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Research article

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Experimental Evaluation Of A New Process For Removing Sulfur Compounds From Sour Oil In A Fixed Nano Bed: Investigation Of Energy Saving In Oil Refineries

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Abstract

Removal of hydrogen sulfide from crude oil is an important process in oil refineries that reduces the concentration of sulfur in oil. The use of nano-catalysts in the removal of sulfur from oil is a new method. The zinc nano oxide with a diameter of 54 to 91 nm has been used in sour oil refining in this study. The experiments have been performed for the catalytic separation of two samples of heavy and light oil. In this study, the effect of different operating parameters on the performance of the sweetening process has been investigated. According to the results, temperature of 55°C and pressure of 1.6 bar can be introduced as optimal temperature and pressure. In addition, zinc oxide with a diameter of 58 nm and 77 nm can be used as the optimal diameter for sweetening of heavy oil and light oil, respectively.

Keywords: Energy saving; Sweetening; Sour petroleum; Optimization; Nano bed; Sulfur compounds.

Introduction

Today, energy is considered as one of the most basic human needs [1]. Energy is a vital need for industry, food production and agricultural production [2]. Therefore, the human need for energy is an unavoidable need. While a large percentage of the world's total energy comes from fossil fuels [3-7]. It is not bad here to make a brief reference to the types of fossil fuels and their formation history [8]. Oil is another fossil fuel that originated more than 300 million years ago [9-11]. Some scientists believe that the source of oil was aquatic organisms, each about the size of a needle, and that they could act just like plants [12-15]. These tiny creatures fall to the sea floor after death and are buried under sedimentary layers and rocks, gradually [16-19]. Rocks put pressure on these tiny creatures and the energy in their bodies cannot be depleted and carbon is converted to oil over time under intense heat and pressure [20-22]. The crude oil desulfurization is an important process in oil refining to reduce sulfur concentrations and produce fuel products such as gasoline, jet fuel, kerosene, diesel and heating oil [23]. Therefore, the resulting fuels are produced in accordance with environmental standards [24]. The growing challenge of the need for energy for transportation around the world is no longer a simple subject and will not be met by the production of hydrocarbon liquid fuel [25]. The complex environmental problems and process problems add to this challenge [26]. Environmental problems emphasize on the production of clean and polluted liquid hydrocarbon fuels based on the demands of society, minimally [27]. In addition, need to use new refining processes and increase the using of new methods for energy production such as fuel such as it is raised [28]. Accordingly, there is an urgent need to desulfurize diesel and jet fuel [29]. On the other hand, when nanoparticle metal particles are present, they break the carbon-sulfur bonds in the asphaltene compounds [30]. The result of this process is an increase in saturation while reducing asphaltene compounds, simultaneously [31]. This process reduces the viscosity of heavy oil and bitumen by reducing the average molecular weight, dramatically [32]. This effect can be enhanced by the presence of a strong hydrogen donor and inhibited by the elimination of all hydrogen donors, dramatically [33]. In general, nanoparticles and nanocomposites can be used in chemical processes, in determining the properties of reservoir fluids and rocks, in increasing the recovery coefficient of reservoirs, in gas and petrochemical industries, in oil, gas and petrochemical industries, in lubricants, in improving The quality of petroleum products is used in environmentally friendly processes, in energy transfer processes, etc. [34-36].

In this study, these materials have been used to increase the mass transfer surface and energy transfer according to the surface to volume ratio of nanoparticles. The results of laboratory studies show that the removal of sulfur compounds will increase if the use of nanotechnology, significantly

Materials and methods

The use of stainless steel equipment is preferred in order to investigate the effect of physical and operational parameters of the process on the efficiency of hydrogen sulfide adsorption from sour oil and for optimization of the process conditions. Sour oil is a corrosive. Also, it has impurities that intensify this effect. Investigation of effective factors in increasing of the efficiency of hydrogen sulfide removal requires attention to operating parameters such as operating pressure, operating temperature and physical characteristics such as diameter and bed height, as well as the concentration of hydrogen sulfide in sour oil. Therefore, a pump is used and a water vapor jacket is used to ensure a uniform temperature in the reactor to provide the pressure and temperature of oil. The use of water vapor jacket has a reasonable operational efficiency and economic justification in terms of cost. The inner wall of the reactor has retaining parts, which are two mesh plates and as made of stainless steel. In addition, the distance between the top and bottom plate is occupied by a large number of steel balls. These plates are responsible for maintaining the nano-catalyst layers. The effective bed height can be increased by adding each layer of nano-catalyst. It is possible to report the process by using the instrumentation system, including sensors, control valves and transducers. All measuring equipment and tools are made of stainless steel.

Preparation of nanoparticles

One molar is purified and a surfactant of 0.05 molar is added to prepare nanoparticles of zinc oxide solution in divalent zinc. Then, 10% ethanol is added under ultrasonic conditions. The obtained solution is stirred and homogenized for 25 to 30 minutes. Folic acid is then added as a surfactant. Then, obtained solution was stirred for 30 minutes. The solution is washed several times with ethanol and distilled water, ultimately. The obtained compounds is heated and dried for 50 minutes at 80°C, finally. Then, it is heated at 450°C for 40 minutes to obtain oxide nanoparticles.

Results and Discussion

The experiments are designed to investigate the effect of temperature, pressure, catalyst diameter and apparent velocity of oil as well as the initial feed concentration and bed diameter on the desalination quality of the oil using the catalyst. The following results show the results. The quality of the process is determined by the ratio of the concentration of the output hydrogen sulfide to the concentration of the input hydrogen sulfide.

Temperature Effect

The temperature and pressure are two very important operational parameters in chemical adsorption processes. This relationship is shown in the Figure 1 and Figure 2 for light oil and heavy oil, respectively. The temperature increase is from 35 to 75 degrees Celsius and the pressure changes are from 1, 1.3, 1.6 and 1.9 bar. Also, the diameter of the catalytic bed is 2.5 cm and its height is 3 cm. the average diameter of used zinc oxide nano particles is 77 nm in this test. In this experiment, the initial concentration of hydrogen sulfide is 58 ppm. According to the Figure 1, increasing the pressure reduces the sweetening index. However, the overall difference between the obtained values for the sweetening index at 75°C and 35°C and at a pressure of 1.6 bar and 1.9 bar is less than the difference between 1 bar and 1.3 bar. The obtained results show the positive effect of increasing pressure on the removal of hydrogen sulfide. This may be related to the void fraction of the catalytic substrate in the adsorption process, which is limited. Laboratory results show that the amount of difference for light oil in 1.6 bar and 1.9 bar are 0.239 and 0.17, respectively. While, the value of this difference was observed 0.38 and 0.3 at a pressure of 1.3 bar and 1 bar, respectively.

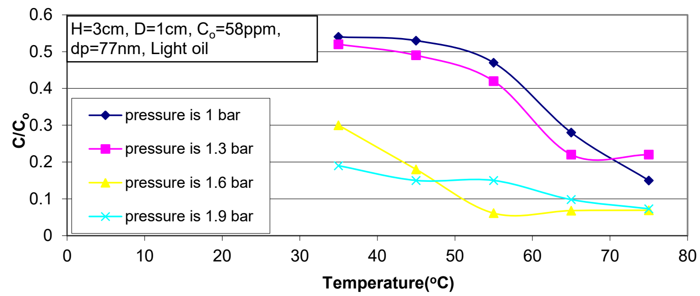

Figure 1. Effect of temperature and pressure on the sweetening index for light oil.

Also, the decreasing trend of sweetening index at a pressure of 1.6 bar in light oil and at temperatures above 55°C is not similar to the observed trend for a pressure of 1.9 bar and similar temperatures. In the mentioned conditions, the operating pressure is 1.6 bar and the operating temperature is 55°C, the minimum amount of sweetening index is equal to 0.05. Increasing of the operating temperature reduces the desalination index for heavy oil according to the results of the Figure 2. Comparison of the results of Figure 1 and Figure 2 shows the low values of the sweetening index for heavy oil compared to light oil under the same conditions, relatively. This may be due to the higher viscosity of the heavy oil than the light oil which makes thin layer on the catalyst surface. Results show that the amount of sweetening index remain constant and equal to 0.05 at 1.6 bar and temperatures above the 55°C.

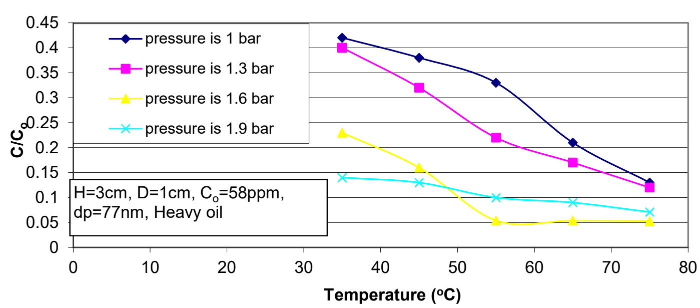

Figure 2. The effect of temperature and pressure on the sweetening index for heavy oil.

Particle Diameter Effect

The effect of bed diameter on the amount of sour oil sweetening index is shown in the Figures 3 and 4 for light and heavy oil, respectively. At a pressure of 1.6 bar and a temperature of 55°C, increasing the diameter of the bed will reduce the sweetening for both types of crude oils.

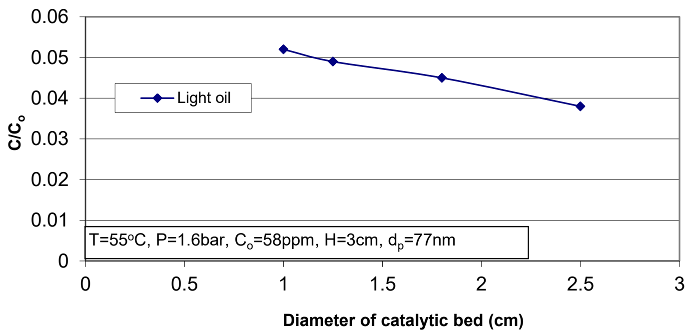

Figure 3. Effect of litter diameter on the sweetening index for light oil.

In this case, the amount of sweetening index will change from 0.052 to 0.038. As a result, it is clear that the larger the bed diameter increases the effective surface area of mass transfer between the oil and the nano-catalyst.

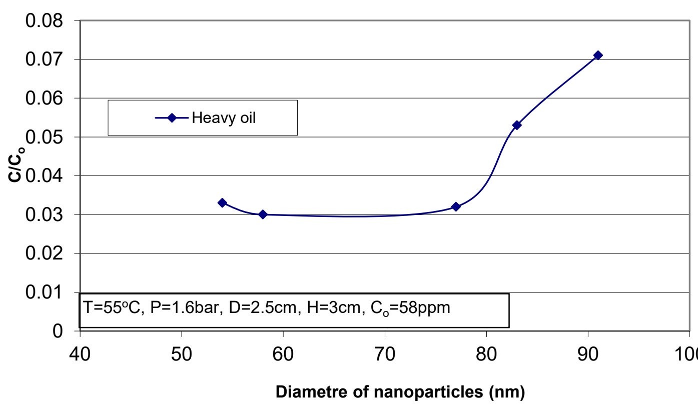

Figure 4. Effect of catalyst diameter on heavy oil sweetening index.

The Figure 4 shows the sweetening index for heavy oil with nano-catalyst diameter changes. The decreasing-increasing trend is also repeated in the Figure 4 for heavy oil. Laboratory results show that the minimum sweetening index is 0.03 for nano-catalyst with diameter of 58 nm.

Effect of Initial Concentration

The effect of initial concentration on the amount of sweetening index for light and heavy oil is shown in the Figure 5 and Figure 6, respectively. The results show that changes in the initial concentration in oil cause changes in the driving force of mass transfer. Increasing the initial concentration from 35 ppm to 73 ppm will increase the sweetening index. In this experiment, the bed contains nano-catalysts with an average diameter of 77 nm, with a height of 3 cm and a diameter of 2.5 cm is used.

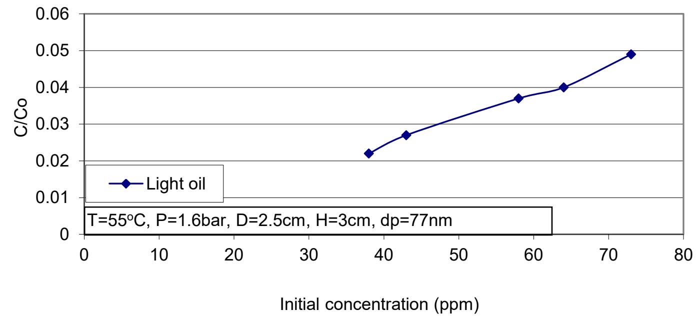

Figure 5. Effect of initial concentration on the amount of sweetening index for light oil.

For light oil, increasing the initial concentration from 35 ppm to 73 ppm will increase the sweetening index from 0.022 to 0.048 at a pressure of 1.6 bar and a temperature of 55°C. This indicates that the catalytic bed will be able to remove hydrogen with the sweetening index of 0.04 for light oil.

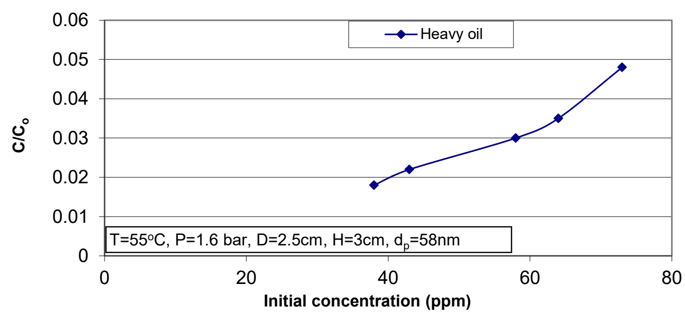

Figure 6. Effect of initial concentration on the amount of sweetening index for heavy oil.

The Figure 6 shows the effect of different initial concentrations for heavy oil on the sweetening index. In physical conditions and optimal geometric conditions in a catalytic bed containing nanoparticles with 58 nm as average size in diameter, increasing the initial concentration from 38 ppm to 73 ppm will increase the sweetening index from 0.018 to 0.048. However, the catalytic bed will be able to remove hydrogen sulfide from heavy oil at a concentration of 64 ppm based on the observed results in the Figure 6.

Conclusion

The experiments for sweetening of two samples of heavy and light oil with densities of API 18.6 and API 33.4 by zinc oxide nano catalyst have been arranged. In this study, the effect of different operating parameters, different geometric parameters and different nano catalysts size on process performance has been investigated. This performance is shown as sweetening index. The obtained results can be considered by related industries and also used in process optimization. Based on the obtained results, temperature of 55°C and pressure of 1.6 bar can be introduced as optimal temperature and pressure, respectivel. In addition, diameters of 58 nm and 77 nm for zinc oxide nano catalyst are the best diameter for sweetening of heavy oil and light oil, respectively.

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