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Focus on psychoacoustics

How is a fan supposed to sound?

Our sense of hearing works constantly and without respite, so our ears receive noises 24 hours a day. About 15,000 hair cells in the inner ear catch the waves from every sound, convert them to signals and relay the signals to the brain, where they are processed. This is the realm of psychoacoustics, a branch of psychophysics. It is concerned with describing personal sound perception in relation to measurable noise levels, i.e. it aims to define why we perceive noises as pleasant or unpleasant. Responsible manufacturers take the results of relevant research into account when developing fans.

When we feel negatively affected by a sound, for example when it disturbs us, we call it noise pollution. Whether this is the case depends on many factors (Fig. 1). Among other things, our current situation plays a role, as do the volume and kind of sound. The same is true of fans, which need to fulfill different requirements depending on where they are used. For example, if they are used on a heat exchanger in a cold storage facility where people spend little time, low volume or pleasant sound is not an issue. But ventilation and air conditioning units in living and working areas have to meet much different expectations. However, that does not mean that fans have to work noiselessly. In many applications, their operating noise serves as a functional check; a typical example of this is a kitchen range hood.

Noise spectrum of a fan

Noise generation is often a crucial consideration when deciding which fan to purchase. In addition to aerodynamic data (air performance), the sound power level becomes an important property. The noise spectrum of a fan generally includes tonal and broadband components. The ways in which these components arise are completely different. Most tonal components arise from the interaction of the rotating impeller with disturbances in the adjacent air flow, which can be caused by struts, guide blades, asymmetric inflow, etc. Their origin thus depends on how the fan impeller is installed. Often, they can be reduced or even prevented by improving the placement of the impeller. In contrast, most broadband noise components are caused by unavoidable turbulence in the inflow and the inherent flow around the blades. The broadband components determine the base level of a fan's noise spectrum. Here manufacturers have made progress and know of many ways to reduce fan noise, including aerodynamically optimized fan impellers, winglets, diffusers and air inlet grilles, with which the sound power and

noise level of fans are reduced considerably. Fig. 2 shows an example of the substantial noise reduction that can be achieved by using the FlowGrid air inlet grille and the AxiTop diffuser.

A drop of a few decibels in the noise level means that a fan works much more quietly. However, the noise level determined by physical measurements in a test system says nothing about whether we perceive the sound as pleasant or unpleasant. For example, trumpet music and an excavator at a construction site have approximately the same sound power, but our psychoacoustic assessment of them is completely different. Fig. 3 shows a further example: In this case, the spectra (the two curves) can be distinguished, but their overall level is (nearly) equal: 69.7 dB(A). What is crucial here is that, based on the spectrum, it is impossible to draw conclusions about whether the sound will be perceived as pleasant or unpleasant. One might assume that the blue spectrum (music!) with its higher proportion of low frequencies would be more unpleasant. But human hearing assesses the sounds quite differently.

Quiet is not enough

For subjective judgments, important characteristics include how “rough” or “sharp” a sound is perceived as being. Such perceptions can arise when a signal is given a temporal structure by changes in its frequency or amplitude. Many sounds also include tonal components that can have a strongly irritating effect that differs from person to person, which further complicates their evaluation.

The motor and fan specialists at ebm-papst Mulfingen have addressed this issue, once again taking on a pioneering role. After all, they want their quiet GreenTech EC motors to have a pleasant sound. For the developers, a worthwhile long-term goal would be a manufacturer-independent standard for noise annoyance similar to the existing regulations for noise protection. For example, even when it satisfies the German Technical Guidelines for noise protection (TA Lärm), an air-heating pump installed outdoors can annoy neighbors with its irritating hum to the extent that harmonious coexistence is no longer possible. In such cases, it is better to work with fans that have been optimized according to psychoacoustic criteria.

Searching for pleasant-sounding fans

To conduct tests, ebm-papst has set up a so-called psychoacoustics lab, the “AudiMax” (Fig. 4). This is a soundproof room with room for up to eight test subjects who listen to recorded fan sounds in various configurations. Employees question the subjects afterwards to build up a scientifically founded database based on the following psychoacoustic parameters: loudness (unit: sone), sharpness (unit: acum), pitch (unit: mel), roughness (unit: asper) and fluctuation strength (unit: vacil). Other important quantities are tonality and impulsiveness. They can be measured with microphones (Fig. 5) and compared with comments made by the test subjects.

Assessments by the test subjects are analyzed with statistical and psychological methods. The results are used in product development; they make it possible to ascertain which measures are effective at reducing noise annoyance caused by fans and which are not. The ultimate aim is to develop a fan that is perceived as pleasant

by as many test subjects as possible. The “AudiMax” thus makes a contribution to the further refinement of GreenTech EC technology. Reducing the annoyance caused by noise is an important development objective from an ecological perspective since noise is a form of pollution. Irritating noise is an impairment to quality of life and, in the worst case, can even lead to illness.

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Fig. 1: Fotolia

Fig. 2-5: ebm-papst

Figure 1: Our sense of hearing works constantly and without respite, so our ears receive noises 24 hours a day. About 15,000 hair cells in the inner ear catch the waves from every sound, convert them to signals and relay the signals to the brain, where they are processed. (Photo: Fotolia)

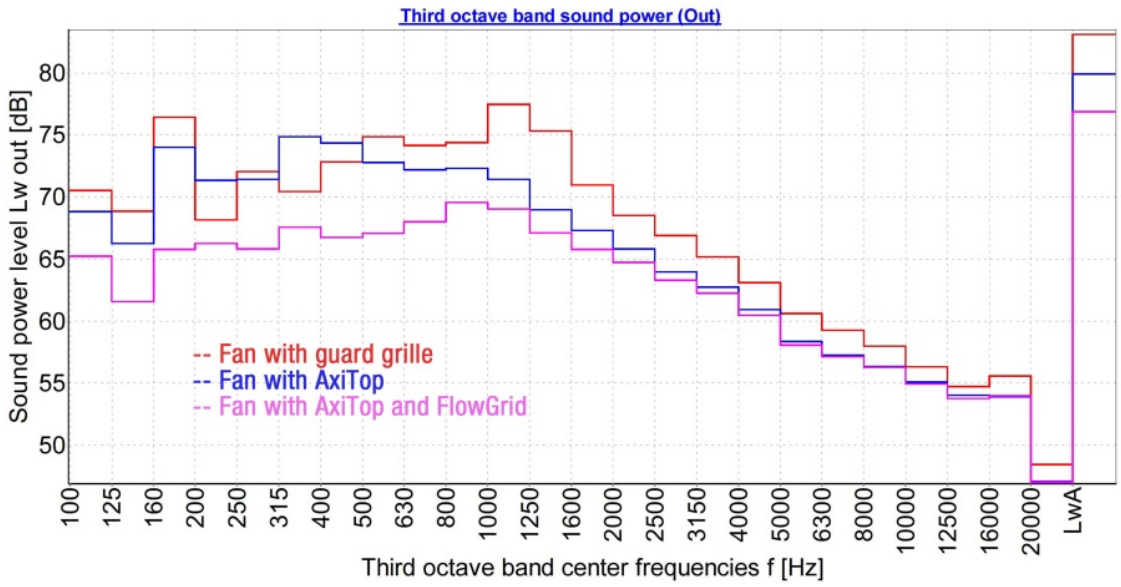

Figure 2: A noticeable reduction in noise can be achieved with the FlowGrid air inlet grille; it can be reduced even more in combination with the AxiTop diffuser. (Photo: ebm-papst)

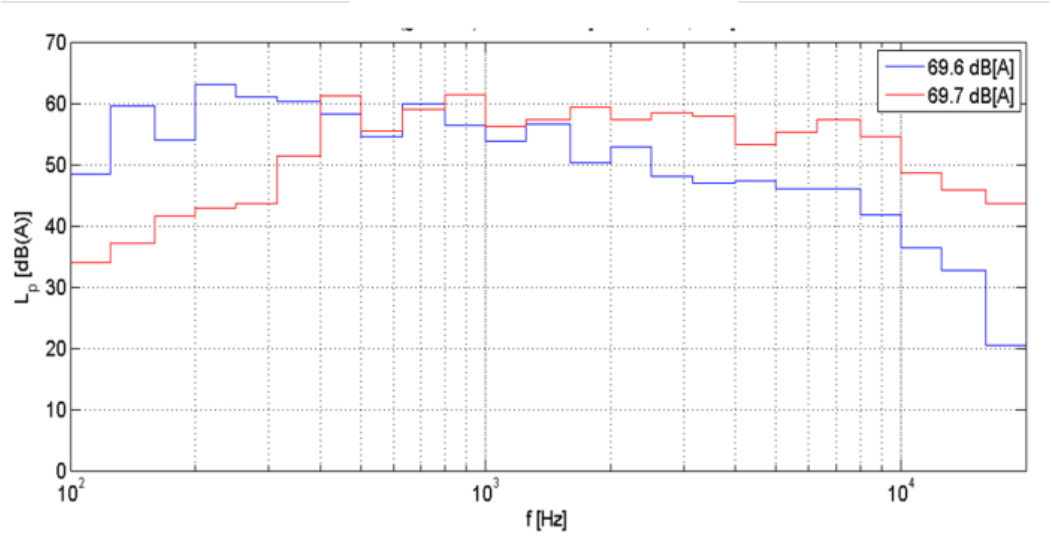

Figure 3: The noise spectra of a piece of music (blue) and a size 250 EC fan (red) are similar but are perceived quite differently. (Photo: ebm-papst)

Figure 4: Searching for pleasant-sounding fans: This is a soundproof room with room for up to eight test subjects who listen to recorded fan sounds in various configurations. (Photo: ebm-papst)

Figure 5: Specially positioned microphones for recording psychoacoustic parameters. (Photo: ebm-papst)

About ebm-papst

The ebm-papst Group is the world's leading manufacturer of fans and motors. Since it was founded, the technology company has continuously set global market standards. Developments have ranged from electronically controlled EC fans, through aerodynamic improvements of fan blades, and on to the resource-conserving selection of materials, with sustainable materials being just one option.

In fiscal year 2015/16, the company achieved sales of almost €1.7 billion. ebm-papst employs approximately 12,500 people at 18 production sites (in Germany, China, the United States and elsewhere) and in 57 sales offices worldwide. Fans and motors from the global market leader can be found in many industries, including ventilation, air conditioning and refrigeration, household appliances, heating, automobiles and drive engineering.