2015 6th International Conference on Environmental Science and Technology
Volume 84 of IPCBEE (2015)
DOI: 10.7763/IPCBEE. 2015. V84. 25

Novel Desulfurization Process of Heavy Fuel Oil Using Surfactant

Isam Al Zubaidi [+], Gnei Lubna Marjan, Hiba Chekkath, Zeinab Hamad, Areej Aref Hassiba, Lina Youssef El Cheikh and Jawaria Saif

Chemical Engineering Department, College of Engineering, American University of Sharjah, Sharjah, UAE

Abstract. This research conveys a unique work in order to remove sulfur from heavy oil using surfactant as extracting materials. Different surfactants were used in this work. Among these surfactants are; demulsifier, Tween 20, Tween 40, and Tween 85. This work was done in a batch wise scale at room temperature. The demulsifier, surfactant and water were added to the heavy oil to extract the sulfur containing compounds from the oil phase to new phase which is produced after settling overnight. Three phases were formed after settlement; oil, water, and solid/semi-solid layers. Sulfur content and other physical properties were measured before and after the treatment process. The sulfur recovery was equal to 35.32% using 5 % tween 20, the other two surfactants showed 33.45 and 34% using 5% Tween 40 and 10% of tween 85. The physical properties were improved during this process due to the deposit semi solid/solid layer of ash and carbon from the heavy oil.

Keywords: Desulfurization process, surfactant, heavy fuel oil.

1. Introduction

Most fuel oils contain sulfur-containing compounds. These compounds when combusted, SO2 is released, resulting in serious pollution such as acid rain [1], [2]. The Environmental Protection Agency of the United States has proposed the reduction of the accepted sulfur level of diesel oil from 500 ppm to 15 ppm by 2006 [3]. Such regulations have urged the petroleum refining industry to produce cleaner products by removing heteroatoms containing molecules from their major products, diesel and gasoline [4]. Although extensive efforts have been made to decrease the sulfur contents of diesel oil, the regulation on the fuel quality is going to be tightened faster than expected. Most of these regulation concentrate on middle distillate but the heavy oil has more complicated sulfur compounds which are difficult to remove. The adsorption-extraction desulfurization was studied by [5]. He found that the use of acid activated bentonite and methyl ethyl ketone was able to reduce the sulfur content to 42.4%. Presently, bio-desulfurization is being investigated intensively because of its low cost, mild reaction conditions, and low impact on the environment [6]-[9]. The research on bio-desulfurization over the past years has been reviewed previously [2], [10]. It is known that surfactants can promote the solubility of hydrophobic substances in water [11], [12]. Among various bio-catalytic conversion methods, bio-desulfurization is a reaction in the two-phase (oil-water) system [13]. They demonstrated the role of Tween 80 in aqueous and biphasic bio-desulfurization processes. Bio-desulfurization of 50:50 water-kerosene emulsions were carried out with sulfur removal was 53% [14].

2. Experimental Work

2.1 Materials

Heavy oil from one local plant in Sharjah/ UAE was used with the properties shown in Table 1. Commercial oil-water demulsifier of the following properties shown in Table 2 was used.

[+] Corresponding author. Tel.: + 0097165152922; fax: +0097165152979.
E-mail address: Isam.Al.Zubaidi@uregina.ca.

Table 1: physical properties of heavy oil

Properties	ASTM Method	Heavy Oil
Water content, vol%	ASTM D 96	0.3
Ash content, wt%	ASTM D 582	2.17
Asphaltene content, wt%	ASTM D 3279	2.857
Carbon residue, wt%	ASTM D 189	2.54
Calorific value, joule/g	ASTM D 240	44,240
Specific gravity@15ºC	ASTM D 1298	0.902
Flash point, ºC	ASTM D 93	126
Viscosity. @50ºC, cst	ASTM D 445	94
Sulfur content, wt%	ASTM- D4294	1.383

Table 2: Properties of commercial oil-water demulsifier

Physical properties	
Color	Clear yellow liquid
Odor	Solvent odor
FPPMCC, oC	69
Kinematic viscosity, cst@38ºC	11.23
Boiling point, oC	185
Specific gravity @21 ºC	0.87
Ash content, wt%	< 0.05

Non-ionic surfactants such as Tween 20, 40, and 85 were used. Tween 20 is commonly known as Poly sorbate 20 and has a molecular formula of $C_{58}H_{114}$ O_{26} (Fig. 1). Tween 40 Is known as Poly-oxy-ethylene-sorbitan- mono-palmitate and it has a molecular formula of $C_{60}H_{123}O_{26}$ (Fig. 2). Tween 85 is also known as poly oxyethylene sorbitan trioleate and has a molecular formula of $C_{60}H_{108}O_8$ (Fig. 3). These materials were used as received without any further treatment.

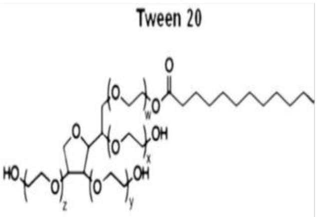

Fig. 1: Tween 20

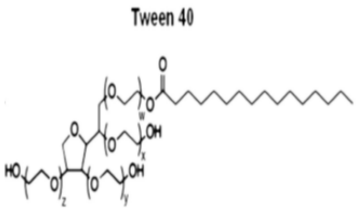

Fig. 2: Tween 40

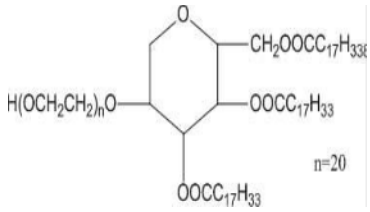

Fig. 3: Tween 85

2.2 Experimental Work

The heavy oil was mixed with demulsifier and different amount of surfactant using overhead stirrer with high speed. The water was added to the mixture as shower then extra water was added. The mixture was transferred to settling vessel to settle overnight. Three layers were formed as shown in Fig. 4.

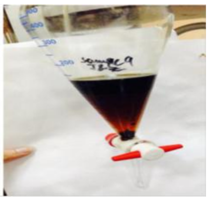

Fig. 4: Three phases of heavy oil, water, and solid deposit formed

The two layers of sediment and water were discarded and the oil layer was centrifuged to separate more water. The oil was analyzed for sulfur content as well as other physical properties. EX-XRF sulfur analyzer was used for measuring the sulfur content of heavy oil. The block process diagram of this work can be summarized as shown in Fig. 5.

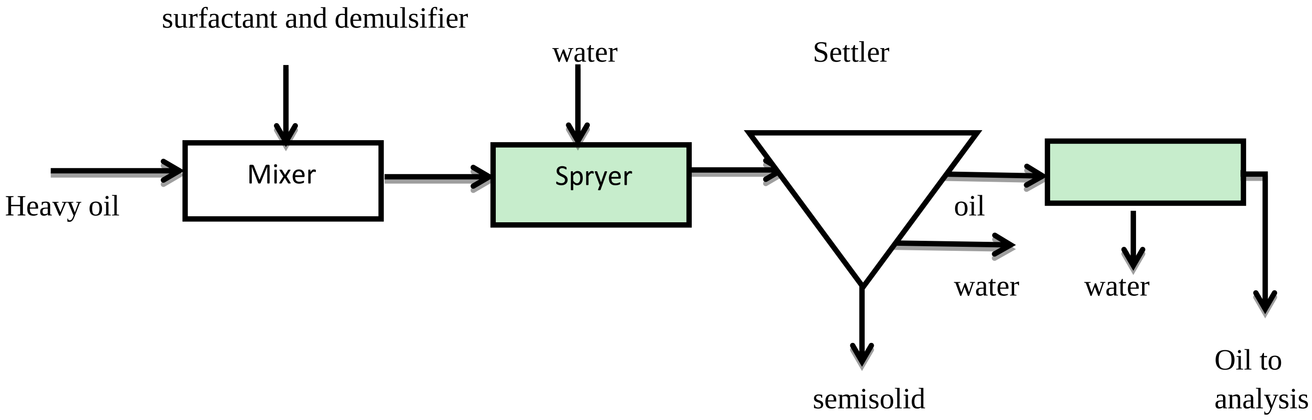

Fig. 5: Process block diagram

3. Result and Discussion

Three surfactants were used during the desulfurization process of heavy oil. Twee 20, tween 40, and tween 84 were added to the heavy oil with different amounts as shown in Fig. 6 and Fig. 7. It was found that the sulfur content was reduced by 35.32% and 33.41% using 5% tween 20 and tween 40 respectively while the addition of 10% of tween 85 caused a reduction of 34.02%.

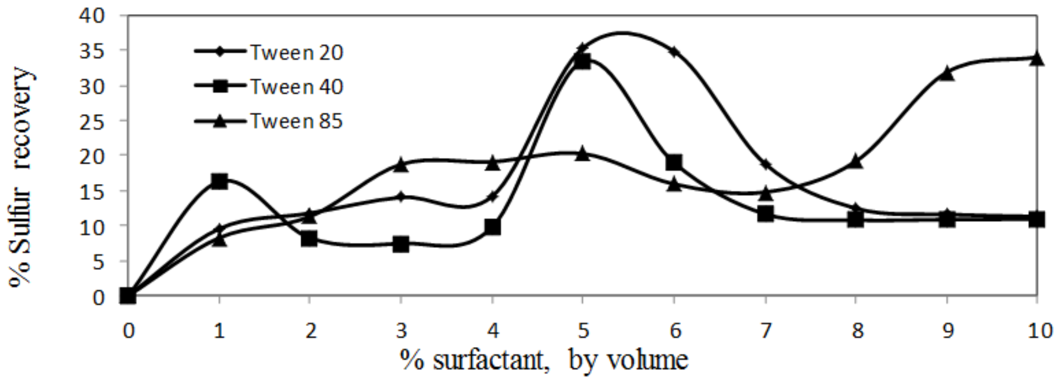

Fig. 6: Sulfur recovery with amount of surfactant

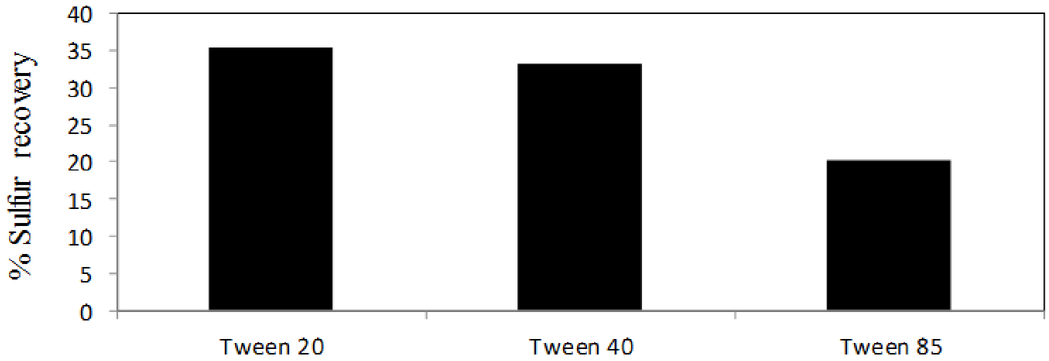

Fig. 7: Sulfur recovery using 5% surfactant

This means that the sulfur content in heavy oil was reduced from 1.383 % to about 0.894%, i.e., the heavy oil was changed from high sulfur content to medium sulfur content. This was believed to have a positive impact effect on environment due to the harmful effect of sulfur on human bodies, machineries, and environment. This is a novel work for sulfur removal from heavy oil. This removal will definitely improve the application of heavy oil as burning fuel in furnaces, marine application, etc.

4. Conclusion

Tween families of 20, 4, and 85 non-ionic surfactants were used to remove sulfur from heavy oil at room temperature. The sulfur content was reduced by 35.32%, 33.41%, and 34.02% using 5% tween 20 and 40, and 10% of tween 85 respectively. More work is needed to study the effect of contact time, type of surfactant, and temperature on desulfurization process of fuel oil.

5. Acknowledgements

The authors would like to thank the Head of Chemical Engineering Department, College of Engineering, and American University of Sharjah for providing all the facilities to perform this work.

6. References

[1] J.J. Kilbane, 1989. Desulfurization of coal: the microbial solution. Trends Biotechnol. 7:97–101.

[2] J.J. Kilbane, 2006. Microbial biocatalyst developments to upgrade fossil fuels. Curr. Opin. Microbiol. 17:1–10.

[3] S.L. Bornge, and R. Quintero. 2003. Biotechnological processes for the refining of petroleum. Fuel Processing Technol. 81:155–169.

[4] S. Yosukei, S.Kazuom, C. Ki-Hyouk, K. Yoz, and M. Isao., "Two-step adsorption process for deep desulphurization of diesel oil, Fuel (2005), Vol.84, No. 7-8, 903-910.

[5] Isam A.H. Al Zubaidy, "Extractive- Adsorptive Desulfurization of heavy fuel oil using natural materials", World Heavy Oil Congress in Aberdeen, UK 10-13 September 2012.

[6] B.R. Folsom, D. R. Schieche, P. M. Digrazia, J. Werner, and S. Palmer. 1999. Microbial desulfurization of alkylated dibenzothiophenes from a hydrodesulfurized middle distillate by *Rhodococcus erythropolis* I-19. Appl. Environ. Microbiol. 65: 4967– 4972.

[7] J.T. Konishi, Y. Onaka, Y. Ishii, and M. Suzuki. 2000. Demonstration of the carbon-sulfur bond targeted desulfurization of benzothiophene by thermophilic Paenibacillus sp. strain A11-2 capable of desulfurization dibenzothiophene. FEMS Microbiol. Lett. 187:151–154.

[8] Li, F. L., P. Xu, C. Q. Ma, L. L. Luo, and X. S. Wang. 2003. Deep desulfurization of hydrodesulfurization-treated diesel oil by a facultative thermophilic bacterium Mycobacterium sp. X7B. FEMS Microbiol. Lett. 223:301–307.

[9] Li, F. L., P. Xu, J. H. Feng, L. Meng, Y. Zheng, L. L. Luo, and C. Q. Ma. 2005. Microbial desulfurization of gasoline in a Mycobacterium goodii X7B immobilized-cell system. Appl. Environ. Microbiol. 71:276–281.

[10] Xu, P., B. Yu, F. L. Li, X. F. Cai, and C. Q. Ma. 2006. Microbial degradation of sulfur, nitrogen and oxygen heterocycles. Trends Microbiol. 14:398–405.

[11] E. De ́ziel, Y. Comeau, and R. Villemur. 1999. Two-liquid-phase bioreactors for enhanced degradation of hydrophobic/toxic compounds. Biodegradation 10:219–233.

[12] Van Hamme, J. D., and O. P. Ward. 2001. Physical and metabolic interactions of Pseudomonas sp. strain JA5-B45 and Rhodococcus sp. strain F9-D79 during growth on crude oil and effect of a chemical surfactant on them. Appl. Environ. Microbiol. 67:4874–4879.

[13] Jinhui Feng, Yiyong Zeng, Cuiqing Ma, Xiaofeng Cai, Quan Zhang, Mingyou Tong, Bo Yu, and Ping Xu, 2006, The Surfactant Tween 80 Enhances Bio-desulfurization, Applied and environmental microbiology, Vol. 72, No. 11, p. 7390–7393.

[14] O. F. Sanchez, C. J. Almeciga-Aiaz, E. Silva, J. C. Cruz, J. D. Valderrama and L. A. Caicedo, Reduction of sulfur level in kerosene by *Pseudomonas sp* Strain in an air lift reactor, Latin American Applied Research 38:329-335(2008)