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EFFECT OF BALL MILLING OF FLY ASH PARTICLE SIZE ON FOAM STABILIZATION FOR EOR APPLICATIONS

Ishaq Ahmad[a], Mariyamni Awang[a*], Suriati Sufian[b], M Irfan Khan[b], Mudassar Mumtaz[b]

[a]Department Of Petroleum Engineering, Universiti Teknologi PETRONAS, 32610 Seri Iskandar, Perak, Malaysia
[b]Department of Chemical Engineering, Universiti Teknologi PETRONAS, 32610 Seri Iskandar, Perak, Malaysia

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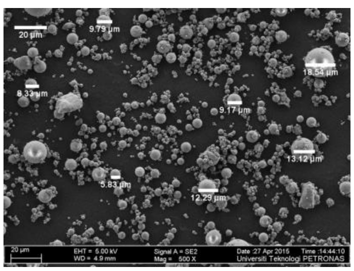
*Corresponding author
mariyamni_awang@petronas.com.my



Abstract

In enhanced oil recovery (EOR), nanoparticles have gained the potential to improve foam stability. In this study, the potential of fly ash to produce stable foam by using shaker was studied. Fly ash nanoparticles were developed by the mechanical treatment using ball mill. Sample to ball ratio of 1 to 10 was applied to investigate the effect of ball milling on particle size distribution of fly ash. The mechanically activated fly ash was mixed at various concentrations (ppm) with the anionic foaming surfactants AOS14-16. Foam stability tests were performed at ambient conditions by making solution through shaker. Stable foams were generated using varies types of fly ash particles. It was observed that the small sized fly ash has more potential towards foam forming ability and foam stability. Therefore, the mechanically activated fly ash resulted in a considerably increased EOR.

Keywords: enhanced oil recovery, fly ash, ball milling, foam stability

1.0 INTRODUCTION

Enhanced oil recovery (EOR) is gaining a lot of energy in today's petroleum industry because it has the possibility to get more amount of oil from oil fields [1] Stable foams have a very important role as a part of oil and gas recovery processes, a portability control and profile adjustment operators. A short-term rundown of froth usages incorporates pressure driven breaking [2]

Foam has the potential to stabilize gas condensate wells experiencing high liquid loading [3, 4]. Foam is good for mobility control which has the power to improve the sweep efficiency[5]. Stable foam is a major concern in reservoirs to achieve good mobility control. Foam stability is essential during interaction of oil with foam. [6]. The result of foam-oil interphase was found in the bulk and porous media data. The oil phase could become the cause of destabilization of foam as indicated by several studies [7, 8]. As The foam stability is necessary for the oil phase, that's why the lighter components are detrimental to foam stability [9]. The timing of foam stability could be reduced by the dispersion of lower molecular weight oil in the surfactant solution. Therefore, additional foaming agents may also stabilize the foam along with oil present [10].

To generate the Nano particles foam the temperature was up to 95c. The researchers noticed the creation of foam with in fractures. Which is even more Beneficial in carbonate [11]. Polyethylene glycol (PEG) coated nanoparticles were able to effectively produce foam and were stable up to 60 °C at very high concentration of brine solution[12] It means that nanoparticles with inerter activated surface may deliver thorough foam stability. Similarly, it is well known that quite in few system proteins and particles exist at the same time. Moreover, these proteins can be taken as nanoparticles with active surfaces [13]. Nanoparticles are used as a form of EOR which alters the possessions of oil to help in freeing the stuck oil. This is done by injecting particles of 1-100 nm of specific chemical mixes into the reservoir to decrease in oil viscosity, agreeing for an easier mobility of the fluids[14]

The use of coal fly ash nanoparticles as a stabilizer to generate stable CO2 foams was explored. Considering the heterogeneous nature of fly ash, the samples were pretreated or separated into several different types of varying carbon content[11]

In this study, mechanically activated fly ash was fabricated using ball milling. The effect of dry and wet milling on particle size of fly ash and foam stability was investigated.

2.0 MATERIAL AND METHODS

2.1 Material

The fly ash used in this study was taken from a coal power plant inside Malaysia. Anionic foaming surfactants, Alpha Olefin Sulphonate (AOS14-16), were used in this research. AOS14-16 (Bio-Terge AS-40) was obtained from the Stepan Company, USA, and. Ball mill size 5mm diameter and the ball wieght was 8.10gram was used in the Fritsch Pulverisette ball mill made by Germany. The oil used was Tapis crude oil. The API gravity of the Tapis crude was 43. X-ray fluorescence spectroscopy was utilized to analyze the chemical composition of the fly ash. And the particles size was used to measure the size before and after treatment.

2.2 Methods

2.2.1 Treatment of Fly Ash

Before mechanical activation, fly ash was characterized by the Field Emission Scanning Electron Microscope (VPFESEM, Zeiss Supra, Switzerland). In this method, the fine powder sample was mounted on an aluminum stub using carbon tape. A Malvern master seizer (AS2000, US) was used for the particle size analysis. Finally the solid particles were used to improve the foam stability performance.

Prior to milling, fly ash was sieved 3 times using sieving equipment. In the ball milling, 10 gram of the fly ash was milled by using 160 gram balls in the ball mill. 1to 10 ratio was used for both wet and dry fly ash. The wet fly ash was made by mixing ethanol. Ball milling time of 60 minutes and the rotational speed was 400 (rpm) was used. After the grinding process, fly ash was analyzed by the zeta seizer to see the size of dry and wet fly ash.

2.2.2 Static Foam Tests

The static foam ability and foam stability tests were performed based on the foam height and foam drainage in a 1000ml measuring cylinder. The shaker was used for the foam generation at a constant rate of dual gear II and the shaker time was 30 second. Shaker has been used for several times for foam generation. The Figures 1(A-B) shows the foam generation with and without crude oil.

The total volume of each solution used for the foam generation was 150ml. The percent composition of the surfactants (AOS) with the nano fly ash is shown in Table 1.

Table 1 Percentage compositions of the surfactant and nano FA solution

Sample ID	AOS	Fly ash (FA)
A	100	--
B	70	30
C	70	30
D	70	30

Figure 1 Shakers used for foam stability (a) without oil (b) with oil

The static foam stability measurements were conducted under ambient conditions of temperature and pressure. The stability of the foam was analyzed by noting the drainage time of the foam generated in the cylinder. The foaming was observed with and without crude oil. For the foam oil study, 10 wt. % of the oil was added in the mixture of 150ml of 1wt% of the surfactant and fly ash solution. The major variables for the foam height and shaking tests were the type of surfactant and fly ash used.

3.0 RESULTS AND DISCUSSION

3.1 Particles Size Analysis

The particle size analysis of the fly ash and the mechanically activated fly ashes is given in Figure 2-4. The particle size of the original fly ash was 16.3 um, whereas it was reduced to approx 250nm after mechanical treatment both in dry and wet conditions. A considerable decrease in particle size was also observed in dry fly ash. The effect was more profound on the overall size of both dry and wet fly ash.

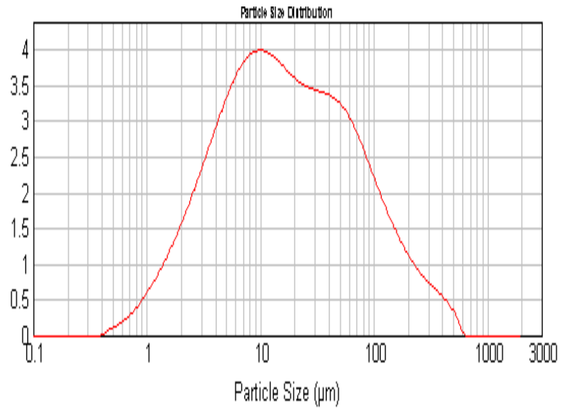


Figure 2 Particle size of the fly ash

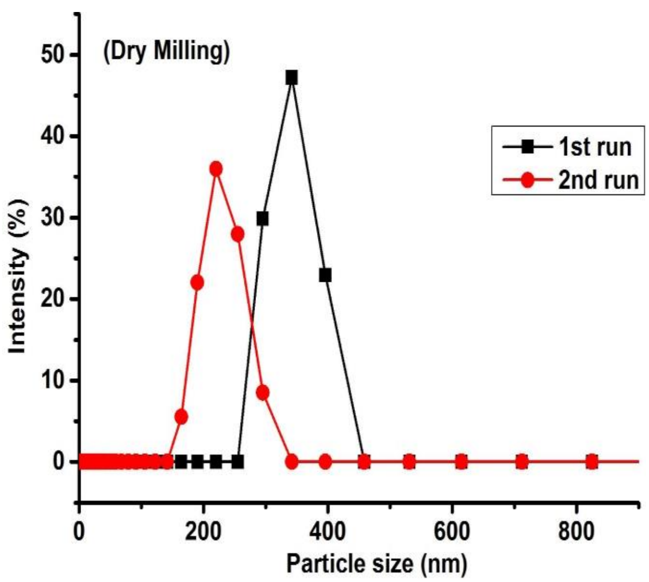


Figure 3 Particle size of the dry mechanicaalyl activated fly ash

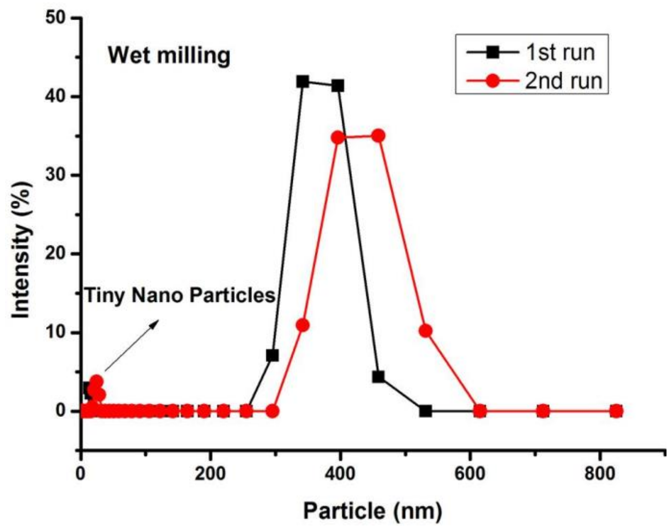


Figure 4 Particle size of the wet mechanical activated fly ash

The decrease in particle size was related to the breakdown of larger fly ash particles in smaller sized particles. Fly ash has SiO_2 as the major components along with considerable amounts of the oxides of aluminum, iron and calcium. The SiO_2 exists in the form of amorphous phase and crystalline quartz and mullite. The Figure 2 shows that, the dry chemical activated fly ash has more reduced size than wet milled fly ash. But in the wet milled FA a small peak representing tiny nano particles in the range of 10-100nm was also observed.

This reduction in size of FA owing to the ball milling is in accordance with the available literature. In the course of mechanical activation, bulk variations, for examples formation of structural faults, structural rearrangements and phase transformation, and making of newer surfaces and surface changes can meaningfully modify the reactive nature of solids[15]. Moreover, the ball milling also results in the reduction of crystal order and hence increasing the amorphousity of fly ash [16].

To know what type of morphological changes have taken place, FESEM analysis was used and is discussed in next section.

3.2 Microscopic Investigation

The Figure 5 shows the FESEM analysis of original fly ash. It is evident from the figure that fly ash is having different size in the different range. Different morphologies were observed in the FESEM analysis of the FA. The majority of the fly ash consisted of spherical particles. The size of the particles was varied in the range of 10-18µm. The particle size is in agreement with the PSA given in Figure 1. The microstructure of fly ash in this study closely matched with the previous literature. Fly ash is consisted of cenospheres, magnetic cenospheres pleurospheres, and carbon residue [16]. The presence of cenospheres can be evidenced in Figure 5.

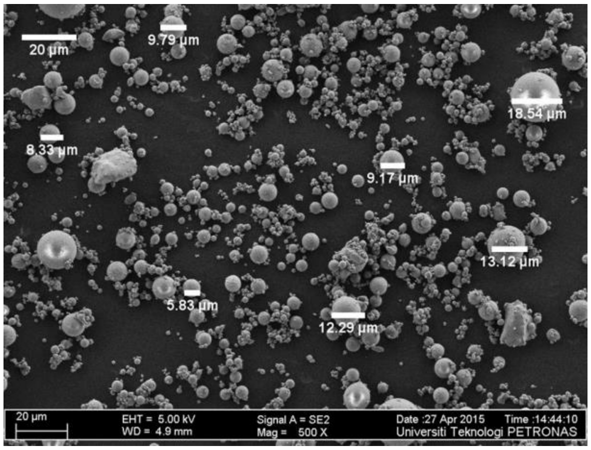


Figure 5 Particle size of fly ash

3.3 Effect of Nano Fly Ash on Foaming

To study the outcome of fly ash behavior on foaming, 3 samples were designed i.e. surfactant alone, fly ash with surfactant, dry fly ash and wet fly ash with surfactant to indicate the single and binary combinations of the surfactants and fly ash.

Figure 6 describes the foaming of AOS, with and without nano fly ash. The addition of the mechanically activated fly ash increased the stability of the foam lamella compared to original fly ash. In the case of the mechanical active nano fly ash when mixed with a surfactant, the improvement of the foam stability was noted. The results show that foam height of approximately 100cm was achieved by surfactant alone. By addition of original fly ash, it was reduced to 20cm and the stability time was 12 minutes. On the other hand, the addition of dry milled FA resulted in increase of both stability time and foam height. The effect of wet fly ash was prominent compared to dry milled FA.

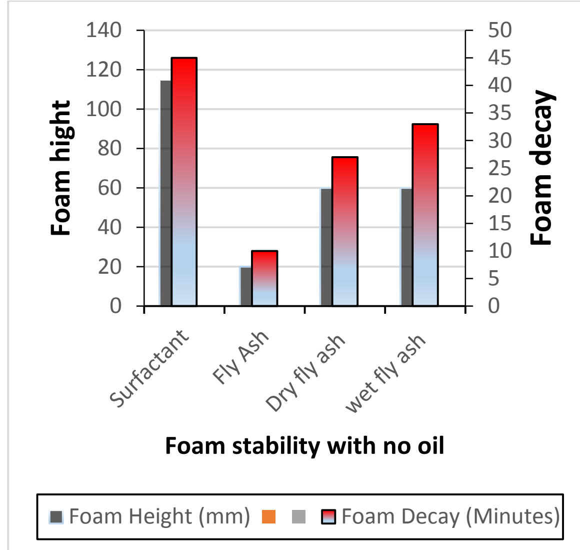


Figure 6 foam stability without oil

The trend in results can be correlated with particle size of fly ash. As the particle size of mechanically activated FA was lower than original FA, therefore the foam stability was expected. The unexpected behavior of wet milled FA may be related to the presence of nano particles in the range of 10-100nm. Therefore, the utilization of nanoparticles led to the successful amplification of the foam stability and helped to reduce the amount and cost of the surfactant for the foam EOR process

3.3. Effect of Crude Oil on Foaming

The effect of Tapis crude oil on foaming was studied to identify the tolerance of oil. The foaming of formulated samples with the Tapis crude is shown in Figure 7.

The foam stability was decreased when the foaming was performed in the existence of oil. The addition of the oil in the solution led to the increase in the foam stability time and height. The formulations presented in Table-1 were each mixed with 10 wt. % of the Tapis crude oil. The foam ability and foam stability in terms of height and time is shown in Figure 7. The foam column height or foam ability of mechanically activated dry and wet fly ash was almost the same with oil but oil effect the time of surfactant and showed less foam stability with pure fly ash

In the case of surfactants, mechanically activated dry and wet fly ash performed better when crude oil was present. But the performance of surfactant and fly ash with tapis crude oil, was found to be less. However, the performance of mechanically activated dry fly ash was 31 minutes and wet was 42 minutes ash for 75% drainage was superior both with and without oil. From the static foam test, it was found that the performance mechanical activates was better than fly ash in each case when in contact with oil.

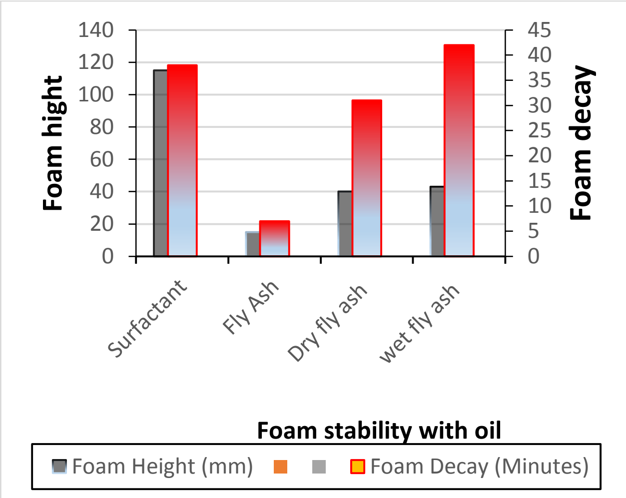


Figure 7 foam stability with oil

4.0 CONCLUSION

The mixture of the surfactant and mechanically activated nano fly ash produced stable foam as compared to with the surfactant and fly ash alone. The mechanically activated fly ash gave the stable foam and in the presence of oil as well. The reduction of the surfactant injection volume tended to lower the cost of the surfactant EOR process. The surfactants performance for the foam generation can be tuned in order to produce the formulation with the nano fly ash essential for a successful EOR. Moreover, considerable foam stability was also observed by using fly ash nanoparticles both in the presence and absence of crude oil. In the future study, development would be required for a precise foam stability analysis with different samples of fly ash nanoparticles. And surfactant

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