SmartAnswer – Reduction of the broadband noise of centrifugal fans used on HVAC in buildings

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Smart Mitigation of flow-induced Acoustic Radiation and Transmission for reduced Aircraft, surface traNSport, Workplaces and wind enERgy noise

Host institution

Partnership

Motivation

In previous years, **serrations** in both the blade **trailing** and **leading edge** have started to be used in the fan industry. Nevertheless, their effects are not yet well understood and for this reason not 100 % effective.

At the same time, most of the academic studies have been focused on **fixed airfoils**, whereas research on full-size fan prototypes is comparatively limited (and usually concentrated on axial fans).

Main objective

To assess different noise control solutions on a commercial **plenum fan** working on **source attenuation** on the leading and the trailing edge.

Ziehl-Abegg's C series fan

Existing background

Broadband noise reduction with **leading edge (LE) serrations** has been investigated on airfoils [1] and fans [2], and the following noise reduction mechanisms have been identified both numerically and experimentally:

- Destructive interference of the scattered surface pressure
- Cutoff effect due to the oblique edge
- Stall delay

Trailing edge (TE) serrations [3] also reduce broadband noise by the following mechanisms:

- Reduction of spanwise correlation associated with sound radiation
- Influence on the hydrodynamic field at the source location
- Vortex shedding suppression

Methodology

Experimental Approach

- Manufacturing of impeller prototypes with serrated blades (LE or TE)
- Acoustic and air performance measurements in a double reverberant room

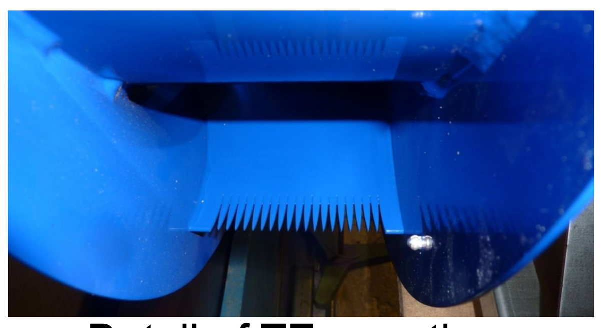
Numerical Approach

- **CFD** simulations to get an insight into the flow pattern through the impeller
- Extraction of significant flow parameters:
  - Design of serrations
  - Input for analytical models

Analytical Approach (secondment in ECL)

- Adaptation of Amiet's model to a plug fan

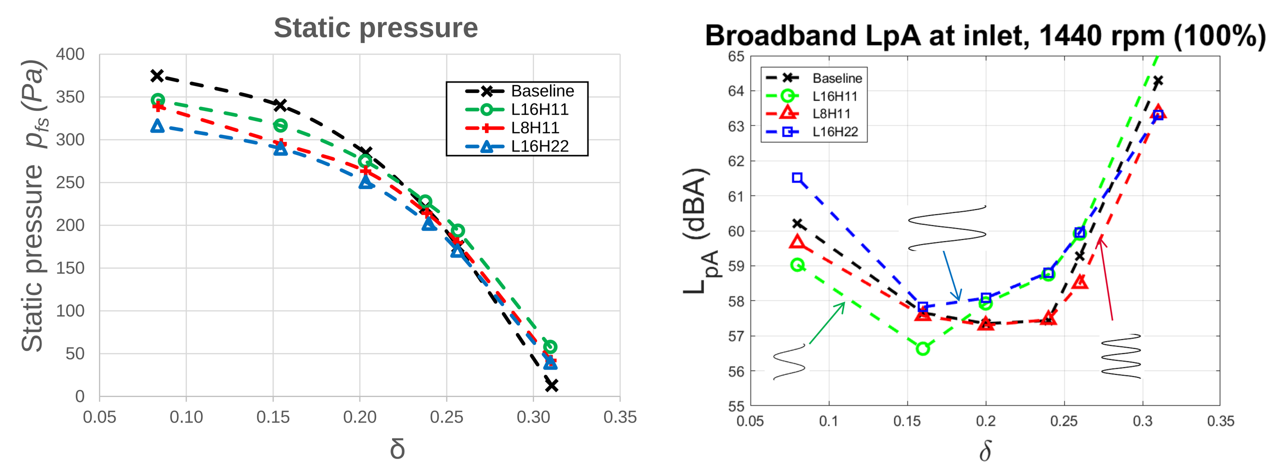
Impeller prototype with LE serrations on the blade



Detail of TE serrations on the fan blade

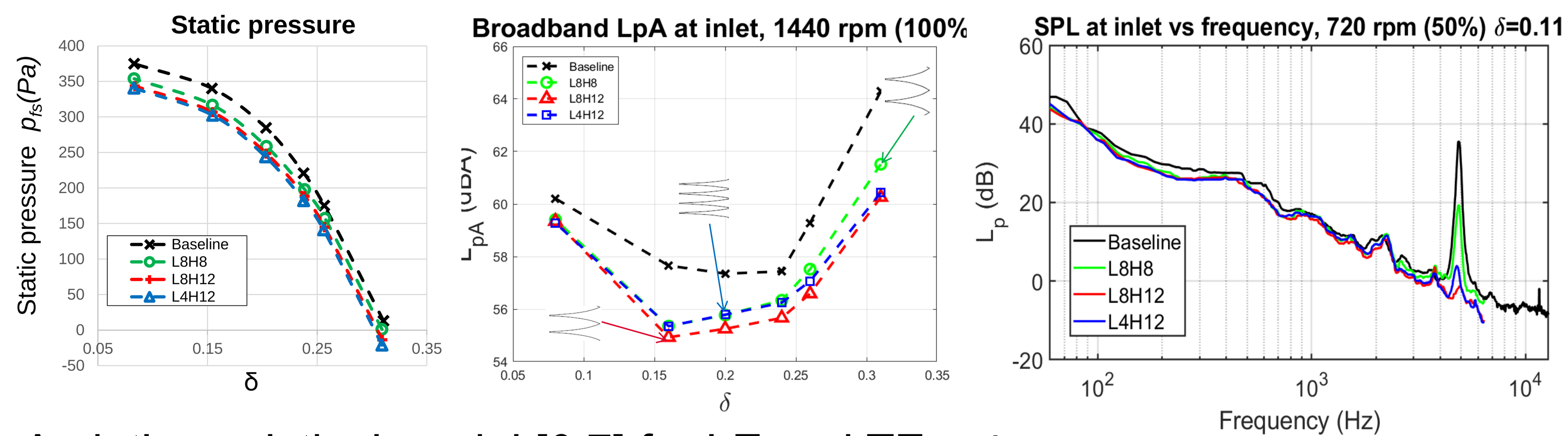
Results

Three impeller prototypes with sinusoidal leading-edge-serrated blades were manufactured, based on design criteria for airfoils [1]. With respect to the baseline fan, a pressure drop has been observed for most operating points, with a slight gain at high flowrate. A mitigated sound power reduction has been measured, only for some configurations and operating points. Moreover, when achieved, noise reduction occurs at low to mid frequencies but there is also a noise increase over 1 kHz.

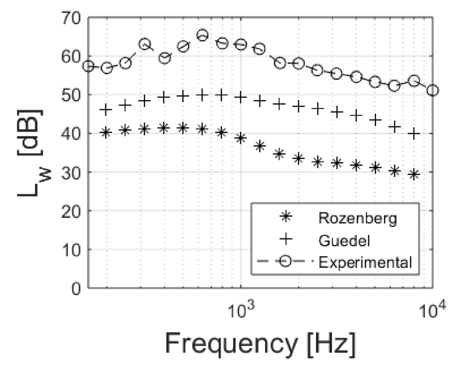


$$\delta = \frac{q_v}{US}$$

Three additional prototypes with iron-shaped TE serrations, based on results for fixed airfoils [4,5], were also built and tested. Experimental results show a drop on the fan pressure. However, noise is reduced for all geometries and operating points, and this along the whole spectrum. A substantial noise reduction has been observed for low flowrates and 50% of the nominal speed, due to the mitigation or cancellation of a high amplitude peak at high frequency (probably laminar boundary-layer vortex shedding).



Amiet's analytical model [6,7] for LE and TE noise was adapted to a centrifugal fan. The latter mechanism seems dominant over the former, but the predictions are way lower than the measurements. Other noise sources may possibly be present.



Conclusions

Prototypes of a plug fan with serrated blade edges

- Leading edge serrations
  - Slight noise reduction for some geometries and operating points
  - Noise increase at high frequency
- Trailing edge serrations
  - Broadband noise reduction for all geometries and operating points
  - Strong reduction of peak at high frequency and low flowrate

Adaptation of Amiet's LE/TE model to a centrifugal impeller

- Strong underprediction of L_W
- TE noise dominant over LE noise

References

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