Effects of mounting on accelerometer performance

Scott Mayo
Line Moisan
Topics

- Introduction
- Test set up
  - Hardware
  - Parameters
  - Test matrix
- Results
- Conclusions
- Future research
Introduction

- Accelerometer users often have questions about how to properly mount their accelerometers
  - Sensor manufacturers publish ideal installation parameter requirements
  - Users must balance ideal requirements with practical limitations on their particular applications
    - What does the user trade-off by not following the ideal requirements?

- We will explore the affects of varying installation parameters on accelerometer performance
  - Focus is on frequency (amplitude) response, in particular the mounted resonant frequency
Introduction

- Mounted resonant frequency: the point of maximum sensitivity in the sensor’s amplitude response
  - Result of the natural resonance of the sensor’s mechanical structure
  - Typical values are 20 kHz and above

- Specified as a minimum
  - Used as a rough measure that sets the upper limit for the sensor’s bandwidth
Introduction

- Piezoelectric accelerometers, in particular, have very high amplitude resonant peaks
  - Sensitivity at the peak is many times the reference sensitivity
  - Vibrations in this region can be highly amplified, possibly resulting in distorted measurements

- Manufacturer’s specification assumes ideal mounting conditions
  - Less than ideal mounting decreases stiffness and increases damping, causing resonant peak to move down in frequency
Introduction

Installation considerations

- How the accelerometer is mounted can have a significant affect on the sensor’s amplitude response

![Graph showing sensitivity vs frequency with a resonant peak]
Introduction

- Ideal installation parameters
  - Threaded stud mount type
    - Surface flatness, max: 0.0003 inch TIR
    - Surface roughness, max: 32 µinch rms
    - Tapped hole perpendicularity: 0° ± 1°
    - Recommended torque
    - Use coupling grease (ultrasonic couplant)
  - Adhesive mount type
    - Bond line as thin as possible
Test Methodology

- **Hardware**
  - Endevco shaker
  - CAACS
  - Accelerometers
    - Piezoelectric (PE)

- **Hardware Details**
  - **7704**
    - 0.9 oz (25 gm)
  - **2221F**
    - 0.4 oz (11 gm)
  - **2222C**
    - 0.02 oz (0.5 gm)
Test Methodology

Parameters

- Vary torque from recommended value to under value (50% of recommended torque)
- Try grease and dry (no grease) conditions
Test Methodology

- Parameters
  - Surface roughness: 16, 32, 64, 125, 250, 500 µinch rms
Test Methodology

Parameters

- Surface flatness: 0.0005, 0.003, 0.001, 0.01, 0.1 inch TIR
Test Methodology

- Parameters
  - Vary adhesives

Petro wax  Aron Alpha  Loctite  Epoxy  Double-back tape  Blanchard wax
Test Set up with shaker

Washer to replicate flatness or roughness
## Test Matrix

<table>
<thead>
<tr>
<th></th>
<th>7704 stud mounted</th>
<th>2221F thru-hole stud mounted</th>
<th>2222C adhesive mounted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torque/Under torque</td>
<td>√</td>
<td>√</td>
<td>X</td>
</tr>
<tr>
<td>Roughness</td>
<td>√</td>
<td>√</td>
<td>X</td>
</tr>
<tr>
<td>Flatness</td>
<td>√</td>
<td>√</td>
<td>X</td>
</tr>
<tr>
<td>Perpendicularity</td>
<td>√</td>
<td>√</td>
<td>X</td>
</tr>
<tr>
<td>Adhesive</td>
<td>X</td>
<td>X</td>
<td>√</td>
</tr>
</tbody>
</table>
Results - Torque

2221F
10 k – 50 kHz

Spec: resonance frequency at 40 kHz

Frequency (Hz)

-10000 to 100000

10000 to 100000

-10 to 35 dB Sensitivity Deviation (norm at 100Hz)

Rec Torque and Grease

Under Torque and Grease

Rec Torque and No Grease

Under Torque and No Grease
Results - Torque

7704
10 k – 50 kHz

Rec Torque and Grease
Under Torque and Grease
Rec Torque and No Grease
Under Torque and No Grease

Spec: resonance frequency at 35 kHz

Frequency (Hz)
Results - Roughness

2221F
10 k – 50 kHz

Spec: resonance frequency at 40 kHz

Frequency (Hz)

-10

0

5

10

15

20

25

30

35

10000 100000

dB Sensitivity Deviation (norm at 100Hz)

16 µinch and Grease

500 µinch and Grease

16 µinch and No Grease

500 µinch and No Grease
0.1” washer to replicate flatness
Results - Flatness

7704
10 k – 50 kHz

Spec: resonance frequency at 35 kHz

dB Sensitivity Deviation (norm at 100Hz)

Frequency (Hz)

-10 to 35

0.0005" and Grease
0.0005" and No Grease
0.1" and Grease
0.1" and No Grease
Results - Flatness

7704
10 k – 50 kHz

Spec: resonance frequency at 35 kHz

-0.0005” and Grease
-0.001” and Grease
-0.01” and Grease
-0.05” and Grease
-0.1” and Grease
Test Set Up

- Parameters
  - Perpendicularity with 0, 2 and 5 degree angle
**Results - Perpendicularity**

Spec: resonance frequency at 35 kHz

- 0 degree and Grease
- 2 degree and Grease
- 5 degree and Grease

Spec: resonance frequency at 40 kHz

- 0 degree and Grease
- 2 degree and Grease
- 5 degree and Grease
Results – Adhesive with Petro Wax
Results – Adhesive with Petro Wax

2222C – Wax
10 k – 50 kHz

Spec: resonance frequency at 25 kHz

Frequency (Hz)

dB Sensitivity Deviation (norm at 100Hz)

Min. thickness
0.003” thickness
0.01” thickness
0.015” thickness
Results – Adhesive
Results - Adhesive

2222C – Glues, Wax and Tape
20 – 10 kHz

% Sensitivity Dev (norm)

Frequency (Hz)

-10 0 5 10 15 20 25 30 35

10 100 1000 10000

Epoxy
Loctite
Petro wax
Tape
Aron Alpha
Blanchard wax
Results - Adhesive

2222C – Glues, Wax and Tape
10 k – 50 kHz

Spec: resonance frequency at 25 kHz

Frequency (Hz)

$\text{dB Sensitivity Deviation (norm at 100Hz)}$

-10 -5 0 5 10 15 20 25 30 35

10000 100000

Aron Alpha
Epoxy
Loctite
Blanchard wax
Petro wax
Tape
Conclusions

- Coupling grease versus dry mounting conditions
  - Grease solves a lot of mounting problems

- Most critical parameters
  - Stud mounted
    - Perpendicularity
    - Flatness
    - Torque
  - Thru-hole stud mounted
    - Flatness
    - Torque
  - Adhesive mounted
    - Thickness of a material is more important than the material itself

- Surface finish (roughness) is not an important parameter as long as grease is present

- Accelerometer design
  - Thru-hole stud mounted is less affected by perpendicularity

- Hard adhesive (Blanchard wax, epoxy, Loctite, Aron Alpha) is more effective than soft adhesive
Future Research

- Accelerometers
  - IEPE
  - Piezoresistive
  - Variable capacitance
  - Triaxial accelerometers
  - Triax mounting blocks

- Parameters
  - Different coupling viscosity materials (grease, oil, etc)
  - Roughness with random patterns
  - Magnetic base
  - Handheld stinger
Thanks to

**Meggitt SJC**
- Marketing/Engineering: Michael Phan (testing), Sandy Smith (console)
- Tools and material: Don Deccico (tools and material), Thu-Van Nguyen (material), Troy Nguyen (material), Dirk Lobbenmeier (factory), Rick Guild (machine shop), Pete Leonhardt (manufacturing)
- Product management: Andy Hohla, Stacy Belanger, Mike Laser (pictures)
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Results - Roughness

7704
10 k – 50 kHz

Spec: resonance frequency at 35 kHz

dB Sensitivity Deviation (norm at 100Hz)

-10 -5 0 5 10 15 20 25 30 35
10000 100000

Frequency (Hz)

16 µinch and Grease
500 µinch and Grease
16 µinch and No Grease
500 µinch and No Grease
Results - Flatness

2221F
10 k – 50 kHz

Spec: resonance frequency at 40 kHz
Results – Adhesive with Wax

2222C – Wax
20 – 10 kHz