Good acoustics?

It's a poor workman who blames his tools, goes the proverb. But on machinery condition monitoring, it's been understandable. However, all of that is about to change, writes Brian Tinham

Who in engineering circles could have imagined that a day might come when sophisticated instrumentation capable of analysing the condition of virtually any rotating machinery would be compressed into a rugged, palm-sized unit? And not just small, but also requiring zero specialist data analysis or interpretation and very little training – simply delivering first-line, instant results, much like any other tool in a technician's toolbox.

Sounds far-fetched? Now add in: no careful positioning required to match the bearing axes; and no need for prior knowledge of the machinery type, component specifications or as-should-be bearing 'signatures'. Just as revolutionary, no poring over waveforms and 'spikes' in the data, scratching heads and wondering what exactly they might be telling you. And also a capacity not only to work with the widest range of machinery in the usual rotational speed ranges, but also ultra-slow moving and even intermittently operating equipment.

No, this is not the stuff of fiction. We're talking about the latest developments in acoustic emissions sensing. This is the culmination of decades of toil, dedication and determination, driven in large part by one man with a belief that conventional vibration monitoring for machinery health is not the only – and not necessarily the best – technique. That man is Trevor Holroyd, who worked with Rolls-Royce many moons ago on bearing condition monitoring techniques before setting up Holroyd Instruments and struggling thereafter to get his voice heard.

Dean Smith

But his patented technology – the interpretive systems that sit on top of acoustic emissions sensing, and make it so simple and elegant to use – may finally be about to hit the big time.

Because, two years ago, his company was taken over by much bigger Kittiwake and now that firm, and Holroyd with it, has, in turn, been acquired by Parker Hannifin. We can expect a sea change in marketing and application engineering, as acoustic emissions sensing enters the mainstream.

Tool box treasure

That sea change will be riding the crest of two new product waves launched by Kittiwake at this year's Maintec exhibition, at the NEC in Birmingham. The first is the aforementioned palm-held portable bearing checker – an all-in-one condition monitoring sensor and readout. The second is an arguably even more impressive device that additionally harnesses time domain signal processing to reveal the condition of machinery that runs only intermittently and for fractions of the overall cycle.

Talking of the former, Holroyd says quite simply: "There should be one of these bearing checkers in every plant technician's toolbox. If an electrician turned up without a DMM [digital multimeter], you'd be rather dismayed. So why is it okay for maintenance engineers to turn up with nothing more than a bag of spanners? In 2012, it's just not good enough. This instrument is the equivalent of a mechanical DMM."

Accelerometer or no accelerometer

There are some similarities, but also significant dissimilarities between the three main elastic wave condition monitoring technologies. Both vibration and shock pulse techniques, for example, use accelerometers as the primary sensor, while acoustic emissions looks for travelling waves generated by inter-surface events.

Meanwhile, both shock pulse and acoustic emissions work on the resonance point (approximately 35kHz and 100kHz respectively), whereas vibration monitoring operates at much lower frequencies, typically below one third of the sensor's natural frequency to get the flat response it needs. Then again, shock pulse looks at the first arriving waves, while acoustic emissions focuses on the overall diffuse 'sound', including the echoes.

Those differences matter. Accelerometers have a seismic mass and it is the forces (measured by distortion of the piezo element) on that moving mass that are translated into acceleration (vibration). That's why, in order to get effective measurements, both the positioning and the orientation of accelerometers are critical. They must be in the plane of the bearing – horizontal, vertical or axial – to render valid results.

But with acoustic emission sensing, there is no seismic mass, because the technique is not based on any net movement of the machine. The technique looks for what expert Trevor Holroyd, now with Parker Hannifin, describes as the "uniform glow of sound" propagated by degradation processes – such as crushing, debris, cracking and poorly lubricated surfaces running over one another – throughout the component. And hence orientation and positioning of the sensor are gloriously irrelevant.

Holroyd gives the example of a UK steel company with "a row of gearboxes the size of a domestic kitchen" and through-wall shaft drives. "The plant engineer told us they had found vibration problems on one and challenged us to find which. He also said that, since position shouldn't matter, we were to put our acoustic emission sensor on the bedplate supporting each gearbox on the concrete floor. We did and we were clearly able to show high distress on the right gearbox."

"Without a doubt, this tool will become at least as popular as thermal imaging cameras are now." Trevor Holroyd

Essentially, Holroyd's MHC (machine health checker) comprises a 'smart' sensor with signal processing, battery and display all in a small magnetic instrument. Technicians simply attach it, in any orientation and location, to the machine in question, press the button and around 10 seconds later they see readings of wear-related surface and sub-surface 'distress' and dB (noise level).

Expert in a box

"Without a doubt, this tool will become at least as popular as thermal imaging cameras are now," insists Holroyd. "Why wouldn't maintenance engineers carry one of these with them as first-line condition monitoring tools? It takes the guesswork out of their jobs. And I'm not just talking about service engineers running around the country in light vans. Think about shipping, too: there's a lot of machinery onboard and no capability to consult a condition monitoring expert. I believe a lot of people will soon find this equipment a basic requirement."

The science behind the opposing technologies

Thinking about the frequency range used in vibration sensing, it's not a million miles from background machine noise. Hence the technique's limits at low rotational machine speeds, where the signal-to-noise ratio becomes poor. More importantly, hence also its use of the frequency domain, looking for defects related to 'signature' frequencies in the spectrum.

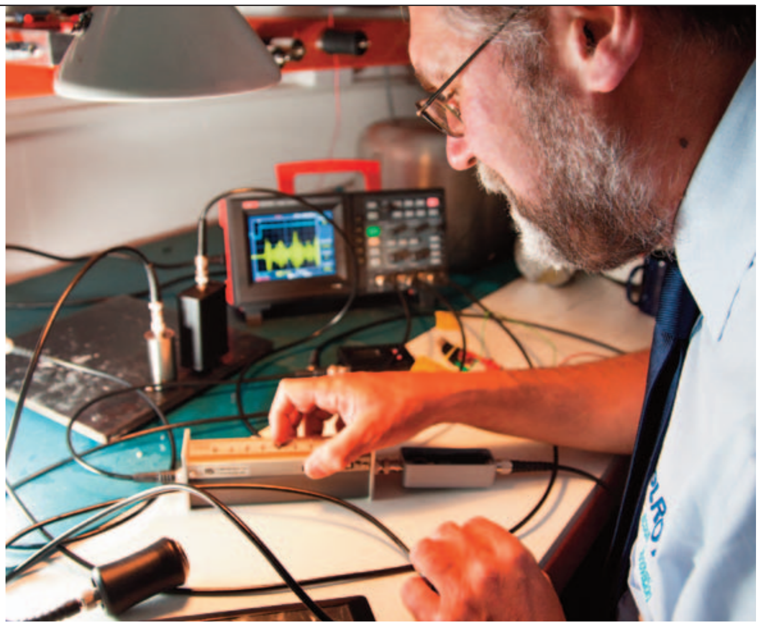
That's why engineers first have to go through the data-gathering exercise – bearing type, shaft diameter, bearing number etc – so that the system knows what it's looking for. It then focuses on relevant frequencies in the spectra it sees and trends magnitudes to pinpoint specific component problems. On the upside, it produces considerable detail over time; on the downside, bearing information is a prerequisite and there is some analysis to get used to.

Acoustic emissions effectively works the other way around. Parameters are instantly recognised as faults and then the monitoring devices are used to see how quickly they're degrading, so that spares can be obtained, the process adjusted and maintenance planned. No bearing data is needed and, for older plants or those where de-manning and/or de-skilling are advanced (meaning no one knows), no stripping plant down is required to find out.

One criticism might be that the technique is not specific, for example, to a bearing outer race or rolling element. That matters if it's a ship's gearbox, but for most plant operations there's no problem, because bearings are replaced whole. However, if it's important, a dip into the frequency domain (as per vibration) reveals the detail. The point is, it's rarely required.

Trevor Holroyd, who concedes no experience with the other wave-based condition monitoring contender – shock pulse – sees it as straddling vibration and acoustic emissions. Why? On the one hand, he argues, because of its dependence on an accelerometer (as per vibration), albeit without the requirement for first-line frequency domain processing. On the other, for its use of the transducer's resonant frequency (like acoustic emissions), in this case to detect the leading edge of shocks, generated by rolling elements moving over raceways.

However, although it's no big deal, he also points out that, for the shock pulse method to work, shaft speed and diameter are required for normalisation. That said, the technique then delivers easy red, amber and green condition diagnoses. Further evaluation again means using FFTs (Fast Fourier Transforms) on the data to detect patterns and bring out the spikes. However, then you also need the bearing type and speed data, as per vibration monitoring.



As for the intermittent machinery variant, it's even smaller, but requires a standard 24V dc supply. The device, which comes in at "well under £500", looks at the same, high-frequency acoustic spectrum (around 100kHz), away from the low-frequency acoustic and mechanical background noise, and is initially connected to a PC.

"You set it up to recognise the running and not running machine conditions, so that it knows when the equipment starts and stops," explains Holroyd. "Then you set up an appropriate delay [500msec or more] for the time it takes for the machine to get up to full speed. Then it starts signal processing. Whenever the machine stops, it sees the dB signal start to drop again and rejects the affected data, just clipping out the element before." And so it goes on, adding the snippets of signal, as and when the machine runs, until it has 10 seconds' worth of good data. Then, again, it delivers the all-important distress and dB readings.

Says Holroyd: "It's pretty mind blowing: there's never been anything like this. You can apply lots of methods to assess the condition of continuous rotating machinery – vibration, shock pulse, acoustic emissions sensing – but there's a lot more equipment on plant that previously couldn't be monitored. Think about belt conveyors that only run intermittently, stacker cranes in a warehouse, and tilting vessels and hoppers.

"Some of this can be critical kit that you couldn't monitor online, unless you were able to put it into a maintenance cycle. But there are limits to that and it's not ideal. So this device is plugging a real gap in condition monitoring." PE