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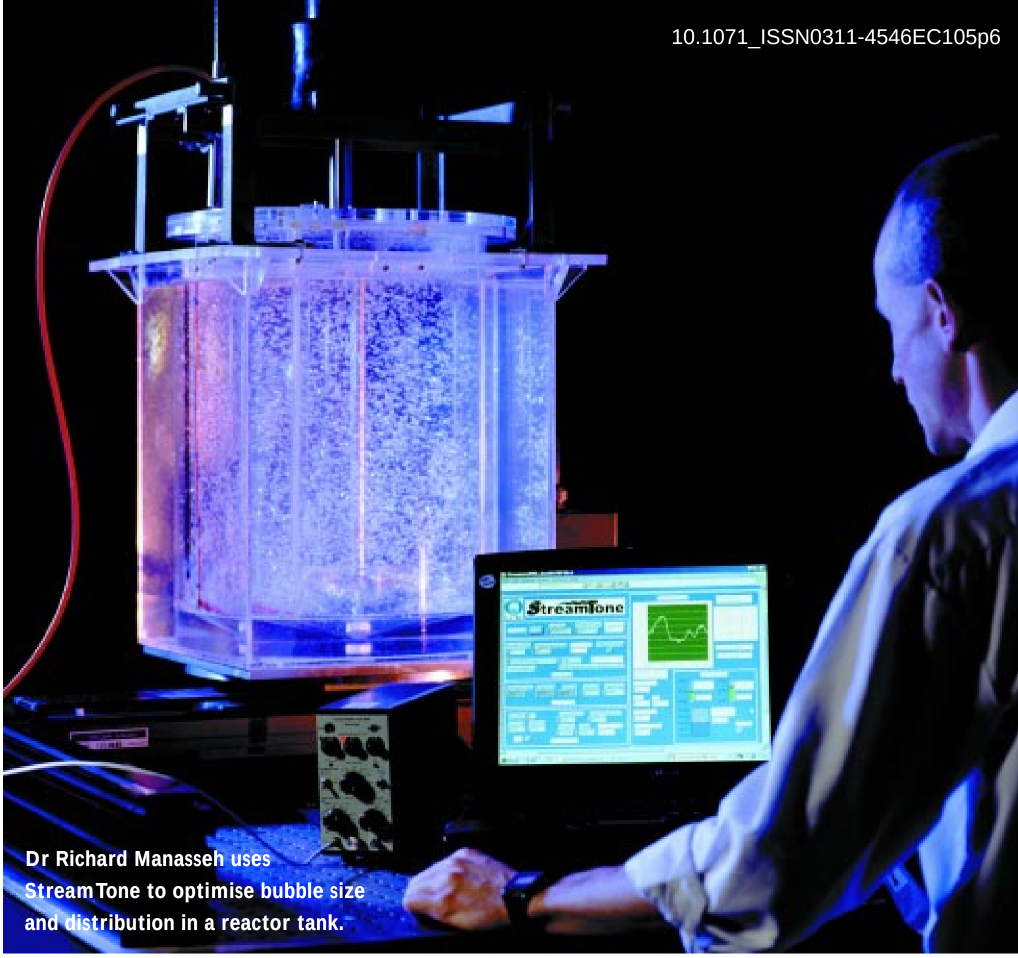
Bubbly solutions

How can you tell if your chemical reactions are on track? **Wendy Pyper** discovers that it's all in the size of the bubble.



Dr Richard Manasseh uses StreamTone to optimise bubble size and distribution in a reactor tank.

Bubbles are the workhorses of industry. From sewage treatment to biscuit baking, metal processing and pharmaceutical production, bubbles are critical to a successful end product. But getting the right size and number of bubbles for the job can be tricky.

'In industry, bubbles are often too big or too few, starving industrial chemical reactions of essential oxygen or other gases and wasting millions in lost production,' Dr Richard Manasseh of CSIRO Thermal and Fluids Engineering says.

But now Manasseh and his colleagues have found a way around industry's bubble trouble. After listening to the sounds (acoustics) bubbles make when they are formed, the scientists have developed acoustic software that calculates bubble size and signals other instrumentation to adjust the bubbling process accordingly.

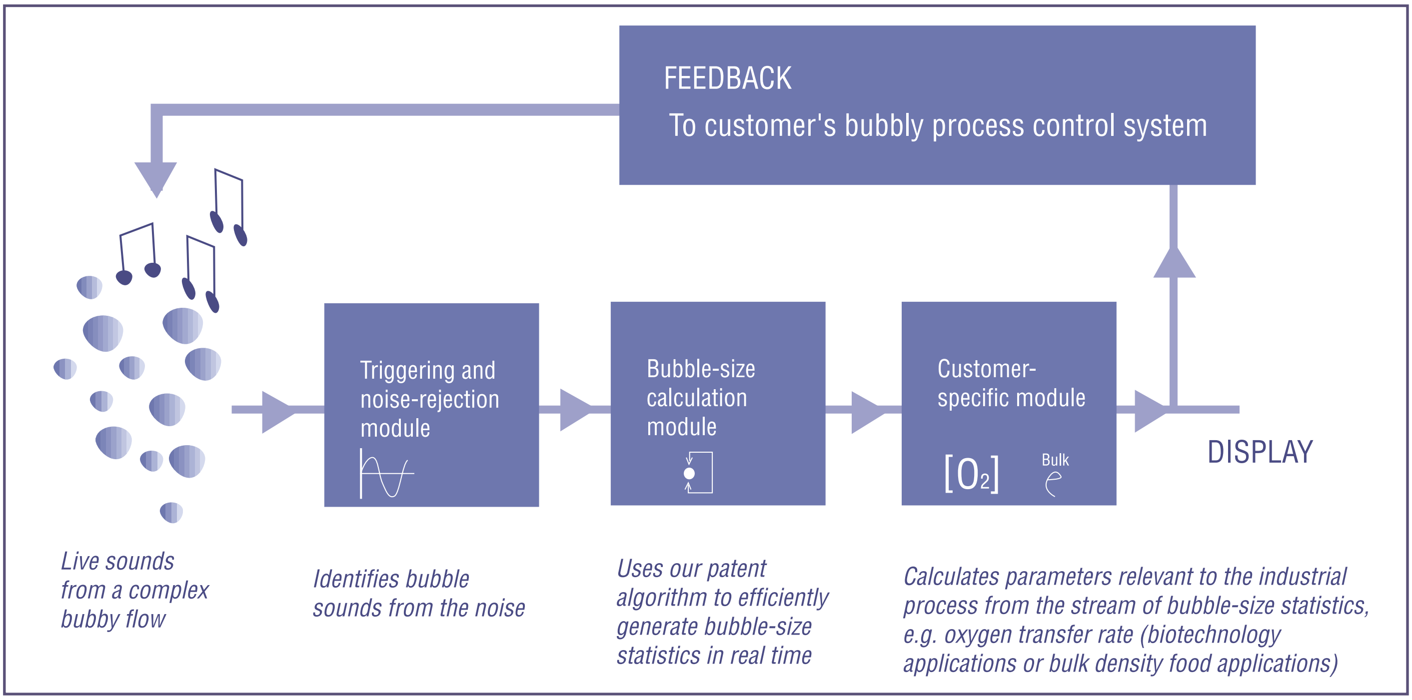
The software, called StreamTone, is based on the principle that the air inside bubbles vibrates. Large bubbles vibrate at a low frequency, while small bubbles vibrate at a high frequency, in the same way that large and small bells vibrate when rung.

'When a bubble forms, the air within it vibrates hundreds of times a second and gives off a pulse of sound,' Manasseh says.

'By measuring the frequency of that sound, whether it's from an individual bubble or a medley of them, StreamTone can determine how big the bubbles are.

The software relies on underwater microphones, called hydrophones, to relay acoustic signals from the bubbling mixture to a computer. This system overcomes many of the problems encountered with other methods used to determine bubble size and distribution.

'Many bubbly processes are conducted in steel tanks, so you can't look into them,'



Manasseh says. 'Or the liquid is opaque, so you can't perform optical tests. And in many cases the temperatures are too high for delicate measuring instruments such as cameras or probes to survive.

'But because StreamTone detects sound, it will work under any conditions.'

The software has already been used to identify problems in the aeration of 20 000-litre, bio-reactor tanks used to produce genetically engineered hormones. While hormone production had initially succeeded in small-scale trials (20 litre), achieving correct oxygenation at the much larger scale had proved difficult.

Using StreamTone, the scientists were able to show that poor oxygen uptake by the bacteria producing the hormones was due to poor aeration at a critical stage of the production process.

'Although the maximum amount of air was being pumped into the bioreactor, making more bubbles, the tank operators were unable to stir the mixture hard enough to break up the bubbles,' Manasseh says. 'So the bubbles were too large for efficient oxygen transfer into the liquid, and the bacteria were being starved of oxygen.'

Manasseh says his team has also applied the StreamTone technology to pyrometallurgical applications. These involve pumping oxygen through molten metal, and to sewage aeration processes in the UK and Melbourne. The group is also looking to work with Food Science Australia to quality test a food extrusion process used to produce dough for biscuits and other crunchy snacks (see story at right).

'Food extrusion processes have no control over raw materials such as flour which can vary substantially from one batch to another,' Manasseh says. 'This variation changes the sounds emitted by bubbles that form as the dough passes through the extruder.

'Food Science Australia has developed acoustic software that correlates product (dough) quality attributes such as texture, moisture content and density with the sounds emitted during food extrusion. We're hoping to use StreamTone as a front end to this quality test.'

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The birth of a bubble

Bubbles start life as a tear shape, with a pointed neck that gets thinner and thinner as the bubble becomes a sphere. The neck eventually retracts at a speed of five metres per second, punching a small jet of liquid inside the bubble and causing tiny droplets to break off. This process compresses the gas inside the bubble, initiating a series of overcorrections – compress, overstretch, compress – causing the gas to vibrate like a bell.

A bubble with a three-millimetre radius will vibrate at a frequency of one kilohertz, which is in the range of human hearing and speech. We hear these vibrations as 'splashing', 'glugging', 'plinking' and 'roaring' sounds wheneve we have a bath, pour wine into a glass or take a dip in the surf.

Coming to the **perfect crunch**

JAY SELLAHEWA from Food Science Australia says food extrusion involves squeezing a biopolymer of melted starch and protein through a small hole or 'die' under high temperature and pressure (150˚C and 800 psi), in order to make breakfast cereals and crispy snacks. As this biopolymer 'melt' passes through the die to the atmosphere, the temperature and pressure drop quickly and the water inside the melt evaporates instantly.

'When the resulting steam escapes, the melt stretches and, with evaporative cooling, a product is formed with air bubbles trapped inside,' Sellahewa says. 'These bubbles give the product a characteristic 'crunchy' texture, which can be controlled by the degree of expansion.'

However the raw materials of the melt, such as flour, can vary substantially from one batch to another, which in turn affects the aeration and bulk density of the product.

'The bulk density is an important quality attribute in extrusion because it affects the weight and texture of the final product,' Sellahewa says. 'A lot of air will give a low bulk density and a crispy texture, while less air will produce a harder, denser product.'

Food products are sold by weight, and if the bulk density is too heavy only half the packet may be filled. On the other hand, if the bulk density is too light, the right volume of product may not fit into the packet.

To get around the problem of variable raw ingredients, Sellahewa and his team developed a software program that correlates the sound bubbles make as the melt passes through the extruder with product quality attributes such as texture, bulk density and moisture content.

'We place microphones at the end of the extruder and capture the crackling sounds made by bubbles as the product expands. We then use statistics to correlate the sound with product quality attributes,' Sellahewa says.

The software can then determine whether the extruded product has the correct density and texture and a trained operator can adjust the process accordingly.

Sellahewa says the next step will be to link Richard Manasseh's StreamTone software into the process, so acoustic data can be collected in real time.

'StreamTone could measure bubble size and distribution as the product exits from the extruder and we could use our software to correlate this data with product quality attributes,' Sellahewa says. 'If we can do that, we'll be able to get a quality indicator in real time, which will streamline monitoring and control of the process.

'And a real time indicator will enable production companies to take immediate corrective action if there is a problem, minimising waste and increasing profitability.'