2011 3rd International Conference on Chemical, Biological and Environmental Engineering
IPCBEE vol.20 (2011) © (2011) IACSIT Press, Singapore

Effect of Mixing Efficiency in Dilution Water Consumption in a Crude Oil Desalting Plant

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Abstract. Oil produced in most of wells contains water and dissolved salts; mainly NaCl, $CaCl_2$ and $MgCl_2$, which can cause several problems in the refining process. At first, dilution water mixes with the formation water. Then, water removes from crude oil. The dilution water injection rate is usually between 3 to 7 percent of the inlet oil flow rate. The pressure drop across mixing valve provides the energy to shear the dilution water droplets. In this research, a two stages desalting plant modelled by using a code and Hysys software. This paper investigates the effect of increasing mixing efficiency of first and second stage, desalting efficiency and dehydration efficiency in a crude oil desalting plant in south west of Iran- Ahwaz. Maximum allowable water content in the outlet crude oil for satisfying purchase conditions has been limited to 0.1% volume and salt content to 10 pounds in thousand barrels. Results showed, by increasing mixing efficiency of first stage by 5% (from 80% to 100%), dilution water decreased 10.5 barrel per day. whereas, increasing mixing efficiency of second stage in a similar way decreased dilution water consumption 88barrels per day.

Keywords:crude oil desalting, two stage desalting, mixing efficiency, static mixer.

1. Introduction

Oil produced in most of wells contains water and dissolved salts; mainly NaCl, $CaCl_2$ and $MgCl_2$, which can cause several problems in the refining processes. In a desalting process, dilution water mixes with the formation water. Then, water removes from crude oil. Settling, chemical, heat, mechanical, electrical coalescences used for crude oil desalting[1, 2]. In chemical coalescence demulsifieragent added to the crude oil [3]. The dilution water must be injected with the same droplet size as the formation water [4]. The dilution water injection rate is usually between 3 to 7 % of the inlet oil flow rate [5]. Maximum allowable water content to satisfy purchase conditions has been limited to 0.1% volume and salt content to 10 pound per thousandbarrels. The most common method of mixing is to inject the dilution water into the crude oil and then flow the oil stream through a mixing valve. The pressure drop across the valve supplies the energy to shear the dilution water droplets [4]. Disposal water flow rate, water content in outlet oil, salinity of inlet oil,and dilution water, mixing efficiency and maximum allowable salt content in the outlet oil are major parameters in a crude oil desalting. Forerro*et al.*investigated implementation of static mixers, which make reduction in maintenance costs [6]. They measured pressure drop, desalting,anddehydration efficiency of Cartagena and Barrancabermeja refinery in Ecopetrol and showed that water content in the outlet crude oil reduced [7]. Static mixers have better particle size distribution rather than other mixing devices [8]. Mahdi *et al.* assessed the effects of mixing time, settling time, dilution water ratio, temperature and demulsifier on dehydration and desalting process [9]. Saudi Aramcoused static mixer in a crude oil desalting plant and had 40 % reduction in amount of dilution water [10]. In this research, a two stagedesalting plant was modelled and effect of increasing mixing efficiencyof first and second stage were investigatedby using a code and Hysys software.

2. Theory

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As solving the material balance for a two stage system with recycle is so difficult, the best method for determining the dilution water rate is trial and error [4]. Fig. 1 revealed a schematic of a twostage desalting system with a recycle. The code (Fortran language) helps to calculate the required dilutionwater flow rate to meet the specified outletsalt content of the oil. According to the assumptions of this research,oil flow rate, inlet water cut, specific gravity of the inlet water, salinity of the inlet water, and dilution water, allowable salt content in the outlet crude oil, water cut at each desalting stage, mixing efficiency at each desalting stage should be known. The inlet and outlet water flow rate could be obtained from equation (1 &2).

$$A = \frac{Q_0 X_a}{1 - X_a} \tag{1}$$

$$C = \frac{Q_0 X_c}{1 - X_c} \tag{2}$$

From the specified outlet oil salt content, outlet salinity could be obtained asbelow:

$$K_c = \frac{Z(1 - X_c)}{1000 X_c} \tag{3}$$

In equation (4), the water cut at outlet of first stage, determines the water flow rates at outlet of first stage.

$$B = \frac{Q_0 X_b}{1 - X_b} \tag{4}$$

Assuming a salinity for K_b and K_s, the required dilutionwater rate could be obtained from equation (5). Mixing efficiency (E_2) defines as the fraction of the dilution water that mixed with crude oil.

$$Y = \frac{B(K_s - K_b)}{E_2(K_y - Ks)} \tag{5}$$

The water material balances around second stage desalter and second stage mixer gives recycle flow rate:

$$V_2 = B + Y - C \tag{6}$$

The salt material balances around second stage desalter and second stage mixer gives recycle water salinity:

$$V_2 K_2 = BK_b + YK_y - CK_c \tag{7}$$

$$R = A + E_1 V_2 \tag{8}$$

$$S = B + E_2 Y \tag{9}$$

Salt material balance around first stage mixer gives K_b. Salt material balance around second stage gives Kc, Substituting K_b andK_c in equation(7) gives:

$$V_2 K_2 = \frac{BAK_a(S - C) + RYK_y(S - E_2 C)}{SR + BE_1(S - C)} \tag{10}$$

By rearranging equation (7), K_b obtained. If the calculated K_b from Equation (7) does not equal the assumed K_b, the next K_b should be determined, and should be returned to equation (5). Desalting/dehydration efficiencies can be calculated from equation (11) and (12) by using desalting plant data [10].

$$\eta_{SRE} = 1 - \frac{Z_{OUT}}{Z_{IN}} \tag{11}$$

$$\eta_{WRE} = 1 - \frac{X_{OUT}}{X_{IN}} \tag{12}$$

3. Results and discussion

Table1, shows operating condition for a crude oil desalting plant in south west of Iran. At first, code validated by design value of the plant. Table 2 shows desalting efficiency and dehydration efficiency. In table3, code results compared with Hysys software and design value. Hysys enables to model mixing efficiency, whichusually assumes 80%. By increasing mixing efficiency of first stage by 5% (80% to 100%), dilution water decreased 10.5BPD(fig. 2). Inlet water flow to second stage (74.108 BPD) and first stage (74.107 BPD) increased (fig. 2 &3). Salinity of first stage desalter reduces 0.327lb/bbl(fig. 4),whereas salinity of recycle water remains constant(fig. 5).By increasing mixing efficiency of second stage in a similar way, dilution water (88 BPD) and inlet water to first and stage (70.78 BPD) decreased(fig. 6, 7). Salinity of both first stage desalter(0.349lb/bbl)and recycle water (0.106 lb/bbl) increased (fig. 8 &9). Dilution water rate has slope -2.217 for mixing efficiency of first stage, whilethe slope of mixing efficiency of second stage is reported -17.6. Finally, it can be inferred that increasing mixing efficiency of first and second stage did not have efficient alteration on salinity of first stage desalter and recycle water.

Table1:Operating condition for a crude oil desalting plant

Inlet value				Dilution water				outlet			
quantity	symbol	value	unit	pressure	-	106	psi	temperature	-	86	F°
Pressure	-	150	psi	Winter	-	60	F°	outlet water	X_c	0.1	%
Winter	-	60	F°	Dilution	Y	1650	BPD	oil salt	Z	9.22	BPD
Crude oil	Q	55000	BPD	Dilution	K_y	1000	ppm				
Inlet water	X_a	10	%								
Salinity of	K_a	210000	ppm								
API degree	-	33.04	-								
Specific	SWG	0.86	Kg/m^3								

Table 2: Desalting efficiency and dehydration efficiency

X_{IN}	X_{OUT}	η_{WRE}	Z_{IN}	Z_{OUT}	η_{SRE}
10%	0.1%	99%	8683 ppm	21 ppm	99.75%

Table3: Crude oil desalting plant result

	symbol	Hysys result	Design value	Model result	Error.%	unit
inlet water flow rate in oil	A	6000	6111	6111.111	0.001	BPD
first stage water-outlet flow rate in oil	B	55	55	55.055	0.1	BPD
flow rate of residual water in the outlet oil	C	55	55	55.055	0.1	BPD
inlet water flow rate to first stage desalter	R	7742	7761	7699	0.79	BPD
inlet water flow rate to second stage	S	1700	1705	1643	3.63	BPD
dilution water flow rate	Y	1645	1650	1643	0.4	BPD
flow rate of water disposal water	V_1	1645	1650	1643	0.4	BPD
salinity of first stage outlet water in oil	K_b	-	71.11	67.42	5.18	ppm
salinity of second stage recycled water	K_2	-	2.56	2.53	1.17	ppm

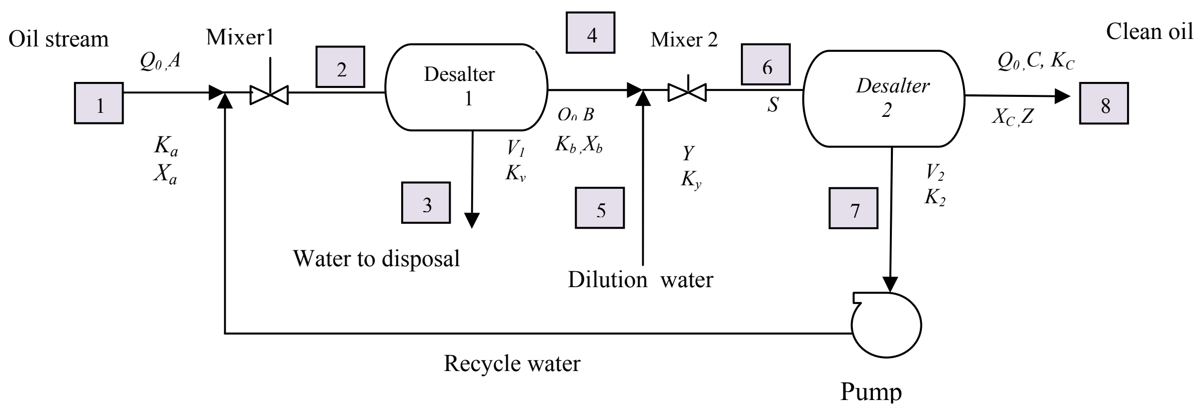

Fig. 1: Two stage desalting system

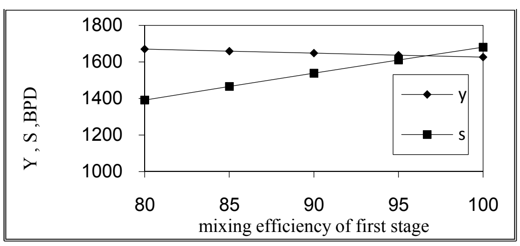

Fig. 2: Y , S versus first stage mixing efficiency

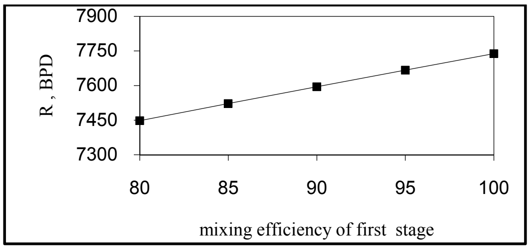

Fig. 3: R versus first stage mixing efficiency

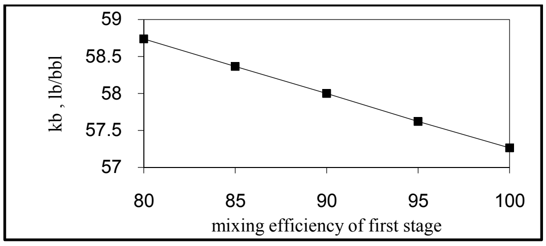

Fig. 4: Salinity of first stage versus first stage mixing efficiency

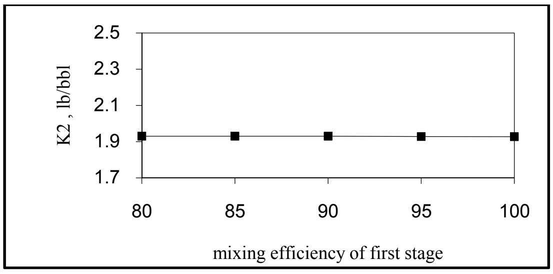

Fig. 5: Salinity of recycle water versus first stage mixing efficiency

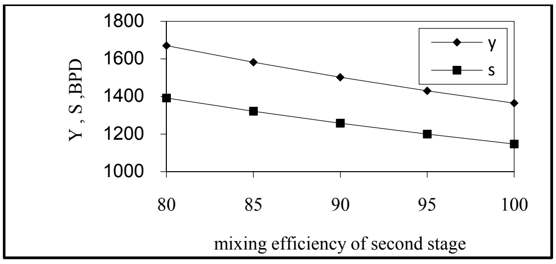

Fig. 6: Y , S versus second stage mixing efficiency

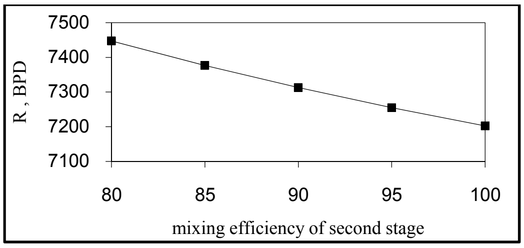

Fig. 7: R versus second stage mixing efficiency

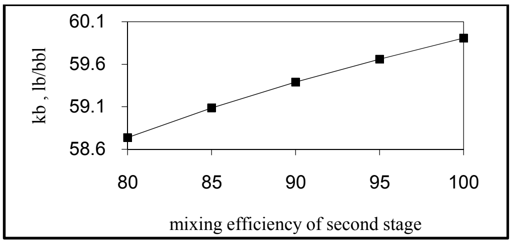

Fig. 8: Salinity of second stage versus first stage mixing efficiency

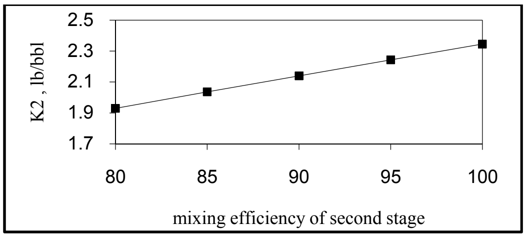

Fig. 9: Salinity of recycle water versus second stage mixing efficiency

4. Conclusion

At this study a two stage desalting plant modelled. Comparison between increasing mixing efficiency of first stage and second stage showed increasing mixing efficiency of second stage has more effect on reducing dilution water consumption. It can be concluded that increasing mixing efficiency of first stage causes rising in amount of water that enter first and second stage desalter, while increasing mixing efficiency of second stage has a reverse effect. On the other hand, there is trivial differences between salinity of first stage outlet water in the oil and salinity of second stage recycled water stream. As increasing mixing efficiency of second stage is more effective, it is recommendedto install static mixer before second stage desalter.

5. Acknowledgements

The authors thank National Iranian oil company (NIOC) and National Iranian South oil company (NISOC) for providing invaluable advice and assistance on fulfilling the work and their financial supports.

6. Nomenclature

A	Inlet water flow rate in oil	SWG	Specific gravity @ 60
B	First stage water outlet flow rate in oil	V_1	flow rate of disposal
C	flow rate of residual water in the outlet oil	V_2	flow rate ofrecycle
K_a	salinity of inlet water	X_a	inlet water cut
K_b	salinity of first stage outlet water in oil	X_b	first stage water cut
K_y	Dilution water salinity	X_c	outlet water cut
K_2	salinity of second stage recycled water stream	Y	Dilution water flow
Q	crude oil flow rate	Z	oil salt content
R	Inlet water flow rate to first stage desalter	η_{WRE}	Dehydration efficiency
S	Inlet water flow rate to second stage desalter	η_{SRE}	Desalting efficiency

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