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Enhancing CO_2 desorption from crude oil by ultrasound

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ABSTRACT

In CO_2 flooding, it is difficult to strip CO_2 from the produced fluids through pressure release alone, which may erode the equipment following the separator. Experiments are conducted to study how ultrasound enhances desorption of CO_2 from crude oil. An analysis of ultrasonic influence on the desorption rate and the percentage of CO_2 desorbed reveals the phenomena and variation rules of desorption peaks, second peaks, oil bubbling and power threshold.

1. Introduction

China is rich in low-permeability reservoirs characterized with low oil recovery on account of their low productivity, insufficient natural drive and rapid pressure drop. To solve this problem, Shengli and Jilin Oilfield Companies have carried out pilot tests of CO_2 flooding [1,2] that produced good EOR results.

Gas channeling in CO_2 flooding may significantly increase the CO_2 content in the produced fluids [3]. If such CO_2 is not stripped promptly, these fluids, containing large amounts of CO_2 and water, will erode the equipment in the united station [46]. The united station is an operation station which is with the centralized processing function for oil and gas.

In the conventional gas-liquid separation, which produces methane as the major associated gas, it is enough for the produced fluids to be retained in the gas-liquid separator for 35min [7]. But when CO_2 is the major gas component in the produced fluids, it becomes a big question whether it can be stripped from the fluids in such a short period of time [8].

No study has yet been found concerning CO_2 desorption from water or crude oil. According to the variation patterns of rates and percentages revealed by research of CO_2 desorption in ammonium bicarbonate solution [9], either higher temperatures or higher concentration of the solution can increase its desorption rate, but the ultimate percentage of the CO_2 desorbed will remain low. Neither of the two traditional methods to increase such percentage, i.e., pressure release and heating, is satisfactory in both applicability and effectiveness [10].

With the technology of ultrasonic-enhanced mass transfer more widely used in sonochemistry, progress has been made in improving gas desorption through ultrasound. Juanqin et al. [11,12] discuss the influence of ultrasound on SO_2 desorption from the citrate-sweetening solution, as opposed to its behaviour without ultrasonic enhancement. Their study finds that ultrasound can dramatically enhance SO_2 desorption from the solution by 25%. Ying et al. [13], after investigating the ultrasound-enhanced CO_2 desorption from the amine solution, find that, compared with mere heating, the use of ultrasound can significantly increase the CO_2 desorption rate, thus proving that ultrasound can effectively improve CO_2 desorption.

Since 2008, PetroChinas Jilin Oilfield Company has carried out pilot tests of CO_2 flooding in several blocks, where gas channeling that began in 2010 leads to high contents of CO_2 in the produced fluids. Therefore, there are several questions to be answered concerning gas liquid separation. The first is to figure out the rate of CO_2 desorption from the crude oil. If such separation needs longer time, is it possible to do it with larger separators and for a longer period of separation time? The second question is, if longer separation time turns out futile, whether ultrasound can be used to improve CO_2 desorption and how effective it can be. Then if ultrasound can improve CO_2 desorption, will the crude oil become bubbling in the separator, thus affecting the measuring accuracy of its liquid level gauge, or even blocking the gas outlet and stopping the separator from normal functioning. The fourth and final question is how to find an optimal combination of ultrasonic frequency and power that can accelerate CO_2 desorption while avoiding large-scale crude oil bubbling.

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2. Experiment methods and principles

2.1. Experiment equipment

Our equipment that explores rules of ultrasonic-enhanced CO_2 desorption from the crude oil is shown in Fig. 1.

Fig. 2 shows the structure of our PVT unit used for the desorption experiment. It has windows in both the upper and the lower parts so that the process of CO_2 desorption and oil bubbling can be observed.

A digital-pulse-based ultrasonic system with variable frequencies is employed to generate ultrasonic waves, with a frequency ranging from 20kHz to 135kHz and a power from 0 to 3000W, both fit for stepless adjustment. This ultrasonic generating system has been patented, with our own intellectual property right reserved [14]. To connect the ultrasonic system with the PVT unit, we take into consideration of the features of ultrasonic transducer and design a special installing pit in flange on the bottom so that the flange surface can be kept close to the ultrasound generating surface, as shown in Fig. 3. The thickness of the metal between the ultrasound generating surface and the liquid medium is kept less than 3mm, effectively reducing energy losses during ultrasound transmission.

2.2. Experiment method

In the PVT unit, 1.5L crude oil from the Hei-59 Block in Jilin Oilfield is used as the solvent, whose physical properties are listed in Table 1. The space above the solvent has a volume of 3.5L. The temperature of the oil-gas system is kept at 50C. The gas CO_2 is pumped into the unit at a speed of 3.04.0L/min (the absolute pressure of 0.103MPa, the temperature of 20C). When the pressure inside the unit reaches 0.650MPa, the CO_2 input totals 2.1æ10^2N m^3. After the CO_2 pumping stops, the PVT is kept closed. The internal pressure drops as the CO_2 dissolves into the crude oil. 30h later, the internal pressure drops from 0.650MPa to 0.520MPa and then keeps unchanged, so the oil-CO_2 system can be regarded as having reached a dissolution equilibrium.

Then the regulating valve is opened to release the internal pressure. The pressure at the desorption end is the atmospheric pressure (amounting to an absolute pressure of 0.103MPa). When the pressure is 0.520MPa and the temperature is 50C, the CO_2 solubility in crude oil from the Hei-59 Block is 4.98Nm^3/m^3, and the CO_2 solubility at the desorption end is 1.40Nm^3/m^3 [8]. In theory the total amount of the CO_2 desorbed from the oil should reach 0.537æ10^2Nm^3. It can be observed that, at the initial stage, the pressure release leads to gas escape from upper space of the PVT unit. But no bubbles are seen within the oil at this stage, which means that no CO_2 has been desorbed from the oil. Then as the internal pressure keeps dropping, tiny bubbles begin to appear in the oil, which indicates that CO_2 desorption has started. This is counted as the starting point for CO_2 desorption here in this paper, and this is also the point of the ultrasound started up, which means that the time of the 0th s is the starting point for CO_2 desorption and ultrasound.

3. Analysis and Discussion of the experiment results

3.1. A comparison between CO_2 desorption through pressure release alone and that enhanced by ultrasound

3.1.1. A comparison of desorption rates

Fig. 4 presents the variations of CO_2 desorption from the crude oil and of the pressure of the oil-gas system under two conditions, i.e., without ultrasonic enhancement and enhanced with ultrasound at 40kHz and 800W.

It can be seen from Fig. 4 that under both conditions, the internal pressure begins to drop rapidly at the start of CO_2 desorption, reaching 0.103MPa at the 42nd s.

In the case without ultrasonic enhancement, the desorption rate reaches its maximum, i.e., 4.87æ10^2Nm^3/(m^{2}s), at the 12th s of

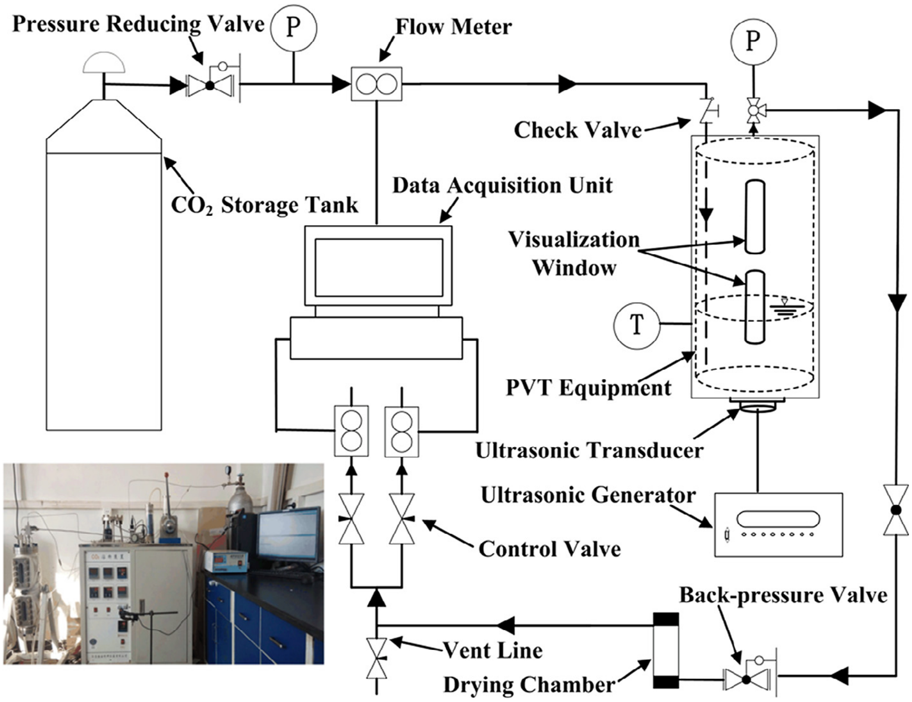

Fig. 1. Diagram of experimental equipment.