PRESENT CHALLENGES IN THE PERFORMANCE OF COAL FINES DEWATERING CIRCUIT

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Coal preparation plant tailings containing fine solid particles present many environmental and economic challenges to the society and industry. Efficient dewatering of coal tailings is therefore fast emerging as one of the priorities in the production of clean coal. All coal preparation plant contains fine coal treatment and dewatering circuits in some form or other with an objective to meet the sales revenue and/or environmental norms to facilitate the handling of tailings. The performance of the dewatering circuit, however appears to be poorly understood and predictive design of dewatering equipment such as thickeners, filters, etc., continue to be empirical at least to an extent. The dewatering processes generally pose problems because of the presence of coal particles of different sizes, shapes, surface area and specific gravities and their unique behavior in the aqueous environment. The selection of right flocculent is also a key factor in enhancing the performance of dewatering circuit. Reducing fresh water consumption by increasing water available for recycle is the other important aspect.

Keywords: Tailing, Settling, Flocculation, Dewatering, Environmental

INTRODUCTION

Since coal mining has essentially become a set of mechanized operations, mining as such and the subsequent processing generate considerable amount of fines in the form of tailings. A typical Coal Preparation Plant (CPP) produces about 20% of the mined coal as minus 0.5 mm. Generally, this fine fraction is discarded abroad due to its high cost of processing. However with the development of advanced coal cleaning technology, such as flotation, Jameson Cell, Pneufloats, etc., cleaning of fine size coal to low ash and low sulphur is feasible. But the main issue for not operating the fine coal treatment circuit in India, though installed in most of the plants, is the presence of high level of moisture in the products which creates dewatering problems and consequently increases the processing cost. Therefore, most of the CPP tailings are subjected to settling in tailing ponds usually at high percentage of water causing continuous loss of water. Relative Density (RD)

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of slurry discarded from CPP to the tailing pond could be as low as 1.1-1.05 and even less. That results in higher rate of make-up water input to the plant. Hence, solid-water separation including those for tailings has become an important and complementary process for the CPPs. To significantly improve the dewatering performance, it is important to understand the characteristics of coal including the impurities present in and the chemistry of career liquid and their influences on dewatering behavior.

**Importance of Coal Characterization**

Dewatering process is known to depend largely on physico-chemical properties of the coal particle surface, and is substantially related to the rank, mineral matter, size distribution and oxidation of the coal (Rong and Hitchins, 1995). The degree of difficulties associated with mechanical dewatering increases as the surface area of the particles increases. Particles finer than 0.5 mm present greatest dewatering problems due to a large surface area of the particles. The variation in the surface area of particles with change in volume and size (assuming spherical shape) is shown in Table 1.

If a spherical particle is broken in ten equal small spherical pieces then the surface area increases to more than double the original value (Table 1). For very fine size particles at large surface areas the downward gravity force on the particles does not effectively dominate the upward drag force and buoyancy force. This results in poor settling rate of particles and hence the poor efficiency of dewatering equipment such as thickener, filter, etc. The increased surface area also results in higher consumption rate of flocculants. Solid concentrations of slurry also pay a role on settling behavior. As these increase the settling rate progressively slows and above a critical solids concentration known as the gel point, the slurry exhibits a network structure and forms a bed at the base of the vessel. Thickeners are most commonly used equipment for dewatering of slurry. The design considerations of thickeners are based on the settling rates of the slowest settling particles and conditions for minimum disturbance of the medium (water) through which the solid particles are allowed to settle (Gupta and Yan, 2006).

**Role of Selected Flocculent in Performance of Dewatering**

The effectiveness of dewatering system is direct

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**Table 1: Variation of Surface Area of Particle With Reduction in Size**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Vol. of Single Spherical Particle, Cu. Micron</th>
<th>No. of Particles of Equal size After Breaking</th>
<th>Vol. of Single Spherical Particle, Cu. Micron</th>
<th>Dia. of Each Particle, Micron</th>
<th>Surface Area of each particle, Sq. Micron</th>
<th>Total Surface Area, Sq. Micron</th>
<th>Multiplying Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100000</td>
<td>1</td>
<td>100000</td>
<td>57.36</td>
<td>10333</td>
<td>10333</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>100000</td>
<td>2</td>
<td>50000</td>
<td>45.54</td>
<td>6512</td>
<td>13025</td>
<td>1.26</td>
</tr>
<tr>
<td>3</td>
<td>100000</td>
<td>5</td>
<td>20000</td>
<td>33.57</td>
<td>3538</td>
<td>17688</td>
<td>1.71</td>
</tr>
<tr>
<td>4</td>
<td>100000</td>
<td>10</td>
<td>10000</td>
<td>26.65</td>
<td>2230</td>
<td>22296</td>
<td>2.16</td>
</tr>
<tr>
<td>5</td>
<td>100000</td>
<td>20</td>
<td>5000</td>
<td>21.15</td>
<td>1405</td>
<td>28104</td>
<td>2.72</td>
</tr>
</tbody>
</table>

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in proportion to the settling rate of solid particles and hence higher rate of settling is a required parameter for it. The rate of settling of any given particle depends on its size, its density relative to that of the suspending medium, the viscosity of the medium, and the interactive forces between the medium and other suspended particles. The major interactive forces between suspended solids are of two kinds—attractive and repulsive. The attractive forces arise from short-range Vander Waals' forces, which is counter balanced by the repulsive force between the particles due to the presence of electrical charge on them. If a repulsive force dominates, particle aggregation cannot occur, whereas, if attractive forces take over, aggregation and settling of the much larger aggregates will take place. Hence, the aim is to reduce the repulsive force between the particles so that the attractive force will dominate. This will accelerate to make large aggregate of fine solids, so as to be settled at faster rate. Such process of aggregation of fine particles to make large floc using chemicals is called flocculation.

Most of the aqueous solutions are either neutral or basic and hence the particles are negatively charged. To reduce the repulsive force between two particles due to presence of negative charges on them it is essentially required to add some electrolytes which have opposite (positive) charge to cause charge neutralization. Such electrolytes are called coagulants. If the aqueous solution is acidic in nature, i.e., particles are positively charged then electrolytes with negative charges are to be added.

Coagulants could be either from inorganic or organic sources. The commonly used inorganic coagulants used for wastewater treatments are alum, ferrous sulphate, ferric chloride. On the other hand the organic coagulants may be either synthetic of natural flocculants. The major drawback of inorganic coagulants is the huge requirement of coagulant for achieving an effective settling rate causing a huge sludge volume which creates disposal problem. On the other hand organic flocculants are highly efficient flocculent though both the synthetic and natural ones have some advantages and some limitations. Synthetic polymers are highly efficient polymers, however, they are not biodegradable and their degradable product is considered as a hazard because of release of toxic monomer which may cause serious threat to environment. Natural polymer based flocculent have been acclaimed as “Green flocculent of 21st Century” (Sarkar et al., 2013). They are shear resistant, biodegradable and eco-friendly, but at the same time less efficient as flocculent. To develop effective dewatering and disposal methods, it requires an improved understanding of the role of flocculent on settling that promotes better water recovery and higher sediment density during settling and consolidation of flocculated solids.

**State of Art of Dewatering Circuit Design**

Conventional fine coal dewatering techniques in coal preparation plants (Figure 1) utilize thickeners, dewatering screens, vacuum filters, centrifuges, and pressure (hyperbaric) filters. Dewatering screen centrifuges and sieve bends provide a low moisture product with plus 600 micron coal; however, their efficiency decreases rapidly with decreasing particle size. Dewatering of minus 600 micron fine coal is often accomplished using either vacuum or pressure filtration. Disk and rotary drum vacuum filters are widely used in the USA, which produces a filter cake with about 30% moisture.

Dewatering of clean coal from coal preparation plants, depending on climate and coal product
requirement, is normally a combination of sedimentation/ Filtration/ Thermal Drying/ Dewatering using screens. But most of these dewatering options up to the moisture level of 20-30% reflect high capital and operating cost and hence conventionally used for dewatering of clean coal (Table 2) and not for coal tailings, this being a plant discard.

The Hyperbaric Filters (HBF) provide the lowest moisture in filter cake. However, HBF being an expensive technique and refuse being waste material, the coal companies do not want to invest in dewatering refuse unless and until compelled by environmental legislation. Hence for coal tailings dewatering, a large amount of dilute suspension has to be treated by some cost effective methods such as thickening (Alam et al., 2011).

**FINE COAL DEWATERING CIRCUIT IN INDIA**

In India, fine coal circuits in coal preparation plants wherever operating, suffer from low clean coal yield, low ash tailings and usually inefficient dewatering. Clean coal yield at 16-19% ash is 20-60% only. Flotation tailings when generated carry 35-50% ash. In contrast to clean coal, the tailings are rarely fed to the dewatering circuits.

A majority of the fine coal treatment circuits in India do not operate at present for a variety of reasons, such as design related issues, changes in mining methods, various operational problems arising out of the changes in feed characteristics, ageing of the technology, absence of standardization of technology and operational practice, etc. Slurries generated, usually with 28-34% ash content, are discharged without any processing and are temporarily stored in the nearby paddy field, along the rivers and are known

| Table 2: A Typical Performance Data For Fine Coal Refuse Dewatering (Parekh, 2009) |
|---------------------------------|----------------|
| **Equipment**                  | **Feed % Solid** | **Cake % Moisture** |
| Thickener                       | 3-5             | 70                |
| Belt Filter Press               | 30              | 50                |
| Hyperbaric Filter              | 30              | 25                |

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as slurry ponds and slurry dumps. The tailing slurries generated (Table 3) are eventually accumulated in the nearby very fertile agricultural land, along the rivers.

Sometimes, the existing coal preparation plants may show inconsistent performance of dewatering circuit for some exceptional reasons also. For example, Madhuban Washery was originally designed for washing Coking Coal. Due to non-availability of Coking Coal because of stoppage of Block-II OCP, the Washery was temporarily converted for Washing Non-Coking Coal which has been reverted back to washing coking coal again from October 2008 (www.bccl.gov.in). In such cases we should take necessary tests to improve the performance of dewatering circuits also while such conversion takes place.

Coal India Limited (CIL) is heading in a big way for Coal Beneficiation of all types of coals. CIL has planned to set up 20 nos. of coal washeries (Coking and Non-Coking) having total capacity of 111.1 Mt of raw coal throughput in the first phase (http://www.coal.nic.in/point8.html). As a rule of thumb in India coal preparation plants operate with solid to water ratio of 1.0: 0.5 – 2.0, the latter value being typical for coking coal preparation plants. This is high as compared to South African plants treating same Gondwana coal with solid to water ratio of 1.0: 1.0 – 1.15. CPCB code of practice for coal washeries stipulates it to be not more than 1 to 1.5 m³. If we consider 10% of the ROM is dumped to the tailing pond in the form of slurry, this will raise the theatrical figures (Table 4) before us in the near future.

The above table indicates that in future we shall loss about 24.76 Mty of water from coming coal washeries along with the plant tailing. This figure is equivalent to approximately 3000 m³/h loss of water. By improving the performance of the dewatering circuit it is possible to minimize the loss of water.

### SELECTED GLOBAL PERSPECTIVE OF DEWATERING

South Africa has large coal reserves, and is one of the world’s leading producers and exporters of

<table>
<thead>
<tr>
<th>Description</th>
<th>Tags</th>
<th>Capacity</th>
</tr>
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<tbody>
<tr>
<td>Total ROM coal from coming washeries</td>
<td>A :</td>
<td>111.1 Mty</td>
</tr>
<tr>
<td>Fines (-0.5mm) present in ROM (considering 20% of A)</td>
<td>B :</td>
<td>22.22 Mty</td>
</tr>
<tr>
<td>Tailings received from fine coal treatment circuit (considering 60% of B)</td>
<td>C :</td>
<td>13.33 Mty</td>
</tr>
<tr>
<td>Concentration of tailing slurry before dewatering, %solid (w/w)</td>
<td>D :</td>
<td>15% (assumed)</td>
</tr>
<tr>
<td>Concentration of tailing slurry after dewatering, %solid (w/w)</td>
<td>D :</td>
<td>35% (assumed)</td>
</tr>
<tr>
<td>Water present with the tailing slurry</td>
<td>E :</td>
<td>24.76 Mty</td>
</tr>
</tbody>
</table>

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coal. The country currently produces approximately 290 Mt of ROM coal per annum, out of which about 14% is believed to be finer than 500 micron (fine coal) and 2-3% finer than 100 micron (ultra-fine coal) (Le Roux et al., 2005). The fines content in the ROM had been increasing in recent years. Coal producers have a few options as to what to do with the fines. Initially, fines and ultra-fines were dumped with the discard streams or tailings ponds, but since the value of these fines had been recognized, it was either added to the product streams as it is, or alternatively, upgraded and sold. The economic potential of coal fines has led to developments in fine coal beneficiation processes, like spirals and froth flotation plants. The main reason for not fully exploiting this energy source is the high levels of moisture associated with the fines fraction of coal. Efficient removal of this moisture will yield definite benefits in finances and handling of the fine coal, while it will also have a positive impact on the environment. A 2001 survey of South African coal beneficiation plants showed that of the then 24 operations, some 18 plants employed processes for fine coal beneficiation. At seven of these plants, the ultra-fine slurries were dewatered using centrifuges or filters. With Tao et al. (2000) showing that a 1% decrease in the final moisture of 3 Mt of clean coal can lead to a saving of US$ 300,000. These amounts of moisture left in the fines are adding up to become a big financial liability.

In Australia, current practice at coal preparation plants is to thicken fine coal tailings with high-rate thickeners utilizing high molecular weight polymeric flocculants (Bickert, 2004). The thickener underflow is either dewatered further or disposed of. Disposal is either in fine tailings ponds or together with coarse reject by co-disposal. Commonly belt press filters are used if thickener underflow has to be dewatered further. Decanter centrifuges are no longer common, while membrane filter presses have just been introduced at Dartbrook due to the high clay content and the need to achieve consistent dry cakes for co-disposal.

For the United States of America, it is forecasted that coal will constitute a principal source of energy for the next several decades. A typical coal preparation plant produces about 20% of the mined coal as minus 0.5 mm (28 mesh). Generally, this fine fraction is discarded due to its high cost of processing. One of the biggest hurdles in utilization of fine coal cleaning technology by the coal industry is the economic dewatering of the fine clean coal product. Until an economical and practical solution to dewatering of fine clean coal is achieved, the efforts devoted to developing fine clean coal technology will be wasted (Parekh, 2009).

**APPROACH FOR EFFECTIVE DEWATERING**

The thickening process, although operated successfully in a large range of sites around the world, is poorly understood and predictive design of thickening equipment is still empirical (Gladman et al., 2006). High moisture in fine coal creates various problems in handling, transportation, and combustion and reduces its marketability and price. Also the huge volume of effluents generated due to the poor efficiency of fine coal treatment circuit has obvious impact on the nearby land area, water bodies and therefore, on the society at large. An economically viable fine coal dewatering process is therefore of great importance for the processing and utilization of fine coal, both coking and non-coking. For a
While designing a coal preparation plant, we normally do the test works which are mostly related to the beneficiation / ash reduction of mined coal such as ‘Sink-Float Test’ to get the product, i.e., clean coal with low ash content to meet the market requirement. The dewatering circuit mostly remains the grey area for the design engineers and normally the related equipments are selected based on their earlier practices and existing data. In majority of the cases the dewatering equipments are selected by the respective manufactures without test of the materials even on laboratory scale; hence, there is an obvious chance of undersize or oversize of the equipments. This results in either poor performance of the dewatering circuit or sometimes very higher capital cost.

Major studies which should be carried out during design stage of a dewatering circuit may be Settling test, Filtration test, Rheological characteristics, Particle Size Analysis, Chemistry of carrier liquid, Selection of proper reagents/flocculants, etc. Such practice will have realistic impact on the performance of a dewatering circuit and thus will be helpful in conserving ecosystem.

CONCLUSION
The study carried out indicates that the design philosophies of coal fine dewatering circuit are varying widely at different places around the world. Need is to carry out detailed test works for fine coal dewatering circuit and select efficient flocculent to precisely select the dewatering equipments for new plants to come and at the same time to enhance the efficiency of existing dewatering circuits. That would significantly improve the land utilization and at the same time protecting and conserving the water bodies. This will also reduce plant capital cost by selection of proper equipments and the plant operating cost as well by reducing the fresh water make up to the plant.

REFERENCES


