ABSTRACT

Dual flue gas conditioning (DFGC) is a technique in which the chemical additives such as ammonia and sulphur trioxide are injected together into the flue gas in order to reduce the suspended particulate matter (SPM) emission and hence, the improvement in ash collection efficiency of electrostatic precipitator (ESP). Since, the low sulphur and high ash contents of Indian coals are the major problem for thermal power stations in controlling the SPM emission, during DFGC process, sulphur trioxide assists in reducing the resistivity of fly ash whereas, ammonia facilitates the agglomeration of ash particles. However, more details on the DFGC in improving ash collection efficiency of ESP are not yet presented in literature. Hence, in this paper, an effort has been made to investigate the effect of dual flue gas conditioning on agglomeration of ash particles, by comparing the scanning electron microscopy (SEM) images of dosed and undosed fly ash samples collected from the thermal power stations located in India. Based on the investigations, the effect of flue gas conditioning on agglomeration of ash particles have been highlighted.

1. INTRODUCTION

The main source of electricity supply in India is coal-fired thermal power stations, which produces more than two third of electricity required. During the combustion process, a huge amount of coal ash (fly ash and bottom ash) is generated. The fly ash particles that are in the form of suspension in the flue gas contribute to an increased suspended particulate matter, SPM. Hence, for safeguarding the environment, reduction in emission levels of the SPM becomes essential. In order to achieve this, various devices, such as cyclone separators, bag filters and/or electrostatic precipitators (ESPs) are employed (Shanthakumar et al. 2008a). However, electrostatic precipitator is employed in majority of the thermal power stations due to its main advantages such as (i) high collection efficiency; (ii) low-operating costs; (iii) low-pressure drop; and (iv) its suitability for dealing with particles of different sizes and variable flue gas volumes (Theodoree & Buonicore 1976). The practice of removing the suspended particles from the flue gas by applying the electric field is termed as electrostatic precipitation (White 1963). Moreover, for reducing the emission of sulphur dioxide from the chimneys of the coal fired power plants, low sulphur coal is being used these days (Ray 2004). However, it has been noted that the resistivity of the fly ash, generally, increases as the ratio of sulphur to ash content of the coal decreases, which results in its very low collection efficiency of ESP(Oglesby & Nichols 1978, EPA 1998). The coal used in various thermal power stations across the country varies widely in its properties. The Indian coal contains high ash (35-45%) and low sulfur (<0.5%) contents (Chandra et al. 2006). Since the sulfur content in Indian coals is low, the resistivity increases to the order of $10^{12}$ ohm-cm or more and hence, the ESP collection efficiency is poor (Chandra et al. 2004). In order to improve the ash collection efficiency of ESPs, flue gas conditioning, FGC, is employed in thermal power stations. This technique involves the injection of the chemical agents (viz., sulphur trioxide, sulphuric acid, ammonium sulphate, ammonium bisulphate, sulphamic acid and ammonia for conditioning of flue gas) and water into the flue gas to modify the properties of the fly ash so that the efficiency of electrostatic precipitators increases
Among all the chemical agents, sulphur trioxide and ammonia are the commonly and commercially in use at thermal power stations. The simultaneous and independent injection of both ammonia and sulphur trioxide is referred as dual flue gas conditioning (Drbal et al. 1996). At times thermal power plants require installation of dual flue gas conditioning, which is found to be more suitable when, (i) percentage of Al$_2$O$_3$ and SiO$_2$ is more than 90% or (ii) fly ashes exhibit high resistivity (Parker 1997, Porle et al. 1996). It has also been demonstrated by the researchers that sulphur trioxide conditioning reduces the resistivity of fly ash particles (Krigmont 1992, Cook 1975, Bayless et al. 2000), where as ammonia conditioning improves its surface charge and hence their cohesive properties and hence minimizes the re-entrainment of particles (Dismukes 1975, Turner et al. 1994). However, more details on effect of flue gas conditioning on agglomeration of ash particles are not yet presented in the literature. Hence, in the present study, an effort has been made to investigate the effect of dual flue gas conditioning on agglomeration of ash particles, by comparing the scanning electron microscopy (SEM) images of dosed and undosed fly ash samples collected from the thermal power stations located in India. Based on the investigations, the influence of flue gas conditioning on agglomeration of ash particles have been highlighted.

**Materials and Methods**

**Materials**

Fly ash samples were collected from the coal-based 210 MW capacity thermal power station, located in India. These samples were collected from hoppers of the ESP, when the power station is operated with out and with different concentrations of chemical agents (Ammonia and Sulphur trioxide). The samples of undosed, ammonia dosed, and dual flue gas conditioning process are denoted as U, A, and D, respectively. Details of the samples along with their designation are presented in Table 1. Details of scanning electron microscopy test conducted on the sample are presented in the following.

**Table 1: Details of the Samples Used in the Present Study**

<table>
<thead>
<tr>
<th>Dosing rate (kg/hr)</th>
<th>Collection Point</th>
<th>Sample Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH$_3$</td>
<td>SO$_3$</td>
<td>Hopper</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>Hopper</td>
</tr>
<tr>
<td>25</td>
<td>-</td>
<td>Hopper</td>
</tr>
<tr>
<td>8</td>
<td>12</td>
<td>ESP Collection Plate</td>
</tr>
</tbody>
</table>

**Scanning Electron Microscopy**

Scanning electron microscopy (SEM) is one of the most widely used techniques for the chemical and physical characterization of fly ash. A focused electron beam is used to scan the surface of a sample and the SEM provides visual information based on gray-scale intensity between chemical phases (Vassilev & Vassileva 2005). SEM images of the sample were obtained by employing Hitachi make S3400N and Quanta make 200 ESEM instruments. A representative portion of fly ash sample was sprinkled on double-sided carbon tape mounted on a SEM stub and the images of various magnifications were captured.

2. **RESULTS AND DISCUSSION**

The morphology obtained at various magnifications by scanning electron microscopy for the fly ash samples collected from hoppers of the ESP are depicted in Figures 1-5. It can be observed from the Figure 1 that the fly ash samples contain hollow spheres, termed as cenospheres (Sample U3) and some irregular shaped particles (Sample U1). Also, Figure 2 illustrate that the fly ash samples consists of broken spheres filled with smaller spheres, termed as pleurospheres. The micrographs of unburned carbon particles present in the fly ash samples are depicted in Figure 3. The presence of unburned carbon particles can be due to poor combustion of coal in the thermal power station. It can be observed from the figure that the unburned carbon particles are highly porous which can be due to the escape of volatile matter during the combustion process, which is consistent with the results reported in the literature (Hwang et al. 2002). Further, in order to exhibit the influence of flue gas conditioning on agglomeration of ash particles, scanning electron microscopy images of different ash samples (undosed, ammonia dosed, dosed with ammonia and sulphur trioxide) were compared, as depicted in Figure 4. It can be noted from these micrographs that for undosed samples (U5), there is almost no agglomeration of particles. In contrast, the ammonia dosed samples (A3) reveal agglomeration of particles, which is consistent with the results reported in the literature (Shanthakumar et al. 2008b). However, samples collected (D3) from the process in which both ammonia and sulphur trioxide are injected together, i.e. DFGC exhibit a substantial agglomeration of fines due to increase in cohesion between the particles. Incidentally, as depicted in Figure 5, SEM micrographs of the samples (D5, D6 and D7) from the collection plate of the ESP, collected immediately after the shutdown, exhibit very thick agglomerated pockets of ash particles. Hence, it is reputable that dual flue gas conditioning helps in more agglomeration of particles, and hence, improves collection efficiency of ESPs, which in turns results in less emission from the stack/chimney of the power stations.
A Scanning Electron Microscopy Study on Flue Gas Conditioned Fly Ashes Collected ....

Fig. 1: SEM Images of Undosed Samples

Fig. 2: SEM Images of Pleurospheres Present in the Samples

Fig. 3: SEM Images of Unburned Carbon Particles Present in the Samples

Fig. 4: Comparison of SEM Micrographs of Different Samples (Undosed [U], Dosed with Ammonia [A], Dosed with Ammonia and Sulphur Trioxide [D])

Fig. 5: SEM Images of Samples Collected from Collection Plate of the ESP
3. CONCLUDING REMARKS

The scanning electron microscopy analysis conducted on the fly ash samples collected from a coal based power station in India reveal that the ash samples contain cenospheres, pleurospheres and unburned carbon particles. On comparison of the SEM micrographs of undosed, ammonia dosed and dual conditioned samples, the agglomeration of ash particles have been observed from the ammonia dosed samples. However, the dual conditioned fly ash samples exhibit a very thick agglomeration of the ash particles, which results in increased collection efficiency of the ESP, which in turn results in less SPM emissions from the stack of the power stations.

REFERENCES


