CHARACTERISATION OF VIBRATORY, PULSATION AND NOISE SOURCES

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Objectives:

- predict the transmission source → surroundings
- allow meaningful spec formulation
- troubleshoot the causes of excessive levels

Difficulty: source excitation depends on its environment!

Challenge: independent source characterisation.

Problem: no norms / standards!

Industrial techniques:

- sound power
- vibration level
- p-p pulsations

Academic techniques:

- holography
- inverse BEM
- beamforming

assembler

supplier

sub supplier

sub supplier

not suitable

sub supplier
source needs a double descriptor

source resistance
open-loop voltage

Mechanical / acoustic
coupled velocity \( V_{cc} \) =

\[ S \]

\[ R \]

resistance \( R_L \)
impedance \( Z_R \)
- blocked excitation $F_b$?
- source impedance $Z_S$?

**Difficulties:**
- forces and moments
- translations and rotations
- multiple coupling points.

How to get $F_b$? $V_c = Z_c^{-1}F_b$

How to get $Z_S$? $Z_c = Z_S + Z_R$

The coupling (operational) forces transmitted to any surroundings of impedance $Z$ will read: $F_c = Z(Z_S + Z)^{-1}F_b$

To make this work: a convenient **calibration receiver** is needed!
smart receiver

6-DOF screw sensor
6-DOF wrench sensor
Fit 6 simple sensors!

Excitation by 6 external forces:
The block measures both source descriptors in all DoF

Source coupled
Source removed

Excitation by 6 external forces:

source

soft mount  solid block  source foot
**Example:**

4 connection points

**Equivalent force approach**

- **Equivalent force:** Resultant of interface wrenches!
- **Equivalent screw:** Mean of interface screws!

Equation: \(4 \text{ wrenches} \times (24 \times 1 \text{ vector}) = \text{impedance} (24 \times 24 \text{ matrix}) \times 4 \text{ screws} \times (24 \times 1 \text{ vector})\)
measurement practice

water pump
compressor
hydromotor
equivalent force application: electro-pump

characterisation

vertical

prediction

lateral
equivalent force application: compressor
insertion of resilient mounts

Blocked forces

Operational forces:
- bolted mounts
- vertical
pulsation

- blocked pressure
- impedance

**Difficulties:**
- impedance measured with the source operating
- blocked pressure impossible to measure directly
multiple load technique

blocked source pressure $p_S$
coupled pressure $p_c$

$$P_c = \frac{Z_L}{Z_S + Z_L} P_S$$

≥2 different loads: $Z_{L1}, Z_{L2}…$

coupled pressure

pulsation characteristic

multiple
laboratory measurement: gear pump

5b, 600 rpm
(gear meshing: 150 Hz)

10b, 1500 rpm
(gear meshing: 375 Hz)
industrial measurement: vane pump

- **measured**
- **predicted**

### Graphs

- **5b, 2000 rpm**
- **3b, 1000 rpm**
- **7b, 3000 rpm**
airborne noise

- blocked pressure
- impedance

**Difficulties:**
- source coupled to receiver through a surface
- physical surface of source extremely complex
- source power depends on the surroundings.

<table>
<thead>
<tr>
<th>Source Space</th>
<th>Receiver Space</th>
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- define an interface surface $S$.
- separate into **source space** and **receiver space**
- identify blocked pressure of running source $P_b$
- identify impedance of idle source space $Z_S$
1. build a simple dummy similar to original source
2. fit the dummy with \( K \) small drivers
3. measure source noise in \( N \) control points
4. replace the source by the dummy
5. establish TRF drivers / control points \( T (N \times K) \)
6. compute driver strengths \( Q \) out of \( P = TQ \) \( Q (K \times 1) \)

Source model applicable to any receiver environment!

dummy source: principle
dummy source: demonstration

200 Hz

1000 Hz
Semi-anechoic space
transfer functions →
analytical computation

dummy source: vibrating box
dummy source: excavator
The normal vibration velocity can be measured by an accelerometer array.

- real source $\rightarrow$ set of monopoles
- reproduce normal boundary velocity
- diffraction disregarded (small sources)
application to a loudspeaker cabinet

Field computed using:
- equivalent source method
- mirror image principle

- measured
- predicted

![Diagram showing field computation results with measured and predicted data points.](Image)
summary

source characterisation methods → industrial applications

dual source descriptor → blocked excitation and impedance

best way to characterise a source → measurement

unified approach to vibration, pulsation and noise

vibration: smart receiver        ****
equivalent force method         ***

pulsation: multi-load method    **

noise: dummy source method      ***
equivalent source approach      **
coupling surface method         *****

* simple          ***** difficult
how to define surface impedance?

In either case:
\[ p, v : N \times 1 \text{ vector} \]
\[ Z : N \times N \text{ matrix} \]
\[ p = Z v \]

expand into \( N \) eigenfunctions

discretize into \( N \) patches
coupling using patches: examples

142 eigenfunctions

patch size < $\lambda/3$
calibration block impedance

steel block, 70 kg
L 400mm
W 280mm
H 80mm