INDUSTRIAL APPLICATION OF SIMPLESILENCE TECHNOLOGY: EVAPORATOR FAN NOISE CONTROL

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1. INTRODUCTION

Tonal noise control from evaporator fans used for cooling a cold storage room is described. The low frequency tone at blade passage frequency (BPF=90Hz) can result in environmental noise penalty (added to the global noise level) in the residential area near the cold storage room. For low frequency, passive techniques are bulky, inefficient and cannot be applied to the food industry due to hygienic constraints, but the SimpleSilence technology is better adapted to those frequencies and have a great potential for hygienic and "at the source" control.

Tonal noise originates from non-uniform flow that causes circumferential varying blade forces and gives rise to considerably larger radiated dipolar sound at the BPF and its harmonics[1]. For the evaporator studied in this paper, the primary non uniform flow mainly came from the motor struts and the ice accretion in the upstream flow field of the fan (in the casing or on the struts supporting the motor). For low speed axial fans, the circumferential flow pattern having the same number of lobes as the number of blades (B) will emit intensive sound at the BPF.

2. METHOD

The concept of SimpleSilence technology is to produce destructive interference between the primary source and a B-periodic obstruction[2,3]. The flow control obstruction (Fig. 1) is located such that the secondary radiated noise is of equal magnitude but opposite in phase compared to the primary noise.

Figure. 1. Left: example of flow control obstructions installation (upstream view). Right: rotor and its environment (strut, ice accretion, radiator…)

The obstruction can be located upstream or downstream. When located upstream, the secondary noise is caused by obstruction/rotor interaction and when it is located downstream, the secondary noise is caused by rotor/obstruction interaction. The magnitude of the secondary noise can be controlled by the axial distance between the rotor and the obstruction, or by the radial extent of the lobes of the obstructions. The phase of the secondary noise can be controlled by the angular location of the obstruction. On the downstream side of the fan, a positioning device allowed for the obstruction to be moved in the angular position. The fan (right of Fig. 1) had B=4 regularly spaced "basic blades" and its rotational velocity was 1370 R.P.M., corresponding to a BPF at 91 Hz. The fan diameter was 91 cm. The B=4 period trapezoidal obstructions used in this study (shown in Fig. 1) were made of stainless steel and had an inner diameter of 67 cm and an outer diameter of 80 cm. Acoustic pressure measurements were performed at 3 microphone locations (2 downstream and 1 upstream), using a multifunction 4 channel acoustic measuring system.

3. RESULTS

3.1. Control near the fan

The average of sound pressure spectra measured at 3 microphone locations around fan 1 and fan 2 are shown in Fig. 2. The attenuations of the BPF were about 6 dBA and 3 dBA for fan 1 and fan 2 respectively. The global attenuations were about 0.8 dBA and 2 dBA for fan 1 and fan 2 respectively.

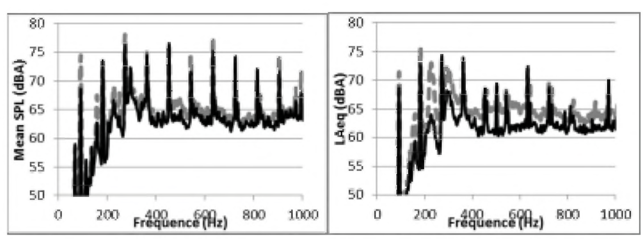

Figure. 2. Averaged sound pressure level spectra from Fan 1 (left) and Fan 2 (right). Dashed grey line: fan noise without the flow control obstruction and solid line: fan noise with flow control obstruction

Close to the evaporator, better attenuations of the BPF tone were obtained in the upstream flow field (up to 10 dB for the two upstream microphones).

3.2. Control in the residential area

The A-weighted sound pressure spectra measured in the residential area near the cold storage room are shown in Fig. 3 (without the obstructions and with the obstruction installed for 5 fans). The BPF tone was decreased by 2.4 dB (several harmonics was also attenuated). The equivalent continuous A-weighted sound pressure level was 55.8 dBA without the flow control obstructions and 51.9 dBA with the flow control obstructions, leading to an attenuation 3.9 dB.

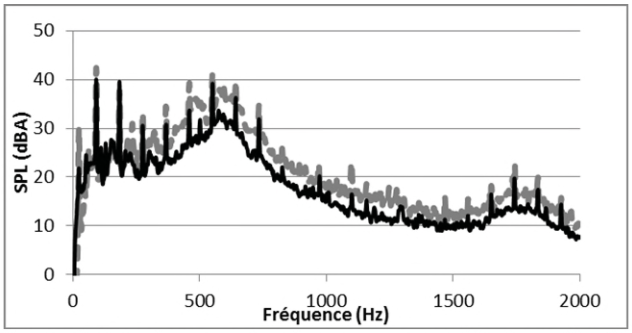

Figure. 3. Sound pressure level spectra measured in the residential area near the cold storage room. Dashed grey line: without flow obstructions and solid line: with flow control obstructions.

4. DISCUSSION

The reduction of the broadband noise from fan 2, and other evaporator fans in the cold storage room (not shown in this paper), was unexpected. For example, the spectrum from fan 2 without flow control obstruction exhibits subharmonic narrowband peaks around the first and the second harmonic of the BPF, which is probably caused by rotating blade flow instabilities at the blade tip. The obstruction probably controlled these instabilities so that the narrowband peak and low frequency broadband noise were decreased. CFD simulations could give more insight in the flow topology without and with the obstruction.

No aerodynamic performance measurements were performed in the cold storage room. However, experiments on several other fans with and without flow control obstruction located in the upstream flow field showed that the control obstruction has low or almost no effect on the fan efficiency. For controlling the BPF tone from an automotive engine cooling axial fan (Siemens-VDO)[3], the effect of a 121 cm2 obstruction (the area of the rotor was 707 cm2) was negligible on the static pressure, the flow and the efficiency of the fan. Same trends were observed for Valeo cooling fans. For large centrifugal fans, the flow decreased by 1% to 2% when the obstruction was in place[4]. The worst flow loss (3.5%) was measured for a tractor axial fan using a large sinusoidal obstruction in the upstream flow field[4].

The proposed approach is well adapted to acoustically compact fan (large wavelength, compared to the source dimension), for which one unsteady lift mode has a major contribution to the radiated noise at BPF. Increasing the rotation Mach number or the radius of the fan leads to an increase of the number of the radiating circumferential unsteady lift modes contributing to the noise at a single frequency (especially the modes B-1, B and B+1). In[5], a method has been proposed to combine a B-1 and a B lobed obstruction to enhance spatially the control of the BPF for a small radiator cooling fan in anechoic conditions.

The control approach is adapted to the control of PC fans, air conditioning fans, residential heat pump, automotive fans, engine cooling fans…

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