Addressing the envelope
by P. Hand* and D. Wiseman†

Synopsis

Most coal plants must run under conditions of varying feed conditions or are asked to produce qualities different from that used in the design. This can cause overloaded conditions as the ‘bottlenecks’ within the plant, depending on plant operation or as the feed changes.

During plant design, geological information can be used to determine washability envelopes and blends that may be expected. Historical data can also be used to develop a size distribution envelope as well as to assign reasonable models for each of the unit processes. In operation, a plant can be sampled to determine changes and to refine process models. The information obtained can then be used in an accurate simulation to define how the plant can deal with the changing environment.

This paper uses Limn: The Flowsheet Processor to simulate the coal plant in detail and will produce an accurate model, in terms of equipment sizing as well as water, medium, and solids balance, for each change in feed condition. It will show examples of running the simulation through complete density and size ranges and will determine the equipment required to address each part of the performance envelope.

Introduction

Simulations of coal washing plants are used for many reasons, from investigation of difficult to wash coals, to the effect of using different separation equipment on yield and quality of product (Clarkson, Edward, and Lahey 1998). In addition, since simulation packages such as Limn: The Flowsheet Processor (Leroux and Hardie. 2003, Wills and Napier-Munn, 2006) carry stream property information such as mass flow, volume and density of slurries as part of the simulation, this information can be used to determine ‘on the fly’ the equipment required to wash the feed coal.

This paper shows an example simulation of coal from three sources, each with a different washability, and with two types of particle size distribution (PSD). Use is made of a ‘scenario solver’ to examine the equipment required to process the washability and PSD envelopes that may be sent to the plant.

The use of efficiencies for each piece of equipment enables a true estimate of washing performance and the development of a ‘practical washability’. This will depend on equipment used and fines and slimes treatment, unlike the theoretical washability generated from geological models, to which ‘fudge factors’ or ‘plant factors’ are normally applied.

The plant flowsheet

For the purposes of simplification of options for this paper, fines and slimes treatment consists of classifying into fines and slimes fractions. The fines are dewatered on a high frequency screen then discarded while the slimes are thickened and the underflow discarded. In more complex studies, treatment of both fractions can be (and often are) simulated.

In addition, also for simplification, the dense medium cyclones are fixed at 810 mm diameter. Once again, in practice the effect of larger or smaller cyclones can be simulated with changes to the model $E_{pm}$ based on cyclone diameter and particle size. This is a critical area, particularly when washing difficult coals such as those from South Africa and India. Figure 1 shows the model of $E_{pm}$ and actual cutpoint versus particle size for a 810 mm dense medium cyclone.

The plant flowsheet used for the simulations in this paper is shown in Figure 2. The plant model is balanced in circuit in coal and reject solids as well as magnetite and water (Hand and Wiseman 2008). This is achieved by calculations within the equipment models as well as by using constraint

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controllers on the water ring main to achieve a balance for water, as shown in Figure 3.

The equipment models used can be either rigorous or rule of thumb, depending on necessity and the available data (Osborne 1988). An example of a dense medium cyclone data page is shown in Figure 4 and an example of the Excel VBA code used in the calculations is shown in Figure 5.

Varying feed conditions
It has been said that ‘constant change is the only true constant’ and this is particularly true of coal washing plant feeds.

Proper blending facilities are needed before a wash plant attempt to remove large variations in feed in terms of both washability and particle size distribution. However, variations will still occur and judgements must be made about the size of envelope that can be allowed to ensure minimal reduction in plant throughput while minimizing plant capital expenditure.

Real world washing plant simulations
Having set up the flowsheet and the feed characteristics, the simulation can be used to obtain information on the equipment required to ‘wash the envelope’.

Practical washability
Figures 6 and 7 show the results of a series of simulations, resulting in the ‘practical washability’ over a blend of the three coal types. A wash is carried out in medium of RD 1.2 to 1.85. From this the cutpoint is calculated at each RD and
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**Figure 3—Constraint controller setup for determining water make up requirement**

<table>
<thead>
<tr>
<th>Model Parameters</th>
<th>Required</th>
<th>Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of Solids in each Product Stream</td>
<td>87.76</td>
<td>268.46</td>
</tr>
<tr>
<td>Flow to Flows fresh water</td>
<td>75.73</td>
<td>75.476</td>
</tr>
<tr>
<td>Water fresh water</td>
<td>67.90</td>
<td>67.66</td>
</tr>
<tr>
<td>Water</td>
<td>681.942</td>
<td>657.539</td>
</tr>
<tr>
<td>Flow to Water return</td>
<td>250.00</td>
<td>238.15</td>
</tr>
<tr>
<td>Total Water</td>
<td>1,068.092</td>
<td>1,064.47</td>
</tr>
<tr>
<td>Excess Water</td>
<td>3.607</td>
<td></td>
</tr>
</tbody>
</table>

#### Water Make Up

| Change the Independent Variable linked to this cell | 44.115 |
| Limit the Independent Variable to a Maximum of | -3.852 |
| and a Minimum of | 2000 |
| Controller K (gain) (Units) | 0.1 |
| Control Enabled | 0.5 |
| Iterations Between Control Actions | 1 |
| Start Control at Iteration | 1 |

### Dense medium cyclone model input

**Figure 4—Dense medium cyclone model input**

**Figure 5—Example VBA Code**

```vba
Public Function DMC_FeedCapacity(CycloneDiameter As Double, _
    InletDiameter As Double, _
    VortexFinderDiameter As Double, _
    HeadPressure As Double) As Double
    Dim Capacity_9D As Double
    Dim HeadUpratingFactor As Double
    If CycloneDiameter < 860 Then
        Capacity_9D = 0.000345 * InletDiameter * VortexFinderDiameter * _
            (CycloneDiameter ^ 0.5) * _
            (2.1265 - (0.2017 * Log(CycloneDiameter)))
    Else
        Capacity_9D = 0.000345 * InletDiameter * VortexFinderDiameter * _
            (CycloneDiameter ^ 0.5) * _
            (1.6157 * (CycloneDiameter ^ -0.1109))
    End If
    HeadUpratingFactor = -0.0009 * (HeadPressure ^ 2) + 0.0707 * HeadPressure + 0.438
    DMC_FeedCapacity = Capacity_9D * HeadUpratingFactor
    End Function
```
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Figure 6—Practical washability

Figure 7—Practical washability and required equipment

Figure 8—Scenario solver showing different feed washabilities (blended before the plant) and two PSDs

the resultant coal qualities determined. Figure 6 is the practical washability showing yield and NCVAR, and Figure 7 shows the number and size of the equipment required to wash at any density. The selected equipment then defines the envelope within which the plant can operate.

For this feed consist and product size distribution, the point at which equipment is adequate to wash the coal can simply be read off the graph. A combination of coal types and feed size ranges can be fed to the simulation using the scenario solver. An example is given in Figure 8.

The graph in Figure 9 shows the yields and CV obtained by washing for a consistent 15% ash, controlled within the simulation using a constraint controller.

Figure 10 shows the total widths required (in metres) for the desliming, float, and sink screens as well as the total width of the 0.9 m diameter magnetic separators required.

Figure 11 then shows the number of 810 mm dense medium cyclones needed and the thicker diameter based on volumetric and solids loading possible obtained from settling tests.

The information gleaned can then be used to determine the number of modules required or the simulations can be repeated using different cyclone diameters, banana screen factors, etc. to match changing design or operating specifications.

Plant balance

The plant consumption of consumables can also be estimated using expected magnetite and water losses from magnetic separators, products, and discards. An example is shown in Figure 12.
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Figure 9—Yields and CV for consistent ash but varying feeds

Figure 10—Screen and magnetic separator dimensions required to wash the envelope

Figure 11—Number of cyclones and thickener diameter

Figure 12—Magnetite and water consumption calculations

<table>
<thead>
<tr>
<th>Total circuit Loss Calculations</th>
<th>Water</th>
<th>Magnetite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>-39.583</td>
<td>0.0000</td>
</tr>
<tr>
<td>Total Product</td>
<td>31.4481</td>
<td>0.1564</td>
</tr>
<tr>
<td>Discards</td>
<td>39.5393</td>
<td>0.1740</td>
</tr>
<tr>
<td>Fine Product</td>
<td>17.1053</td>
<td>0.0387</td>
</tr>
<tr>
<td>Thickener uflow</td>
<td>76.3290</td>
<td>0.6255</td>
</tr>
<tr>
<td>TOTAL</td>
<td>124.8384</td>
<td>0.9745</td>
</tr>
<tr>
<td>Consumption per feed tonne (Kg / Tonne)</td>
<td>0.131</td>
<td>1.026</td>
</tr>
</tbody>
</table>
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Conclusions

The paper has given an illustration of the use of a simulation package to determine the equipment required in a wash plant needed to accommodate varying feeds, in terms of washability and PSD, plant layout, and indeed any variable that may be encountered.

The plant simulation can be set up to be fully balanced in terms of material, water, and magnetite. The ‘practical washability’ can also be used, even at an early stage in the mine planning process, to give a true estimate of yield at a given quality, particularly with difficult to treat coals.

All plants have bottlenecks; the key is in moving them to where they are less important. The use of a simulation package can facilitate the design of wash plants to ‘address the envelope’ while minimizing overdesign.

References


HAME, P.E. and WHISMAN D.M. Combined Coal And Medium Circuit Simulation For Design And Optimisation 12th ACPC (Australian Coal Preparation Society Conference), Sydney 2008.


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