Brake Pad Design Against Brake Squeal

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InnoTesting 2015, 20th February
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Brake noise

Different noises receive different names: squeal, moan, groan...

Brake noise

Brake noise is a problem because it affects the quality perception the final customer has on the car.

This is why the Noise, Vibration and Harshness industry has worked for decades trying to solve these problems.
Noise, Vibration and Harshness (NVH)

Is the study of vibration and noise in vehicles. The measurement is done by analytical tools and also by jury evaluation.

Experimental Modal Analysis

Experimental Modal Analysis is one of the techniques that allows us to know the resonant modes of a structure.

Experimental Modal Analysis

Measurements are typically made with the structure on free-free conditions.
Experimental Modal Analysis

But on a braking event, brake pads are not precisely under free-free conditions...

The modal parameters of all components change during braking.

Source: NUCAP – Piston Cushion 2014 Video
Proof of Concept

[Diagram of brake pad with labels: Workshop clamp, Laser beam, Brake piston, Brake pad, Brake disc, Scalable Automatic Modal Hammer, Foam mat, Machine bed]
Proof of Concept: Methodology
Proof of Concept: Methodology
Proof of Concept:
Scalable Automatic Modal Hammer
Proof of Concept: Scalable Automatic Modal Hammer

Impact – time signal

![Graph showing impact force over time](image-url)
Proof of Concept: Scalable Automatic Modal Hammer

Impact - time signal - zoom

Impact - autospectrum signal

In grey, autospectrum signal of a magnet-driven automatic hammer
Proof of Concept: Scalable Automatic Modal Hammer

Repeatability test, applied to a brake pad backing plate.
Proof of Concept: Scalable Automatic Modal Hammer

Application examples with magnetic arm
Proof of Concept: Scalable Automatic Modal Hammer

Heavier structures?

Larger hammer!
Proof of Concept: Scalable Automatic Modal Hammer

Heavier structures?

... but narrower excitation band!
Proof of Concept: Assemblies

- Pad/disc assembly
  - Weak clamping force
  - High clamping force

- Piston/pad/disc assembly
  - Weak clamping force
  - High clamping force
## Proof of Concept: Experiments

### Pad A

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disc</td>
<td>Free-free condition</td>
</tr>
<tr>
<td>Pad</td>
<td>Free-free condition</td>
</tr>
<tr>
<td>Pad/disc</td>
<td>Weak clamping force</td>
</tr>
<tr>
<td>Piston/pad/disc</td>
<td>Weak clamping force</td>
</tr>
<tr>
<td></td>
<td>Grounded condition</td>
</tr>
<tr>
<td></td>
<td>High clamping force</td>
</tr>
<tr>
<td></td>
<td>High clamping force</td>
</tr>
</tbody>
</table>
Proof of Concept: Experiments

Pad B

Disc
- Free-free condition

Pad
- Free-free condition
- Grounded condition

Pad/disc
- Weak clamping force
- High clamping force

Piston/pad/disc
- Weak clamping force
- High clamping force
Study Results: Direct Comparison of FRF Additions

![Graph showing FRF magnitudes for different configurations: free-free, grounded, and piston/pad/disc. The graph plots magnitude (log scale) against frequency in Hz.]

- **Free-free**
- **Grounded**
- **Piston/pad/disc**
Study Results: Direct Comparison of FRF Additions

Frequency shifts between pads at higher frequencies \(\rightarrow\) different dynamic properties. Caused by different compressibility value?
Study Results: Direct Comparison of FRF Additions

Weaker vibration $\rightarrow$ 5 orders of magnitude less. Signal- to- noise ratio decreases, due to the weak vibration amplitude.
Study Results: Direct Comparison of FRF Additions

Prominent but erratic peaks on the low frequency range.
The first two modes of the brake disc are coincident with the first two peaks on the FRFs additions.

Both components seem to be affecting each other in terms of mass, stiffness and damping.
Study Results: High Freq. Range

The high frequency range is less erratic and the peaks are not coincident anymore.

Modal parameters become easier to extract.
Study Results: Mode Shapes Comparison
Study Results: Mode Shapes Comparison

Up-and-down Shapes

It is suspected that they are caused by the brake disc first mode, which is transmitted onto the pad.

In reality, the whole assembly is vibrating.
Study Results: Mode Shapes Comparison

“Flip-flop” Shapes

Further tests without disc have shown that they are inherent to the pad under compression.
Conclusions

✓ The feasibility of the proposed proof of concept has been evaluated.

✓ Mode shapes up to 6 kHz have been successfully extracted. Data acquisition has been done in a quasi-automatic approach.

✓ The vibration of the brake disc where the assemblies are mounted has an influence on the low-frequency results.

✓ The dynamic differences between pads seem to increase when the pads are analyzed under compression loads.
Further Work

The proposed setup still has some drawbacks and practical limitations. Several improvements to this research have been proposed to:

- Brake pads testing without brake disc in order to remove the low-frequency distortions. As a result, the compression load would be applied onto the pads in a similar manner as a pad compressibility test stand does.
- Quantifiable compression load, by means of a force sensor.
- Results’ correlation with FEA models.
- Modal damping should be evaluated on next studies.
Thanks for your attention!

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The Young Researchers Group for Structural Dynamics Optimization is funded by: