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Economics of Produced Water Separation by Optimizing The Demulsification Process of Petroleum

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ABSTRACT : The demulsification process is very necessary process to reduce the water content in the oil. To increase the separated water, a good demulsifier with a demulsifier concentration that is able to separate water optimally; it is needed in the emulsion breaking process. The demulsifier is not only optimal, but most importantly it is also the most economical; which its concentration is able to separate the highest water. The large cost increases as the concentration of the demusifier increases, that is in line with the increase of separated water. Therefore, problem formulation in this study is to determine the volumes of separated water, to determine factors affecting demulsification process, to determine the most optimal demulsifier concentration, and to determine the more economical demulsifier concentration. The result gives the smallest separated water of 49% by using 40% KCl concentration. The highest separated water of 93% was obtained by using 80% NaCl concentration. The result also shows that the demulsifier processing time and concentration greatly affect the separated water; the higher the concentration, the more water separated, and the longer the demulsifier processing time, the larger the water separated. 80% NaCl concentration takes 120 minutes to separate 22% water, and it takes 1440 minutes to increase separation to 93%. The most optimal concentration in this study is 80% NaCl concentration with 93% separated water, the most economical concentration is 60% NaCl concentration with 91% separated water, and with the economics cash flow of Rp. 803, IRR of 12.6% and NPV of Rp. 200.96.

KEYWORDS: cash flow, chemical method, concentration, demulsification, demulsifier.

I. INTRODUCTION

The quality of produced petroleum through the exploitation process, either by natural flow, artificial lifted, or EOR greatly affects the price of the petroleum. The quality of crude oil is the reference for selling price of petroleum, they are the API gravity and the composition of the produced crude oil. One important component in the composition of petroleum that affects the quality of crude oil is the produced water content. With a large water content production which is not being separated from the produced oil, the quality of the crude oil will decrease. The water content that cannot be separated from the produced oil will usually in a form of emulsion. The formed emulsion can be treated with several demulsifications to optimize the produced oil. The process used to decompose the emulsion is also known as the demulsification process. The demulsification process also needs to be looked into, in order to further optimize the economics of the process. The success of the demulsification process can be determined by how much water volume is separated, by what factors affects the demulsification process, by knowing the most optimal demulsifier concentration, and by knowing what demulsifier concentration is more economical.

Literature Review: Emulsion is defined as a liquid phase system containing at least two immiscible liquids (immiscible liquid) which are stabilized by an emulsifier (surfactant) (Rosen, 2004). Emulsifiers stabilize emulsions by being adsorbed at the immiscible liquid–liquid interface. Based on the particle size, emulsions are divided into three types, namely (Rosen, 2004):

- Macroemulsion
- It is a non-transparent emulsion with a dispersed phase size of more than 400 nm (0.4 m).
- Mickroemulsion
- It is a transparent emulsion with the size of the dispersed phase smaller than 100 nm (0.1 m).
- Nanoemulsion

➢ It is an emulsion with a dispersed phase size between 100-400 nm (0.1-0.4 m).
One of the factors that can cause an emulsion is the disolvation of asphaltene molecules contained in petroleum by the resin (Sullivan, 2002). Purnomo, 2011 obtained research results which showed that the precipitation of asphaltene contained in petroleum was caused by changes in pressure, temperature, and composition of the produced crude oil.The occurrence of colloidal aggregated by resin against asphaltene will provide greater emulsion stabilization when compared to individual asphaltene molecules. (Djuve et al, 2001)

Natural surfactants will form an emulsion in the produced oil and water. Some natural surfactants that can form emulsions are asphaltene, resin, wax, and naphthenic acid (Sjöblom, 2001). The types of surfactants that are generally used as demulsifiers are polyglycols, polyglycol esters, ethoxylated alcohols and amines, ethoxylated resins, ethoxylates phenol formaldehyde, ethoxylated nonylphenols, polyhydric alcholos, ethylene oxide, propylene oxide block copolymer fatty acids, fatty alcohols, and salts sulfonate (Micula, 2010). The process of breaking the emulsion can be done by several methods as follows: mechanical, thermal, electrical, and chemical methods (Goldszal, 2000). To be able to increase the effectiveness and efficiency of the emulsion breaking process, it can be done by combining several methods in the process, such as combining chemical methods with mechanical methods (Schramm, 2010).

Economic value reference can be determined through economic indicators, such as Net Cash Flow (NCF), Net Present Value (NPV), Internal Rate of Return (IRR), and Pay Out Time (POT).

Methodology: The methodology in this study is a laboratory test carried out by adding demulsification agents to help break the emulsion bonds contained in the oil with different temperature conditions. Figure 1 is the flow chart of this research.

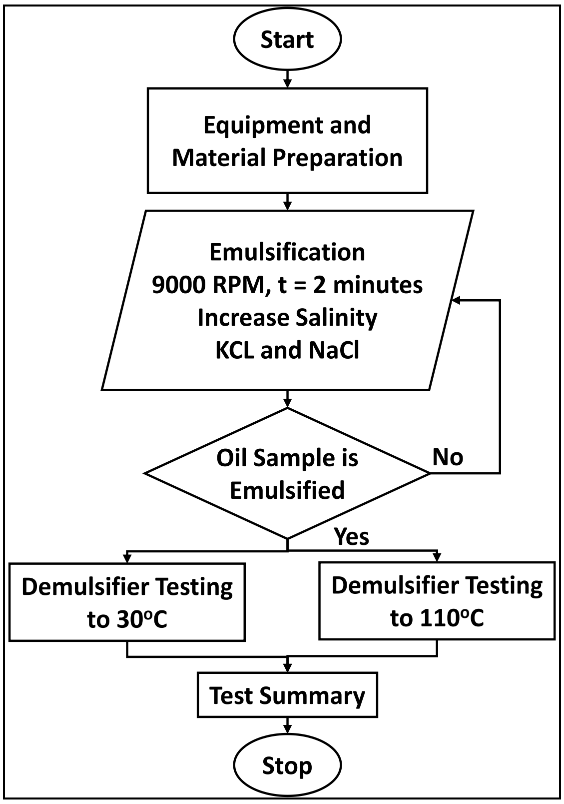

Figure 1.
research flow chart

It shown Figure 1 that the method used to break the emulsion is the chemical method, by using a demulsifier, and comparing to effectiveness and efficiency with respect to temperature differences. After the results of demulsification are obtained, the economics of each temperature difference are calculated.

II. RESULT AND DISCUSSION

Physical characterization carried out on the sample of crude oil field X is to determine the values of specific gravity, density, API Gravity, and viscosity as depicted in Table 1. This test will facilitate researchers in determining emulsion stability based on physical factors of crude oil samples.

Table 1.
Oil Sample Characteristic Results

Physical Fluid Characteristics	Value and Unit	
Specific Gravity 60°F	0,807	
Density 60°F	0,803	g/cm^3
API Gravity 60°F	41,89	°API
Viskositas 60°F	0,046	cp

Density, specific gravity and API gravity are data to determine the type of crude oil. Density is the value of molecular weight per unit volume, which is indirectly also showing the value of constituent molecules density in the subject field crude oil sample. The results show that the subject field crude oil has a density value of 0.803 g/cm3, the conversion result in specific gravity is 0.807 and API gravity is 41.89°API. Based on the crude oil type, the subject field crude oil sample is included in the light crude oil type, because of the large API gravity value. The heavy crude oil type has an API gravity value of less than 22.3°API, and an extra heavy crude oil has an API gravity value of 10°API. The demulsification process was carried out with KCl and NaCl with concentrations of 40%, 60% and 80% respectively for 1440 minutes at 80^{o}C, where the obtained results are shown in table 2, which is table of percent water being separated.

Table 2.
Water Separated Demulsification Process

Waktu (menit)	(KCl 40%)	(NaCl 40%)	(KCl 60%)	(NaCl 60%)	(KCl 80%)	(NaCl 80%)
	% water	% water	% water	% water	% water	% water
0	0	0	0	0	0	0
120	0	0	15	16	18	22
240	2	2	25	25	30	43
360	9	11	35	35	40	53
480	12	17	45	45	50	61
600	24	26	55	55	58	69
720	27	31	65	65	66	75
840	35	39	72	73	74	81
960	42	47	78	79	80	86
1080	44	52	82	83	84	90
1200	47	55	86	87	91	93
1320	49	55	89	90	92	93
1440	49	56	90	91	92	93

The results obtained from the demulsification process is that the highest separated water occurred in 80% concentration of NaCl delmusifier, where the water separated as much as 93%. The smallest was in the 40% KCl demulsifier process, which was only able to separate 49% water. The NaCl demulsifier was better than on KCl demulsifier, in all percentage of demulsifier concentrations. The effect of concentration and the effect of time on the demulsifier process is depicted in Figure 2.

Figure 2 is the results of the time effect on separating water, and it could be clearly seen that the longer the demulsification process, the more water is separated. From 0 to 1440 minutes, the separated water continues to increase, and 1440 minutes is the maximum time for this laboratory scale demulsification process. From 1200 minutes to 1440 minutes the separated water reached a plateau. The 40% concentration of the delmusifier was able to separate the water at 240 minutes, while the 60% and 80% concentrations of 120 minutes were still able to separate the water. The graph also shows that the higher the demulsifier concentration, the higher the water is separated, even though at 40% KCl concentration it is only able to separate 49% water, and 40% NaCl is able to separate 56% water. At a demulsifier concentration of 60% the separated water experienced a significant increase, namely at 60% KCl the water separated as much as 90% and NaCl 60% as much as 91%. The last increase in experiment concentration was 80 %, it did not experience any significant increase in separated water, such that of from concentration of 40% to 60%. The 80% KCl demulsifier was only able to separate 92% water, and 80% NaCl to separate 93% water. Although there was no significant increase in separated water but the demulsification process at 80% NaCl demulsifier is the most optimal demulsification process, this study wanted to prove whether the optimal percentage of demulsification will head to economical demulsification.

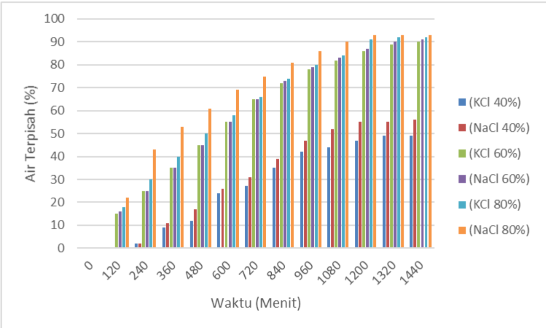

Figure 2.
effect of time on separating water

This study used NaCl and KCl, each of which used a concentration of 40%, 60% and 80%, but the manufacturer is in solution of 100 ml. It means that to have 40% NaCl and KCl, they need 40 gr of NaCl and KCl; to have 60% NaCl and KCl, they need 60 g of NaCl and KCl; and so on. The prices for NaCl are depinted in table 3.

Table 3.
NaCl and KCl Price

No	Material	Weight, gr	Price, Rp.	Price/ml, Rp.
1	NaCl	500	10.000	Rp. 20
2	KCl	500	20.000	Rp. 40

Table 4.
Cash Flow (in Rp.)

No	Material	Cash In	Cash Out	Cash Flow
1	KCl 40%	1.079	1.600	-521
2	NaCl 40%	1.233	800	433
3	KCl 60%	1.981	2.400	-419
4	NaCl 60%	2.003	1.200	803
5	KCl 80%	2.025	3.200	-1.175
6	NaCl 80%	2.047	1.600	447

In Table 4, it could be seen that all cash flows obtained with KCl material are negatives, which means that the expenditure is greater than the income, as the oil price is low, and the KCl price is quite expensive. Thus, the results of using the KCl demulsifier process is not economical; it is recommended to not perform any KCl demulsification activity to be carried out, because of these losses. But the economics for the NaCl demulsification process is on the contrary; all NaCl demulsification processes using NaCl give good cash flows. This occure since NaCl is cheaper than KCl, and also the NaCl demulsification process is better than KCl demulsification process. Moreover, the cash flow results show that the higher the NaCL delmusifier concentration, the higher the cash flow. But it is not directly proportional to the demulsification results, where in the case of demulsification process, the 80% NaCl concentration is the most optimal, but in term of cash flow calculations, the 60% NaCl concentration is the most optimal one. The highest cash flow of 60% NaCl is Rp. 803 while 80% NaCl only gives Rp. 447 cash flow. But the 80% NaCl cash flow is better than 40% NaCl cash flow, which is only Rp. 433. To get more detail results, the researcher tries to see the economic value of NPV and IRR point of view. This study is using MaRR of 8%, because Marr 8% is already higher than bank interest and bank deposits, for more detail the economic value of NPV and IRR, they could be seen in Table 5.

The results of the economic values are the prove that NaCl 60% is the most economical, with the IRR resulted in 12.6% and the NPV resulted in Rp. 200.96. Moreover, 40% NaCl is more economical than 80% NaCl, where at 40% NaCl the IRR is 9.5% and the NPV is Rp. 47.83, while the NaCl 80% IRR was obtained below the MaRR with only 7.2%, and the NPV negative Rp. 3412. For KCl demulsifier at all concentrations are not economical in this crude price assumption. Where all IRR obtained are negatives, and all the NPV are also negative. The best IRR obtained at 60% KCl is negative-3.8%, while the is 40% KCl has NPV of negative Rp. 791.59, and the worst negative case value was obtained from 80% KCl with IRR negative 8.4% and NPV negative Rp. 1,646.36.

Table 5.
The Economics (in Rp.)

	NaCl 40%	NaCl 60%	NaCl 80%	KCl 40%	KCl 60%	KCL 80%
IRR	9,5%	12,6%	7,2%	-7,3%	-3,8%	-8,4%
NPV	Rp. 47,83	Rp. 200,96	Rp. - 34,12	Rp. - 791,59	Rp. - 923,44	Rp. - 1.646,36

Sensitivity analysis is very necessary to find out how sensitive income is if there is an increase or decrease in costs and income, knowing the existing limits enable the company to maintain these limits so that the company is always profitable and economical. Like the sensitivity that has been tested by researchers, where the sensitivity tested is the sensitivity of material prices and oil prices, and how the impact on economic values, namely IRR and NVP, for the results of sensitivity of material prices and oil prices in terms of IRR can be seen clearly as shown in the picture. 3

The economic sensitivity was performed for 60% NaCl, the results is in Figure 3. The sensitivity is on the crude price and the material price. The researcher made sensitivity on both crude price and material price decrease by 80% and 60%, and increase by 120% and 140%. The result shows that reduce the oil price by 20% causing the IRR below the Marr, the IRR is only 6.6%. With an IRR of only 6.6%, the company does not get the minimum profit that is set at 8%. Figure 3 indicates that to achieve the desired minimum Marr, the price of oil should not fall below 15% of the oil price that has been set in this research. While for the material prices, with an increase of 20%, the IRR is below the Marr, which is only 7.6%. To achieve a safe value, the increase in the price of materials should not be more than 18%, so that the IRR is the same as the Marr. If there is a 40% increase in the price of oil, the IRR value obtained could be 23.7%. And while pressing the price of materials down to 40%, will increase the IRR which is very significant, namely 30.8%; it means reduce the material price will affect very significant increase in IRR. It can be concluded that the price of materials is significantly higher influence the economics as compared to that of the crude price

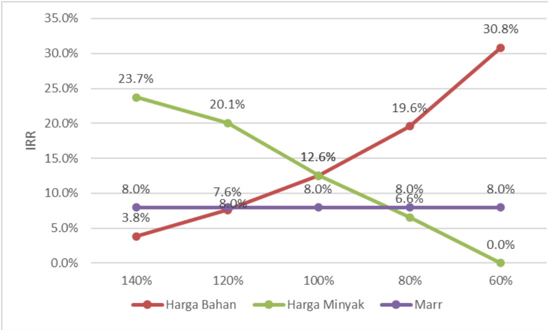

Figure 3.
economics sensitivity irr

Meanwhile, when viewed from the value of the economics from NPV, it can be seen in Figure 4 of economic sensitivity of NPV. Increase in crude price by 20%, will make the IRR value below Marr; this also occurs in the NPV sensitivity; the NPV value is negative when the oil price is reduced by 20%. Therefore, the company will maintain material price as low as possible, and the oil price does not fall below the economics with IRR below Marr, and the NPV obtained is still positive; so, the company still makes some profit. From the NPV sensitivity results, oil prices are the most influencing in the sensitive. In the end, by showing the sensitivity results of material prices and oil prices toward the economics of IRR and NPV values, they show that these two factors greatly affect the IRR and NPV, each of which has the same role.

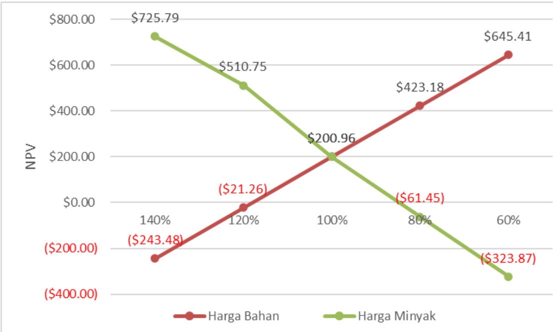

Figure 4.
economic sensitivity npv

III. CONCLUSIONS

1. The smallest separated water is found at 40% KCl concentration, which is 49%, while the largest separated water is found at 80% NaCl concentration, which is 93%
2. The demulsifier process time and concentration greatly affect the separated water, where the higher the concentration the more water is separated, and the longer the demulsifier process the greater the water is separated, where 80% NaCl concentration at 120 minutes is only able to make water separated by 22% and at 1440 minutes it increases up to 93% water separated.
3. The most optimal concentration in this study is 80% NaCl concentration with 93% separated water.
4. The most economical concentration is the concentration of NaCl 60% with Cash Flow Rp. 803, IRR 12.6% and NPV Rp. 200.96.

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