Testing of Fans with Microperforated Housings

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Testing of Fans with Microperforated Housings

Seungkyu Lee and J. Stuart Bolton

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Purdue University
Acknowledgement

The author acknowledge the support of 3M Corporation through the provision of materials for the fan noise test and the financial support for this work.
Outline

- Objectives
- Literature Review
- Experimental Set Up
  - Fan Specification
  - Housing Materials
  - Fan specification and performance curve
- Measurement Results
  - Sound Power Level spectrum and Cumulative Spectrum
  - Blade Passage Tone level values
  - Contour Plots
- Conclusion
Objective

- To reduce the blade passage tone level of axial cooling fan (120 mm)
  - Focusing on reducing tip clearance noise.
- Tip noise can be reduced by installing a finite flow resistance strip in the housing around the fan circumference.
  - Finite level of flow resistance created by the slightly Permeable housing may reduce turbulence levels in the tip region.
- The fan noise was quantified on the basis of the blade passage tone level.
Literature Review

- **Structural Design of the Fan: Strut designs, etc.**
  - W. M. Gresho (1985)
  - J. Wang and L. Huang (2005)

- **Impact of the guard grille design**
  - A. Gregor, M. Hocevar and B. Sirok (2009)

- **Active noise control**
  - D. A. Quinlan (1992)
Tip Clearance region

» G. Jin, H. Ouyang, Y. Wu and Z. Du (2011):
  - Blade Design

  - perforated resonator within the housing

» D. L. Sutliff and M. G. Jones (2009):
  - Beneficial effect of foam metal liner in turbine blade-tip.
Experimental Equipment Setup

- Plenum designed based on ISO 10302.
- The test plenum is intended for measuring the flow rate and the fan static pressure.
- Controllable opening from 2x2 cm² to 10x10 cm² to control flow resistance.
10 Microphone positions on equal areas on the surface of a hemisphere to measure sound power. [ISO 3744]

Radius of hemispherical frame is **5.5 ft.**

Test equipment including the hemispherical frame was set up in the anechoic chamber at Herrick Laboratories.
Fan Specification

Model: 4710KL-05W-B20

Characteristic Curve

Manufacturer provided Specification

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<td>1900</td>
<td>2.15</td>
<td>24.8</td>
<td>31.0</td>
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Modified fan to attach the housing materials

Microperforated casing attached!
Materials

Impermeable (Regular)  MPP 751 Rayls

MPP 1204 Rayls  MPP 1759 Rayls

Impermeable Casing  MPP Casing
MPP used for comparison

- Flow Resistance: 751 rayls
- MPPs with higher flow resistance than 751 rayls gave similar performance curve as Regular Casing
P-Q Curve and Operating Points

### Fan operation condition for comparison

- Rotation speed was controlled by giving different input voltage 19V, 21V and 23V of input voltage
- Flow exit area was varied from 2x2 to 10x10 cm²
Measurement Procedure

- Pick a measurement point from P-Q curve
- Operate the fan attached to plenum at required voltage (speed).
- Acquire noise signals from 10 different microphone positions.
  - Sampling time: 120 sec; Sampling rate: 25.6 kHz
- Signal processing
  - Power Spectral Density
  - Welch’s method of PSD
  - Hann Window
  - 50% overlap
- Calculate sound power level according to ISO 3744
Sound Power Level Calculation

The Sound Power Level estimation from the sound pressure level

\[ L_w = L_p + 10 \log_{10} \frac{S}{S_{ref}} \]

- \( L_p \): Space – averaged sound pressure level
- \( S_{ref} \): Reference area, 1 m²
- \( S \): Surface area of the hemisphere

10 microphone arrays for the sound power level estimation [ISO 3744]

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<td>0.15R</td>
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<td>8</td>
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<td>9</td>
<td>0.75R</td>
</tr>
<tr>
<td>10</td>
<td>1R</td>
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R: Radius of Hemispherical frame
Acoustic Measurement Results – Point #3

- 2x2 cm² Opening Area
- High Pressure (17.8 Pa) / Low Flow Rate (0.05 m³/min)

At Blade Passage Frequency Region

Blade Passage Frequency Region
Acoustic Measurement Results – Point #4

- 3x3 cm² Opening Area
- Mid Pressure (12.03 Pa) / Low Flow Rate (0.21 m³/min)

At Blade Passage Frequency Region

![Sound Power Level at Point 4](image1)

![Cumulative spectra at Point 4](image2)

![SPL at Point 4](image3)

![P-Q Curve - Regular Fan casing vs MPP (751 rayls)](image4)
Acoustic Measurement Results – Point #7

- 5x5 cm² Opening Area
- Mid Pressure (9.58 Pa) / Low Flow Rate (0.49 m³/min)

At Blade Passage Frequency Region

Sound Power Level at Point 7

Cumulative spectra at Point 7

P-Q Curve - Regular Fan casing vs MPP (751 rayls)
Acoustic Measurement Results – Point #11

- 7x7 cm² Opening Area
- Mid Pressure (8.23 Pa) / Mid Flow Rate (0.88 m³/min)

At Blade Passage Frequency Region

![Sound Power Level at Point 11](image)

Cumulative spectra at Point 11

![SPL (dBA) vs Frequency (Hz)](image)

P-Q Curve - Regular Fan casing vs MPP (751 rayls)

![P-Q Curve](image)
Acoustic Measurement Results – Point #13

- 10x10 cm² Opening Area
- Low Pressure (4.49 Pa) / High Flow Rate (1.25 m³/min)

At Blade Passage Frequency Region

Sound Power Level at Point 13

Cumulative spectra at Point 13

P-Q Curve - Regular Fan casing vs MPP (751 rayls)
Blade Passage Tone levels

Sound Power Level at Point 1

Sound Power Level at Point 4

Sound Power Level at Point 7

Sound Power Level at Point 10

Sound Power Level at Point 13

P-Q Curve - Regular Fan casing vs MPP (751 rayls)

2x2 cm²

3x3 cm²

5x5 cm²

7x7 cm²

10x10 cm²

Pressure [Pa]

Flow Rate [m³/min]

1759 rayls

1204 rayls

751 rayls

751 rayls

751 rayls
# Blade Passage Frequency Tones

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<th>Point</th>
<th>BPF [Hz]</th>
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Reduction of Sound Power at BPF

- **Reduction of Sound Power:**
  - Actual Sound Power was used in comparison
  - $L_w = 10\log_{10} \frac{P}{P_0}$
    - $P$ : Sound Power
    - $P_0$ : Reference value, 1 pW

- **Red** region: BPF tone was reduced by using MPP casing
- **Blue** region: BPF tone was increased by using MPP casing
Final Comments on the results

**Red:** MPPs with **High** flow resistivity showed better performance in reducing BPF tone

**Blue:** MPPs with **Low** flow resistivity showed better performance in reducing BPF tone
Conclusion

- Detailed experiments in reducing the Blade Passage Frequency tone level of the 120 mm fan using microperforated materials were conducted.

- Repeatable and accurate measurement procedure was established and achieved reliable results.

- Microperforated panel casing reduced the Blade Passage Frequency tone level of the fan.
  - MPPs with flow resistance of 751 rayls and 1204 rayls reduced BPF tone level for most of the operating condition

- Different flow resistivity of MPP is required to reduce the Blade Passage Frequency tone of the fan that operates at different operating condition.
Future Plan

- Provide guidelines for design treatments that can be integrated into typical fan design.

- Suggesting the optimal design of the fan for better reduction in the noise level.
  - Optimal flow resistivity of the housing
  - Better structural design; the struts and bell mouth of the fan.