Influence of Additive for Optimize and Sustainable Fly Ash Suspension

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Abstract. The pipeline at the thermal power station is now being used to conveying fly ash in the form of slurry. The objective of this research is to investigate the rheological behaviour of slurry suspensions of finer particles (FA) with and without coarser particles added (BA). In terms of weight, the ratios of fly ash to bottom ash (BA) are as follows: 9:1, 8:1, 7:3, and 6:4 respectively. Experiments on the rheology of each and every sample of slurry are carried out at shear rates ranging from 100 to 250 seconds-1. The temperature of the slurry suspension might range anywhere from 25 to 35 °C when it has a solid concentration of 30% (by weight). When finer fly ash slurry particles are combined with coarser bottom ash particles, the rheological properties of the resulting slurry suspension are significantly improved in terms of sustainable flow. The exhaustive assessments also investigate whether or not it is possible to conveying ash slurry by pipeline through sustainability.

Keywords: Sustainability, Fly ash, Bottom ash, Temperature, Relative viscosity, Rheology.

1 Introduction

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In thermal power plants, coal is the primary source of fuel, and the combustion of this coal results in the production of a significant amount of ash. The term "fly ash" (FA) refers to the finer ash particles that are discharged with vent gases, whereas the term "bottom ash" (BA) refers to the coarser particles that are collected underneath the boiler's furnace. India generates approximately 226.139 million metric tons of FA every year, as stated in the study that was compiled by the Central Electricity Authority of New Delhi in 2019-20 [1]. Despite the fact that the utilization of FA is a major concern among researchers and scientists, a great number of applications have been found in the fields of building, composites, and other areas [2–6]. The pneumatic mode is typically used to transport FA, whereas the hydraulic method is used to transport BA through pipelines connecting the generating unit and the ash pond. Typically, the pneumatic mode is used to transport FA. A number of scholars [5-9] have looked into the rheological properties of ash slurry suspensions and found some interesting results. Extensive pilot plant test loops have been used to investigate the rheological characteristics of FA slurry, among other things [10-13]. The rheological properties of the ash slurry were also said to have been improved as a result of the combination of chemicals [14]. To anticipate slurry suspension, however, there have been just a few or a restricted number of researches done thus far.

Fig. 1. Generation of ash from thermal power plants during last five calendar years

In this work, the rheological behavior of FA (fine particle) slurry was evaluated both without and with the addition of BA (coarser particulate). Without BA, the behavior was shown to be more similar to that of a slurry containing fine particles. In terms of weight, the ratios of FA to BA are as follows: 9:1, 8:2, 7:3, and 6:4 respectively.

2 Materials testing and methods

In order to evaluate the physical and morphological characteristics of the samples, a number of tests, including particle size distribution, settling, and scanning electron microscopy, were carried out. RGTPS (Rajiv Gandhi Thermal Power Station), which is located in the southernmost section of Haryana, India, provided the samples of ash that were collected. Both FA and BA are collected, with FA coming from the ESP and BA coming from under the boiler furnace. Fig. 2 showed a graphical perspective as well as a scanning electron micrograph analysis of BA and FA samples, respectively. In contrast to the small particles with uniform shapes that make up FA, the particles that make up BA are coarse, irregular, and have an unfavorable level of surface roughness. When compared to the tiny particulate
FA samples, the BA particles have a color that is quite a bit darker. An examination of the particle size distribution has been achieved through the use of sieve analysis. Checking the settling of the slurry sample has been done with the help of the gravitational settling methods. When calculating the static settling concentration of slurry suspension (by weight), the initial solid concentration of 30% is utilized as the basis for the calculation. As can be seen in figure 3, the concentrations of BA and FA after they had undergone static settling were found to be 59.68 and 52.15% (by weight), respectively.

![Pictorial view of coal ash sample](image)

**Fig. 2.** Pictorial and SEM analysis of ash samples

![SEM of ash sample](image)

**Fig. 3.** Settling Characteristics of the ash samples
3 Rheological measurement

For the purpose of determining the rheological characteristics of a suspension, a typical rheometer based on the Searle principle is utilized. Experiments involving rheology need the preparation of a 100 mL ash slurry, which is accomplished by completely combining the ash with the requisite quantity of water. When weighing the slurry suspension, a machine with a least count of 0.1 mg is employed. It is necessary to make use of a lead crystal rod in order to guarantee that the slurry suspension is well mixed. A padlocking device is used to keep the spinning cylinder assembly in place before it is put through its paces in the laboratory. A graphical illustration of the rheometer that was utilized in the rheological experiment may be seen in Figure 4. Changing the shear rate setting from 100 to 250 s\(^{-1}\) is the first step in conducting rheological testing for any concentration. During the course of the experiment, slurries of FA, BA, and combinations of the two will be utilized.

![Graphical illustration of rheometer used for the rheological experimentation](image)

**Fig. 4.** Symbolic view of rheometer used for the rheological experimentation

4 Results and discussion

4.1 Influence of additive on rheology of fly ash

The process is carried out at room temperature throughout its entirety in order to eliminate the influence of temperature on the outcome. An investigation is carried out into the relative viscosity of an FA slurry at concentrations ranging from 10 to 50 percent (by weight). In the same manner, the rheological data for each FA sample is observed in the concentration ranges described before. It is possible to calculate how slurry will behave in suspension.

\[
\tau = \tau_y + \eta \frac{du}{dv} \tag{1}
\]

In equation (1), \(\tau\) = Shear stress, \(\tau_y\) = Yield stress and \(\eta\) = Coefficient’s of rigidity. The shear stress-shear rate of FA is depicted in Figure 5 for a variety of different solid
concentrations. According to the data presented in Figure 5, the shear stress is exactly proportional to the shear strain rate for FA suspensions with a solid content of up to 30% (in terms of weight). However, up to a concentration of 30% (by weight), the stress-strain rate relation displays Newtonian flow qualities; above that concentration, the FA slurry displays non-Newtonian flow characteristics. The amount of yield stress that is present within the Non-Newtonian flow characteristics of an FA suspension shifts depending on the amount of solid that is present. Studies [10-14] make observations about fly ash slurry that are comparable to one another.

At a concentration of 30% (by weight), a slurry suspension of FA including extra material (BA) was investigated. The data were gathered at a temperature of 25°C, and they are displayed in Figure 6. When BA is introduced to FA slurry at a constant shear rate, it has been found that the shear tension of the slurry decreases. This was a discovery made by FA. As a consequence of this, the relative viscosity of the FA slurry is reduced when BA ash is added to it. With a mixture of FA and BA in the ratios 9:1, 8:2, 7:3, and 6:4 at solid content 30% (by weight), the greatest decrease in shear stress value for the FA slurry is 1.06 to 0.97, 0.84, and 0.78 Pascal, respectively. This is the case when the solid content is kept at the same level. The relative viscosity of the slurry experiences a drop that falls somewhere between 1.36 and 4.26%. The shear stress and relative viscosity of the mixture are ultimately reduced to the greatest extent when the mixture ratio of 8:2 is utilized as opposed to 9:1, 7:3, and 6:4. The relative viscosity of the slurry has decreased, which has the effect of lowering the pressure drop and the amount of energy required for the slurry to flow through the pipeline. Researchers looked at the rheological behavior of FA slurry with a variety of additives and found some interesting results [11-13].
4.2 Influences of additive at varying temperature for rheology of FA

In the rheological experiment, the temperature was changed from 25°C to 35°C and assessed. When the concentration of the slurry suspension is increased to 30%, there is a corresponding rise in temperature of 5°C (by weight). The relative viscosity of a slurry suspension is shown to be affected by temperature in the chart shown in figure 7. When the temperature rises, all slurry suspensions experience a decrease in their relative viscosity. At a temperature of 35 degrees Celsius, the relative viscosity of the slurry suspension was determined to be the lowest for all of the data that was evaluated. When there are a greater number of solid particles present in the slurry solution, the shearing process needs to start with a high initial shear tension [7,14-18].

When the temperature of the slurry suspension increases from 25 to 30°C, the relative viscosity decreases by approximately 2.5 to 2.8%. This occurs when the FA and BA ratios...
are, respectively, 9:1, 8:2, 7:3, and 6:4. A similar decrease in relative viscosity can be achieved by raising the temperature of the slurry from 30°C to 35°C. This is also possible since the dissolving effect of the surfactant is amplified at higher temperatures [7]. The temperature 35°C is considered to be the optimal temperature for alteration. When the temperature is raised from 25 to 35°C, there is a slight decrease in the relative viscosity of the substance, as determined by the thorough experiments.

5 Conclusions

When compared to the irregularly shaped and bulkier particles of BA, the FA particles have a smoother surface texture, are more uniform in size, and have finer particle sizes overall. The performance of the slurry suspension can be improved by combining BA particles with fine FA particles in the mixture. When the temperature was elevated, there was a corresponding drop in the relative viscosity of the FA slurry in both cases of BA. The blend of FA and BA in an 8:2 ratio produced the greatest reduction in shear stress as well as relative viscosity. 35 degrees Celsius is the optimal temperature for modification. When the temperature is increased from 25 to 35 degrees Celsius, a little decrease in the relative viscosity is noted for all of the test shear rate parameters.

Acknowledgement: The authors are thankful to K.R. Mangalam University, Gurugram, an autonomous organization Gurugram, India, for providing financial support for carrying out this study in terms of the Seed Grant (SEED), [Grant number: KRMU/ADMIN/SEED/2022-23/3101].

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