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Different analysis methods for centrifugal fan noise

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This work tackles the difficulties that appear with measuring- and analysis techniques for industrial centrifugal fans. In the made study we've tried to achieve data of a centrifugal fan in order to find a characterising fingerprint of the fan itself. Simply looking to the spectral information seems not to offer a detailed view of the underlying phenomenons. This due to several reasons: like the enormous impact of the generated wind and the limits of the techniques themselves. We've analysed the fan using soundpressure techniques and intensity techniques in anechoic and reverberant rooms respectively.We believe that a fingerprint requires at least both time and frequency information even if fan noise is considered stationary. The made measurements are analysed using wavelet analysis which offers a broader platform to characterise different relations between the mechanical construct and the noise. This by looking to self similarities, discontinuities, pure tones and short term evolution of the noise.

1. INTRODUCTION

Measuring fannoise is traditionally done using a pressure microphone on a distance of one meter from the fan. This technique gives the necessary measures that allows one to quantify the produced noise. However, the generality of this measuring approach doesn't result in information about the sources for the produced noise. In particular cases it is interesting to be able to tell something about the fanstructure given the measured noise data. A better approach is to use intensity measurements which offer also information about the directionality of the measured noise.
A standardized, reliable noise measurement method is not available yet. There are a number of national and international standards dealing with the problem: they prescribe measures in free-field conditions, in reverberant room (with or without a plenum connected to the fan) and in-duct measurements. Each of these techniques has its advantages, as well as its limits. We explored, specifically, the intensity technique in diffuse field (not in a reverberant room) and pressure measurements in a semi-anechoic room.

2. The studied fan

Figure 1: Used Centrifugal Fan with grid for Experimental Study

The machine we studied in detail is a centrifugal fan with forward-curved blades. It is a medium sized machine with double inlet with a nominal speed of 1260 rpm, a minimal pressure increase of 190 Pa with maximum volume flow rate of 6670 m3/h. It is driven by a single-phase asynchronous integrated motor that can be adjusted in speed via voltage control.
The operational configuration chosen for the measurements is free *inlets-free outlet*; considering that fan noise is strictly dependent on the point of rating and on the installation conditions, it has been used a configuration that does not imply any ducts connected to the fan. In this way, the source could be analyzed independently.

3. Used Measuring and Analysis Methods

We've used the traditional pressure measurements and also intensity meaurements to retrieve information about the generated fannoise.
The pressure measurements have been done using the EUTERPE probe [2] in a semi-anechoic room. The intensity measurements were done by a Bruel& Kjaer intensity analyser in a diffuse labroom.

To analyse the fannoise we've used three analysis methods.
1) The EUTERPE analyser was used to calculate the pressure based acoustic properties.
2) The Bruel&Kjaer Noise Source Location (NSL) software is used to analyse the measured intensity and to map it on a grid.
3) The Mathlab wavelettoolbox [3] to apply a waveletanalysis on measured soundfragments.

4. Measured Data

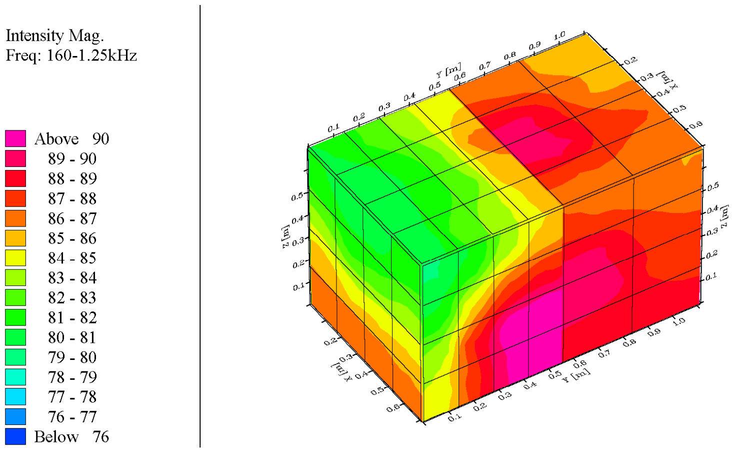

Figure 2: Intensity map calculated by the software NSL (Bruel&Kjaer) from the measurements with a 50 mm spacer.

In Figure 2 you can see the relative importance of the main noise sources: the inlets (red and purple) and the housing (green and orange). It was impossible to make measurements on the front side, this is why the pictures refer just to the rear, the top, and the right and left sides of the measurements surface. The intensity measurements showed this big limit: a flow impinging on the probe influences a lot the results.

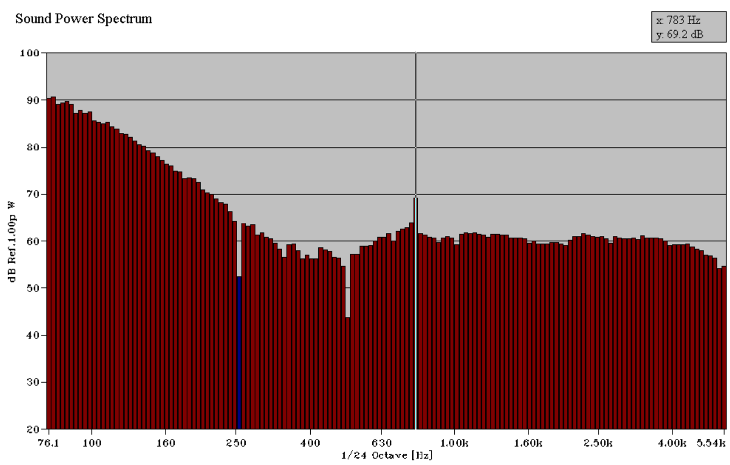

Figure 3: The effect of the wind

Figure 3 shows clearly the effect of the generated air flow on the front measurements. All the lowerfrequency components are influenced. This makes it very difficult to put a link between lowfrequency noise created by the machine and the measured data.

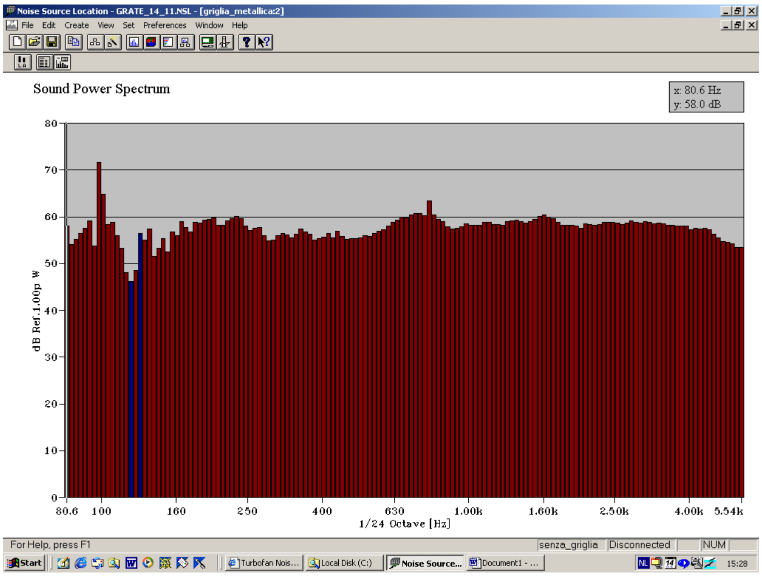

Figure 4: The effect of a grate in front of the fan

In fugure 4 we've demonstrated what happens when a grate with holes is put in front of the wind generating parts. It is clear that the measurement is les influenced by the airflow and new frequency components become visible in the lowfrequency part. The largest among them (around 100 Hz) is related to the motor rotational speed.

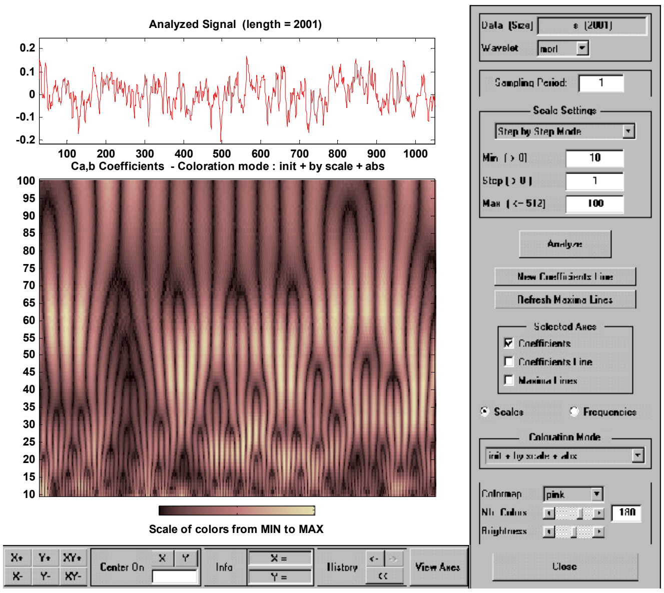

Fig. 5: this is the results of Continuous Wavelet Transform with Morlet Wavelet.

A continuous Wavelet Transform with Morlet Wavelet was done on about 1000 samples of one of the signals recorded in the anechoic chamber (sample frequency=48000 Hz). Apparently it is nothing useful but if you put it in comparison with the Wavelet Transform of a FRACTAL signal, you can realize that there are a lot of points in common. In particular, the self-similarities that one can see are related to the chaotic nature of the signal. Realise that the main cause of fan noise is turbulence: more precisely, the turbulent boundary layer on the blades causes chaotic forces on the blades that become sound sources this way. Maybe it's possible to relate the blade passing to the maxima one can see in the figure. Finally, fan noise is intrinsically no-stationary even if we always assume the contrary when are analyzing it.

5. CONCLUSIONS

This research has been able to stress on the need of further investigation on centrifugal fan noise, firstly on a definitive reliable measurement method and then through innovative analysis techniques. As far as signal processing, it is interesting to notice that frequency domain is not the only possible research mean; even time domain and time-scale domain can supply useful information. Time-scale domain, for example, by means of the Wavelet transform, throws light on the intrinsic non-stationarity of these signals and of their origins. In contrast to other analysis methods, such as Short Time Fourier transform, wavelets are able to reveal self-similarities at different scales. This reveals the fractal or pseudo-fractal nature of this kind of phenomena. Actually, it is worth noticing that aerodynamic noise is substantially chaotic in nature, being caused by turbulence.

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