COLD MODELLING OF SLAG-MATTE EMULSIONS

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ABSTRACT

The purpose of this work was to study the phenomena of coalescence and breakage of sulphide matte droplets in the slag-matte emulsions of the Vanyukov Process. This is a Russian designed non-ferrous bath smelter utilising side injection of the blast into a slag melt. A two dimensional, 1/6 scale perspex model with a continuous sample flow was developed. The model incorporated the use of digital camera and image analysis technology. Water and a low viscosity paraffin oil were chosen to represent the matte and slag phases respectively. Operating regimes described by Reynolds, Weber and Modified Froude dimensionless number groups were selected to assess the relationship between gas flow rates and matte droplet size distribution. The gas flow rates studied in this project ranged from 0 to 140 l/min. Increasing flow rates from zero to 96 l/min resulted in an increase in the mean droplet diameter. An optimum flow rate in terms of maximising mean droplet diameter, and hence settling velocity, was found to occur with flow rates of 96 l/min. Increasing gas flow rates above this value resulted in a decrease in the mean droplet diameter.

1. INTRODUCTION

A number of bath smelting designs are presently used in the nonferrous industry, including the Noranda, Ausmelt, Mitsubishi and Vanyukov processes. These designs incorporate either top or side blowing into a molten bath which, according to Hunt, Komkov and Sorokin (1992), can be separated into two distinct stages, of (a) heating and smelting, then (b) phase separation. During the smelting stage, high heat and mass transfer rates occur as a consequence of the intense mixing and the large interface developed between matte, slag and reactive gases. The intensity of gas agitation in these processes leads to a suspension of matte droplets in the slag, and the rate of phase separation can have an impact upon the reactor productivity and the recovery of matte.
Studies into systems where gas injection and not mechanical stirring is the source of energy input are not widely reported. Zaidi and Sohn (1995) used a water-kerosene system to model the effect of bottom blowing on droplet generation. Their work concentrated upon correlating the Sauter diameter of water droplets generated in the kerosene phase to the Weber number for gas injection to the ratio of the kerosene to water head. Other studies into the modeling of metallurgical emulsions have been undertaken by Lin and Guthrie (1994), who studied the emulsification due to bottom blowing a melt with a slag layer, and Hannan and Cramb (1996), who studied the emulsification of mold flux in continuous casting of steels. Coalescence and breakage of matte droplets in high intensity reactors has not been widely assessed, and therefore the study of this phenomena can be considered useful.

2 EXPERIMENTAL PROCEDURE

2.1 Model Design. A “2-dimensional” 1/6 scale model of a tuyere section in a Vanyukov furnace, with a bath width of 0.2m breadth, and 0.75m high, was used to study slag-matte emulsions. The design represented in Fig. 1, utilizes a CC TV camera to capture images of the emulsion, continuously sampled from the primary tank. Images were downloaded onto a PC for digital image analysis using the UTHSCSA Image Tool program (developed at the University of Texas Health Science Center San Antonio, Texas and available from the Internet by anonymous FTP from maxrad6.uthscsa.edu). A continuous sample was drawn from a point below the mixed zone, via means of a 3mm diameter perspex tube. The sampled emulsion flows through a plain glass fronted viewing chamber, and images are captured using the CCTV. An image was captured every 30 seconds.
The selection of model criteria such as flow rate, \( Q \), phase material properties and tuyere diameter was based upon methods espoused by Matway, Fruehan and Heinein (1989) and Abel, Fruehan and Vassilicos (1995, a,b). Initially the dimensionless numbers Reynolds, Weber and Modified Froude were chosen to describe the system, Table 1 compares the Vanyukov process and our 1/6 scale model. In terms of operating regimes, our model and the Vanyukov process are in agreement, indicating a logical basis for the model’s design. The materials selected to represent matte, slag and process gas are water, paraffin oil and air, as listed in Table 2. These materials were selected on the criteria of density, viscosity and interfacial surface tension.

Table 1. Dimensionless Number Values for Full scale and Model

<table>
<thead>
<tr>
<th>Number</th>
<th>Vanyukov Process</th>
<th>Cold Model</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Re} = \frac{\rho_U P L}{\mu_3} )</td>
<td>8x10^5</td>
<td>8.9x10^3</td>
<td>turbulent flow</td>
</tr>
<tr>
<td>( \text{We} = \frac{\rho_m U_p^2 L}{\sigma} )</td>
<td>7.4x10^5</td>
<td>1x10^4</td>
<td>inertial &gt;&gt; surface tension forces</td>
</tr>
<tr>
<td>( \text{Fr'} = \frac{\rho_U U_p^2}{(\rho_d - \rho_s)g L} )</td>
<td>0.273 to 2.14</td>
<td>1.0078</td>
<td>equivalent</td>
</tr>
</tbody>
</table>

Table 2. Phase Materials Selected and Relevant Properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Phase Representing</th>
<th>Density, kg/m^3</th>
<th>Viscosity, kg/ms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ondina 15 (Paraffin oil)</td>
<td>Slag</td>
<td>815</td>
<td>0.0163</td>
</tr>
<tr>
<td>Water</td>
<td>Matte</td>
<td>1000</td>
<td>0.0009</td>
</tr>
<tr>
<td>Air</td>
<td>Industrial Oxygen</td>
<td>1.19</td>
<td>--</td>
</tr>
</tbody>
</table>

3 RESULTS AND DISCUSSION

3.1 Effect of tuyere diameter. Three tuyere diameters of 5, 7.5 and 10 mm were selected which in terms of similarity criteria correspond to operational dimensions in a full scale Vanyukov reactor. Two gas flow rates were selected and the results obtained are graphed in Fig. 2. Statistically no relationship between tuyere diameter and mean droplet diameter was observed.
3.2 Effect of Gas Flow Rate. The gas flow rates studied were between 60 and 140 l/min, with additional experiment where no gas was injected. With reference to Fig. 3, it was shown that relationship exists between gas flow rate and mean droplet diameter. Based upon a 97.5% confidence interval, it can be seen that as the gas flow rate increases from zero to 961/min the mean droplet diameter increases, corresponding to an increase in the coalescence in the system. As the flow rate increases above this point, the mean droplet diameter decreases. It is proposed that at these higher flow rates, coalesced droplets become unstable and break into smaller droplets, hence decreasing the mean droplet diameter.
4. CONCLUSIONS

The authors concluded that no relationship between tuyere diameter and mean droplet diameter was found for the range of tuyere diameters and gas flow rates studied. A relationship was observed between gas flow rates and mean droplet diameters. A maximum mean droplet diameter was seen with a gas flow rate of 96l/min, this corresponds to a gas flow rate of 430Nm³/m³/h in a full scale Vanyukov reactor. This relationship indicates that at this flow rate the phase separation of matte from slag would be maximised as per Stokes Law. Additionally, the use of digital cameras and image analysis packages were shown to be effective in this study.

5. NOMENCLATURE

Re : Reynolds Number
We : Webers Number
Fr' : Modified Froude Number
ρs, ρg, ρm : Density of slag, gas and matte phases kg/m³
σ : Interfacial surface tension matte-slag, N/m
Ug : Gas injection velocity, m/s
Up : Plume Velocity, m/s (Abel, Fruehan and Vassilicos 1995 a)
L : Bath width, m
g : acceleration due to gravity, m/s²
μs : slag viscosity, kg/ms

6. ACKNOWLEDGEMENTS

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7. REFERENCES


