Online Analysis of Bubbling Phenomena

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Bubbling is commonly used in the chemical and mineral refining processes to enhance temperature and chemical composition homogeneity, and control mass transfer and heat transfer. In the case of high temperature operations, it is very difficult to measure directly the effect of stirring on the system and thus the control of such processes is dominated by manual procedures. In the case of bottom bubbling processes involving two fluids (e.g. steel and slag in ladle refining operations), the disturbance of the surface of the top layer (“spout eye”) provides a visual indication of the bubbling process and is accompanied by sound and vibration signals that all originate from the same phenomena and are clearly closely related to each other. In this study, we construct an experimental rig using five depths of the secondary layer (5-25mm) and 10 flow gas rates (2-20lpm) to simulate the secondary steelmaking process. Images from the top view, sound and vibration signals were collected simultaneously and they were manipulated into a state matrix after pre-treatment. The state matrix carries all the information which can be reliably measured from the bubbling phenomena, as shown in Figure 1. In this study, we propose to analyse the matrix using the PCA technique as means to reduce the dimensions of the matrix and hopefully produce a useful control signal.

Figure 1 State matrix describing the bubbling phenomena

Figure 2 shows an image from the top of cold model experimental rig, the spout area in the image is caused by bottom stirring. Analysing the images using a threshold
technique based on Matlab software, it takes approximately 0.36 second to calculate the size of the spout area. However, only 0.10 second is required to calculate the spout area size of an industrial image, as shown in Figure 3, because of the greater contrast from high temperatures.

![Figure 2 Image from the cold model](image1)

![Figure 3 Image from the industrial trial, original image and post treated image](image2)

Sound and vibration signals were pre-treated by both intensities or magnitudes and frequencies. A typical sound signal sample and vibration signal sample are shown in Figure 4 and Figure 5. Sound intensities and vibration magnitudes were integrated respectively and combined with the associated spout area size calculated by image analysis. This state matrix was analysed by PCA techniques. The initial results showed that the first principal explains 40-60% of all the variations. Further efforts are required to interpret the results and evaluate the approach taken.
The sound and vibration signals can be collected and analysed quickly. However, the spout size calculation is comparatively time consuming, and work is underway to increase the speed of image processing. It is hoped that this approach will lead to a more highly correlated state matrix and allow greater reduction of variables.