Acoustic conversion efficiency

Acoustic conversion efficiency describes what fraction of the input power to a machine is converted to noise. A low acoustic conversion efficiency is required. Typical values are between 10^{-5} to 10^{-8}, with many sources in the 10^{-7} to 10^{-6} region. A kilowatt machine (10^{3}W) might produce 10^{-3} watt of acoustic power, giving a sound power level of 90dB, and leading to a sound pressure level of about 80dB a meter away.

There are equations, based on measurement and experience, for predicting machine sound power, but these are only indicative and limited to the range for which they were developed. An example is for reciprocating compressors, in which the sound power level over the 500Hz to 4000 Hz octave bands is approximated by

$$Lp \approx 10\log W + 85$$

where W is electrical input power (kW) of the compressor motor. Then for a 50kW motor the compressor sound power is in the region of 102dB, which is an acoustic conversion efficiency of $3x10^{-7}$.

Wind turbines are interesting. The wind gains its power from the sun, so that wind is a form of solar energy. The power of the wind flowing through area A, at wind speed υ and air and density ρ is

$$W_{wind} = \frac{1}{2} \rho A \upsilon^3 \text{ watts}$$

which shows dependence on the cube of the wind speed. A wind turbine with 80m diameter rotor at a wind speed of 10m/s will be intercepting about 3MW of wind power and producing around a third of this (1MW) of electrical power[1]. The wind turbine might have an A-weighted sound power of 100dB (0.01W) and a linear power of 110dB (0.1W). Referenced to the wind, these give $3x10^{-9}$ and $3x10^{-8}$ power conversion, but referenced to the electrical output they give 10^{-8} and 10^{-7}. Either way, wind turbines are amongst the most inefficient converters of energy to noise, and relatively quiet. It is, of course, the sound quality of the repetitive swish, sometimes occurring with wind turbines and typically in the 500Hz to 1000Hz region, or higher, rather than its sound level which might lead to disturbance.

Microturbines are claimed to be "whisper quiet". This is not surprising since they rarely produce more than about a kilowatt of electrical power. Most problems are likely to occur where the mast is attached to a building, flexes under gusts of wind, then resonates and transmits vibration into the building, leading to structure borne sound.

Noise reduction of a machine should be aimed at reducing the magnitude of the acoustic conversion efficiency, focussing attention on the motive power of the machine, its transmission within the machine and the interface with the surrounding air, whether through surface vibration or aerodynamic interaction.

Quietness comes from careful design for low acoustic conversion efficiency.

COMBAT NOISE

On modern battlefields, a major problem is noise. All the gunfire, equipment sounds and explosions makes it difficult for the troops to communicate. Radios for each soldier have become common in the past few years, but there's still the noise problem. Noting the growing capabilities of noise cancellation systems, several former American special operations soldiers founded a company (Silynx) to produce a solution especially designed to deal with the needs of the combat trooper. Out of that came QuietOps, an in-the-ear (iPod style ear buds) noise cancellation system that plugs into military communications systems. The noise-cancellation hardware and software are state-of-the-art, and the user can quickly switch modes via a wireless controller that attaches to the rail that comes on most assault rifles these days. That way, the user never has to take their hand away from their weapon. The system can be set to just suppress sudden loud noises, or all loud noise, while letting quieter sounds through. So far, Silynx has not shipped the product. But something like QuietOps is certainly feasible. The device also has civilian uses, as in noisy construction sites, manufacturing facilities, the flight line, among others.

FOOTBALL STARS 'SHOULD WEAR EAR DEFENDERS'

As part of its 'Shout About Noise Reduction' campaign, UK construction equipment rental company Hewden, is issuing a stark safety warning to football clubs that are failing to comply with the latest health and safety legislation regarding harmful levels of noise. The 'Control of Noise at Work Regulations', introduced in April 2006, require that hearing protection must be made available to all employees exposed to excessive noise levels over a specific period of time. In football terms, this level equates to 87dB over the course of a match. According to Hewden, research carried out to date shows that the permitted noise level is exceeded at no fewer than eight Premiership grounds. However, none of the clubs provide hearing protection for their employees - or players! "Like any business, football clubs have a responsibility to protect their employees. The regulations are not about preventing noise, simply controlling it," said Jeff Schofield, Head of Marketing at Hewden. Furthermore, the clubs with the loudest fans, such as Manchester United, Portsmouth, Liverpool and Newcastle, experience noise levels well in excess of 92dB. According to the legislation, all members of staff, such as managers, stewards, officials and players are legally required to wear ear defenders provided by their employers. "Football stars may soon find themselves in a position where the latest 'must have' accessory is a set of designer earmuffs!" added Jeff Schofield.