Hittite Journal of Science and Engineering, 2018, 5 (3) 215-218
ISSN NUMBER: 2148-4171
DOI: 10.17350/HJSE19030000097

Characterization of Flocs in Dewatering of Coal Plant Tailings

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Article History:
Received: 2017/11/07
Accepted: 2018/02/20
Online: 2018/04/06

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ABSTRACT

Flocculation is a widely used method for dewatering fine coal tailings. Flocs must resist to the shear stresses during the following processes such as flotation, cyclone separation, and pumping. Therefore, the strength of the flocs must be considered during flocculation. In this study, the fine coal tailings were dewatered with an anionic flocculant (SNF-923) at various dosages, and the floc size of the coal tailings was characterized using a laser diffraction particle size analyzer with respect to time in order to determine the change in the floc size and hence the floc strength. The results of this study clearly indicated that the determination of the floc size with a laser particle size analyzer could be a simple and good method to observe the flocculation efficiency in terms of the floc strength.

Keywords:
Coal tailings; Flocculation; Floc size; Floc strength; Laser diffraction particle size analyzer

INTRODUCTION

Lignite coal, which has a large share in world coal reserves, must be subjected to coal preparation processes in coal washing plants due to its low calorific value and high ash content. After these processes, the huge amount of tailings is produced from the plants, and they must be dewatered before disposal. For this purpose, flocculation is a widely preferred method for solid-liquid separation of fine coal tailings. In this method, long-chain polymers are used to bind particles together to form bigger particles to settle them easier and faster.

Flocculation process is affected by various parameters including solid ratio, pH, temperature, stirring speed and time, molecular weight, chain length, charge, and dosage of flocculant. In the flocculation process, flocs with several physical characteristics such as size, structure, and strength are formed depending on these flocculation conditions. Different floc characteristics are preferred for various processes. For example, strong and high-density flocs are favorable in filtration, but not in sedimentation processes. Therefore, it is extremely important to characterize the flocs to optimize the flocculation processes [1-7].

For this reason, there have been various studies on the investigation of floc size, density, structure, and strength [8-13]. Different techniques were used for the floc strength measurements such as image-based techniques [14], computational fluid dynamics (CFD) [15], shear stress [16, 17] sonication/capillary suction time (CST) [18], and light scattering technique [3, 19, 20]. Particularly, floc strength is a very important floc property because flocs are exposed to shear stresses in the flocculation. Therefore, the flocs must resist these stresses in order not to break into smaller pieces [6, 13].

Floc strength is actually dependent upon the strength and number of the inter-particle bonds between the components of the floc. If the stress applied to a floc is larger than the bonding strength within the floc, it will break. Therefore, in this study, SNF-923 was chosen as a typical commercial anionic flocculant to flocculate the coal tailings more effectively. During the flocculation experiments, the turbidity measurements were also conducted. Furthermore, the size and strength of the flocs were determined with respect to time employing a laser diffraction particle size analyzer.

MATERIAL AND METHODS

The lignite coal tailing samples were taken from a coal processing plant in Soma, Manisa, Turkey. The maximum particle size of the samples was determined as 150 μm with 49.99 μm average size. 70.6% of the sample was under 38 μm. A commercial flocculant (SNF-923 from SNF s.a.s, France) was used for the flocculation studies at various dosages (50, 150, and 300 g/t). The turbidity measurements were performed with AQUAfast II turbidimeter (Thermo Scientific, USA). A laser diffraction particle size analyzer (Malvern Mastersizer 3000, UK) was employed for the floc size measurements. Distilled water was used during in all experiments all of the experiments.

In the flocculation experiments, the coal tailings were stirred in a glass beaker with 250 mL volume at 200 rpm stirring speed for 10 min using a magnetic stirrer. The experiments were performed at 5% solid-in-pulp ratio and at room temperature (23°C). Then, the suspension was transferred to a graduated cylinder followed by adding flocculant at a specific dosage, and stirred for an additional 1 min at the same speed. The suspension was left for settling, and the settlement distance was recorded at each 1 min for first 10 min and at each 5 min for next 20 min. Meanwhile, the turbidity measurements of the residual solution were performed at the 10th, 20th, and 30th min.

For the floc size and strength measurements, 0.5 g coal tailing in 50 mL distilled water was mixed at 500 rpm with a magnetic stirrer. The flocculant at desired dosage was added into the suspension during the mixing, and the stirring was continued for an extra 2 min. A small amount of the flocs was taken with a wide-diameter pipette (in order not to break the flocs) from the bottom of the beaker to measure the floc size, and added to 1 L water. The suspension was stirred gently again at 800 rpm with an overhead stirrer in order to keep the flocs pending in the suspension during the measurements. An embedded

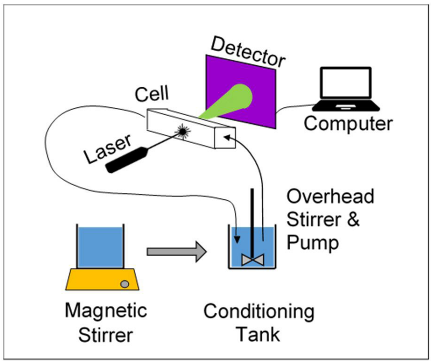

Figure 1. Schematic representation of the experimental setup for the floc size measurements.

software was used to determine the size distribution of the flocs. In addition, the floc size measurements were carried out at different times for observing the change in the floc size and hence floc strength. The schematic representation of the experimental setup for the floc size measurements is seen in Fig. 1.

RESULTS

In order to investigate the settling behavior of the coal tailings, the flocculation tests were carried out with SNF-923 at different dosages (50, 150, and 300 g/t dosages), and the results are shown in Fig. 2. As seen from Fig. 2a, while the change in the height of the sediment bed of the coal tailing showed no change in the absence of flocculant this is because of the electrical repulsion forces between coal particles due to their zeta potentials. With the addition of the flocculant, the flocculant molecules begun to form bridges between the coal particles. The results seen in Fig. 2a showed that the coal particles settled more easily and faster in the presence of flocculant. The results presented in Fig. 2 also revealed that the particle settling velocity is dependent on the flocculant dosage. For example, the sample treated with the 150 and 300 g/t flocculant dosages achieved a high settling rate compared to that of 50 g/t flocculant dosage. Actually, there was no specific difference between 150 g/t and 300 g/t which indicated that 150 g/t dosage was much enough to settle down of the particles successfully. Even though the same settling rate was obtained at both dosages, 150 g/t flocculant resulted in clearer water, which indicates that the flocculation mechanism for anionic flocculant incorporates an electrical charge attraction between the flocculant and particles. An excessive flocculant adsorption on the particle surfaces caused repulsion of the particles therefore the turbidity of the suspension increased at 300 g/t.

As known from literature, flocculation performance depends on floc size distribution and floc structure [21]. For this reason, the size distribution of flocs was determined in the absence and the presence of the flocculant. The size

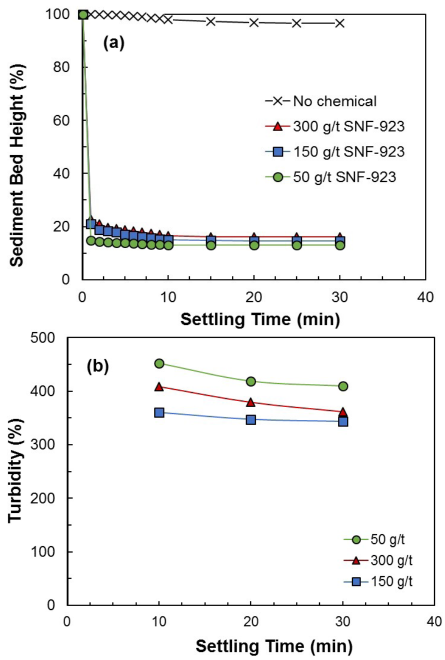

Figure 2. (a) Change in sediment bed height and (b) turbidity of the coal tailings at various flocculant dosages.

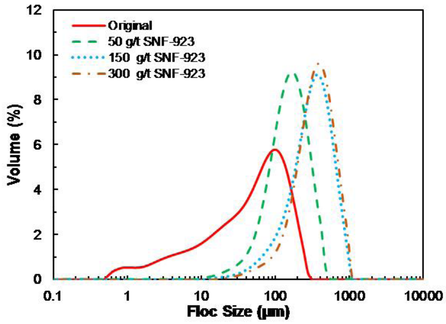

Figure 3. Size distribution of the flocs at various (50, 150, and 300 g/t) SNF-923 dosages at the end of 4 min stirring time.

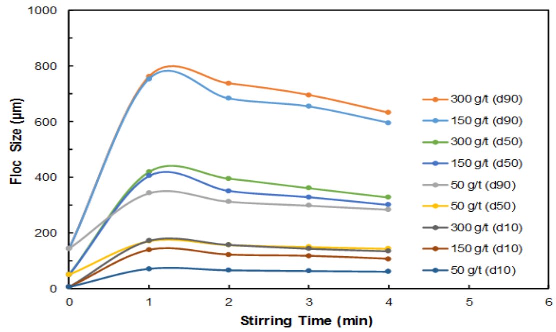

Figure 4. (a) d_{10} (b) d_{50} (c) d_{90} sizes in respect to stirring time at various flocculant dosages.

distributions of the flocs produced with 50, 150, and 300 g/t flocculant along with the unflocculated particles are shown in Fig. 3. It is seen from Fig. 3 that the size of the flocs increased with an increase with the flocculant dosage, and the floc size distribution shifted to bigger sizes. It is seen that the size of the flocs formed at 50 g/t flocculant dosage was smaller than the flocs formed at 150 and 300 g/t SNF-923. This is because of the amount of the flocculant molecules was not enough to bind more coal particles at 50 g/t dosage. However, the change on the size of the flocs formed with 150 and 300 g/t SNF-923 was not much. Therefore, it is understood that the floc sizes could not be increased any more due to some factors such as initial size and surface area of the coal particles, ambient pH, the chemical structure of the flocculant, and the shear stress generated on the flocs during the measurement process even though, the flocculant dosage increased up to 300 g/t. The results along with the previous result clearly indicated that 150 g/t could be chosen as an optimum flocculant dosage for the dewatering of the coal tailings.

In general, floc strength increases with floc size [6]. Therefore, it can be said that 150 g/t SNF-923 is the optimum flocculant dosage for the floc stability according to the change in the floc size in time. The size distributions of the flocs as a function of stirring time are shown in Fig. 4 which shows the average size (d50), as well as the d90, and d10 size of the flocs produced with the flocculant at different dosages. These results showed that the flocs produced at low flocculant dosage were not enough to produce larger flocs. As seen from Fig. 4, as the dosage of flocculant increased, the d90, d50, and d10 of the flocs increased in all cases. The size distributions of the flocs produced with the flocculant show that there was no significant change in floc size at 150 g/t and 300 g/t flocculant dosages because of the static repulsion forces between the coal particles due to the excessive use of flocculant. The increase of the flocculant dosage to 300 g/t did not change the floc strength as well as floc size. Therefore, it can be said that 150 g/t SNF-923 is the optimum flocculant dosage for the floc stability according to the change in the floc size in time.

Fig. 4 also shows that the flocs do not grow continuously as a function of time. On the contrary, they were weak and broken during the measurements Most probably, they reached a steady state size for a specific shear condition. When the shear rate increases above a critical level, flocs will break until a new steady state is reached. Therefore, the aggregation rate is in a balance between the floc formation and floc breakage. Accordingly, the stability of a flocculated suspension is dependent upon the breakability of the flocs [22, 23].

CONCLUSION

The results of this study showed that the coal tailings could be flocculated considerably with the use of SNF-923. Although the increase in the flocculant dosage showed considerable effect on the settlement speed, the lowest turbidity values obtained at 150 g/t SNF-923.

As known from literature, flocs can be broken by the shear forces during the dewatering processes. Therefore, the floc strength is crucial for a successful solid-liquid separation. The change in the floc size in time at a given shear stress is an important indicator of the floc strength.

The floc size measurements in respect to time indicated that the floc strength at a constant shear stress depended on the SNF-923 dosage and stirring time. The flocs formed at 50 g/t were finer compared to 150 and 300 g/t SNF-923. According to the stability of the flocs in stirring time 150 g/t SNF-923 seems the optimum flocculant dosage at these conditions.

Overall, the results obtained from this study indicated that it was possible to determine the flocculation efficiency in terms of floc size as well as floc strength. And, this can be considered as a simple and effective method in order to characterize the flocs during the dewatering of the mineral processing tailings.

ACKNOWLEDGEMENTS

This work was supported by Scientific Research Projects

Coordination Unit of Istanbul University. Project number 48866.

This paper presents an extended work of a conference paper which was presented in ISME 2017.

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