Application Example: Oxygen Dispersion in Pulp Delignification

Motivation

Oxygen delignification is widely used in pulp mills for its better selectivity and yield in comparison to extended cooking. It also reduces the usage of bleaching chemicals and the load of waste water in pulp mills. In oxygen delignification, it is important to disperse the gas into small bubbles, as this increases the interfacial surface area and results in better solubility of oxygen. High pressure (typically 3-10 bars), pH (10) and temperature (ca. 90°C) make the conditions challenging for measurement equipment, and to our knowledge this is the first measurement system that can continuously monitor gas dispersion within the oxygen phase: it has been used nonstop for several weeks in hardwood and softwood pulp mills.

Application and results

A Pixact Bubble Monitoring (PBM) system was installed on the reactor inlet of an oxygen delignification tower at a pulp mill to monitor the oxygen delignification process. The system is equipped with a Pixscope measurement probe with an outer diameter of just 32 mm. The probe houses a front light setup and a camera, which produces image data on the process at the rate of 5 images per second. The bubbles in the tower are mainly 10 to 800 µm in size, but in certain conditions their diameter can exceed 1 mm. Examples of the image data captured by the system are presented in Figures 1 and 2.

The image stream is analyzed in real time by the Pixact software. The software recognizes hundreds of bubbles in each image utilizing iterative least squares circle fitting. The data is used to compute the size distribution of the bubbles and derived statistics such as mean, standard deviation, and arithmetic, Sauter and volumetric percentiles (D10, D50 and D90).

Figure 3 shows 30-minute average Sauter mean diameter values for a one-week period. During the week process parameters were changed stepwise for a few hours and then returned to normal. The differences in the Sauter values for each parameter are remarkable. In addition, when good dispersion is achieved, timewise variation in the Sauter value is smaller. In normal conditions, the Sauter value varies between 0.18 and 0.25, but when it is lower, the variation is within just 0.02 mm.

Another measurement system was placed at the top of the reactor to monitor bubble size near the outlet. The Sauter mean size remained below 1 mm for the most part, but when the Sauter value was above 0.3 mm at the inlet of the reactor, the gas formed pockets at the outlet, which were too large to be analyzed. An image of such a gas pocket is presented in Figure 4. Gas pockets indicate that too much oxygen has been fed into the reactor.

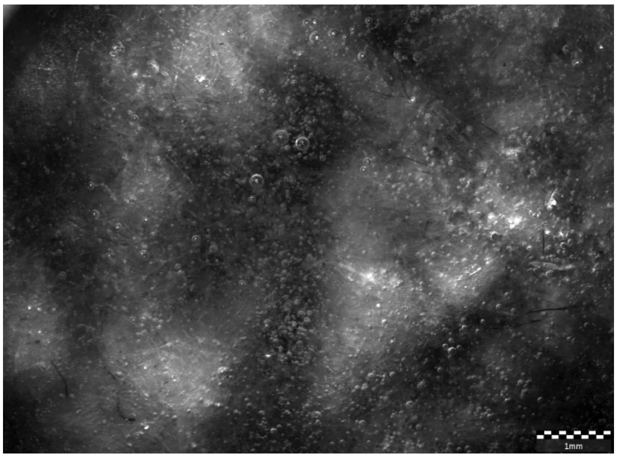

Figure 1. Oxygen bubbles in medium consistency hardwood pulp near the reactor inlet. The image shows that good dispersion has been achieved. 1 mm scale bar.

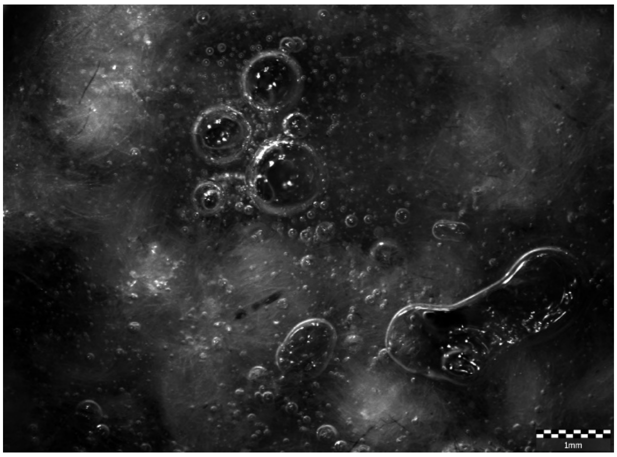

Figure 2. Oxygen bubbles near the reactor inlet. The image shows that dispersion has been far from optimal. 1 mm scale bar.

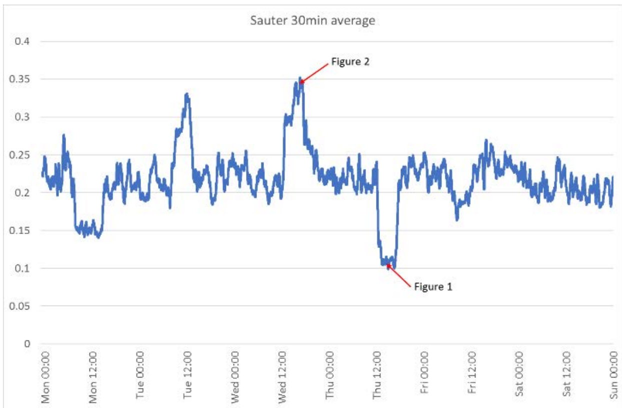

Figure 3. Sauter 30min average trend for a one-week period. Stepwise changes in process parameters are clearly reflected in the size trend. The bubble images in Figures 1 and 2 are taken at the points marked in the trend.

Benefits

The PBM system enables the continuous, 24/7 monitoring of gas dispersion in oxygen delignification. The tests carried out help optimize the process by showing how changes in key parameters affect gas dispersion. The system is a versatile tool for R&D during trial runs and for service personnel in troubleshooting, as it shows what really happens inside the reactor. The system is used in hardwood and softwood mills, which has produced useful information about the differences between the two. As our customer said: "The Pixact Bubble Monitoring system has helped us decisively in developing next generation process equipment and we will continue using it to further increase our knowledge."

Figure 4. Image data from the camera at the top of the reactor. When gas dispersion in the inlet is not optimal, the bubbles coalesce into large gas pockets before the outlet.

Technical implementation

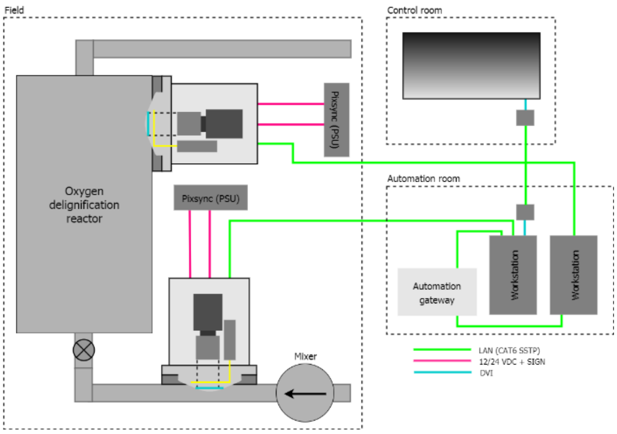

Figure 5. Connection diagram

Figure 6. Pixact Bubble Monitoring system installed on the reactor inlet

The installation consists of two Pixact Bubble Monitoring systems with Pixscope probes as the imaging units. Figure 5 displays an outline of the set-up and connections of the system and Figure 6 shows the imaging unit installed on the reactor inlet. A summary of the specifications of the measurement system is presented in the table below.

Probe diameter	32 mm
Material	Stainless steel AISI316L
Setup	Front-light, Pixstrobe illumination unit
Process interface	Sapphire window
Sealing	NBR
Cooling	Pressurized air
Protection	IP67
Bubble measurement range	20 µm … 3 mm

More information on the Pixact Bubble Monitoring system and configuration options can be found in the Pixact Bubble Monitoring brochure.

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