DETECTING BOLT LOOSENING ON THE BASIS OF VIBRATION SIGNALS AS LOW AS A FEW HERTZ

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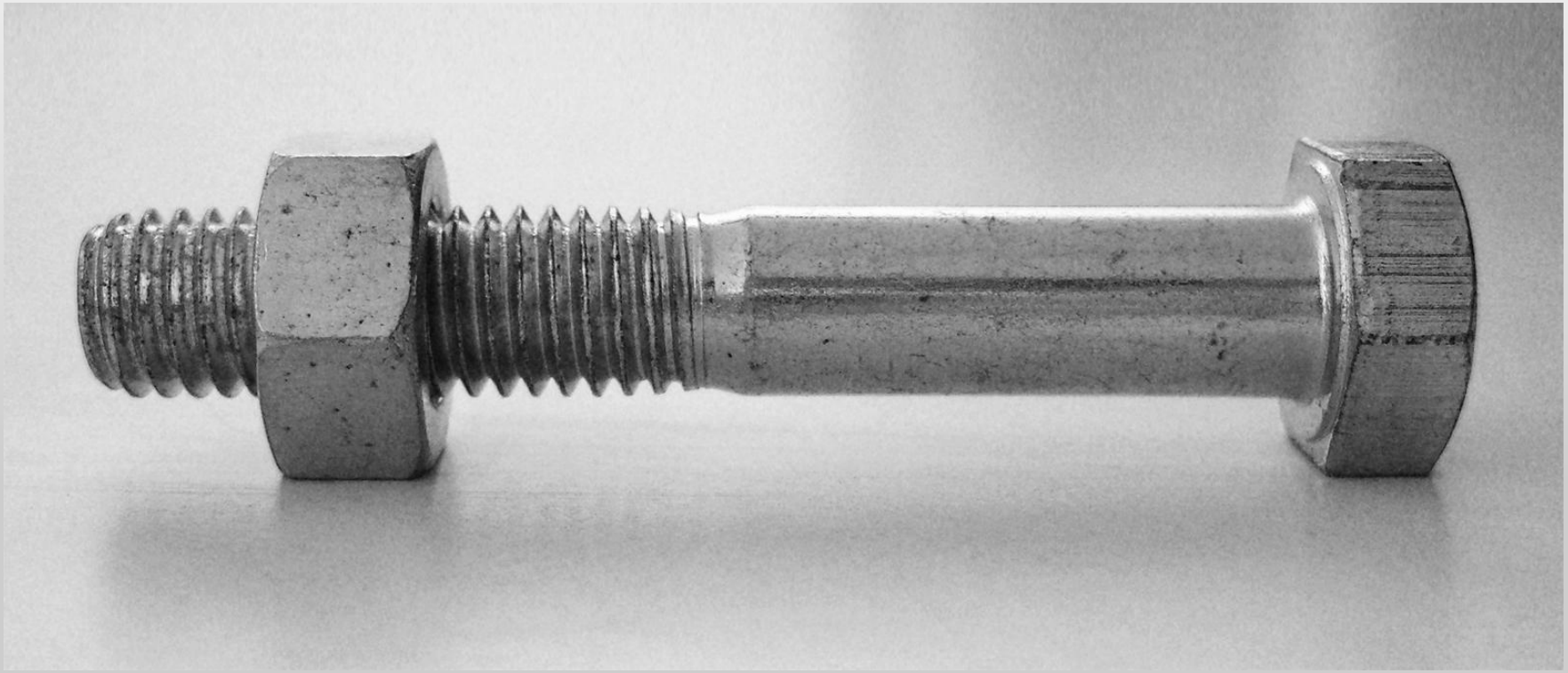
0. CONTENTS

1. BACKGROUND

Bolts are one of the most fundamental and common elements in modern society.



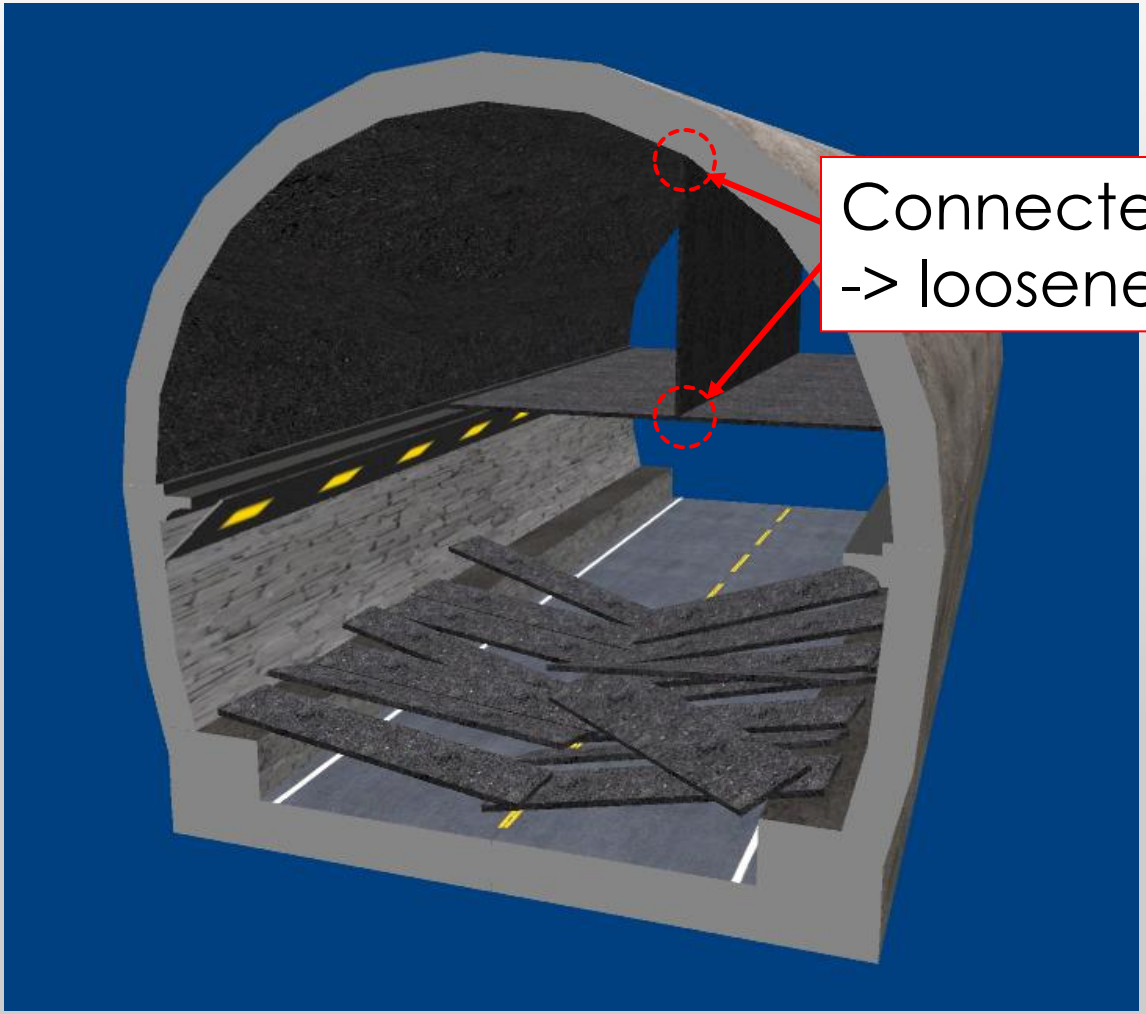
Loosened bolts would cause serious situation.

1. BACKGROUND

About 270 concrete plates fixed at the ceiling of a tunnel suddenly dropped.

http://gendai.ismedia.jp/articles/-/34525

1. BACKGROUND



https://upload.wikimedia.org/wikipedia/commons/1/11/Sasago_Tunnel%28Ch%C5%AB%C5%8D_Expwy%29_collapsed_3D_model_2.png

1. BACKGROUND

SELF-LOOSENING

Sometimes bolts are gradually loosened
while they are in use
even though they were sufficiently tightened
initially!!

Periodical inspections are indispensable.

1. BACKGROUND

CONVENTIONAL METHOD: IMPACT TEST

https://jp.images-monotaro.com/Monotaro3/pi/full/mono10784523-090203-02.jpg

Simple, but not so objective or quantitative

1. BACKGROUND

RECENT STUDIES

- ✓ Ultrasonic (~MHz)
- ✓ Vibration (~kHz)
- ✓ Magnetic
  - ●
  - ●
  - ●
  - ●

1. BACKGROUND

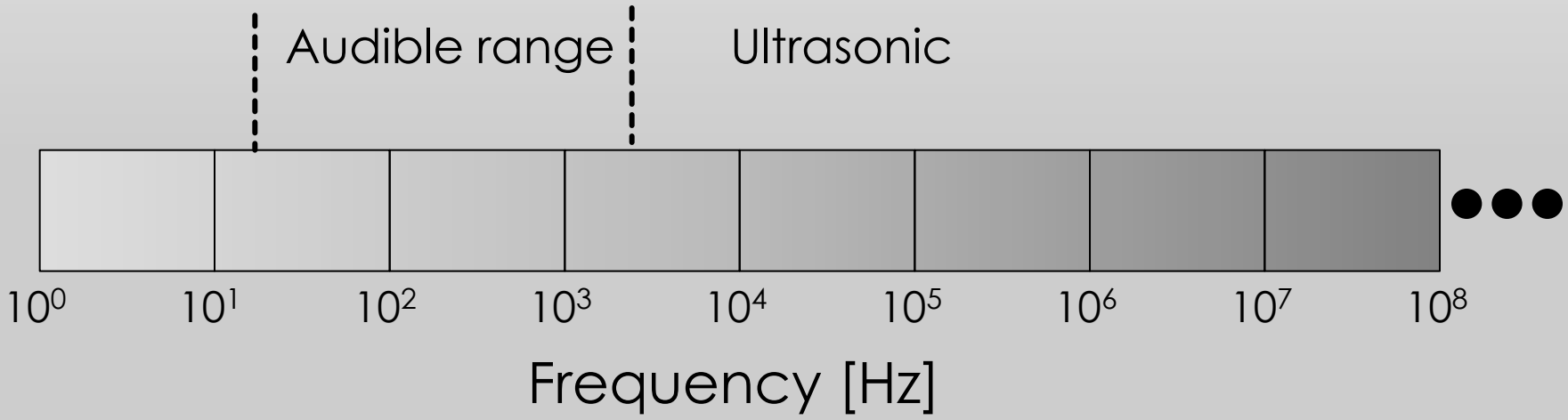
RECENT STUDIES

- ✓ Ultrasonic (~MHz)
- ✓ Vibration (~kHz)
- ✓ Magnetic
- ●
- ●
- ●
- ●

A simpler, easier, and cheaper method is preferable.

2. OBJECTIVE

TO DEVELOP A SIMPLE AND COST-EFFECTIVE METHOD TO EVALUATE BOLT LOOSENING USING LOW-FREQUENCY VIBRATION SIGNALS.



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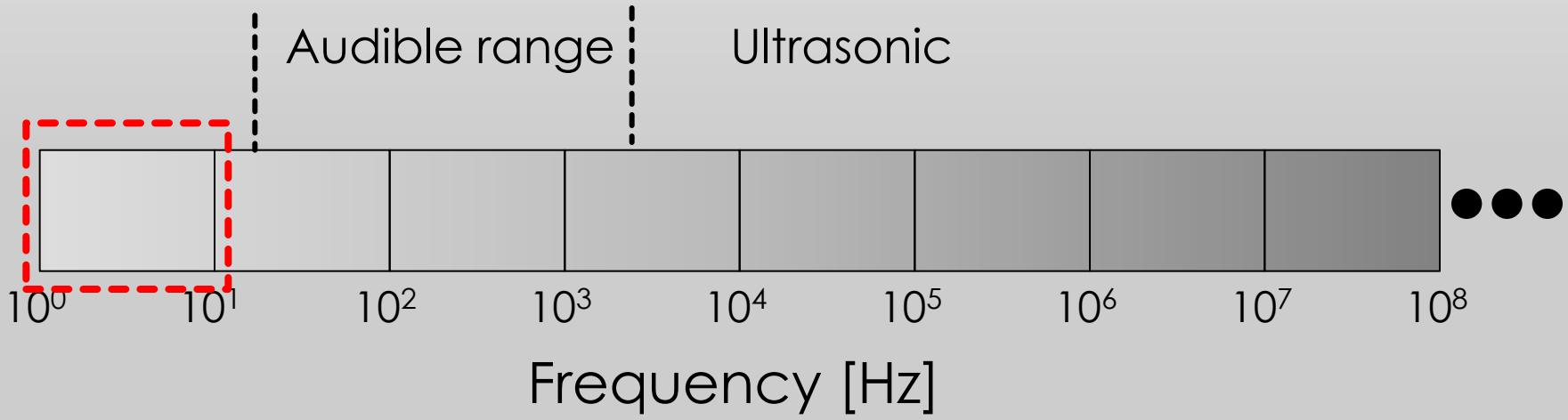
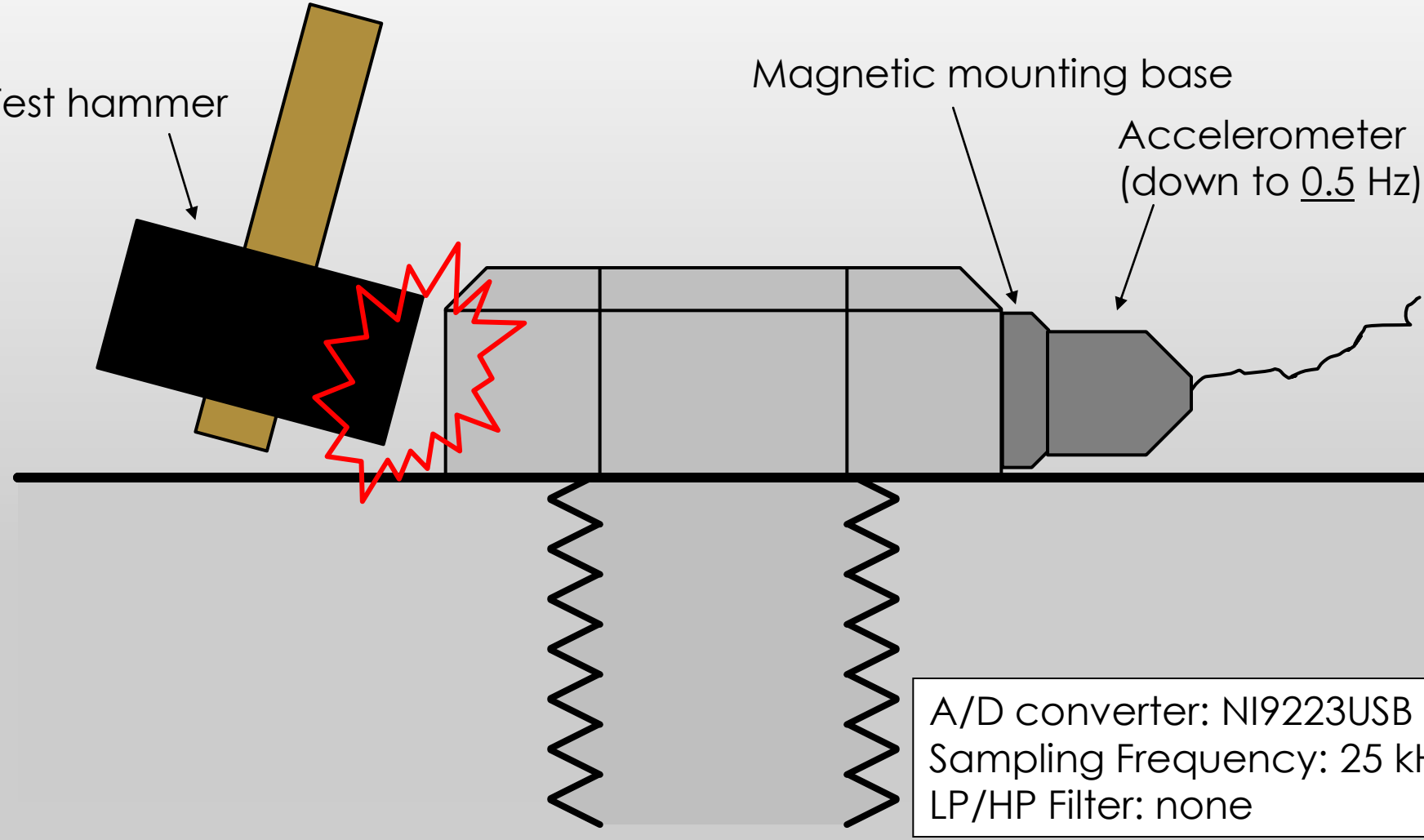


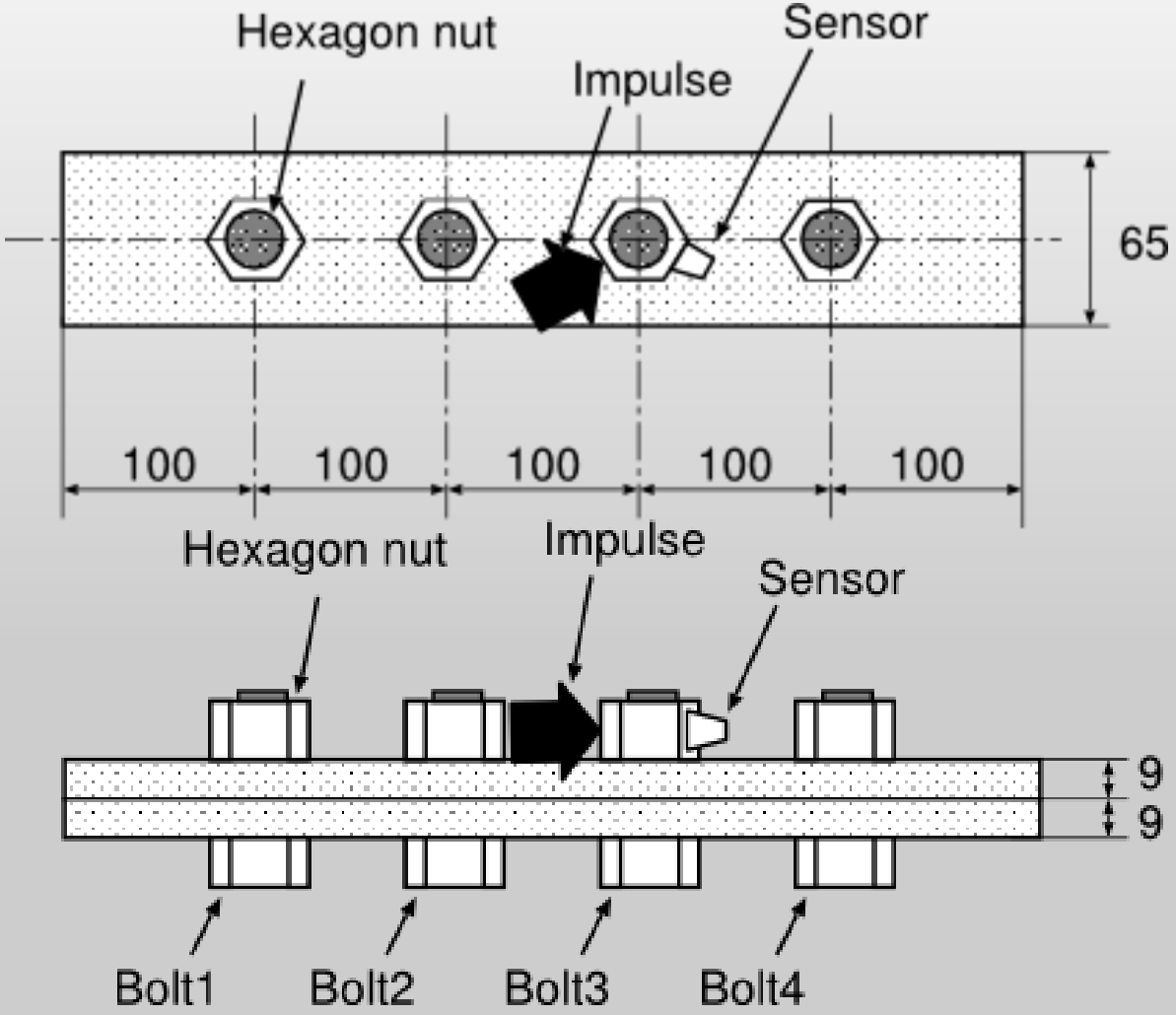
3. METHOD



A/D converter: NI9223USB
Sampling Frequency: 25 kHz
LP/HP Filter: none

4. RESULTS

4.1 LABORATORY TEST – EXPERIMENTAL SETUP

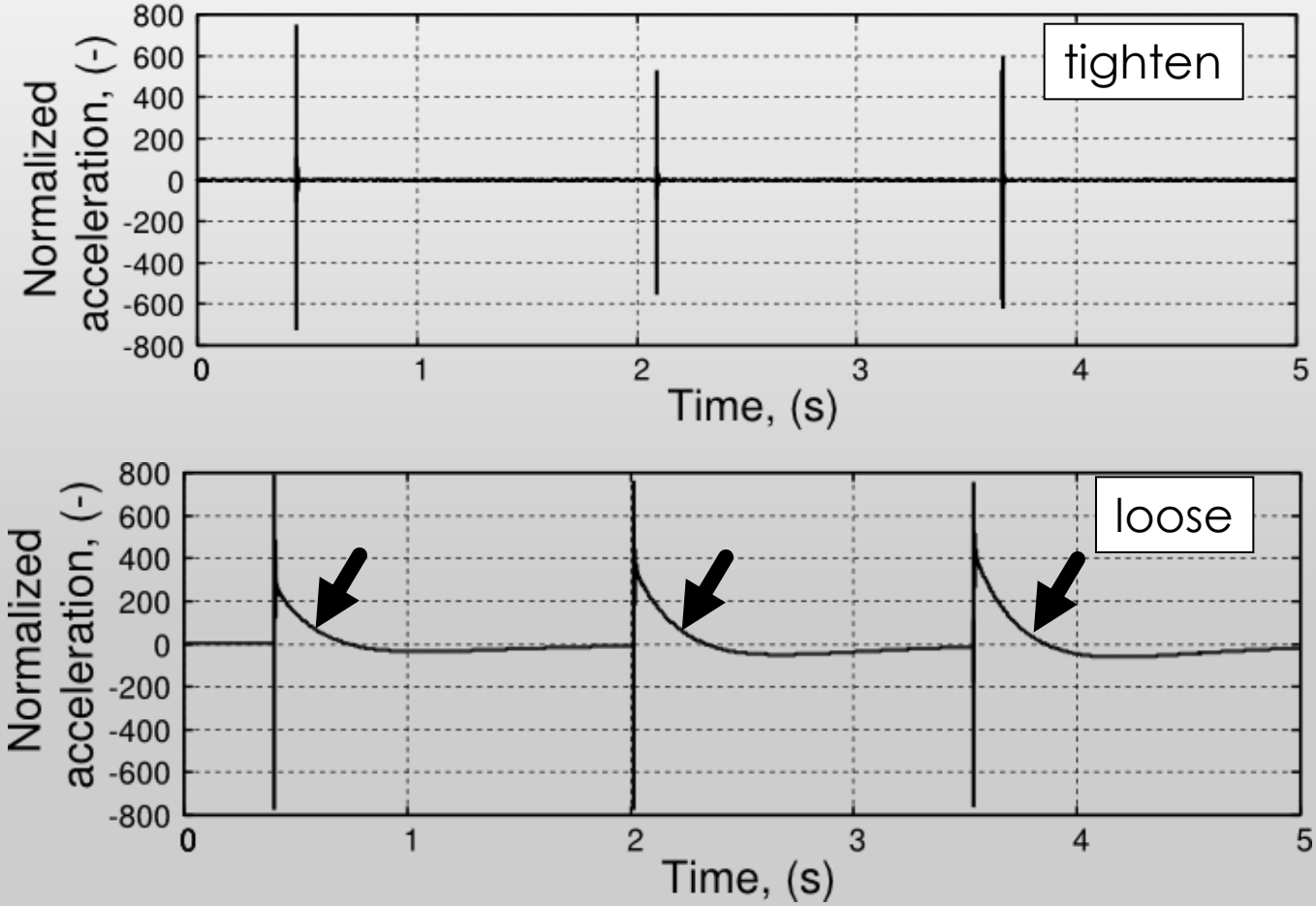


4. RESULTS

4.1 LABORATORY TEST – EXPERIMENTAL SETUP

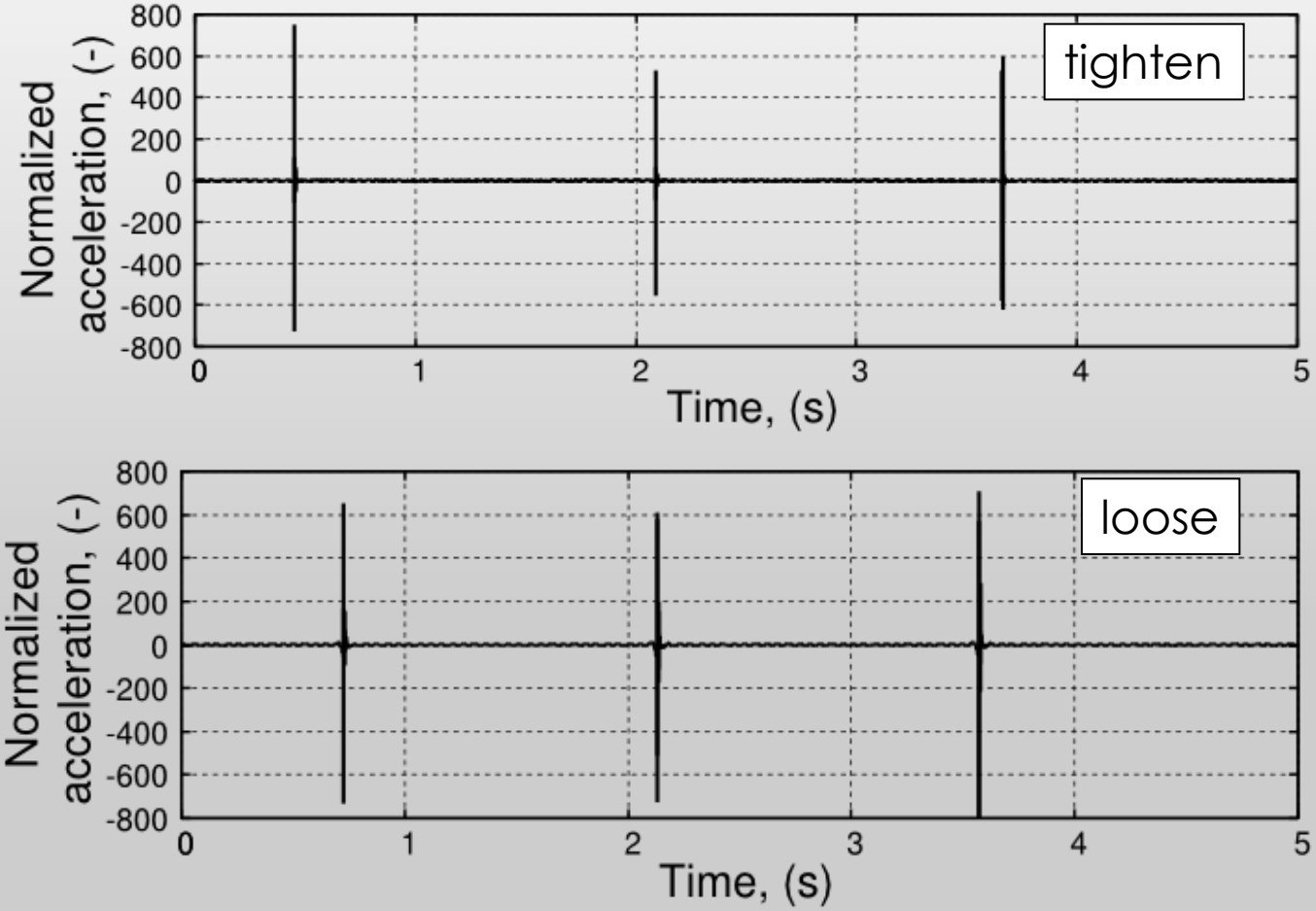
4. RESULTS

4.1 LABORATORY TEST – TYPICAL RESPONSE



4. RESULTS

4.1 Laboratory Test – typical response (with 20 Hz High Pass)



Low frequency components are quite important.

4. RESULTS

4.1 LABORATORY TEST – RESULTS

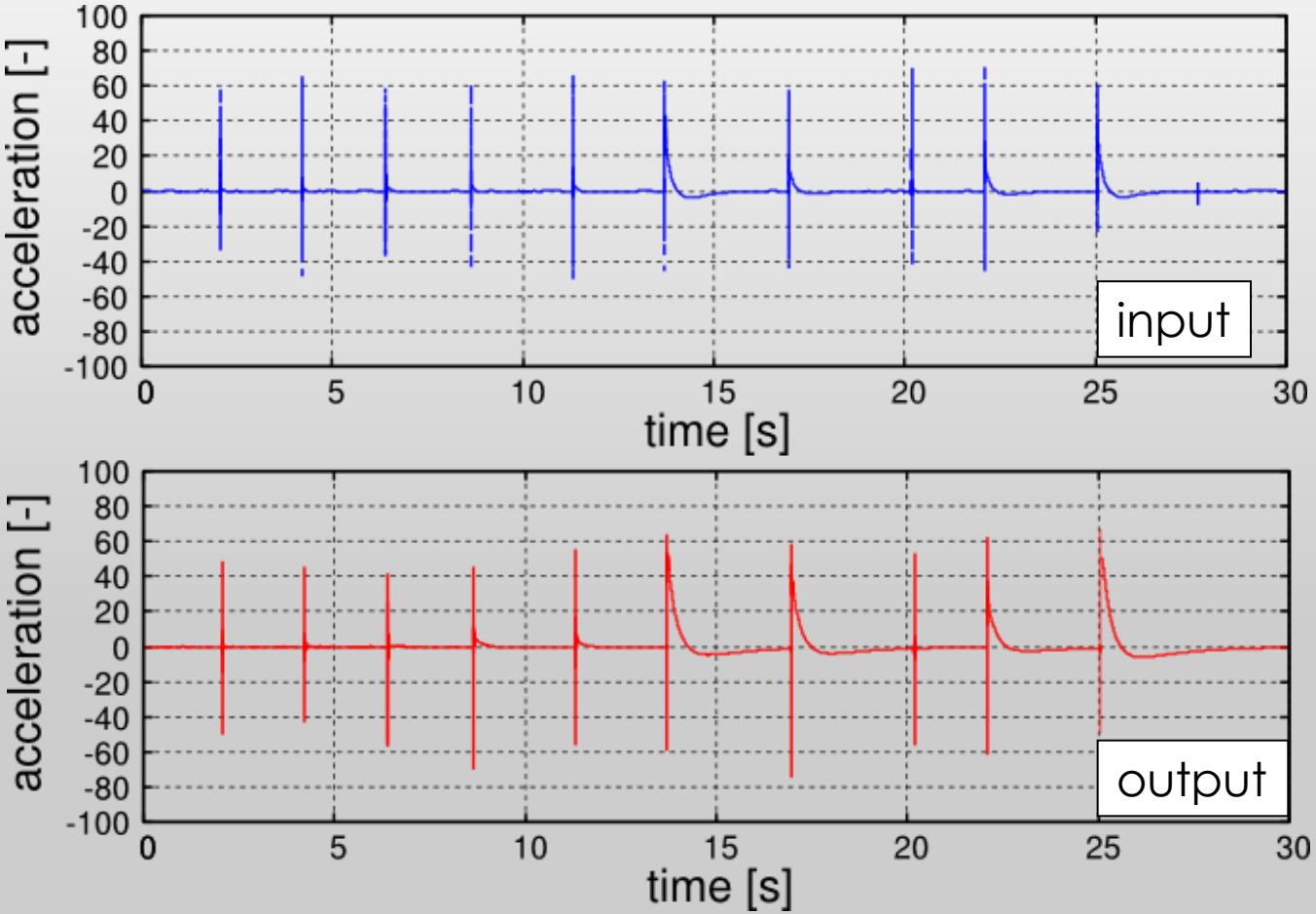
- When a bolt is loosened,
  the decay of vibration tends to become 'gradual'.

- The most plausible reason for 'Not always' is that
  the impulse to vibrate the nut was imposed manually.

  - Where to hit is unclear yet.
  - Too weak impulse leads to no clear vibration signals; too strong impulse causes too global vibration (probably). [difficulty in experiments using a small specimen]
  - Impulse to vibration the nut should not contain too much low frequency components.

4. RESULTS

4.1 LABORATORY TEST – RESULTS



Vibration signals when bolts were tightened to rated torque

4. RESULTS

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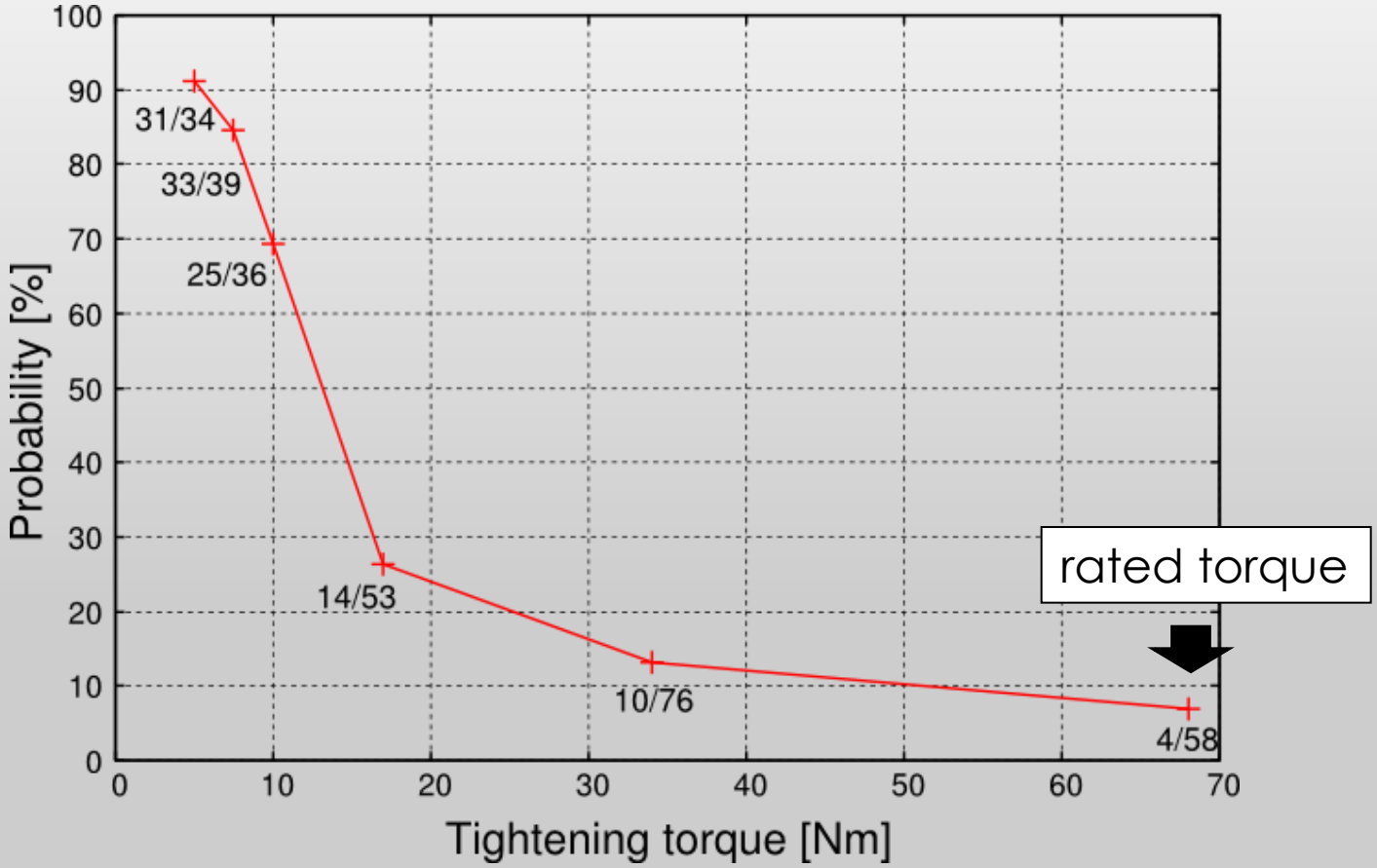
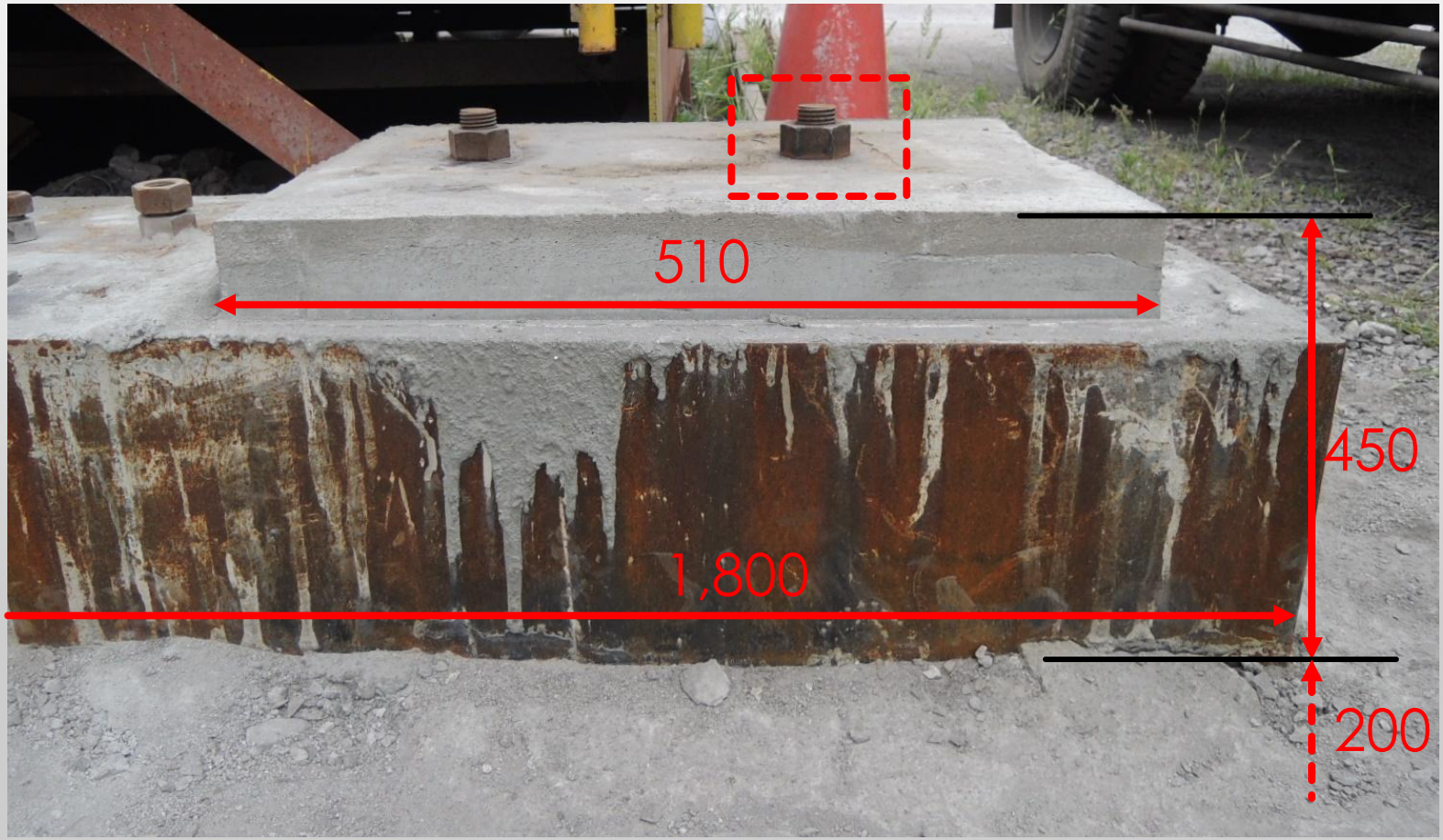


Probability that the decay of vibration became gradual.

4. RESULTS

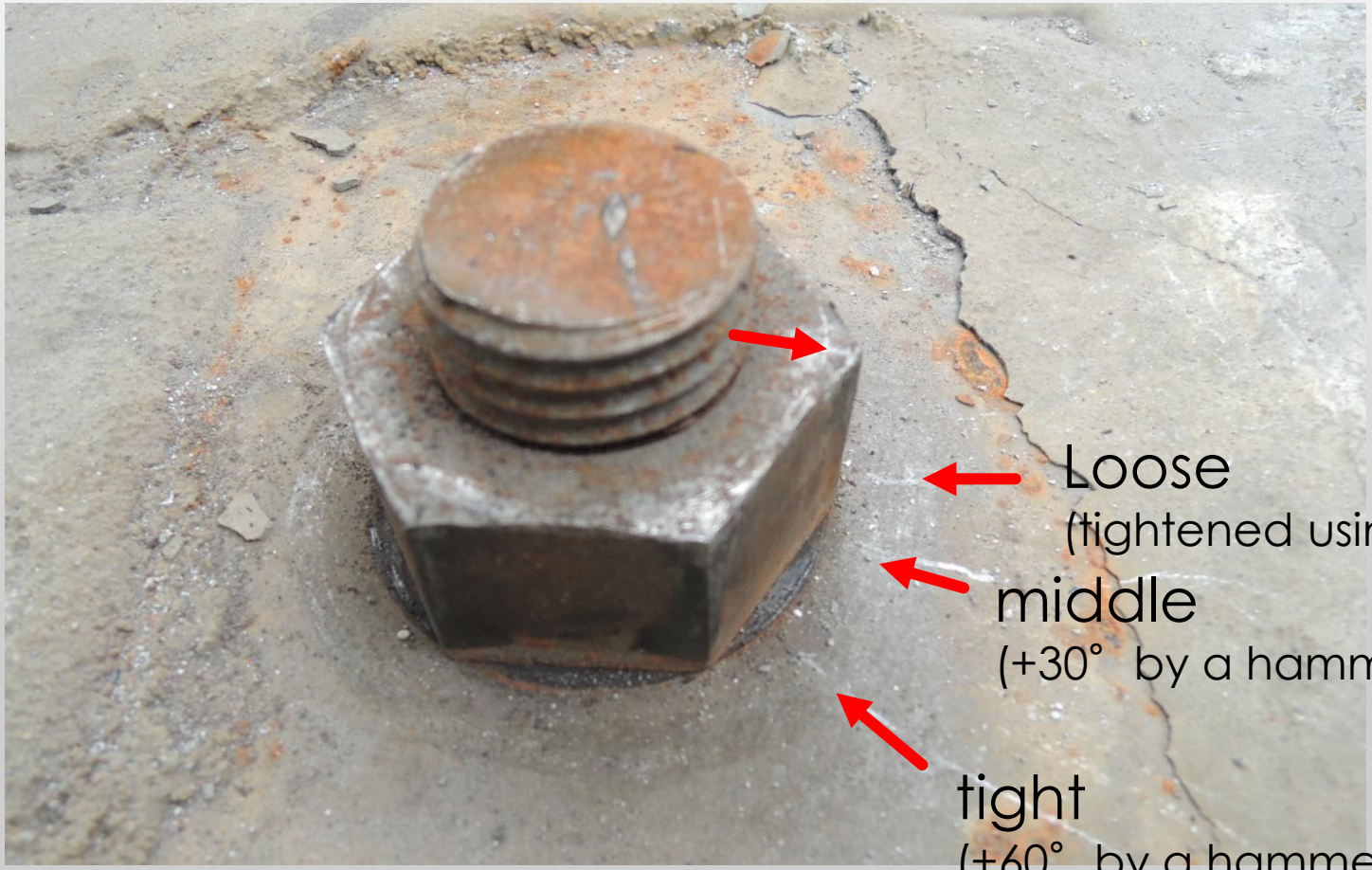
4.2 Field Test - Sample



M36 bolt on non-shrinkage mortar base

4. RESULTS

4.2 FIELD TEST – EXPERIMENTAL CONDITION



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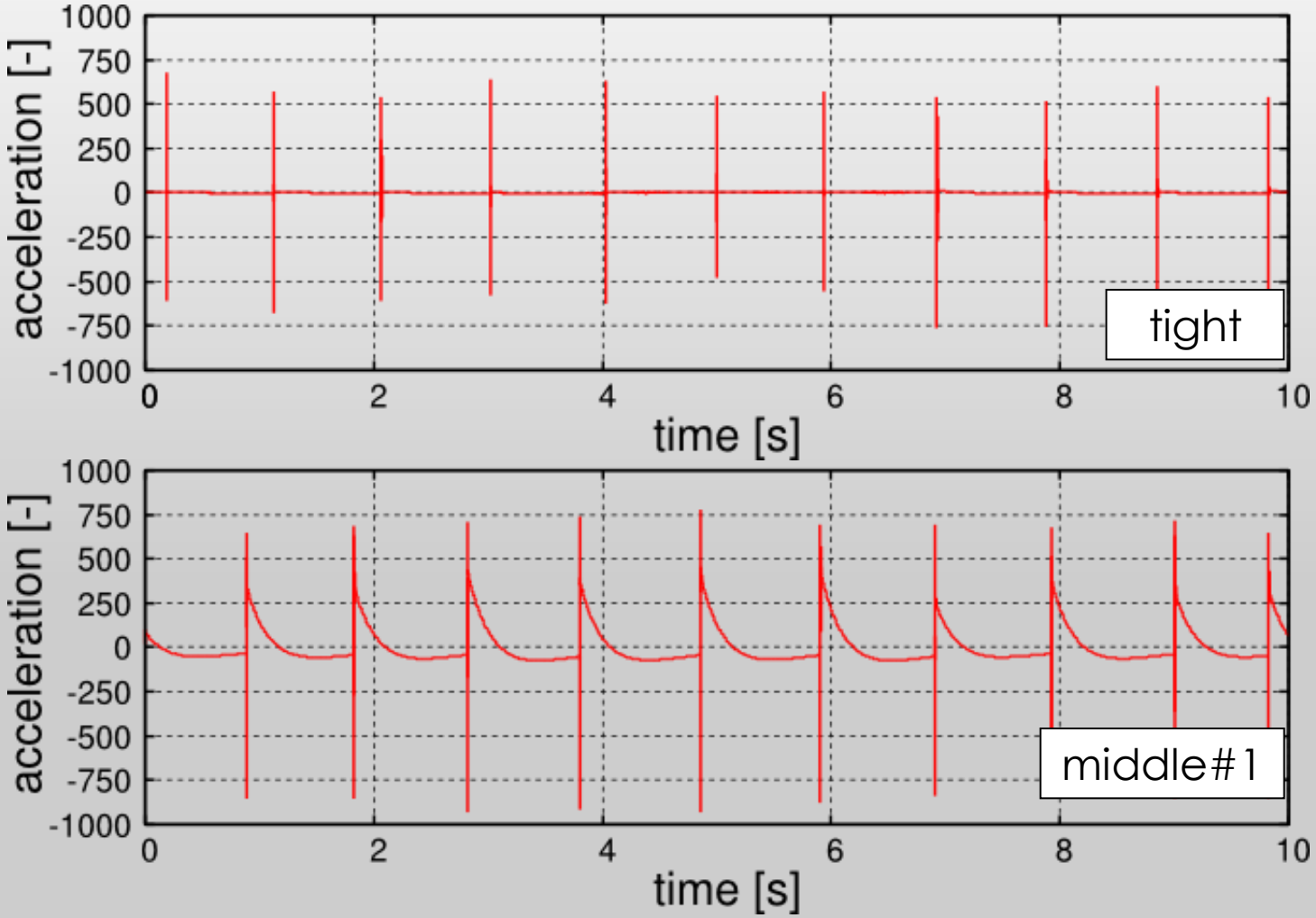
4.2 FIELD TEST – RESULT



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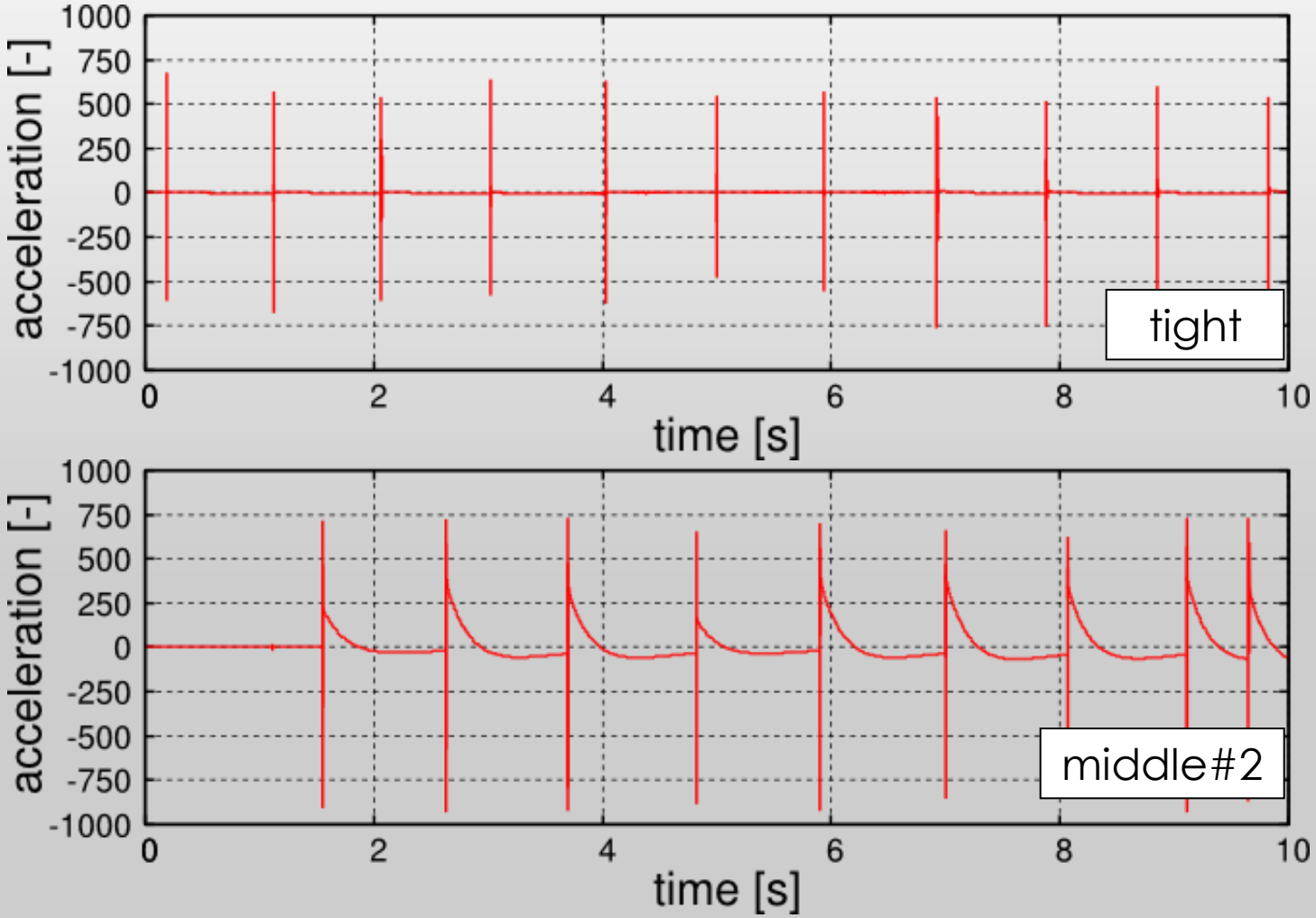

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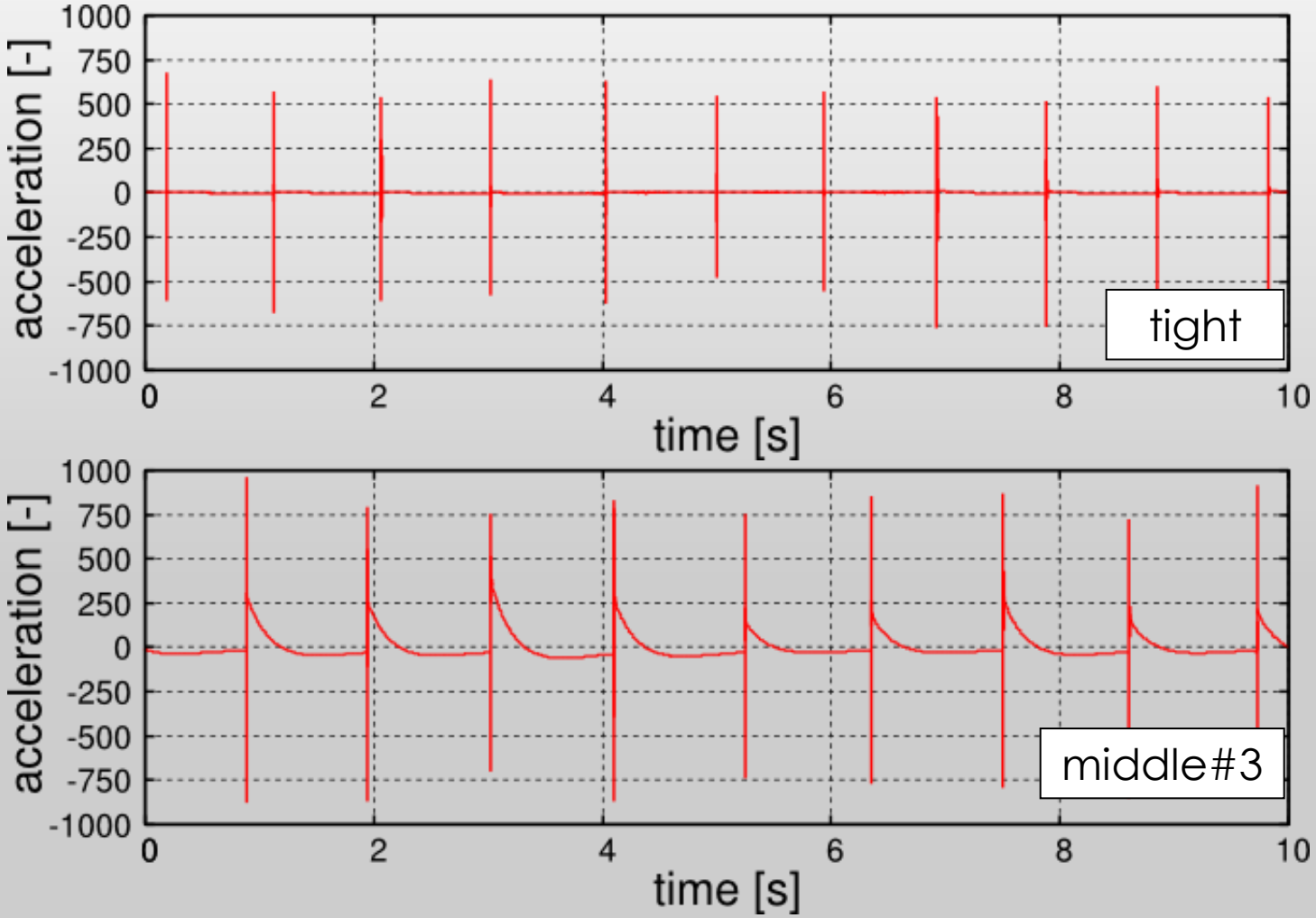

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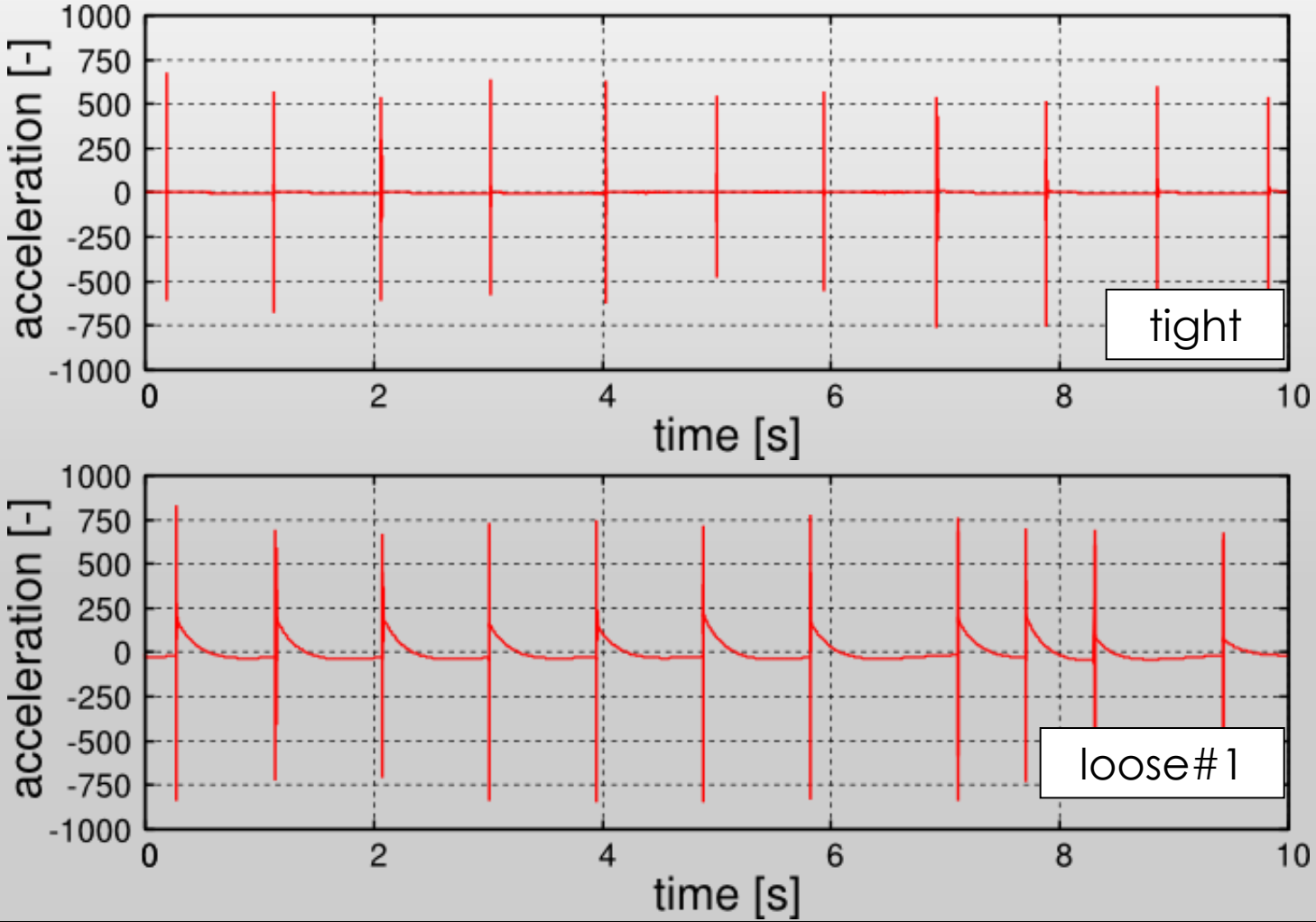

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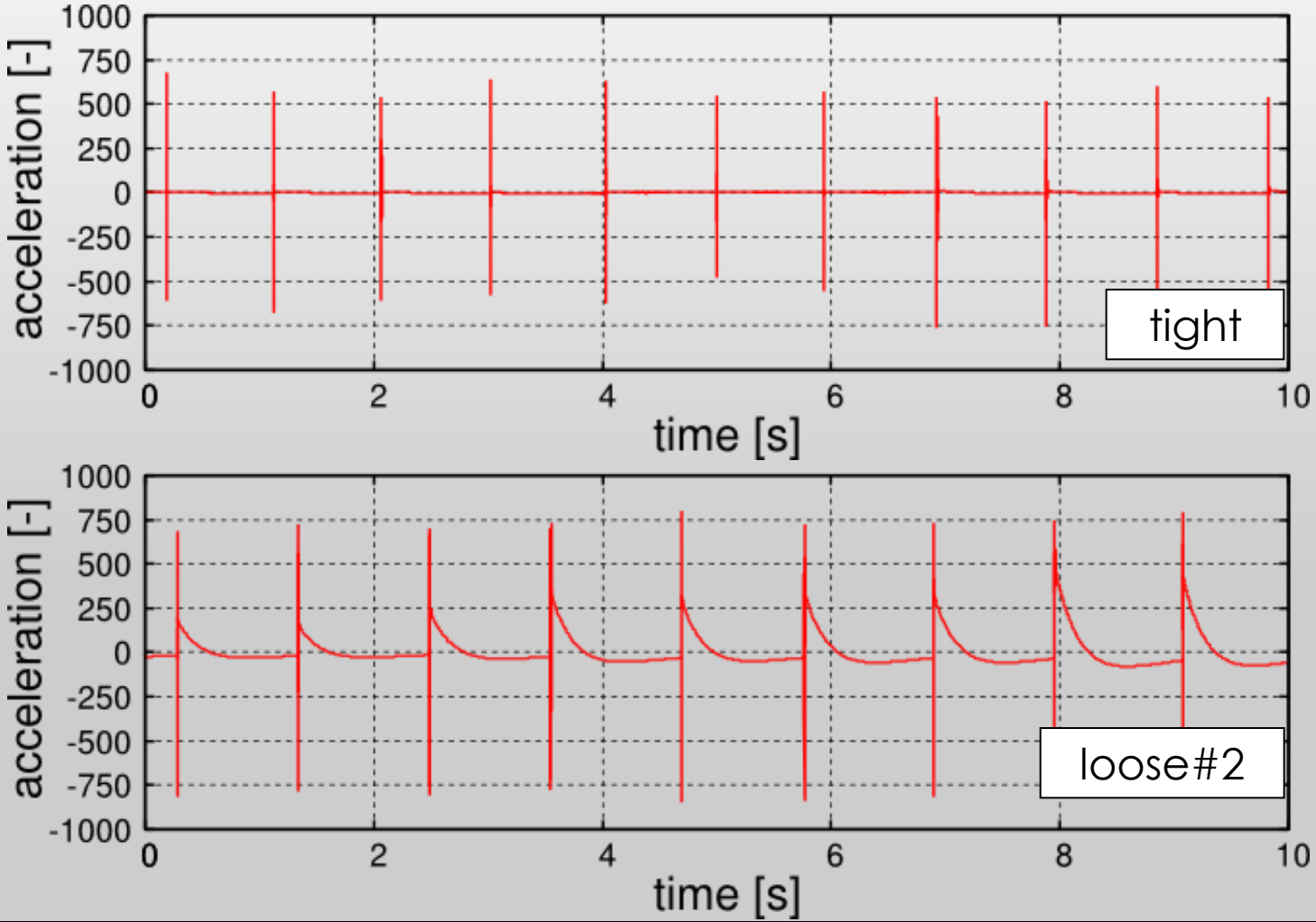

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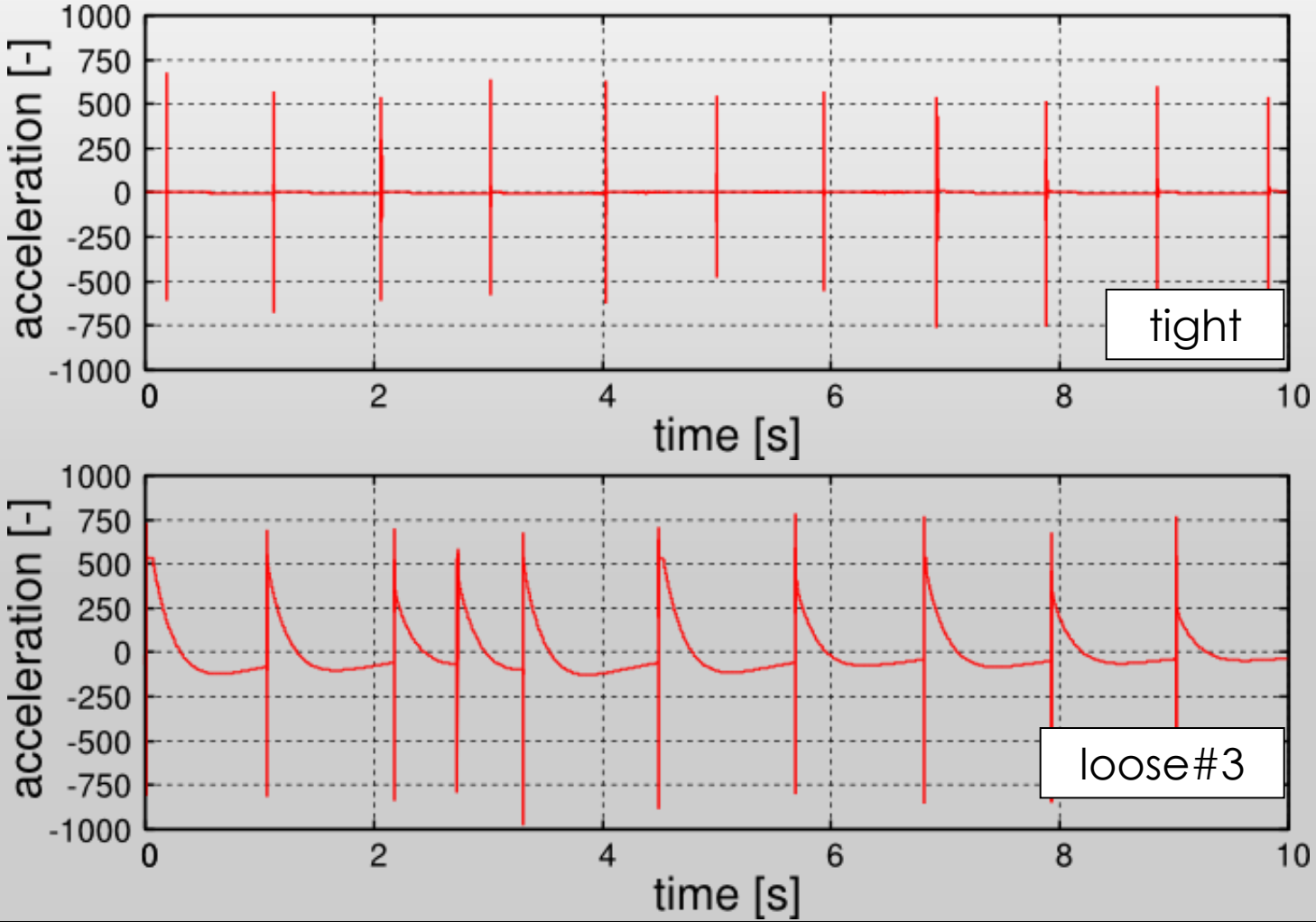
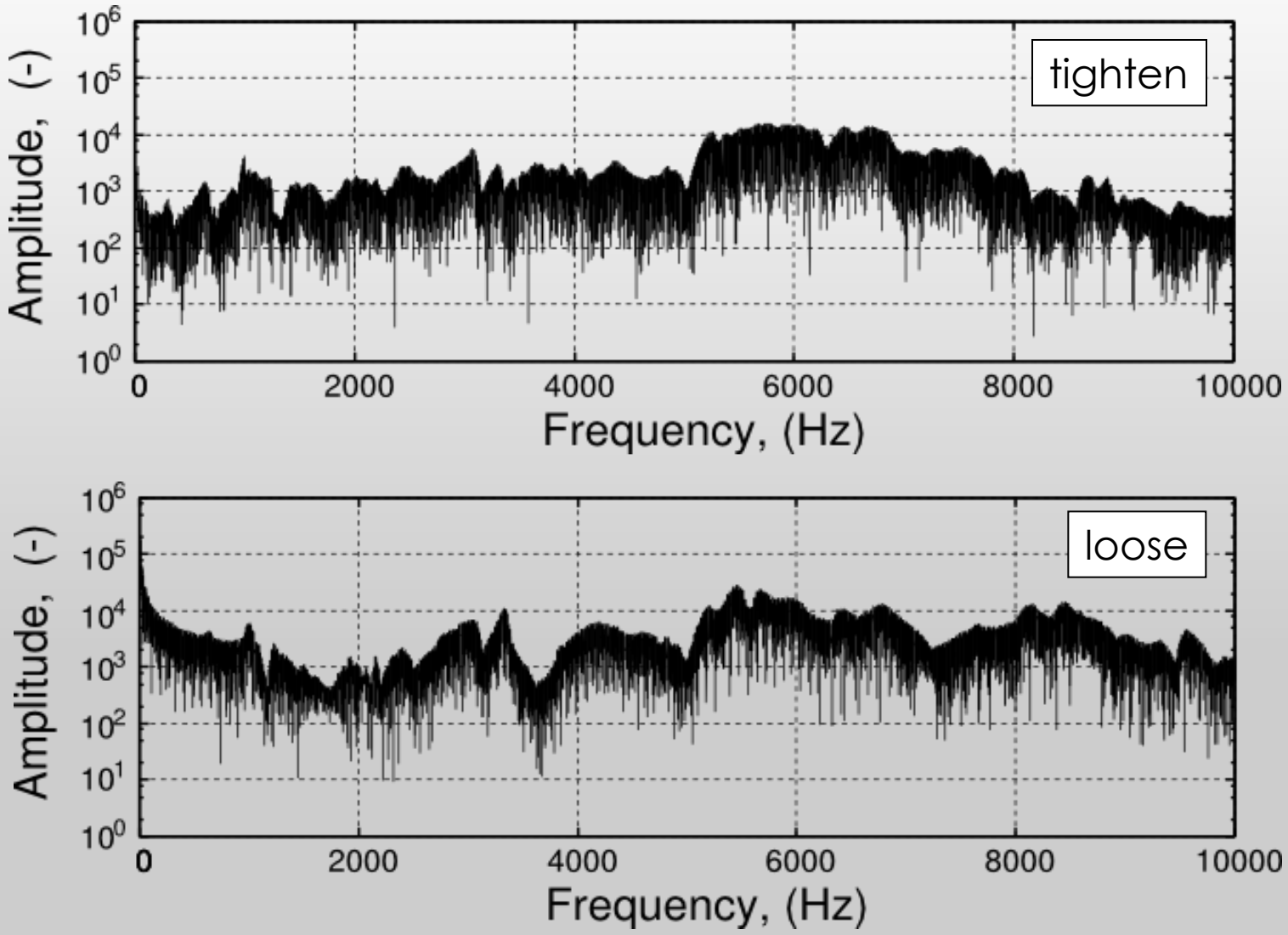


5. CONCLUSION

THIS STUDY HAS DEMONSTRATED, THROUGH LABORATORY AND FIELD TESTS, THAT BOLT LOOSENING CAN BE EASILY DETECTED ON THE BASIS OF LOW-FREQUENCY VIBRATION SIGNALS.

- ADVANTAGE:
  - SIMPLE AND CLEAR INDICATION
  - COST-EFFECTIVE
- DISADVANTAGE:
  - NOT APPLICABLE TO SMALL STRUCTURE (PROBABLY)
  - NOT SO CLEAR MECHANISM (FURTHER STUDY IS ONGOING)


tighten
Amplitude, (-)
10^6
10^5
10^4
10^3
10^2
10^1
10^0
0
2000
4000
6000
8000
10000
Frequency, (Hz)
loose
Amplitude, (-)
10^6
10^5
10^4
10^3
10^2
10^1
10^0
0
2000
4000
6000
8000
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Frequency, (Hz)