Optimal processing parameters of electrostatic crude oil desalting

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ABSTRACT: Crude oil often contains dilute dispersion of ultrafine water droplets with a variety of salts, solids and metals. To prevent corrosion, plugging, and fouling, electrostatic desalting plants are often installed in oil production units in order to remove water-soluble salts from the oil stream. To meet business requirements, the salinity of the crude is limited to less than 40 mg /l and (BS&W) Basic Sediments and Water must to be lower than 1%.

This work presents the results of an experimental study conducted regarding the variation of important processing parameters, namely: the rate of wash water, demulsifier amount, and processing temperature in aim to reach the optimum of each of those parameters and then to obtain the lowest values of oil salinity and (BS&W).

Experiments conducted in the two-stage electrostatic desalter of South Crud Treatment Unit (UTBS/HMD/Algeria), showed that the Salts Removal Efficiency (SRE) increases with the increase of wash water rate, demulsifier amount and processing temperature. For 2% of wash water rate and 15 ppm of demulsifier for each stage at 70°C, the (SRE) was 95.78% and the final salinity value of treated oil was 11 mg/L. The mean value recorded for (BS&W) during experiments was only 0.05%.

KEYWORDS: Oil, electrostatic desalter, salinity, demulsifier, droplets, emulsion, BS&W.

1. Introduction

In almost all cases, salts are found dissolved in the water droplets that are dispersed in the crude oil. Salts mainly $CaCl_2$ and $MgCl_2$ can cause corrosion problems in the refining processes by hydrochloric acid which is formed by hydrolysis of these salts during the distillation process.

Solids and metals are also found with water/oil emulsion. To prevent corrosion, plugging, fouling of petroleum equipments, electrical desalting plants are often installed in crude oil production units in order to remove these foreign compounds from the oil stream.

The fundamental functions of desalting plants are the following:

1. Remove chloride salts, typically calcium, magnesium, and sodium to prevent and minimize equipments corrosion.
2. Remove solids and sediments that can cause erosion, plugging or fouling of preheat exchanger tubes which results in reduced heat transfer.
3. Minimize unit upsets by preventing water slugs from tankage to be charged directly to the distillation column.

For an effective desalting/dewatering of crude oil, the following steps shall be met:

- Preheating the crude to decrease its viscosity and its specific gravity for an easy separation of water from oil and hence obtain an easy desalt. Preheating also increases demulsifier reactivity, and destabilizing emulsion by breaking the film surrounding droplets. However, the crude temperature is limited to avoid its vaporization in the desalter, and prevent damage to the electrical grid insulator bushings.
- In desalting systems, and before sending a stream of crude oil to the distillation process, it was put in contact with fresh water by means of a mixing system that promotes close contact between oil and water phases in order to remove salts, metals and solids from the crude. Fresh water must be added to reach salt crystals and saturated saline droplets. The wash water injection rate is usually between 3 to 7 % of the inlet oil flow rate [1]. Generally, a considerable amount of wastewater is generated after desalting. Its volume is typically about

15% of the crude oil desalting plant capacity, consists 10% of associated formation water and 5% of added fresh water.

Dilution water must be injected with the same droplet size as the formation water [2]. Wastewater generated by chemical, heat, mechanical, electrical coalescences and settling, was removed and collected in sloughs [3 - 5].

- Chemical demulsifier agent is added in crude oil to break droplets and destabilize water/oil emulsion [6]. Its amount is generally fixed by refiners after experimental tests.
- The oil stream is then flowed through a mixing valve to ensure the best contact between the two phases of oil and fresh water. The pressure drop across the valve facilitates the role of demulsifier to reach and break the interfacial film, allow to fresh water to dissolve salt crystals, dilute and grow up droplets. There are different techniques that use conventional devices such as: mix valve, orifice plates, and scattering flutes, which are subject to numerous operational limitations. Static mixers have better particle size distribution rather than other mixing devices [7].
- High-voltage electric field is applied in the desalter. Water droplets are polarized and the induced electric forces between them accelerate their motion towards each to other and results in their coalescence. Due to Stokes law, the larger droplets formed in this way can more easily be separated from the crude oil by settling [8]. There are three fundamental types of electrostatic fields to enhance coalescence of the dispersed water droplets:

- Direct Current (DC) fields are highly efficient but can promote electrolytic corrosion. Therefore, they are used only to dehydrate refined oils having low conductivity.
- Alternating current (AC) fields are used by all manufacturers due to their tolerance of high water cuts and non-electrolytic nature.
- Combined (AC/DC) fields provide the high water tolerance of the (AC) fields with the high efficiency of the (DC) fields [8, 9].

Fig.1 shows a schematic cross-section of one stage electrostatic desalter of crude oil.

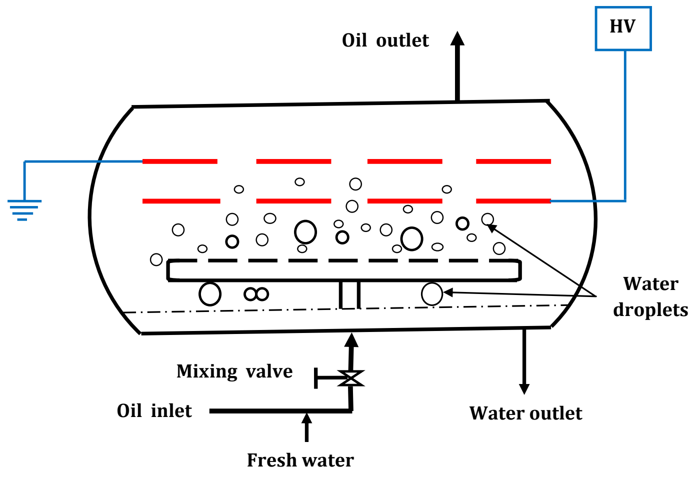

Fig.1: Schematic cross section of electrostatic oil desalter

Several researchers in the field of oil desalting have developed studies and gave their suggestions and investigations in the aim to improve the efficiency of desalting and dewatering of crude oil, and hence to troubleshoot encountered problems in order to save processing facilities and increasing the selling price of a crude barrel.

W. H Thomason et al. [9], L. Vafajoo et al. [10] and K. Mahdi et al. [11] have studied the effects of wash water ratio, processing temperature, mixing time, settling time, and chemical demulsifying amount on dewatering/desalting process. H. Linga et al. [12] and J. E. Forero et al. [13, 14] studied the effect of other mixing devices on dewatering and desalting efficiencies. V. Meidanshahi et al. [8], R. E. P. Cunha et al. [15], M. Chiesa et al. [16], J. A. Melheim et al. [17], R. P. Alves et al. [18] and M. B. Al-Otaibi et al. [19] have established a mathematical model to study theoretically the key parameters of electrostatic oil desalting in aim to apply them in treatment units for decreasing amounts of water and salts in outlet treated crude.

2. Experimental procedure

The aim of this work conduced in south unit of crude treatment (UTBS) is to study the effect of important processing parameters, namely: the wash water volume rate, injected demulsifier amount, and operating temperature in order to reach the optimum of each of them and hence to obtain the lowest values of oil salinity and (BS&W).

The treatment unit receives crude from different wells, and this is the cause that the salinity of the crude inlet is not fixed; it can sometimes be changed from one day to another. The unit has two stages of electrostatic desalting which work depending on the salinity of the crude inlet. When high salinities, both stages operate simultaneously and the same amount of wash water and demulsifier is added to the oil input of each stage; otherwise, the amount of wash water and demulsifier is added only to the crude inlet of the first stage. In other words, it is the salinity value of final desalted crude that allows refiners to decide.

2.1. Determination of crude oil salinity by Titration (Mohr's Method)

The crude oil salinity is expressed in (mg of Cl^- / Liter of crude oil).

The well known Mohr's method in which alkaline or alkaline earth chlorides react with silver nitrate ($AgNO_3$ 0.1 mol/l) in the presence of a few drops of potassium chromate solution (K_2CrO_4 0.25 mol/l) as indicator, is a simple, direct and accurate method for chloride determination. Potassium chromate serves as an indicator for the Mohr's method. This was obtained by reacting with silver ions to form a brick-red silver chromate (Ag_2CrO_4) which precipitate in the equivalence point region. About 1 ml of (K_2CrO_4) was added and the solution was titrated until the permanent appearance of the red color of (Ag_2CrO_4). Followed reactions have been occurred in the water phase extracted from crude:

$$Ag^+ + Cl^- \rightarrow AgCl_{(s)} \qquad (I)$$

$$2Ag^+ + CrO_4^{2-} \rightarrow Ag_2CrO_{4\,(s)} \qquad (II)$$

The titration was carried out at pH between 7 and 10; a suitable pH was achieved by saturating the analyzed solution with sodium hydrogen carbonate ($NaHCO_3$). In order to adjust the pH of the solutions, small quantities of this latter salt were added until effervescence was ceased.

2.2. Determination of (BSW) procedure

To determinate the (BS&W), these steps must be followed:

- Fill two centrifuge tubes to 50% mark with xylene.
- Mix oil sample thoroughly and fill the tubes remainder to the 100% mark and mix.
- Add 1ml of demulsifier to each tube and mix.
- Place tubes in water bath at (70-80ºC) for about 10 min.
- Centrifuge the tubes for 5 min.
- Record observations to include volume of saline water, solids and oil.

2.3. Effect of wash water rate

During the study of wash water rate effect, the processing temperature was maintained at 64°C, and demulsifier amount was fixed at 15 ppm for each stage desalter. The volume rate of fresh water was varied from 1 to 5% for each stage desalter. In this first experiment, the crude salinity before desalting was 245 mg/L.

2.4. Effect of demulsifier amount

When studying the effect of chemical demulsifying amount, processing temperature and wash water volume rate were respectively 64°C and 2%, which were maintained as constants during this second experiment. Demulsifier amount was varied between 5 and 30 ppm and crude salinity before treatment was 249 mg/L.

2.5. Effect of processing temperature

In this experiment, demulsifier amount and wash water rate values were fixed respectively at 15ppm and 2%, and to show the processing temperature effect, the latter was varied between 64 and 72°C. This restricted range of 8 °C is due to the stabilizer column, because the enlargement of the temperature range disrupts it. When studying the effect of processing temperature, the salinity of the crude inlet was 261 mg/l.

3. Results and discussion

3.1. Effect of wash water rate

Fig.2 and Fig.3 display respectively the variation of final desalted oil salinity and Salinity Removal Efficiency (SRE) according to the volume rate of wash water injected in each desalter. It is clear that treated crude salinity decreased with the increasing of fresh water amount. In this experiment, the crude salinity before desalting was 245 mg/l, processing temperature and demulsifier amount were fixed respectively at 64°C and 15 ppm for each stage desalter. The Salinity Removal Efficiency (SRE) reached its maximum value of 96% after adding 5% of wash water for each stage i.e. 10% of wash water for the two stages desalter.

The amount of fresh water to be added must be well studied because the water must be removed again as a wastewater which requires treatment before being used. Generally the volume rate of wash water added depends on the value of crude salinity before treatment; if the latter is low, the volume rate of wash water must be lower and vice versa.

Assuming that the maximum salinity before desalting is 300 mg /l, and for reducing this salinity to less than 40 mg /l, the (SRE) calculated should be equal to 86.6%, so the percentage of wash water to be deduced from Fig.3 is about 3.7% for each stage desalter i.e. 7.5% of wash water for the two stage desalter. The Basic Sediment and Water (BS&W) recorded in this experiment was 0.05%

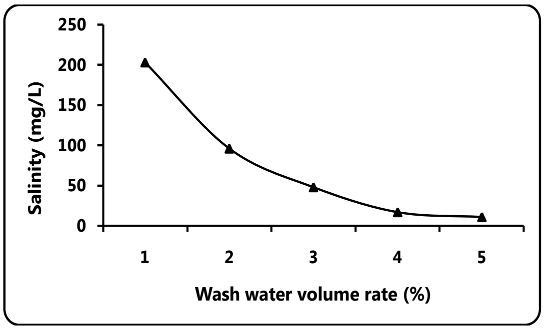

Fig.2. Variation of oil salinity according to wash water rate for (T=64 °C and 15 ppm demulsifier)

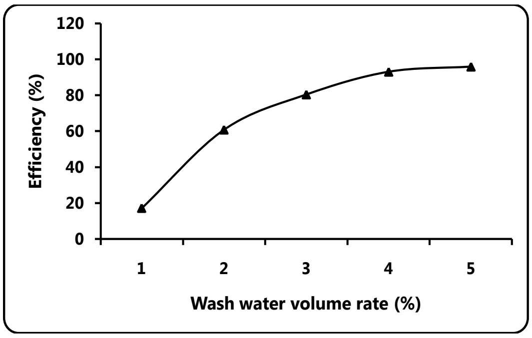

Fig.3. Salinity Removal Efficiency according to wash water rate for (T=64 °C and 15 ppm demulsifier)

3.2. Effect of demulsifier amount

Fig.4 and Fig.5 show respectively the variation of desalted crude salinity and the salinity removal efficiency (SRE) according to the amount of commercial chemical demulsifier added to each stage desalter. During this second experiment, processing temperature and wash water volume rate were fixed respectively at 64°C and 2%. Demulsifier amount was varied between 5 and 30 ppm and the value of crude salinity before treatment was 249 mg/L.

The maximal Salinity Removal Efficiency (SRE) recorded after adding 30 ppm of demulsifier was 95.18%. The amount of demulsifier depends on the nature and stability of water/oil emulsion

encountered. If we apply the previous assumption (paragraph 3.1.), the amount of demulsifier to be added would be around 22 ppm for each stage desalter i.e. 45 ppm of demulsifier for the two-stage desalter.
The Basic Sediment &Water (BS&W) recorded in this experiment was 0.06%.

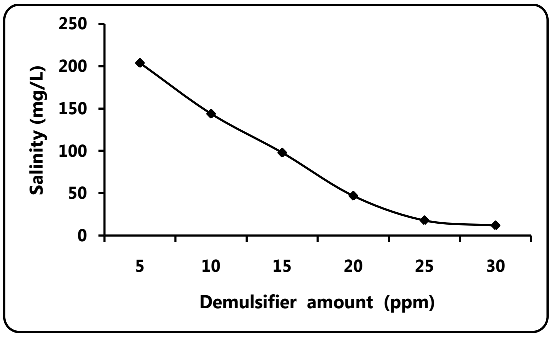

Fig.4. Variation of oil salinity according to the demulsifier amount for (T=64 °C and 2 % wash water rate)

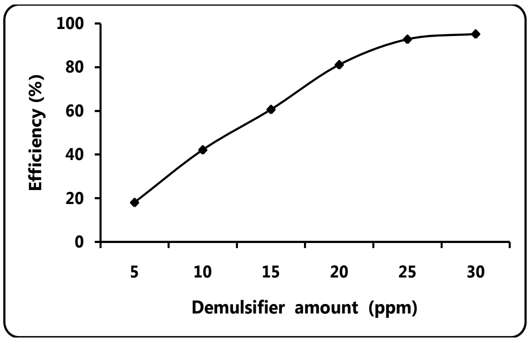

Fig.5. Variation of Salinity Removal Efficiency according to demulsifier amount for (T=64 °C, 2 % wash water rate)

3.3. Effect of processing temperature

Fig.6 and Fig.7 show the processing temperature effect on crude desalting; the latter was varied between 64 and 72°C, because the enlargement of the temperature range disrupts stabilizing column, and in addition, the processing temperature was limited to avoid crude vaporization in the desalter which causes damage to the electrical grid insulator bushings. During this third experiment, the salinity of the crude inlet was 261 mg/L and demulsifier amount and wash water rate values were fixed respectively at 15 ppm and 2%. Preheating crude to 64°C rapidly decreased the salinity from 261 to 105 mg/l and increased Salinity Removal Efficiency (SRE) to 59.77%. By increasing crude oil temperature to 70°C, the (SRE) reached 95.78% despite the low values of wash water rate and demulsifier amount (2% and 15ppm respectively).
This means that the temperature plays a very important role in desalting/dewatering of crude oil than the wash water rate or demulsifier amount because it affects several points:

- Enhances demulsifier reactivity.
- Decreases the viscosity and the specific gravity of crude oil; and then
- Accelerates droplets coalescence and settling.

The maximal processing temperature allowed was 72°C; so to stay within the standards and for security reasons; we recommend the use of 70°C as processing temperature design.
The Basic Sediment and Water (BS&W) recorded in this experiment was 0.04%.

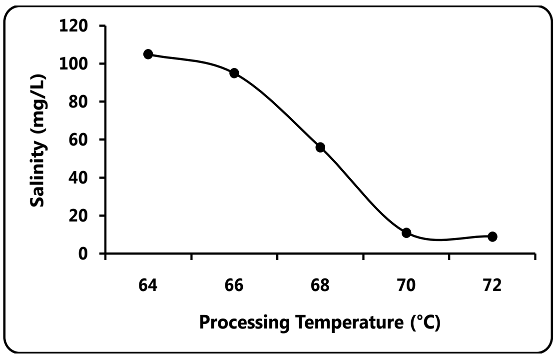

Fig.6. Variation of oil salinity according to the processing temperature for (wash water rate 2 %, 15 ppm demulsifier)

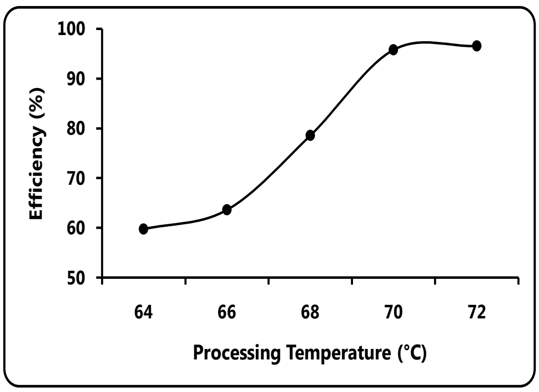

Fig.7. Variation of Salinity Removal Efficiency according to the processing temperature for (2 % wash water rate 15 ppm demulsifier)

4. Conclusion

To prevent corrosion, plugging and equipment fouling caused by saline dispersion/emulsion of water droplets in crude, electrostatic desalting plants are often installed in oil production units in order to remove water-soluble salts from the oil stream. To meet business requirements, the salinity of the crude is limited to less than or equal to 40 mg/l and the Basic Sediment and Water (BS&W) must be lower than 1%.

This work presents the results of an experimental study conducted regarding the impact of important processing parameters, namely: the rate of wash water, injected demulsifier amount, and processing temperature in aim to reach the optimum of each of them and hence obtain the lowest values of oil salinity and (BS&W).

Experiments conducted in the two-stage electrostatic desalter of South Crud Treatment Unit (UTBS/HMD/Algeria), showed that the salts removal efficiency (SRE) increases with the increase of the wash water rate, demulsifier amount and processing temperature. For 2% of wash water rate and 15ppm of commercial demulsifier for each stage at 70°C, the (SRE) was 95.78% and the salinity of treated crude was 11 mg/l. In the case of high crude inlet salinity, and if necessary, wash water ratio can be increased to 3% and/or demulsifir amount to 20 ppm for further enhancing the (SRE).

During these three experiments, the mean value recorded for (BS&W) was only 0.05%; so it can be concluded that the treated crude has a high quality.

5. Abbreviations

BS&W : Basic Sediments and Water.
HMD : Hassi Messaoud region (South-east of Algeria).
SRE : Salts Removal Efficiency.
UTBS : South Crud Treatment Unit.

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