 \times 10^{-3}$  dyne/cm). This might be caused by less amount of electrolytes, in addition to NaCl, in demineralized water than in formation water. The existence of other electrolytes originating from other molecules was suspected to inhibit the reaction to reduce IFT values by surfactant

Hard water, like formation water used in this study, contains cations including  $\text{Ca}^{2+}$  (12.2 mg/L) or  $\text{Mg}^{2+}$  (9.08 mg/L). Physicochemical properties of water are given in Table 1. Cation concentration is water with high hardness level. MES surfactant is an anionic surfactant with active group containing negative charge. When this surfactant meet hard water, the active group would form a bond with  $\text{Ca}^{2+}$  or  $\text{Mg}^{2+}$  ions. The bonds between negative ions in surfactant and these cations would decrease performance of MES surfactant at lowering interfacial tension as indicated by high IFT values. The undissolved component formed is  $(\text{RCH}(\text{SO}_3\text{Na})\text{CO}_2\text{Ca})$  [17]. This undissolved component in surfactant solution decreases surfactant

solubility in water making the performance of MES surfactant in lowering interfacial tension reduced.

TABLE 1  
PHYSICO-CHEMICAL PROPERTIES OF FLUID TAKEN FROM SANDSTONE FIELD WATER USED IN THIS STUDY

Parameter	Unit	Injection Water	Formation water	Methods *)	Part Number
<b>Anion</b>					
$\text{SO}_4^{2-}$	mg/L	<1.44	<1.44	4500-SO <sub>4</sub> <sup>2-</sup>	E
$\text{HCO}_3^-$	mg/L	2947	1989	2320	B
$\text{Cl}^-$	mg/L	5105	3515	4500-Cl	D
<b>Kation</b>					
$\text{Na}^+$	mg/L	2933	2344	3120 B, 3030	E
$\text{K}^+$	mg/L	24.3	13.9	3121 B, 3030	E
$\text{Ca}^{2+}$	mg/L	25.7	12.2	3122 B, 3030	E
$\text{Mg}^{2+}$	mg/L	12.9	9.08	3123 B, 3030	E
$\text{Ba}^{2+}$	mg/L	0.73	0.14	3124 B, 3030	E
$\text{Sr}^{2+}$	mg/L	3.71	1.87	3125 B, 3030	E
$\text{Fe}^{3+}$	mg/L	0.26	0.1	3126 B, 3030	E
pH		8.3	8.5	4500-H <sup>+</sup>	B
Salinity	as				
NaCl	mg/L	8417	5795	2520	B
Total Hardness	as				
$\text{CaCO}_3$	mg/L	117	67.9	2346	B
Total Suspended Solid	mg/L	32	18	2540	D
Oil & Grace	mg/L	< 2	< 2	5520	B
Dissolved Oxygen	mg/L	5.59	5.74	4500-O	G

TABLE 2  
PHYSICO-CHEMICAL PROPERTIES OF FLUID TAKEN FROM SANDSTONE FIELD OIL USED IN THIS STUDY

Parameter	Measurement Temperature (°C)					
	40		50		60	
Density (g/cm <sup>3</sup> )	0.91483		0.90803		0.90142	
Temperature	40.02		49.99		59.97	
API Density (g/cm <sup>3</sup> ) (15°C)	0.9314		0.9313		0.9313	
API Gravity (15°C)	20.27		20.3		20.28	
API Specific Gravity (15°C)	0.9323		0.9322		0.932	
Viscosity (cP)	25.60	25.24	16.53	16.45	11.69	11.76
Speed (rpm)	60.00	90.00	60.00	90.00	60.00	90.00
Torque (%)	51.22	75.73	33.09	49.36	23.39	35.28
Shear Stress	20.27	29.98	13.10	19.54	9.26	13.97
Shear Rate (1/s)	79.20	118.80	79.20	118.80	79.20	118.80

#### IV. CONCLUSIONS AND RECOMMENDATIONS

##### A. Conclusions

Performance of surfactant was affected by the addition of surfactant concentration and inorganic salt. Methyl Ester Sulfonic surfactant reacted well at salinity ranges of 5000–25000 ppm. Minimum IFT values in demineralized water dispersion medium were obtained at salt formula addition of 5000 ppm. The addition of 0.3% surfactant in formation water dispersion medium resulted in IFT values which met oil industry requirements.

### B. Recommendations

Further studies on additive inclusion and other tests need to be done in order to make this MES surfactant ready for use in oil industry.

### ACKNOWLEDGMENT

Facility supports from SBRC LPPM IPB were acknowledged.

### REFERENCES

- [1] BPMIGAS. "Spesifikasi Teknis Surfaktan untuk Aplikasi EOR." Jakarta: BPMIGAS. 2009.
- [2] Aczo Nobel Surfactants. "Enhanced Oil Recovery (EOR) Chemicals and Formulations". Sitation from : Rivai M, Tun Tedja I, Ani S, Dwi S. Eds.. "Perbaikan Proses Produksi Surfaktan Metil Ester Sulfonat dan Formulasinya untuk Aplikasi Enhance Oil Recovery (EOR)". Jurnal Teknologi Industri Pertanian. 2010 Mei. 21(1):41-49. 2006.
- [3] K.L. Matheson . "Formulation of Household and Industrial Detergents". Sitation from : Spitz L, ed. "Soap and Detergents: A Theoretical and Practical Review". Illinois: AOCSS Press.1996.
- [4] C.C. Emegwalu. "Enhanced Oil Recovery: Surfactant Flooding As A Possibility For The Norne E-Segment." P E Thesis. Department Of Petroleum Engineering And Applied Geophysics, Norwegian University of Science and Technology, Norwegia 2009. [2014 September 23]. Available : <http://www.ipt.ntnu.no>.
- [5] J.L. Cayias, Schechter R.S., Wade W.H., " The Utilization of Petroleum Sulfonics for Producing Low Interfacial Tension Between Hydrocarbons and Water". Sitation from: Sheng JJ, ed., " Modern Chemical Enhance Oil Recovery : Theory and Practice". Burlington : Gulf Professional Publishing-Elsevier, 1977
- [6] S. Ajith , A.C. John and A.R. Rakshit. "Physicochemical Studies of Microemulsions. Pure & Appl". Chem (online), Vol. 66, No. 3, 1994. Great Britain. [2014 October 05]. Available : <http://www.iupac.org/publications/pae/1994/pdf/6603x0509.pdf>
- [7] R. Sampath. L.T. Moeti, M.J. Pitts and D.H. Smith. "Characterization of Surfactants for Enhanced Oil Recovery" [online]. Proceedings. 1998. [2014 Oktober 01]. Available : [ww.netl.doe.gov/publications/proceedings/98/98hbcu/SAMPATH2.PDF](http://www.netl.doe.gov/publications/proceedings/98/98hbcu/SAMPATH2.PDF)
- [8] J. Drelich, Fang Ch., Whit C.L., "Measurement of Interfacial Tension in Fluid-Fluid System. Encyclopedia of Surface and Colloid Science". Michigan Technological University, Michigan: Marcel Dekker, Inc., 2002
- [9] S.Kumar , S.L. David, V.K. Aswal, P.S. Goyal, Kabir-ud-Din. "Growth of sodium dodecyl sulfate micelles in aqueous ammonium salts". American Chemical Society. Journal of Langmuir 13 (24):6461-6464. 1997
- [10] R.J. Hunter. "Foundation of Colloids Science." New York : Oxford University Press Inc.,2001.
- [11] E.G.R. Putra, Ikram A., "A 36m SANS BATAN spectrometer (SMARTer); Probing  $n$ -dodecyl- $\beta$ -d-maltoside micelles structures by a contrast variation." Journal of Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 2009. 288-290.
- [12] A. Patriati, E.G.R. Putra. " Ellipsoid to Worm-like Micelle Structures Transition Revealed by a Small-Angle Neutron Scattering Technique." ICMNS 2008; 28-30 Oktober 2008; Bandung: ITB Bandung, 2008
- [13] E. Affiati. "Pengaruh Kualitatif co-surfactant Terhadap Peningkatan Recovery Minyak." Petroleum Engineer Thesis Dept. Engineer Petroleum, Universitas of Trisakti., Jakarta,1992.
- [14] M. Baviere, P. Glenat, N. Plazenet, and J. Labrod. " SPE Reservoir Engineering." USA: Macmillan Publishing Company, 1992.
- [15] K. Hovda.. "The Challenge of Methyl Ester Sulfonation ." (online). The Chemithon Corporation, 2002. [ 2014 September 29]. Available : [http://www.chemithon.com/papers\\_brochures/The\\_Challengeof\\_MES.doc](http://www.chemithon.com/papers_brochures/The_Challengeof_MES.doc).
- [16] Mac Arthur, W. Brian, W.B. Sheats. "Methyl Ester Sulfonic Products." [online]. 2002 [2014 September 30]. Available : <http://www.chemithon.com/>
- [17] R. J. Fessenden, Fessenden J. S., "Organis Chemistry." 2nd Ed. Jakarta: Penerbit Erlangga, 1982.

