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Study on the divided-wall electric desalting technology for Suizhong crude oil

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HIGHLIGHTS

► Experimental study on new equipment for heavy oil desalting and dehydrating.
► Mass fraction of 6% is more appropriate for the injection water.
► Optimal operating temperature is in the range between 130–140 °C.
► Mixing intensity from 40 to 50 kPa is suitable for the desalting process.
► All key indexes of treated oil can meet Sinopec required standards.

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ABSTRACT

Electrostatic desalting and dewatering for Suizhong crude oil was studied by investigating the dynamic electric desalting process parameters in the divided-wall electric desalting apparatus. Several demulsifying agents were tested for obtaining the optimum static desalting results. In addition, the dynamic electrostatic desalting experiments were studied to find the optimal conditions. Under the optimal conditions, the salt content of the crude oil in the first desalt stage could be decreased to 5.2 mg/L, the water content to 0.28%; and the salt content of the crude oil in the second desalt stage could be decreased to 2.3 mg/L, the water content to 0.22%, the oil in the outlet water to 138 μg/g, which meet the technical requirements of Sinopec standard. The micrograph of the treated oil indicated that the water content had been decreased to a very low level, and the diameter in the water droplets in the treated crude oil ranged from 10 to 30 μm.

1. Introduction

In general, crude oil often contains water, inorganic salts, suspended solids, and water-soluble trace metals [1]. The mineral salt content of the different crude oils varies with the geologic formation, and sometimes even high up to 200,000 μg/g [2]. In addition, salt water introduced during shipment by tanker may also contribute to the total salt content in refinery [3]. In almost all cases, the salt content of the crude oil composed of salt dissolved in small water droplets that are dispersed in the crude oil [4]. As a current preliminary step of refinery treatment, crude oil desalting is normally used to remove species such as chloride which could deactivate the refinery catalysts and cause further corrosion of overhead distillation columns. It is also an issue of great concern that in desalting process, water is deliberately mixed into the crude oil to dissolve hydrophilic materials and form one or a mixture of water-in-oil types, such as stable, unstable, meso-stable, and entrained [5,6]. The emulsions must subsequently be broken down to recover the "clean" crude oil. Electric desalting and dewatering is one of application technique in crude oils desalting [7], and which has sustained improvement and enhancement [8–10]. Then some new approaches to desalting and dewatering of crude oil have been explored, such as ultrasonic-electric desalting and dewatering [11–13], pulse electric desalting/dehydration [14], hydrocyclone technology [15], research and development of novel demulsifiers [16], and hybrid UF/RO membrane separation on crude oil desalter effluent [17].

Some oil fields have already got into the stage of secondary or tertiary oil recovery. The crude oil recovered by this way tends to become ropier and heavier, containing more salts. Crude oil contains varying amounts of inorganic salts NaCl, $CaCl_2$, $MgCl_2$, and metal ions Fe, Al. It may be hard to desalt those oils with conventional method of electric desalting and dewatering processes. Blackout of the desalting device and current collapse of the electric field usually happen. So, the crude oil pretreatment is hardly to be continuous and steady.

The presence of such salts can cause problems during crude oil processing such as corrosion, plugging and fouling of equipment, and poisoning the catalysts in subsequent processing units. In order to mitigate the effects resulting from the presence of salts, it is advantageous to reduce the salt concentration to the range of 3–5 mg/L [18]. And according to the requirement of Sinopec(China Petro-Chemical Corporation) standard, it strictly limits the water content less than 0.3%, salt content less than

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3 mg/L in the desalted heavy crude oil, and oil content in waste water less than 150 μg/g.

For the increase of density and viscosity of crude oil, the traditional AC-DC devices, working under full capacity, have difficulty in satisfying the required specification. In order to have an enhanced effect of desalination and dehydration, it is required to decrease the treating capacity or increase the tank size. Although dual electric fields in high-speed electric desalting technology have been applied and show some advantages, it is impossible to adjust the flow in processing of heavy crude oil [19], for water droplets settled in the upper will be in contact with the counter-current flow of clean oil, which would reduce the effect of desalination and dehydration. By studying the emulsion stability of the >520 fraction, it suggests that the amphiphiles with the highest weight, i.e., resins and asphaltenes play a major role in the protection of water droplets against coalescence [20]. It shows that stable emulsions are easy to be formed with the heavy crude oil with high contents of resins and asphaltenes. So, the original emulsion of water in the crude oil is very stable and difficult to be broken [21]. So it becomes more urgent to develop new effective methods to treat heavy crude oil. To solve this problem, a new type of divided-wall electric desalting and dehydrating technology and equipment has been developed. Compared to other desalting equipment design, its outstanding characteristic is to set divided wall and accessories in the middle of the electric vessel, which makes it with independent electric desalting systems on both sides of the divided-wall. The two electric desalting systems have the characteristics as follows: operating independently, relative independent inside and outside area of electric field, and respective control system, etc. [22]. A comparison study of treatment capacities of divided-wall electric desalting device and conventional desalting device shows that the treatment capacity could be improved by 20%–30% for the divided-wall electric desalting device. Based on studying oil dewatering and desalination for Suizhong crude in small test equipment, this paper have demonstrated the divided-wall electric desalting and dehydrating technique and optimized its process conditions. The experimental results have shown that the water content and salt content in the treated crude oil meet the technical requirements of Sinopec after the treatment.

2. Experimental

2.1. Crude oil and demulsifier

Basic properties of the crude from Suizhong are listed in Table 1. The demulsifiers are purchased from Changfiang (Yangzhong) Electric Desalting Equipment Co.,Ltd.

2.2. Laboratory equipment and instruments

Using a divided-wall desalting and dehydrating device shown in Fig. 1 and a static evaluation instrument for crude oil demulsifier selection, the divided-wall dynamic simulation test instrument, with processing capacity of 30 L/h, which is shown in Fig. 2, is used for evaluation of the electric desalting and dehydrating effect.

Table 1
The properties of crude oil.

Property	Value
Specific gravity, 20 °C, g/cm^3	0.9192
Viscosity, 50 °C, mPa s	617
Solidifying point, °C	−6
Flash point, °C	82
Carbon residue, m%	12.75
Ignition point, °C	91
Acid value, mg KOH/g	3.96
Salt content, mg NaCl/L	38.8
Water content, m%	7.3

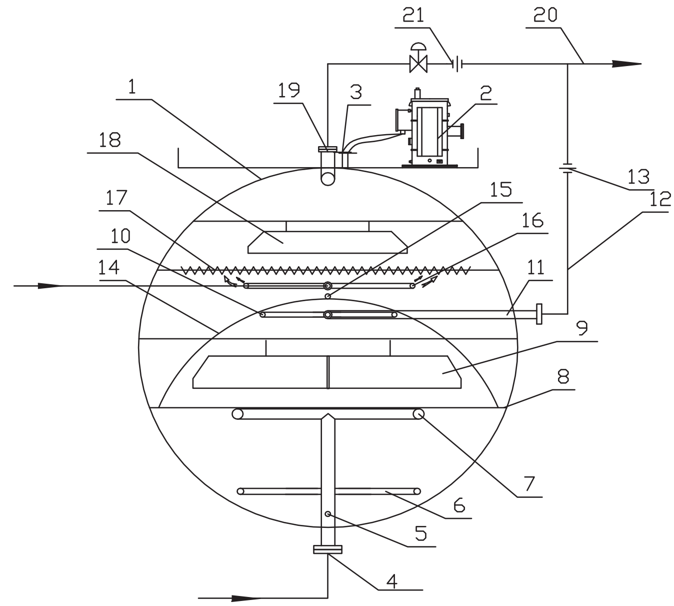

Fig. 1. The divided wall electric desalting equipment.

The salt content in the desalted crude oil is detected with a micro-coulomb method, using a LC-II micro coulomb salt content tester produced by Jiangsu Jiangyan Analytical Instrument Factory. And the micro-coulomb method complies with SY/T0536, the total value of water-soluble chloride (including NaCl, $CaCl_2$, etc.) is converted into NaCl and titrated by the acetate electrolyte with silver ion, and the salt content is calculated by measuring the consumed electric quantity for producing silver ion and Faraday Law.

The water content in the desalted crude oil is determined with a distillation method, which complies with GB/T8929-2006. The measuring principle is that an aquiferous crude oil sample is heated under reflux, and the water is to be distilled, condensed and settled in the graduated tube of an acceptor.

The oil content of drain waste water is detected using an infrared photometric method, which complies with GB/T16488-96.

Motic AE31-typed optical microscope produced by Motic Instrument Co., Ltd is used for observational study of Suizhong crude oil with and without desalting and dewatering process.

2.3. Processes

After heat exchange, crude oil at about 120–140 °C mixes with demulsifier, corrosion inhibitor from dosing station and water from first stage water injection pump, and then enters the first stage vessel passing through AC feeble, DC intermediate and high field in turn for dewatering. Salty water settles down at the vessel's bottom and is sent to a waste water treatment unit. Meanwhile the crude oil goes to the top section of the vessel and mixes with the water from offsite. It then enters the second stage vessel passing through AC feeble, DC intermediate and high field in turn for oil–water separation. Salty water settles down at the vessel's bottom and is sent back to the first stage vessel by the first stage water injection pump. Crude oil goes to the top of the vessel and is sent to a group of downstream heat exchange units.

3. Results and discussion

Suizhong crude is a kind of typical sea-based oil produced by China National Offshore Oil Corporation. As seen from Table 1, Suizhong heavy crude oil properties are: specific gravity of 20 °C more than 0.91 g/cm^3, water content high to 7.3%, acid value and viscosity of 50 °C reached