EMULATING THE DIRECT BLISTER FURNACE (DBF) PROCESS WITH COAL COMBUSTION CAPABILITIES IN STAR-CCM+ V4.06

joint development venture between Bateman & Aerotherm

CONTENTS

• Numerical Model Details - DBF.

• Boundary Conditions - DBF.

• Direct Blister Furnace – Phase One.

• US / Throat / WHB – Phase Two.

• Way Forward.

• Conclusions.

• Questions.
NUMERICAL MODEL DETAILS - DBF

- **Chemical Reactions** – C12H26 (multi-component gas):
  \[ C12H26 + 18.5O2 = 12CO2 + 13H20. \]

- **Fuel Injection @ oil burners** - C12H26 (liquid) - Lagrangian:
  \{Quasi-Steady Evaporation to C12H26 vapor component\}.

- **Coal Injection @ chute inlet** – coal combustion activates char oxidation by oxygen, devolatilisation & moisture evaporation.
  \{Current approach to emulate concentrate / dust / flux process\}


- **Reports to monitor outlet gas temperature & heat transfer.**

- **Results shown at pseudo-steady state stage (minimum temp).**
BOUNDARY CONDITIONS - DBF

- **Velocities @ inlet boundaries** (Table 2).
- **Temperatures @ inlet boundaries** (Table 2).
- **Fuel Injection @ 62.84 kg/hr/burner @ 60 °C.**
- **Raw Coal Injection @ 0.2 kg/s, partially-premixed through the chute gas inlet boundary @ 80 °C (release same chemical energy as copper).**
- **Fixed Flux Wall Patches** (Reaction Shaft only).
- **Forced Convection Walls** (copper & refractory).
- **Adiabatic walls** (settler region & slag bath).

### Table 2 Inlet Boundary Conditions for Run 1 – Base Case.

<table>
<thead>
<tr>
<th>Inlet</th>
<th>Input stream</th>
<th>Run 1</th>
<th>O₂ conc (vol%)</th>
<th>Temp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chute</td>
<td>Concentrate</td>
<td>70000 kg/hr</td>
<td>-</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Dust</td>
<td>8400 kg/hr</td>
<td>-</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Flux</td>
<td>3567 kg/hr</td>
<td>-</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Chute gas</td>
<td>3.5 m/s (deducted from Comb’n gas)</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Comb’n gas</td>
<td>Combustion gas</td>
<td>37976 Nm³/hr</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Dispersers</td>
<td>Dispersion gas</td>
<td>1297 Nm³/hr</td>
<td>21</td>
<td>40</td>
</tr>
<tr>
<td>Central pipe</td>
<td>Central pipe gas</td>
<td>810 Nm³/hr</td>
<td>95</td>
<td>40</td>
</tr>
<tr>
<td>Oil burners</td>
<td>Oil</td>
<td>62.84 kg/hr/bnr</td>
<td>-</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Oil combustion gas</td>
<td>178.33 Nm³/hr/bnr</td>
<td>45</td>
<td>50</td>
</tr>
</tbody>
</table>
Outotec® Direct Blister Flash Smelting Process
Direct Blister Furnace – Shaft & Settler

Stopping criterion: $T_{\min} = 1200 \, ^\circ C$

Heat Flux = -26.1 kW/m$^2$
Local hot spots due to the combustion of the fuel, influenced by the 3D recirculation flow pattern in the reaction shaft.
Direct Blister Furnace – Mass Fraction (CO2)
Direct Blister Furnace – Velocity Contours
Direct Blister Furnace – Sectional Contours

Symmetry plane temperature scale

Perpendicular plane temperature scale

Temperature (°C)

- 2726.8
- 2189.5
- 1652.1
- 1114.7
- 577.37
- 40.000
Direct Blister Furnace – Velocity Vectors
Direct Blister Furnace – Fuel & Coal Results
### Direct Blister Furnace – Heat Transfer Results

<table>
<thead>
<tr>
<th>Boundary / Region Name</th>
<th>Temperature (°C)</th>
<th>Convection coeff (W/m².K)</th>
<th>Heat Flux (W/m²)</th>
<th>Heat Transfer Rate (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction Shaft</td>
<td></td>
<td><strong>CCM+ calculates</strong></td>
<td><strong>-130900</strong> (input)</td>
<td><strong>-0.779</strong> (-0.893)</td>
</tr>
<tr>
<td>Roof (Copper)</td>
<td><strong>40</strong> (input)</td>
<td><strong>143 &amp; 180</strong> (input)</td>
<td><strong>CCM+ calculates</strong></td>
<td><strong>-0.446</strong> (-0.159)</td>
</tr>
<tr>
<td>Roof (Refractory)</td>
<td><strong>40</strong> (input)</td>
<td><strong>10</strong> (input)</td>
<td><strong>CCM+ calculates</strong></td>
<td></td>
</tr>
<tr>
<td>Outlet (Excess)</td>
<td><strong>1279</strong> (1290)</td>
<td>N/A</td>
<td>N/A</td>
<td><strong>-1.23</strong> (-1.19)</td>
</tr>
<tr>
<td>Total Heat</td>
<td></td>
<td></td>
<td></td>
<td><strong>-2.45</strong> (-2.24)</td>
</tr>
</tbody>
</table>

**Symmetrical Model Values**
RESULTS SUMMARY – PHASE ONE

• Pressure outlet: Area-weighted averaged CFD outlet temperature = 1279 °C vs. 1290 °C obtained by CSIRO @ 70 tons per hour of copper concentrate fed (excl. dust & flux additions) into DBF.

• Reaction Shaft Wall Heat Removal Rate: q = 0.78 MW vs. 0.89 MW calculated for plant operations (transition zone heat flux patch value 30 kW/m² less than that specified in CSIRO report).

• Composite Roof Heat Removal Rate: q = 0.45 MW vs. 0.16 MW calculated for plant operations (current CFD ambient heat transfer coefficients limited to ensure top maximum copper nestling block temperature = 500 °C).
US / Throat / WHB – Phase Two
US/Throat/WHB – Modifications/Concepts
WAY FORWARD

• Incorporate copper sulphide concentrate / dust / flux reaction kinetics data & all properties for the DBF: obtaining necessary info from client (March 2010).

• Uptake Shaft, Throat & Waste Heat Boiler simulated separately - mapping CFD results obtained @ Reaction Shaft outlet onto inlet of 2nd CFD model (project started: February 2010 for coal combustion outlet results).

• STAR-CCM+ v4.06 enabled us to emulate the copper concentrate DBF process on the interim with pulverised coal combustion. Aim downstream: apply more accurate hot face temperatures and heat transfer coefficients to design better furnace containment equipment.
CONCLUSIONS

• Developed DBF numerical model for CFD purposes.


• COAL combustion capability applied to emulate copper concentrate / dust / flux energy release with calculated coal mass flow rate in DBF (fixed coal composition).

• STAR-CCM+ applied to emulate real process with latest pulverised coal combustion capability successfully.

• Transferred symmetrical DBF outlet data to full WHB model inlet to analyse fluid flow & improve possibly.
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QUESTIONS?