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The Use of Intensity Techniques for Noise Source Identification in Small Machinery

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THE USE OF INTENSITY TECHNIQUES FOR NOISE SOURCE IDENTIFICATION IN SMALL MACHINERY

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INTRODUCTION

- **INTENSITY MEASUREMENTS ARE USED:**

- to measure sound power
- to identify sources, transmission paths and radiating surfaces.

INTRODUCTION

• THE NOISE CONTROL PROCESS

1. SOURCE IDENTIFICATION

- knowledge of machine operation
- acoustic "blueprints" (sound power spectrum, intensity maps)
- Result: frequency and spatial location of source

2. CONTROL OF SOURCES

- redesign or shield source
- eliminate path or reduce radiation efficiency

3. VERIFIATION

- acoustic "blue print" of modified machine

4. ITERATION

MEASUREMENT OF ACOUSTIC INTENSITY

Four Types of Measurements

1. SURFACE

- surface velocity of vibrating object (accelerometer)
- surface pressure (microphone)
- normal intensity

2. TWO (OR MORE) MICROPHONES

- infer particle velocity from pressure gradient
- cross-spectrum
- intensity vector at a point

3. PRESSURE-VELOCITY

- measure particle velocity ultrasonically
- microphone to measure pressure
- intensity vector at a point

4. NEARFIELD ACOUSTIC HOLOGRAPHY

- complex pressure on a plane near source in anechoic environment
- reconstruct entire acoustic field: velocity, pressure, intensity vector (3-D)

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PROJECT OBJECTIVES

1. INTENSITY MEASUREMENT SYSTEM

- based on two-microphone cross-spectral technique
- FFT analyzer
- personal computer for control and display

2. MACHINERY NOISE CONTROL

- domestic vacuum cleaner
- measurement of normal intensity on planes near surface to give source and path information
- distinguish between
 - a. airborne noise
 - b. exterior surface radiation
 - i. structure-borne noise
 - ii. sound transmission

IMPLEMENTATION

- CALCULATE INTENSITY AS

$$I_r(\omega) \approx \frac{\text{Im}\left\{G_{12}\right\}}{\omega\rho\Delta r}$$

- FREQUENCY BAND DETERMINED BY

1. Finite difference approximation

— high frequency limit

$$\frac{\partial p}{\partial r} \approx \frac{p_2 - p_1}{\Delta r}$$

IMPLEMENTATION

- **FREQUENCY BAND DETERMINED BY**

2. **Instrumentation phase mismatch**

- measure inter-channel transfer function, H_{12}
- low frequency limit

$$I_c(\omega) = \frac{\text{Im}\left\{\frac{G_{12}}{H_{12}}\right\}}{\omega \rho \Delta r}$$

3. **Source nearfield effects**

- intensity changes within distance Δr
- minimum distance to source

IMPLEMENTATION

• PROCEDURE

1. measure inter-channel transfer function using plane wave tube
2. absolute calibration of one microphone
3. measure normal intensity on plane near source
4. create single frequency data file
5. display spatial distribution of normal intensity for a single frequency band

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SOUND POWER OF REFERENCE SOURCE

- MEASUREMENT OF SOUND POWER IN SEMI-ANECHOIC ENVIRONMENT

1. Intensity Technique
2. Hemispherical array of microphones centered on source

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NOISE SOURCE TESTED

Power-Nozzle

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INTENSITY MEASUREMENT PLANES

- POWER-NOZZLE

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INTENSITY MEASUREMENT PLANES

- CANISTER

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INTENSITY MEASUREMENT SETUP

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SOUND POWER SPECTRUM

- CANISTER

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INTENSITY MEASUREMENTS

- **CANISTER**

- **375 Hz - motor fundametal**
- **2225 Hz - blower blade passage fundamental**
- **Note: difference between structure-borne and airborne radiation**

INTENSITY MEASUREMENTS

a)

b)

Top plane (no. 1) of canister - 375 Hz

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TOP (Plane #1)

INTENSITY MEASUREMENTS

a)

b)

Left plane (no. 2) of canister - 375 Hz

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LEFT SIDE (Plane #2)

RIGHT SIDE (Plane #3)

INTENSITY MEASUREMENTS

a)

b)

Right plane (no. 3) of canister - 375 Hz

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LEFT SIDE (Plane #5)

RIGHT SIDE (Plane #3)

INTENSITY MEASUREMENTS

a)

b)

Rear plane (no. 4) of canister - 375 Hz

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REAR (Plane #4)

INTENSITY MEASUREMENTS

a)

b)

Top plane (no. 1) of canister - 2225 Hz

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TOP (Plane #1)

INTENSITY MEASUREMENTS

Left plane (no. 2) of canister - 2225 Hz

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LEFT SIDE (Plane #2)

RIGHT SIDE (Plane #3)

INTENSITY MEASUREMENTS

a)

b)

Right plane (no. 3) of canister - 2225 Hz

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LEFT SIDE (Plane #5)

RIGHT SIDE (Plane #3)

INTENSITY MEASUREMENTS

a)

b)

Rear plane (no. 4) of canister - 2225 Hz

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REAR (Plane #4)

SOUND POWER SPECTRUM

- POWER-NOZZLE

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INTENSITY MEASUREMENTS

- **POWER-NOZZLE**

- **300 Hz - motor fundametal**
- **2137 Hz - belt tooth passage frequency**
- **Note:**
 - **direct excitation of housing by motor**
 - **"modal" response of housing**

INTENSITY MEASUREMENTS

a)

b)

Power-nozzle - 300 Hz

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INTENSITY MEASUREMENTS

a)

b)

Power-nozzle - 2137 Hz

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INTENSITY MEASUREMENTS

a)

b)

Modified power-nozzle - 300 Hz

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CONCLUSIONS

- Nearfield narrow band intensity surveys visualize spatial regions of high acoustic energy flux
- Source identification is greatly enhanced when combining knowledge of machine components, frequency content of noise and intensity radiation patterns in space
- As a result, different modes of sound radiation are identifiable:
 - aerodynamic and airborne noise (direct transmission through housing)
 - structure-borne noise induced by internal sources exciting housing panels
 - internal sources in direct contact with housing panels
- Effectiveness of noise control modifications can be investigated by repeating measurements