AN OVERVIEW OF THE PREDICTIVE MAINTENANCE APPLICATIONS OF AIRBORNE ULTRASOUND TESTING.

Joseph M. Buckley
Sonatest Ltd,
Milton Keynes England
joe@sonatest.com

ABSTRACT

Detection of Low Frequency (around 40kHz) Ultrasound is a powerful method for maintenance inspection of plant and machinery. Many failure conditions give early indication by the production of ultrasound. These include pressure leaks, electrical discharge and deterioration of bearings and other machinery.

Leakage of compressed air has become a particular issue recently with the promotion of energy / CO2 emission reduction initiatives – most estimates suggest that in excess of 5% of industrial energy use represents wasted compressed air.

This talk will briefly discuss the operating principles and typical equipment, and give detailed examples of industrial, transport, military and aerospace applications.

KEYWORDS
Ultrasonic, ultrasound, leak detection, bearing monitoring, compressed air, partial discharge detection

INTRODUCTION

A Note on Terminology

There is an obvious area of potential confusion between Ultrasonic inspection methods as discussed here, where ultrasound produced by a physical process, or by an Omni directional transmitter, is detected and analysed and Ultrasonic testing as more commonly understood within the NDT community, where a precisely directed beam of ultrasound is used to interrogate a passive physical structure to analyse its properties. While there is an obvious area of overlap in the technologies we will endeavour to distinguish between them by referring to this technique as ULTRASOUND, rather than ultrasonic, testing.

Principles of Operation

As we are aware many physical 'events' cause sound at audible frequencies, which can frequently indicate correct or incorrect operation, for example escaping air or steam, faulty bearings, impacts, friction, electrical discharges etc. etc. Similarly sound at Ultrasonic frequencies (in this context the range from around 20-100 kHz) is also produced. Ultrasound has many advantages for diagnostic purposes:

- Typically ultrasound does not travel huge distances from its source, the attenuation rate in air is significantly higher.

- Ultrasound is more directional – it tends to travel from its source as a 'cone'

- Ultrasound disperses less, and in consequence does not tend to travel round corners. Ultrasound is easily shielded. Given appropriate sensors, airborne sources of ultrasound can be located to within a few mm. With contact probes, sources of ultrasound within a metal structure can often be localised to a few cm.

- Damage processes, such as bearing before, tend to produce detectable levels of ultrasound long before they are severe enough to be apparent audibly.

- Because of the short wavelength (40kHz corresponds to 8mm wavelength in air at standard Temperature and Pressure) It is easy to use highly directional sensing apparatus, allowing the direction of an ultrasound source to be determined to a degree or two.

Therefore ultrasound can be used as an 'earlier warning' of fault processes and the source of the ultrasound can be easily located.

Figure 1: Ultrasound Detector with Parabolic Concentrator

Typical Equipment

The Sonatest SoundScan 101 Receiver consists of:

1. A sensitive high-frequency Microphone
2. An adjustable amplifier
3. Circuitry to "Down-convert" the ultrasound to audible frequencies
4. An analogue meter allowing the ultrasound amplitude to be measured.

Figure 2: Sonatest SoundScan 101 Receiver

All contained in a small hand held package powered by a 9V battery. Headphones are connected to allow identification of the sound source, and in many cases are preferable to the meter for assessment of problems – Typically there are many factors involved, rendering Quantitative measurements of limited validity.

To match the instrument to the application a variety of sound guiding accessories are used. Typically these consist of Airborne ultrasound 'concentrators' attached to the microphone to give an optimised sound detection pattern, alternatively for detecting ultrasound transmitted within a structure, solid 'contact probes' are used.

For localisation of sound in inaccessible areas a set of 'acoustic probes' is used, These can be screwed together to reach approximately 1 metre. An Insulated probe is used when listening around electrical apparatus.

Figure 3: Concentrators

Figure 4: Contact Probes

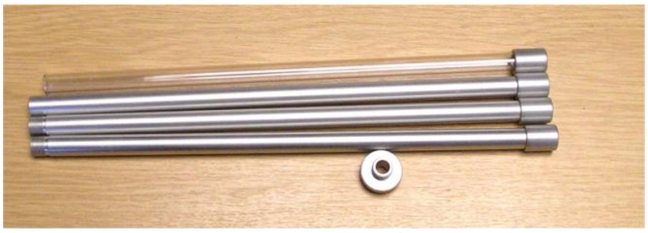


Figure 5: Acoustic probe set

Other manufacturer's equipment is broadly similar in principle. Particular variations include:

1. The use of separate receiving transducers for different applications, which plug in directly or via a cable.
2. A greater emphasis of Quantitative Results. Opinions vary on this. Ours is that it can in most applications, lead to a false impression of precision. Others accept its limitations, but consider it extremely useful in defining acceptance criteria
3. Some instruments have inbuilt data loggers or signal recorders. Typically this requires digital circuitry which imposes a significant increase in the power requirement. This impacts the weight, convenience and battery life.
4. Variable frequency , This is seldom essential, since ultrasound generators are normally broadband, however it can give advantages in certain applications, such as detecting underground water leaks, where lower frequencies are attenuated less by concrete or earth.

Enhancements to Equipment

Commonly used enhancements include:

1. More sophisticated reflection and focussing systems, for example the Sonatest Powerbeam 300 shown in figure 1 extends the range of the equipment by a factor of around 3 times, and reduces the angle of peak sensitivity to approximately 2 degrees. This allows distant noise sources such as overhead air leaks and electrical discharges (for example from defective high voltage power line insulators) to be localised with great accuracy.
2. A separate ultrasound transmitter for use in detecting 'passive leaks' i.e. where no pressure is present, examples of this include enclosure seals, vehicle window seals, weld lines on tanks (quite small pinholes can be found), and marine cargo hatches.

3. Data or signal logging equipment, allowing down-converted waveforms to be recorded and analysed. This can be internal , PDA or PC based. Some systems record full waveforms, allowing detailed analysis others just amplitude points.

APPLICATIONS

Pressure Leak Detection

Turbulent flow of Gas through a small orifice will generate significant ultrasound allowing very small leaks to be detected from quite a range –

Airborne Ultrasound is the method of choice for detecting leaks in Steam, process gas, vacuum and particularly compressed air systems.

This has gained particular importance recently as companies strive to improve energy efficiency and reduce their CO2 emissions. Many governments are actively promoting the use of this equipment and supporting it with tax incentives, as a wide variety of surveys in different countries[(1)(2)(3)] have found Compressed air leak reduction to be one of the most cost effective energy conservation programs. – The ‘average’ manufacturing company is reckoned to waste around 4% of its energy bill in leaked compressed air. A regular survey using an ultrasonic leak detector allows leaks to be detected, tagged and prioritised for repair. As well as the environmental benefits the financial payback is very rapid, often a matter of a few months or even weeks.

Leaks of other kinds of gas can be detected equally easily, Sound propagates both sides of the hole, and the principle is equally applicable to location of vacuum leaks- This equipment is used by NASA to find leaks to space in the Shuttle and International Space stations, Important from both a safety and an economic point of view - Air transported into orbit costs around $25,000 per kilo

Monitoring of Bearing condition

As ball or Roller bearings rotate the friction and impacts between the parts generate ultrasound. Normally operating bearings produce a steady level of ultrasound. If the bearings are under lubricated this becomes much louder and harsher. Conversely over lubricated (this can give rise to overheating and rapid degradation of the lubricant) bearings make very little sound.

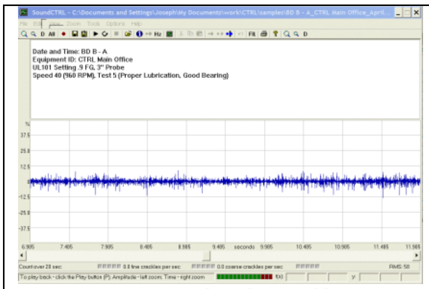


Figure 6 : Properly Lubricated bearing

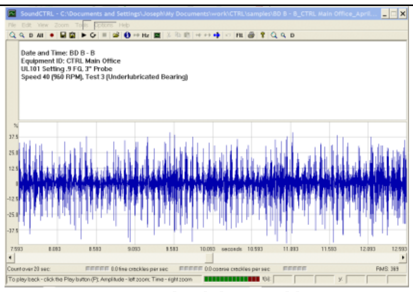


Figure 7: Under-lubricated bearing

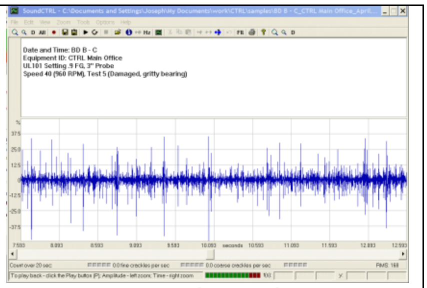


Figure 8: Bearing with minor damage / grit in grease

Bearings which are beginning to fail typically have small particles of metal in the lubricant or have small surface irregularity

Electrical Discharge Detection.

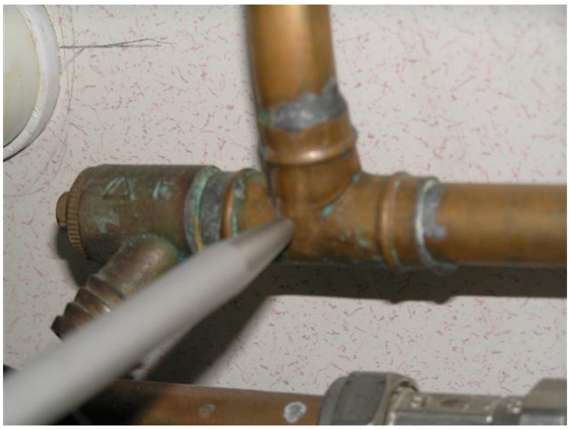
Most electrical discharges emit ultrasound which can be used to detect them. Examples include:

- Arcing at Loose / Poorly terminated connection
- Corona discharge from high voltage connections
- Partial discharge from voids in insulators, or where air gaps exist between high voltage connections [Because the dielectric strength of air is less than that of insulation materials such as silicone rubbers, an air gap actually reduces the insulation strength]
- Tracking across high voltage insulators

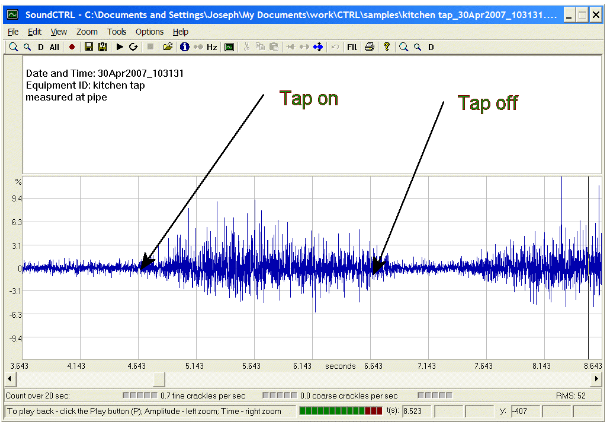
Ultrasound allows these problems to be located:

- In industrial environments where background noise prevents sound being used to hear arcing
- In bright lighting conditions which prevent visible indications. (Sparks)
- From a safe distance
- Without special access equipment especially using parabolic concentrators, which can detect ultrasound from overhead power lines

Liquid Flow Monitoring



Quite small fluid flows passing through a restriction or bend can produce significant turbulence, generating enough ultrasound to be easily detected. The example illustrated shows the ultrasound levels measured with a contact probe at a joint approximately 30cm from a domestic tap. The smallest stable flow from the tap (approx 0.1 l/minute) produces a signal approximately 15dB higher than the noise level. Signals measured at the tap are far higher



Tightness Testing

By using an ultrasound Transmitter placed inside an enclosure which is 'meant to be sealed' ultrasound technology can find leaks where no inherent source of ultrasound is present.

Examples of this include:

- Investigation of tank seals, both military and storage.
- Vehicle seals around windows etc.
- Checking for leaks in welded/ fabricated vessels
- Waterproof enclosures for equipment or switchgear
- Marine Cargo hatches
- Shipping containers
- Checking of sealing around access points on bulkheads, for example where cable s pass from one compartment of a ship to another.

Other Applications

Ultrasound can be used to listen to a wide range of equipment (4) in order to verify its correct function or identify problems. Examples include:

- Steam traps
- Vehicle engines, listening to spark plugs, bearings, fuel injectors, valve operation, exhaust leaks etc.
- Gearboxes.
- Valves in industrial compressors.
- Location of hidden water leaks
- Switchgear, for example you can listen to one of a row of industrial contactors.

CONCLUSIONS

Ultrasound Testing is a very useful general purpose tool to have in the inspection box. From my own personal view of having worked in NDT for over twenty year until I became aware of its full capabilities I was very surprised at the range and versatility of the technique. While many of the tasks are outside the traditional NDT field there is a considerable overlap, and it offers a straightforward and low cost solution to a number of problems that I have previously encountered, and been unable to solve.

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