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Evaluation of Foaming Chemical Composition and Performance of Commonly Used Detergents

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Abstract: The foaming chemical composition of commonly used detergents mainly includes surfactants, auxiliaries and solvents. Surfactants are the most important components in detergents. Surfactants reduce the surface tension of water, allowing it to better contact dirt and provide a cleansing effect. This paper focuses on two commonly used detergents, alpha olefin sulfonate (AOS) and sodium dodecylbenzene sulfonate (SDS). Then the foaming properties and half-life of these two surfactant solutions at different concentrations were investigated. The results show that AOS has the best foaming property and the longest half-life at 0.7%, while SDS has the best foaming property at 0.3%. The solutions with the best foaming concentration ratios were added with sodium chloride and calcium chloride respectively. And the salt resistance of these two solutions was found to be good. Secondly, the temperature resistance of AOS and SDS decreases with increasing temperature. In addition, the two surfactants showed structured, regular and stable foams under optical microscope study.

Keywords: Detergent; Foaming properties; Performance evaluation.

1. Introduction

Detergents play an important role in the petroleum industry and are used to clean oil well equipment and pipelines, remove deposits, dirt and clogs, and improve the production and efficiency of oil wells[1]. In the process of oilfield development, detergents can be used to improve the permeability and wettability of oil reservoirs, promote the flow of crude oil, and increase the recovery rate. In oil refining, they can also be used in desulfurization, deacidification, dehydration and other aspects of the oil refining process to remove impurities and harmful substances and improve the quality and purity of petroleum products[2]. Anionic surfactants are common ingredients in detergents. Anionic surfactants are a class of chemicals with good cleaning properties that form micellar structures in water to help dissolve grease and dirt and keep them in suspension[3]. This makes anionic surfactants an important ingredient in a wide range of detergent applications[4]. Anionic surfactants react with hard water ions (e.g., calcium and magnesium ions) to reduce the hardness of the water and improve the effectiveness of the detergent. In addition, anionic surfactants emulsify and disperse, encapsulating grease and dirt in tiny micelles that are more easily washed away by water[5]. Common anionic surfactants include sodium dodecyl sulfate (SDS) and sodium lauryl ether sulfate. In this paper, the composition and properties of SDS and AOS are investigated.

2. Experimental Details

2.1. Materials and Instruments

Sodium dodecylbenzene sulfonate and sodium α-alkenylsulfonate were purchased from Tianjin Damao Chemical Reagent Factory. Automatic Surface Tension Tester (QBZY) purchased from Shanghai Fangrui Instrument Co., Ltd. Polarizing microscope (XP-400) purchased from Shanghai Guangmi Instrument Co., Ltd.

2.2. Preparation of detergent solution

Take 0.1g, 0.3g, 0.5g, 0.7g and 0.9g of SDS and AOS were added to 100mL of water and stirred, respectively, and mixed to form 0.1%, 0.3%, 0.5%, 0.7% and 0.9% concentration of SDS and AOS solution respectively.

2.3. Foaming properties

Configured 0.1%, 0.3%, 0.5%, 0.7% and 0.9% concentrations of SDS solution and AOS solution were added to the foaming apparatus, the stirring rate of 7000r/min, stirring time of 3min. When the stirring stops, the foam was poured into a 500mL cylinder and timed with a stopwatch to record the volume of the foam and the half-life of the foam (time of precipitation of 50mL of water) were recorded[6].

2.4. Salt resistance

After measuring the anionic surfactant solution with the best foaming property, 0.1g, 0.3g, 0.5g, 0.7g and 0.9g of sodium chloride were added to the solution at this concentration. And 0.1g, 0.3g, 0.5g, 0.7g and 0.9g of calcium chloride were added to the other solution, respectively. The configured solutions were poured into a foaming apparatus with a stirring rate of 7000 r/min and a stirring time of 3 min. When the stirring stopped, the formed foam was immediately poured into a 500mL measuring cylinder and timed with a stopwatch, and the volume of the foam and the half-life of the foam were recorded. Then compare the foaming height of SDS and AOS powder solution before and after adding salt[7].

2.5. Temperature resistance

Prepare 300 mL of SDS and AOS solution at the concentration with the best foaming property, pour 50 mL of the solution to the lowest scale of the instrument. Then adjust the water bath to 30°C, 40°C, 50°C, 60°C and 70°C, respectively, and measure the temperature resistance of the two solutions at different temperatures. Finally, 200 mL of the target solution was added to the apparatus, and the foam height was observed and recorded every 5 min from 0 min to 20 min[8].

2.6. Surface tension

SDS and AOS solutions with mass fractions of 0.0001%, 0.0004%, 0.001%, 0.003%, 0.006%, 0.01%, 0.05%, 0.1%, 0.3%, 0.5%, and 0.75%, respectively, were prepared and the surface tension of the solutions was determined using the hanging ring method[9].

2.7. Microstructure

SDS and AOS solutions were prepared separately, and the foam was generated by stirring method, the stirring time was 180 s. The same volume of foam was taken, and the microstructures of the foam were observed by optical microscope (4×10), and the polarized light was chosen as the light source, and the experimental temperature was room temperature[10].

3. Results and Discussion

3.1. Foaming performance

The foaming performance of sodium dodecylbenzene sulfonate and AOS powder solutions were evaluated by stirring method, and the foam volume and half-life were recorded. The method mainly reflects the different degrees of separation between the liquid present in the foam and the foam itself. The longer the time to precipitate half the volume of water (half-life), the less likely the liquid present in the foam will be lost and the more stable the foam will be. The optimum concentration for foaming was determined by measuring the half-life of the foam and the foam height after high-speed mixing, with the speed of the high-speed mixer fixed at 7000 r/min for 3 min. As can be seen in the figure 1, the foam volume of the AOS powder increased more evenly with the concentration, and reached the highest value at concentrations of 0.1% and 0.7%. The foam volume of sodium dodecylbenzene sulfonate reaches the highest value at 0.3% concentration, with the best foaming performance.

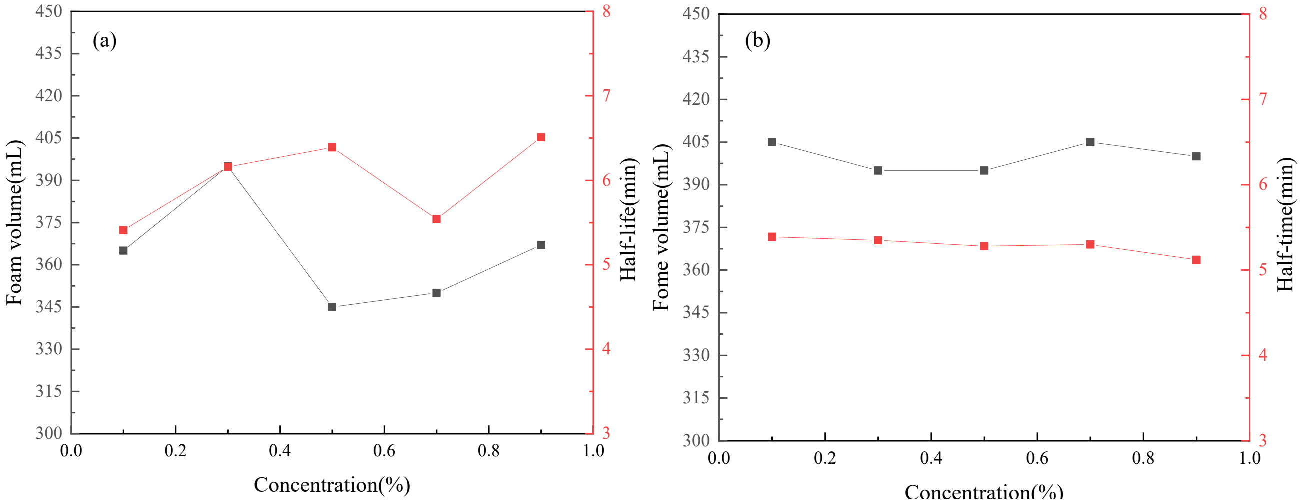

Figure 1. Foaming ability and foam half-life of SDS (a), AOS(b).

3.2. Salt resistance

In the construction site of many oil and gas fields, it is often necessary to inject a certain amount of surfactant into the wellbore, due to the surfactant has a special structure, so that it can contact with the formation water, so as to produce a large number of bubbles, and bring out the required gas from the wellbore, this foam gas extraction process is most widely used in the actual construction site. Since formation water contains some mineral ions that can accelerate the foam rupture, such as Na^+, Ga^{2+}, Mg^{2+}, Ba^{2+}, Cl^-, etc., different surfactant solutions will weaken the foaming performance of the surfactant solutions when they come into contact with formation water containing mineralized ions. Therefore, it is crucial for different surfactant solutions to have salt resistance for practical application sites. The salt resistance of sodium dodecylbenzene sulfonate and AOS powder solutions at the concentration with the best foaming performance measured in 3.1 were evaluated separately by stirring method, and their foam volumes and half-lives were recorded after the addition of salt (sodium chloride and calcium chloride) to the mixture. As can be seen from the figure, the foaming performance of the mixed solution of AOS powder and sodium dodecylbenzene sulfonate after the addition of salt is still very superior, and the half-life is basically unchanged, which proves that the anti-salt performance of the two surfactants is good.

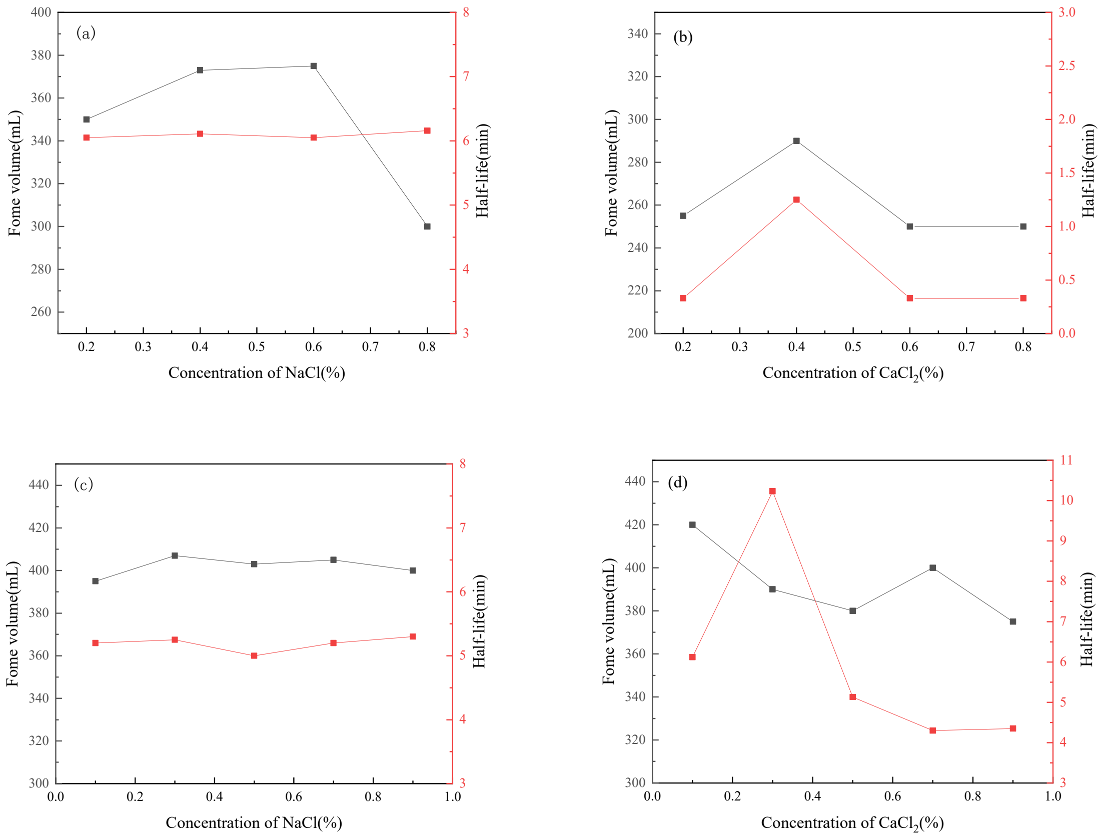

Figure 2. Foaming ability and foam half-life of SDS (a) and (b), AOS (c) and (d).

3.3. Temperature resistance

In the process of oil and gas well extraction, the extraction depth is increasing, the bottom temperature will also rise, which will make the foam gas extraction process to bring serious impact. Mainly due to the temperature increases, surfactants in aqueous solution dissociation speed up, its positively charged hydrophilic group between each other and the water medium to enhance the force, accelerate the mobility of bubbles with each other, resulting in the loss of liquid in the bubbles, bubbles due to the temperature rise and lead to intermolecular movement is active, so that the neighboring bubbles began to gather, merge into an area of large bubbles, and further make the free energy decrease, the formation of bubbles wall gradually become thinner and thinner. The wall of the formed bubbles gradually becomes thin until rupture. In view of the above reasons, the foam produced by the synthesized new surface activity must still have good stabilizing ability in the wellbore at high temperature.

The temperature resistance of sodium dodecylbenzene sulfonate and AOS powder solutions at the concentrations with the best foaming performance as measured in 3.1 were evaluated using the water bath method, respectively. As can be seen from the figure 3, comparing the same point in time, the foam height of this surfactant decreased with increasing temperature. Comparing the same temperature, with the time gradually increasing, the foam height gradually decreases, the higher the temperature the faster the foam height decreases, and the temperature resistance performance gradually decreases.

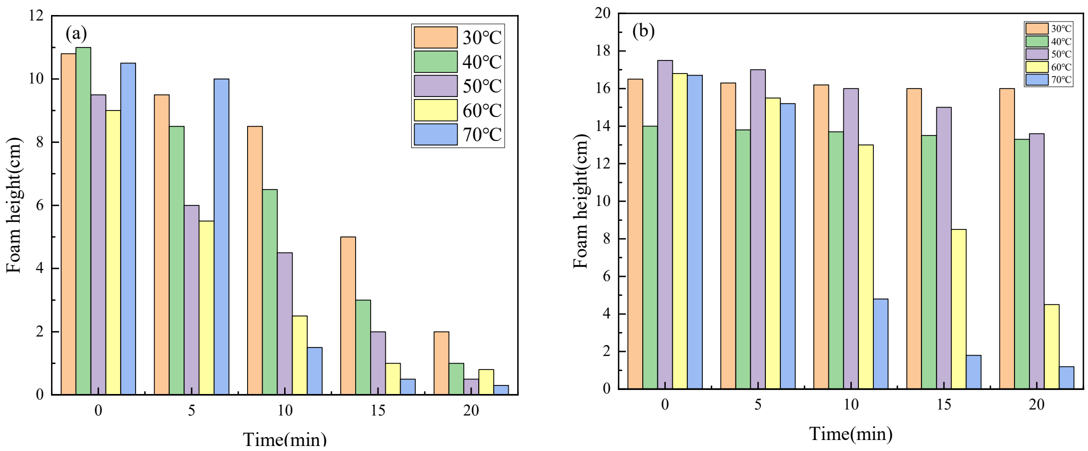

Figure 3. Temperature resistance of SDS (a) and AOS(b).

3.4. Determination of surface tension

The reason for surfactant foaming is that in the aqueous medium, the surfactant molecules can be neatly arranged at the interface between the gas phase and the liquid phase, and when the concentration of the surfactant solution is lower than the critical micelle concentration, it makes the surface tension decrease, and it is not easy to gather and merge between neighboring bubbles. At the same time, the lower the surface tension, the easier the gas-liquid system is dispersed, and the more ideal the surfactant foaming effect. When the concentration of surfactant solution is lower than the critical micelle concentration, the surface tension will decrease with the increase of solution concentration. It is because individual surfactant molecules are not easy to form micelles with each other. When the concentration of the surfactant solution is higher than the critical micelle concentration, the surface tension will remain in equilibrium or decrease slightly. This is because as the concentration of the solution continues to increase, the concentration of individual surfactant molecules does not change, but rather increases the number of micelles or the concentration of micelles. Surface tension measurement is one of the more researched and widely used methods, which measures the performance of the foaming agent on gas-liquid dispersion by comparing the magnitude of the surface tension and the dynamic stability characteristics. Under the condition of room temperature, the performance of different surfactant solutions in reducing surface tension was evaluated, and the experimental results are shown in the following table: when the concentration of AOS powder solution is 0.01%, the lowest surface tension can be up to 32.73mN/m. When the concentration of sodium dodecylbenzene sulfonate is 0.75%, the lowest surface tension can be up to 32.75mN/m. The results is shown in the Fig. 4.

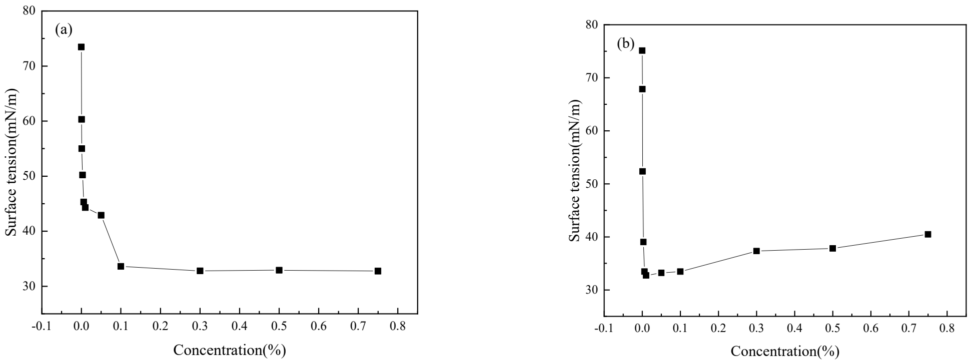

Figure 4. Surface tension of SDS (a) and AOS(b).

3.5. Microstructure of foam

Different surfactant solutions with a concentration of 2.0 g/L were prepared to produce foams using the stirring method, and the same volume of foams was taken at the same time, and the microstructure of five different foams was observed by using an optical microscope, with polarized light as the light source. The microstructures of the foams produced by different surfactant solutions when the stirring was stopped for 1500 s at room temperature are shown in the figure 5 and 6:

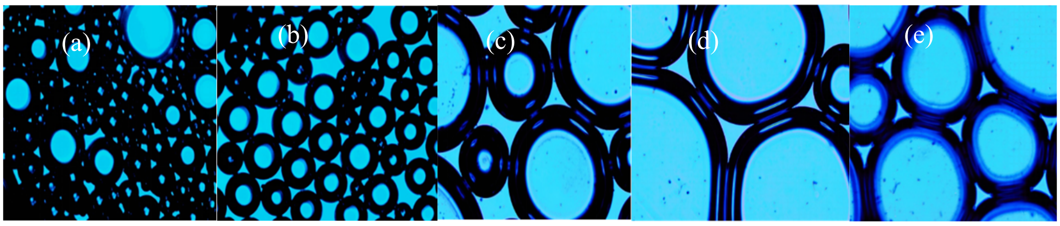

Figure 5. Microstructure of foam of SDS((a)0min; (b)5min; (c)10min; (d)15min; (e)20min).

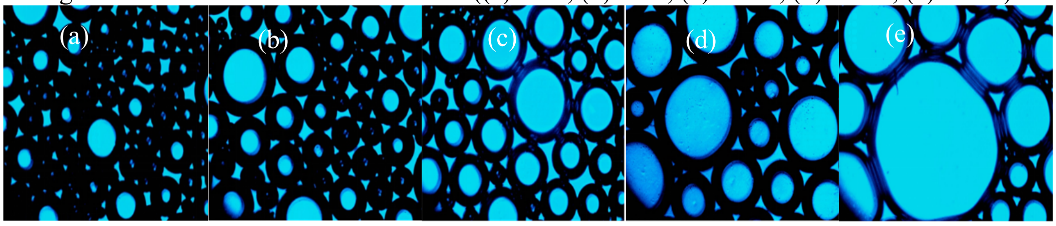

Figure 6. Microstructure of foam of AOS((a)0min; (b)5min; (c)10min; (d)15min; (e)20min).

4. Conclusion

The foaming performance and salt resistance of both SDS and AOS solutions are superior. After measuring the temperature resistance of the two surfactants, it can be seen that the foam height of the two solutions decreased sharply with the increase of temperature, while the time increment had little effect on the foam height. Through optical microscope, it can be seen that the foam of the solution of the two surfactants has a regular shape and is more stable. Both surfactants were effective in reducing the surface tension of the solution, down to 32.73 mN/m.

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