The University of Texas Rio Grande Valley
Center for Multidisciplinary Research Excellence in Cyber-Physical Infrastructure Systems (MECIS)

Vibration analysis and mitigation to enhance the performance of sensors integrated into UAVs

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Abstract

Unmanned Aerial Vehicles (UAVs) equipped with sensors offer an efficient means for infrastructure condition monitoring. However, their stability during measurements is crucial for the reliability and accuracy of the results. This study explores the effects of UAV vibration on the readings acquired from a laser-photodiode sensor used to detect and quantify cracks on infrastructure. Vibration dampening techniques are investigated. Results show that vibration dampening improves signal stability, especially at high vibrations, and enhances detection accuracy.

Introduction & Background

- Crack detection is crucial for maintaining infrastructure health to prevent costly repairs and catastrophic failures.
- Traditional crack detection methods are time-consuming, labor-intensive, and potentially dangerous in some cases.
- UAV technology offers a solution by enabling automated and efficient crack detection and measurement.
- Integrating crack detection sensors into UAVs allows for faster, safer, and more precise inspections.
- Deploying sensors on drones introduces challenges like vibration from drone motors and unpredictable wind gusts, which can distort sensor readings and impact the reliability of crack detection.
- Effective design and mitigation strategies are needed to ensure consistent sensor performance across varied environments.

Figure 1: Manual crack detection method (ONESTOP NDT)

Methodology

- The sensor was tested under different vibration conditions to simulate drone-induced instabilities.
- Crack profiles with varying widths and depths were 3D-printed and moved along a linear track to simulate structural defects.
- Testing was conducted across multiple speeds to observe how speed impacts sensor accuracy.
- Data was collected as resistance versus time, with resistance fluctuations indicating crack detection effectiveness.
- Tests with and without vibration-dampening measures were conducted to compare their impact on sensor stability and reliability.

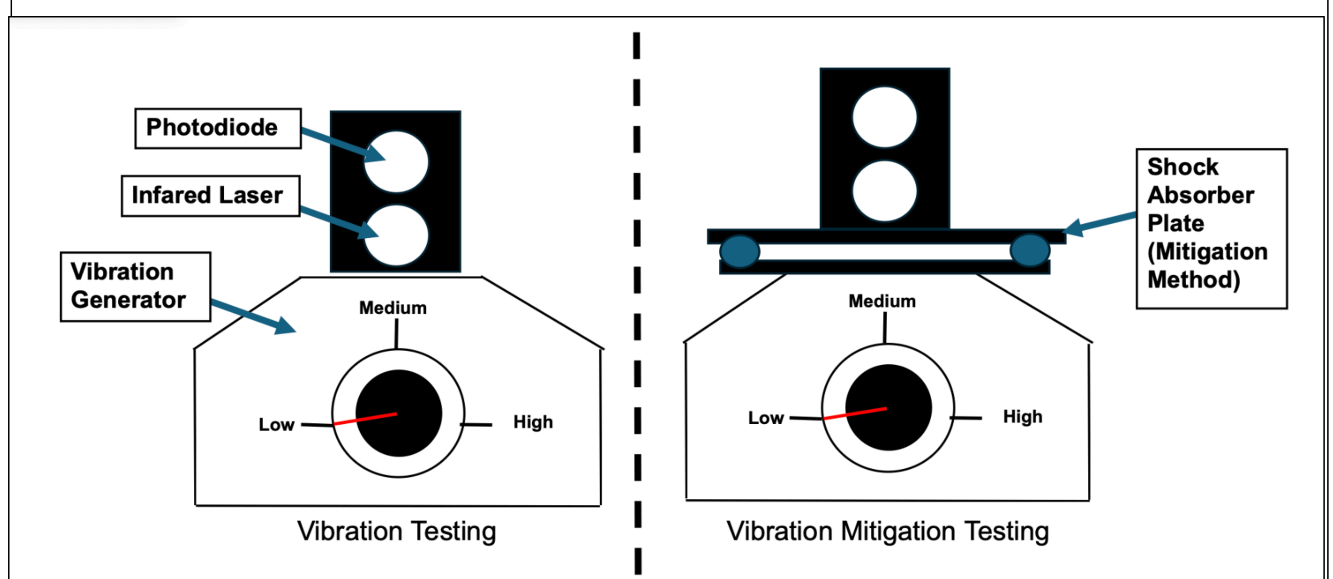

Figure 2: Vibration testing schematic

Data and Results

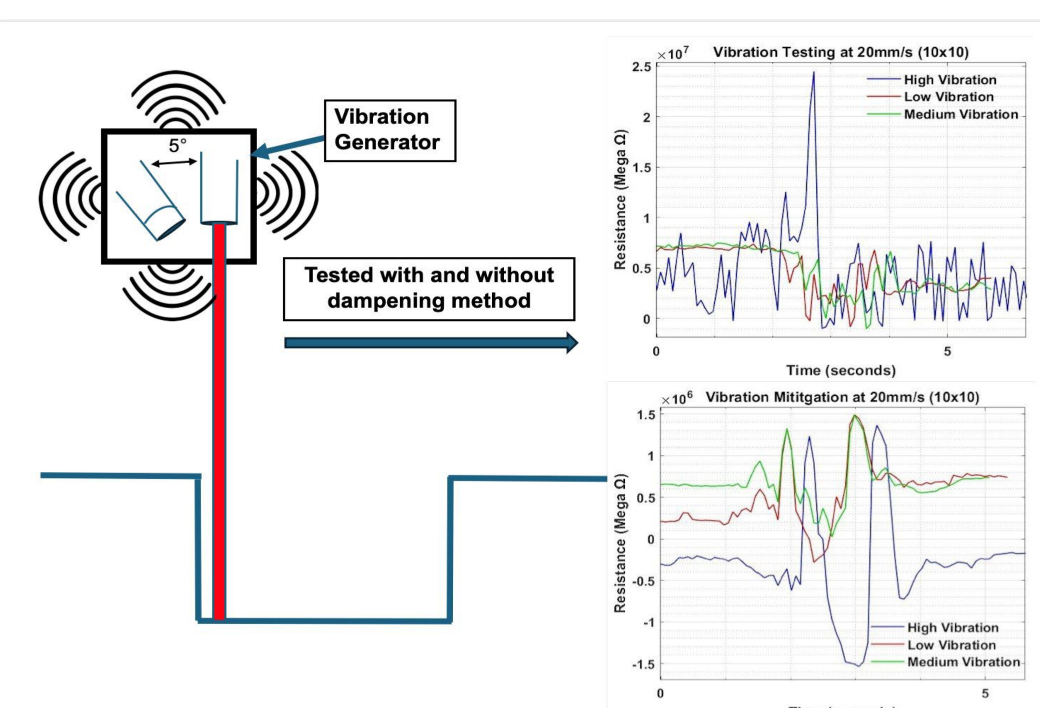

Figure 3: Experimental setup for vibration testing

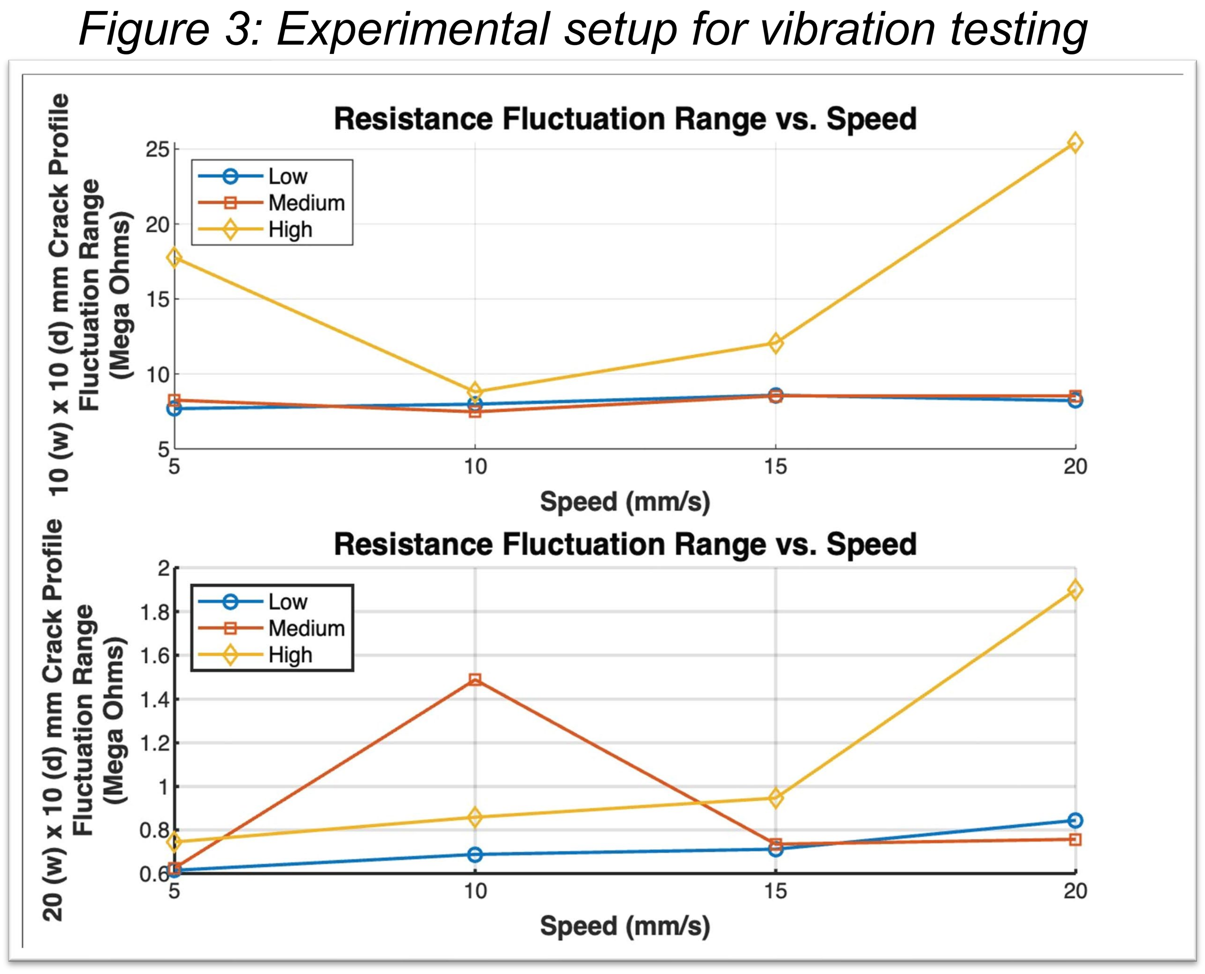

Figure 4: Resistance fluctuation range vs. speed for each crack size

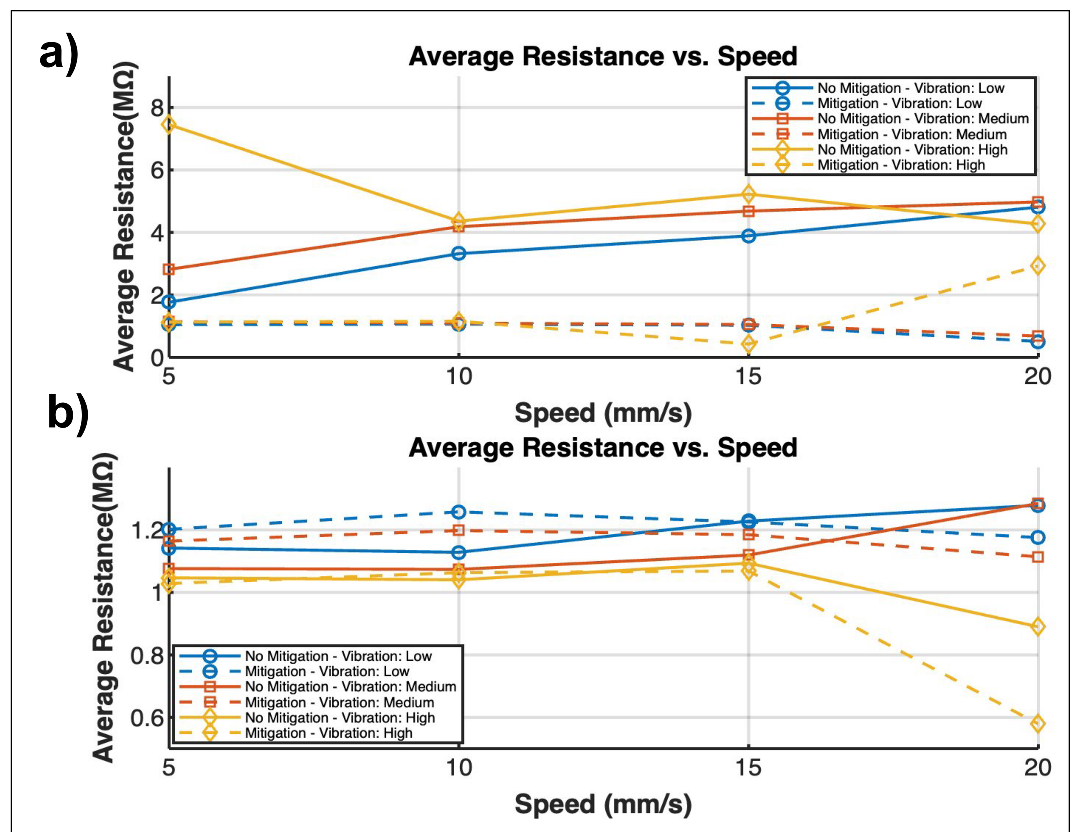

Figure 5: Average Resistance vs Speed (a) 10 x 10 mm (b) 20 x 10 mm

Conclusions & Future Work

- Resistance signal stabilizes with dampening pads, even at high vibration levels, improving crack detection accuracy
- Higher speeds increase amplitude fluctuations, suggesting speed sensitivity
- Larger cracks produce more pronounced resistance changes
- Initial trendlines show amplitude and period patterns that vary with vibration intensity
- Analyze amplitude, period, and frequency data
- Explore alternative dampening methods to enhance sensor stability and accuracy

Acknowledgments

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References

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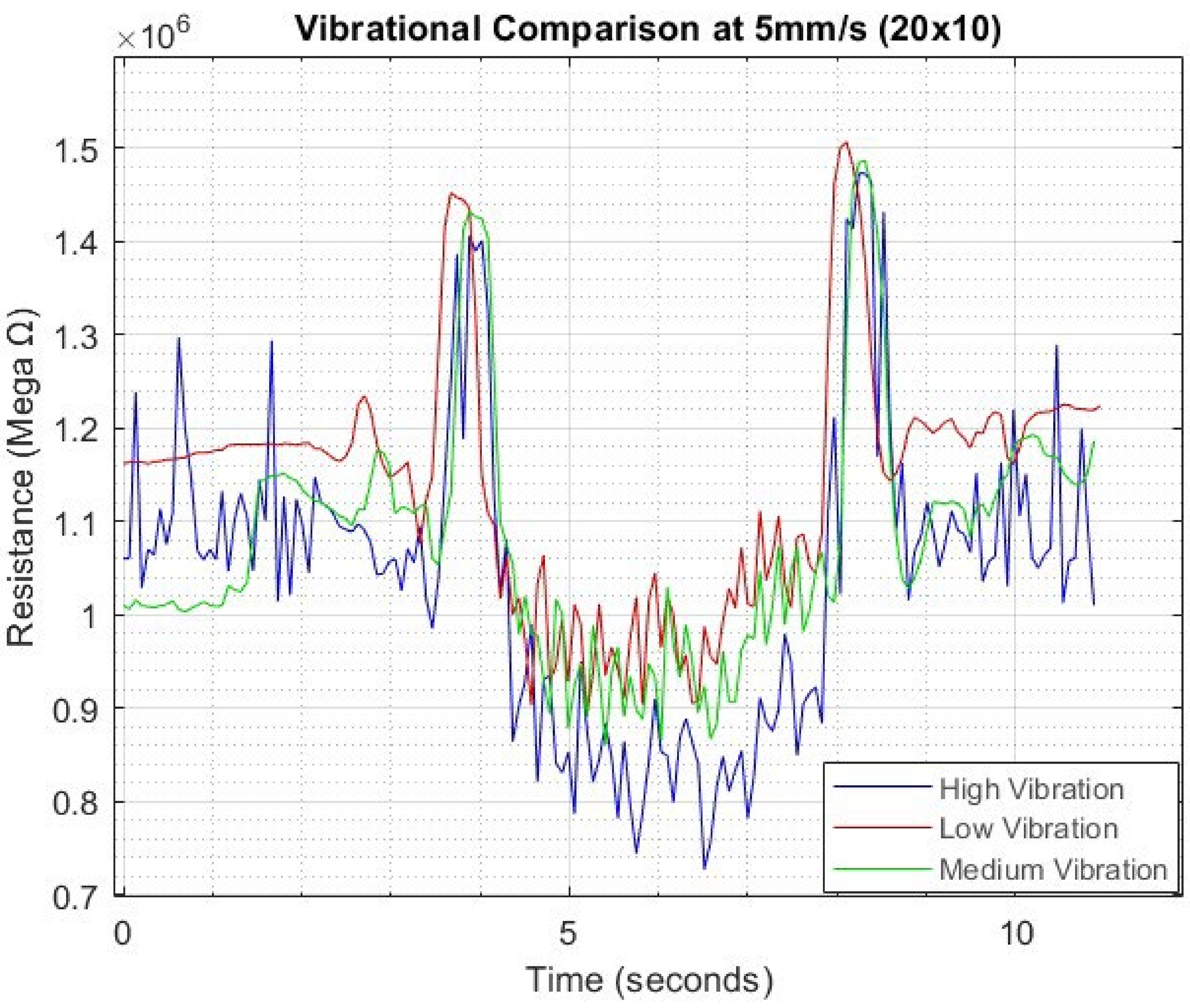
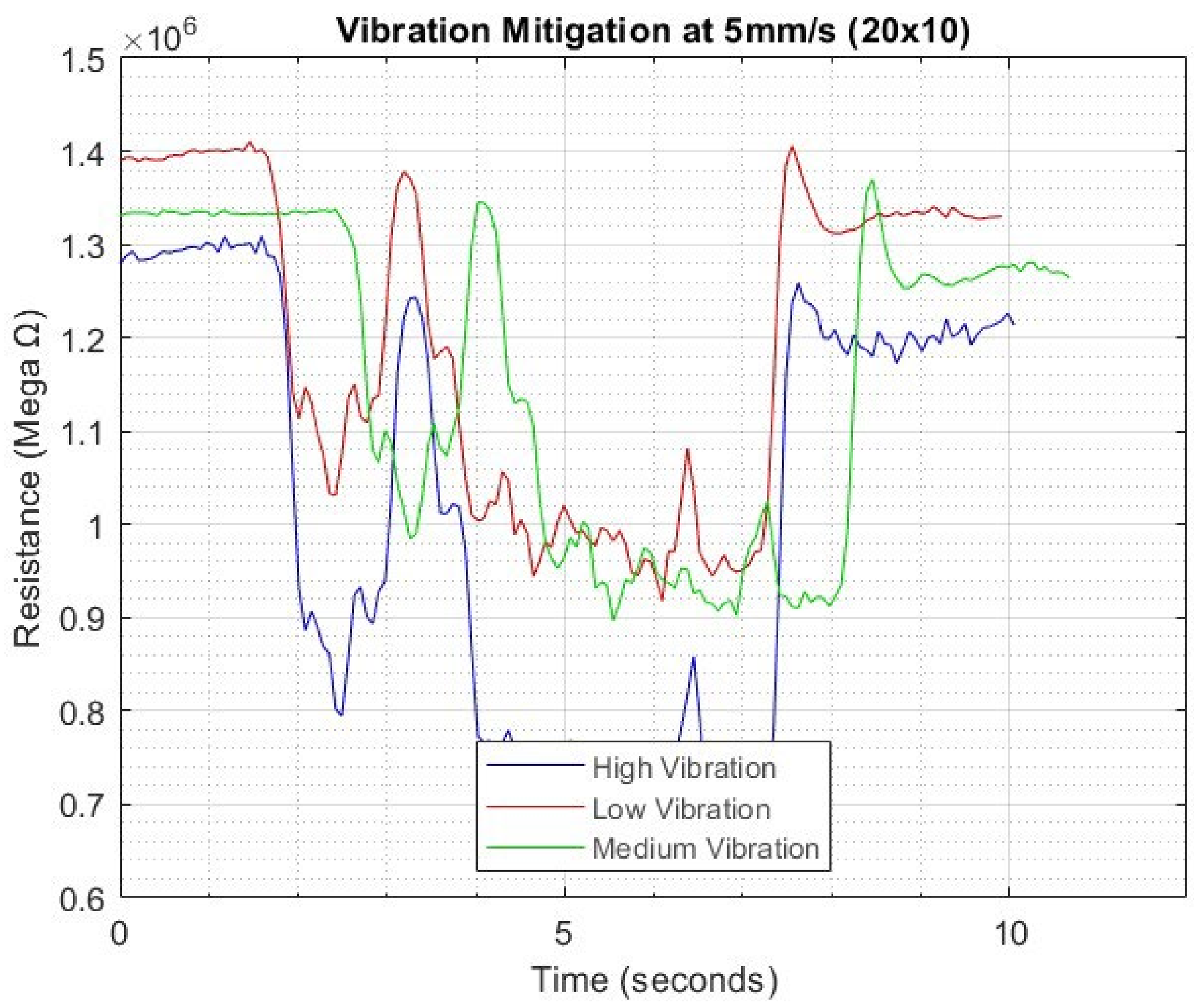
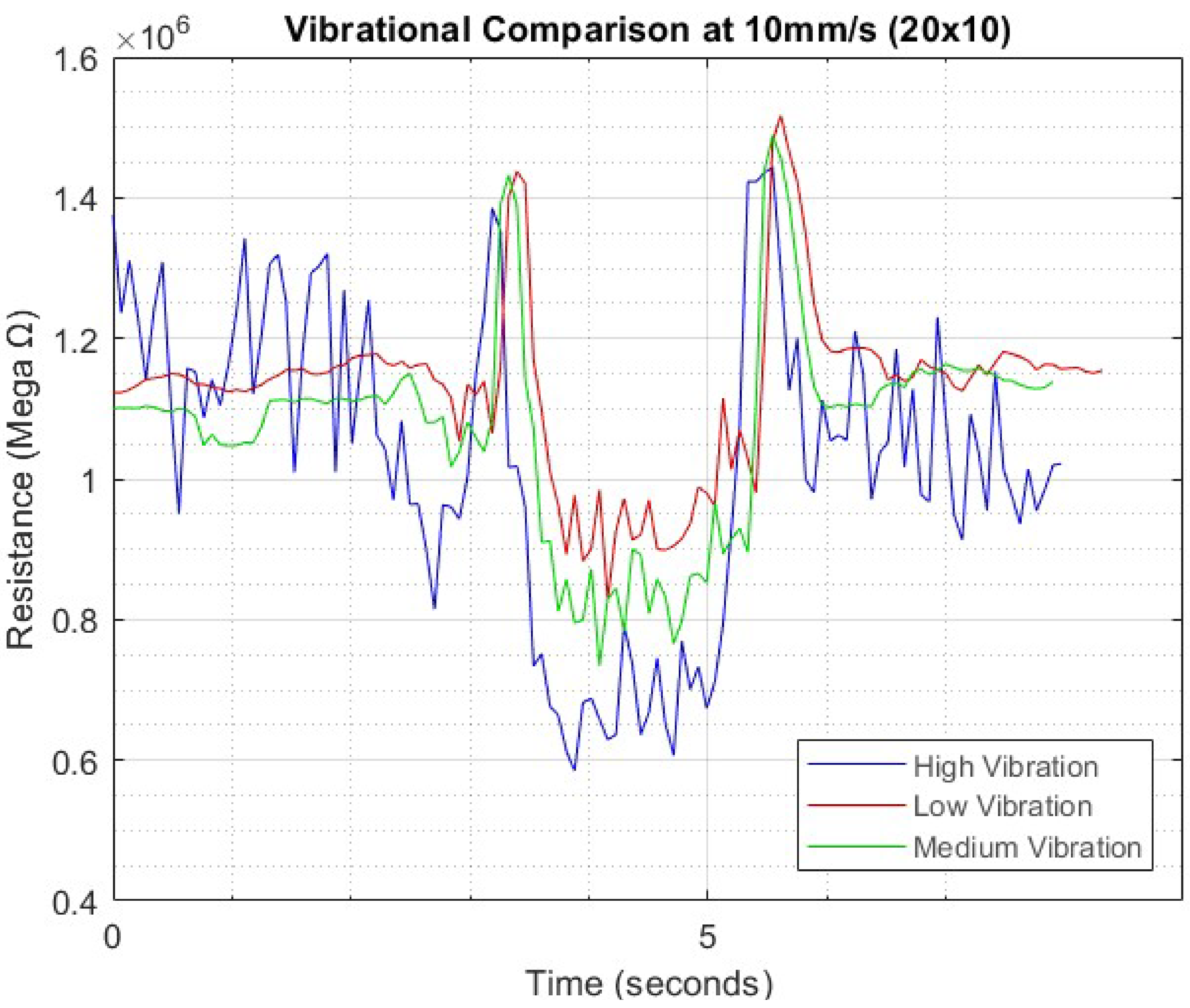
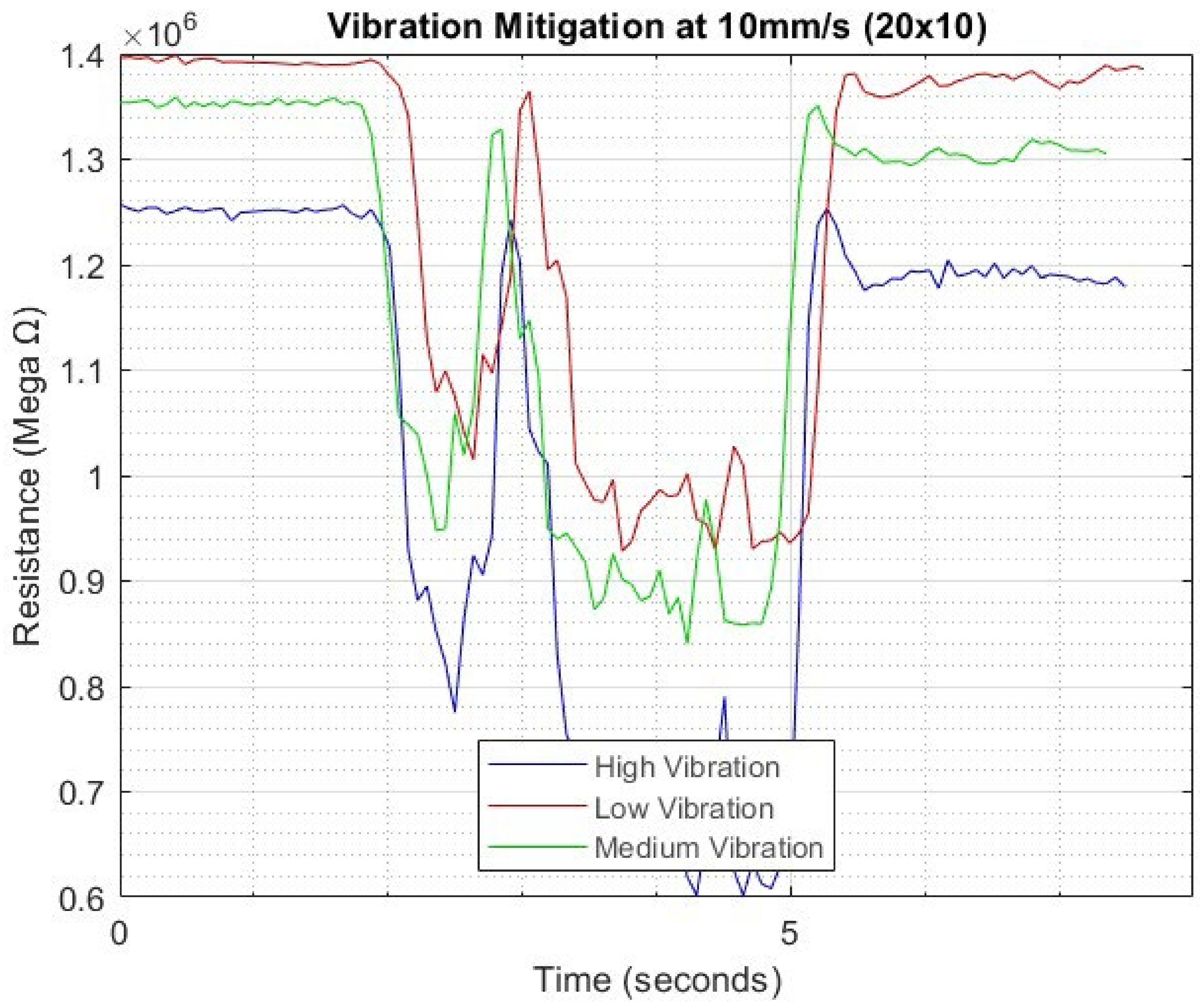
[2] Hou, X., Bai, H., & Li, Z. (2023). Automated crack detection and mapping of bridge decks with UAVs. *Journal of Civil Structural Health Monitoring.* https://doi.org/10.1007/s13349-023-00750-0


Vibrational Comparison at 5mm/s (20x10)
Resistance (Mega Ω)
Time (seconds)
High Vibration
Low Vibration
Medium Vibration


Vibration Mitigation at 5mm/s (20x10)
Resistance (Mega Ω)
Time (seconds)
High Vibration
Low Vibration
Medium Vibration


Vibrational Comparison at 10mm/s (20x10)
Resistance (Mega Ω)
Time (seconds)
High Vibration
Low Vibration
Medium Vibration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Resistance (Mega Ω)
Time (seconds)
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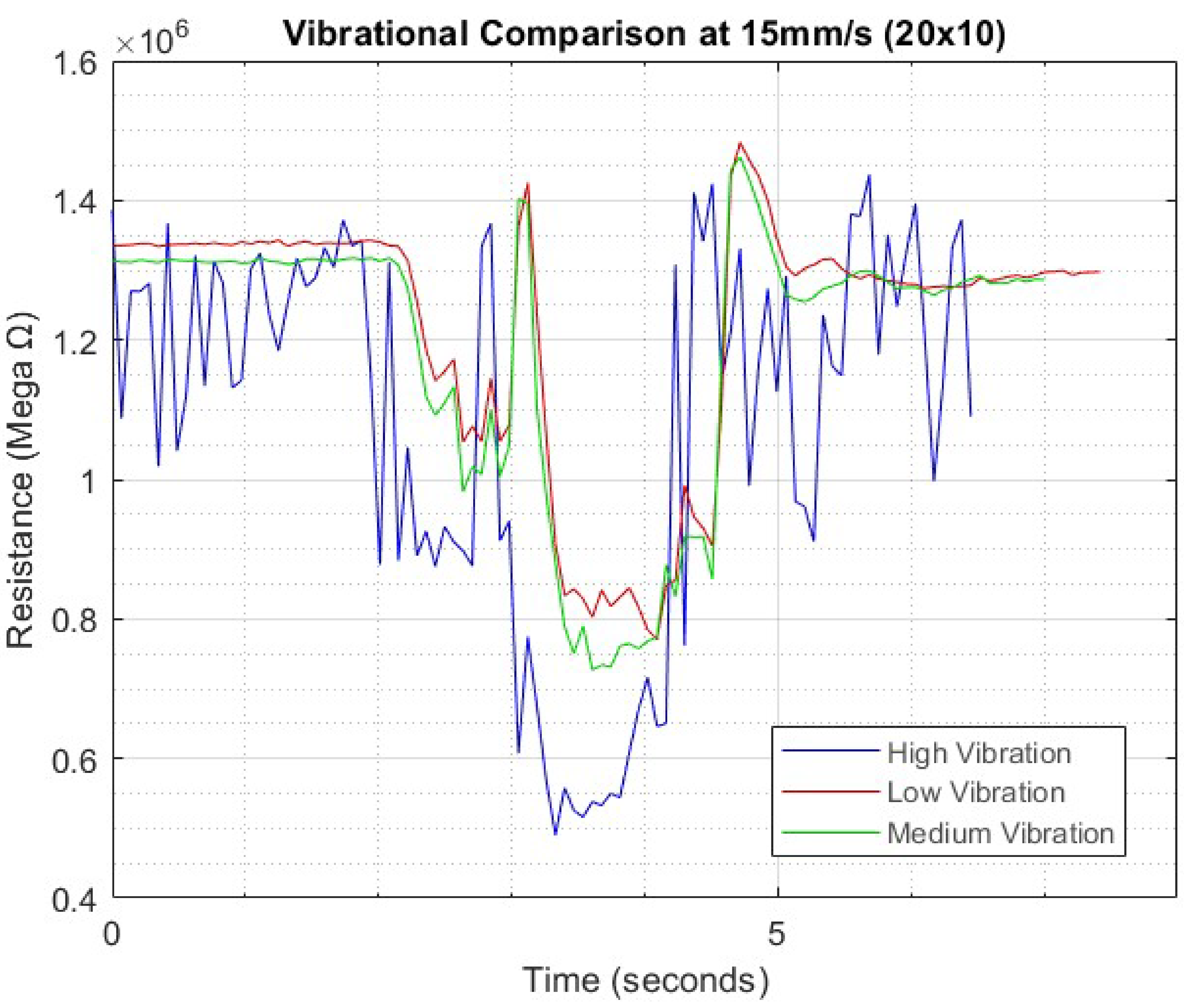
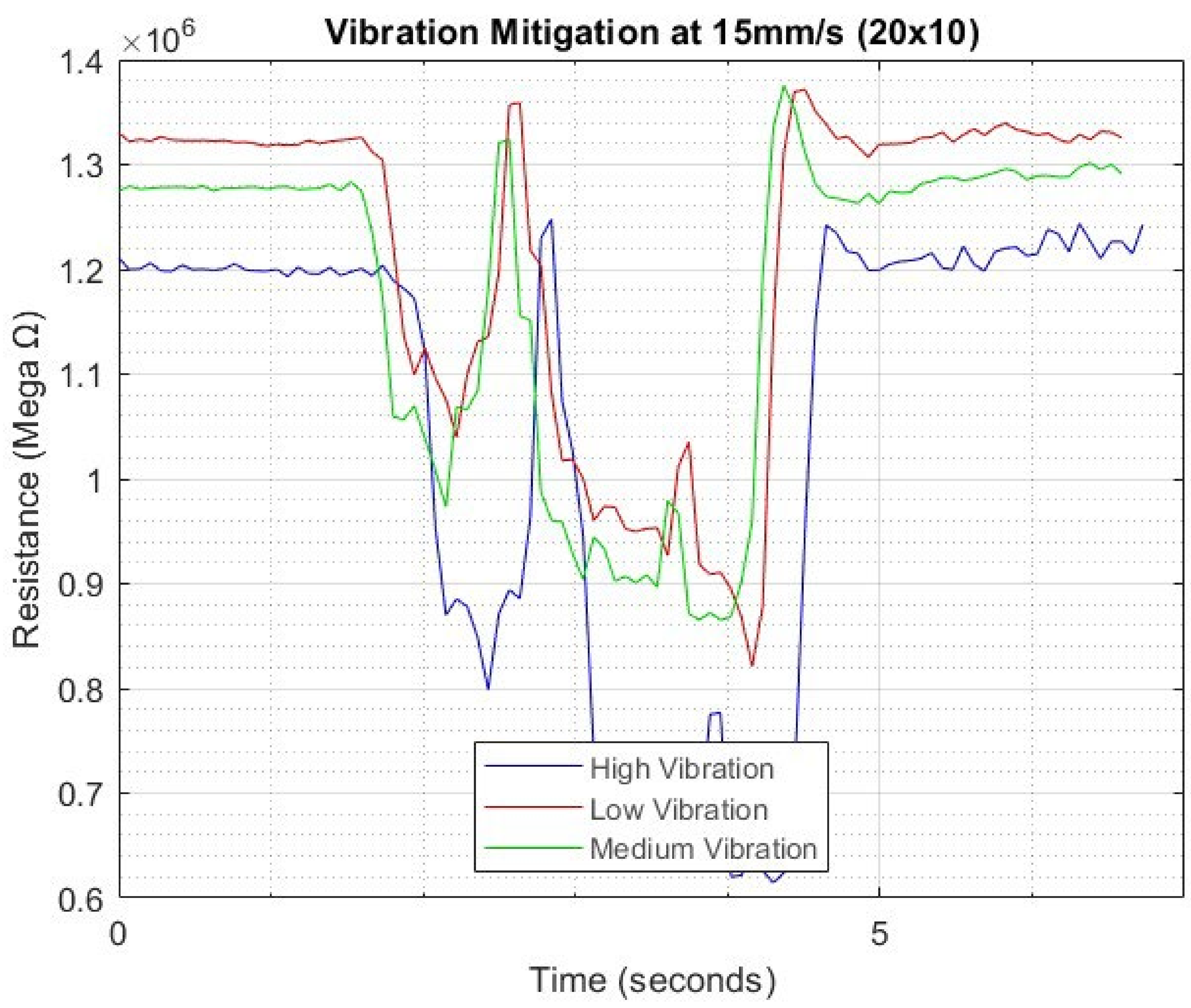
Low Vibration
Medium Vibration


Vibrational Comparison at 15mm/s (20x10)
Resistance (Mega Ω)
Time (seconds)
High Vibration
Low Vibration
Medium Vibration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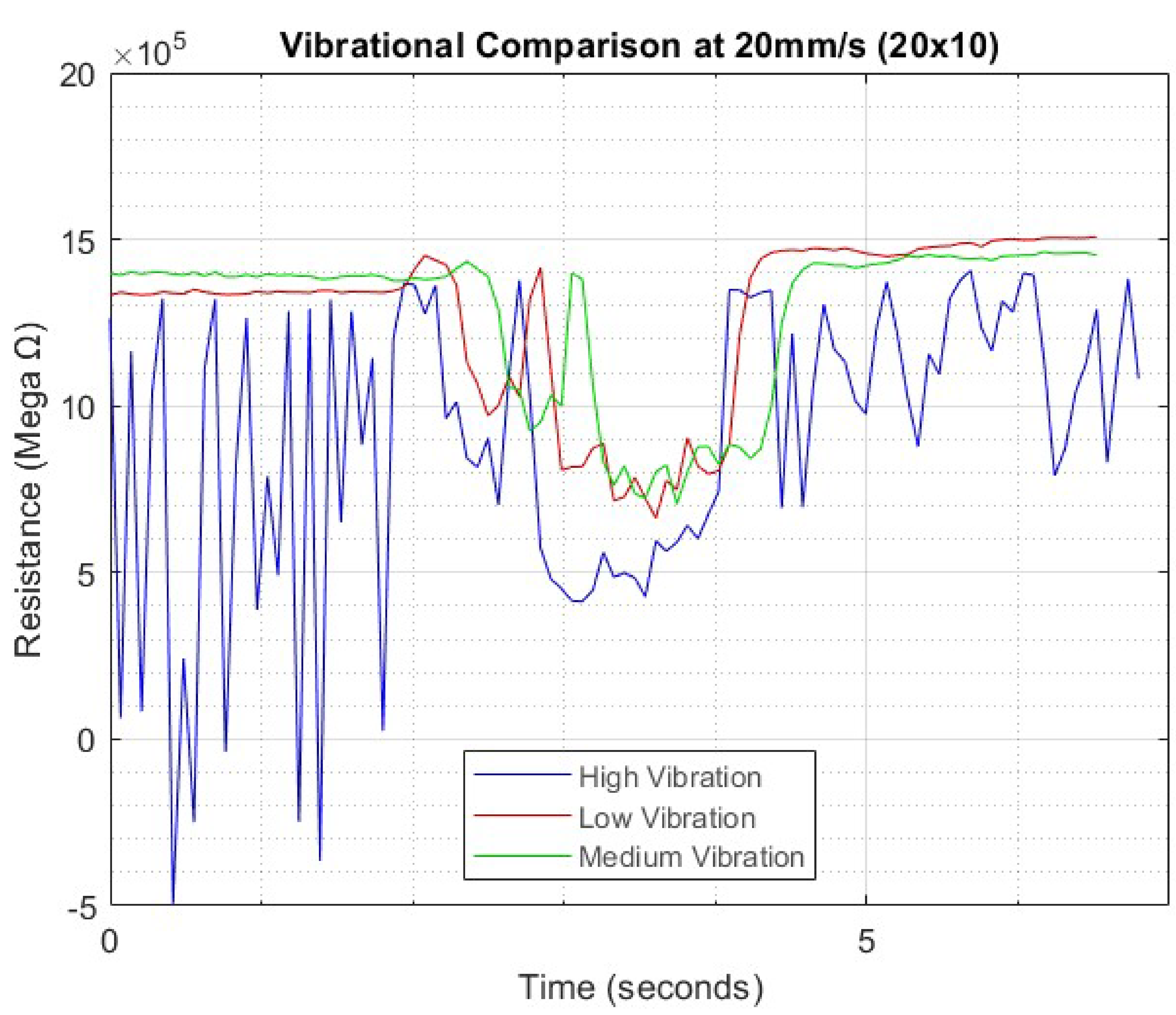
Resistance (Mega Ω)
Time (seconds)
High Vibration
Low Vibration
Medium Vibration


Vibrational Comparison at 20mm/s (20x10)
Resistance (Mega Ω)
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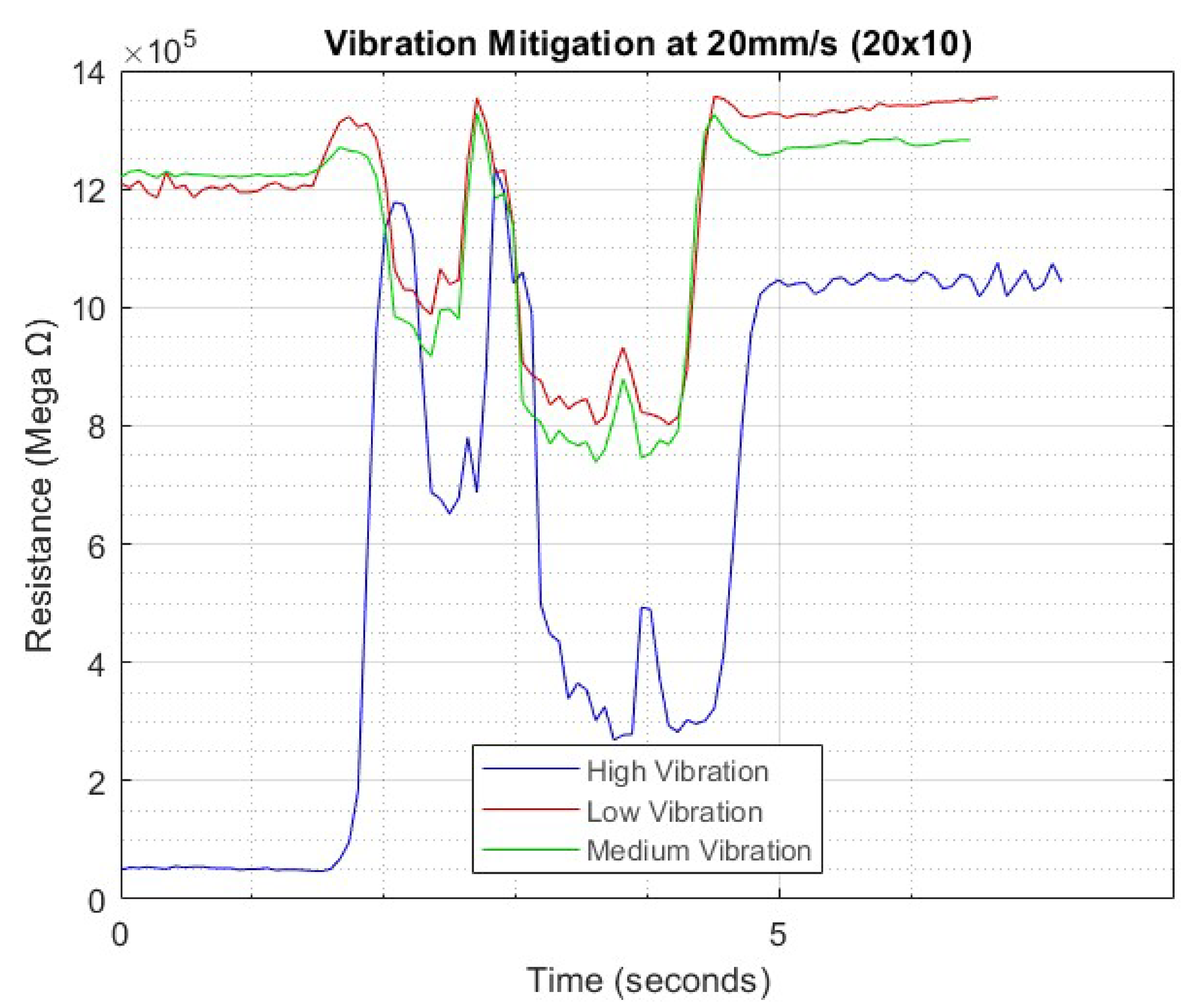
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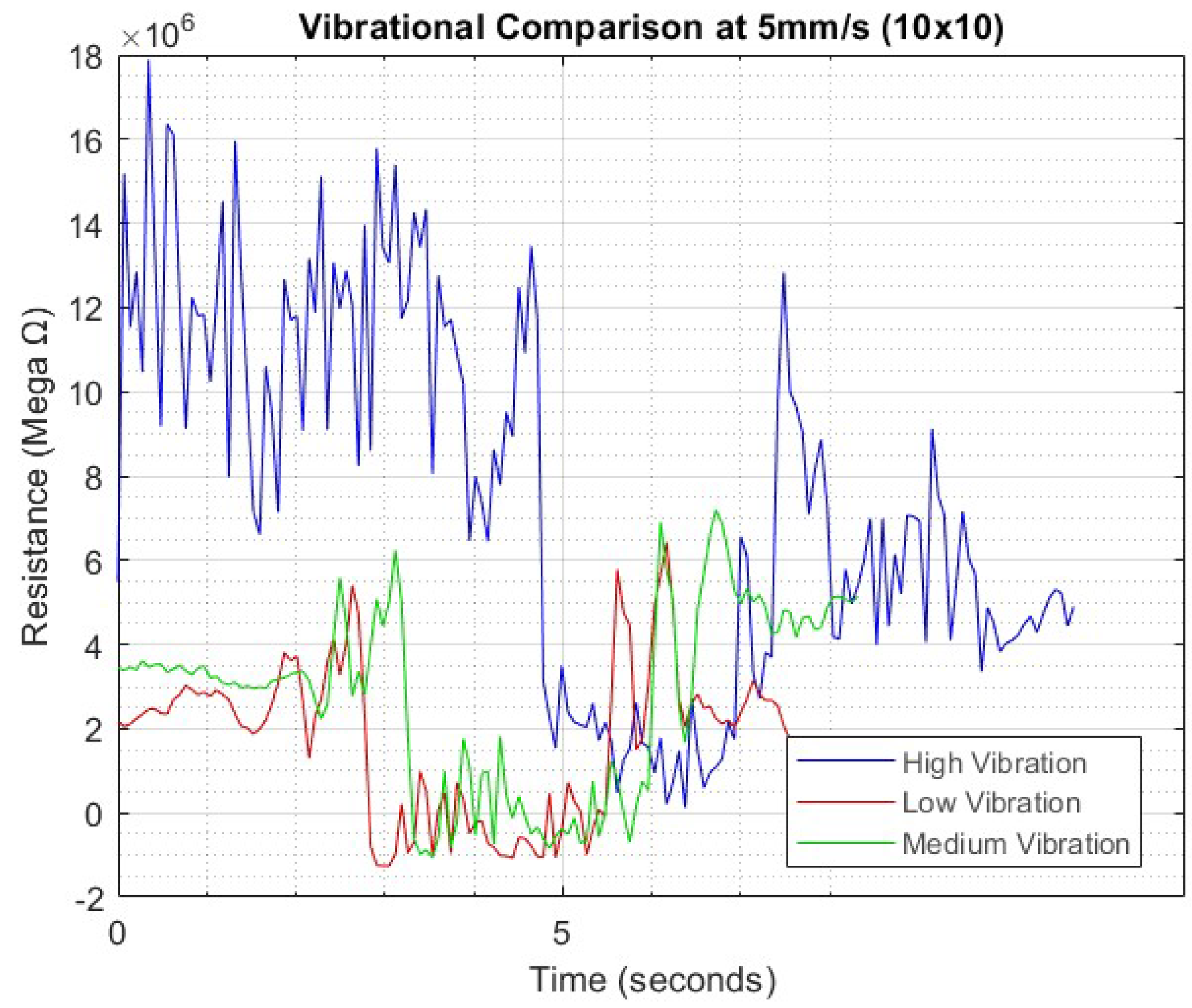
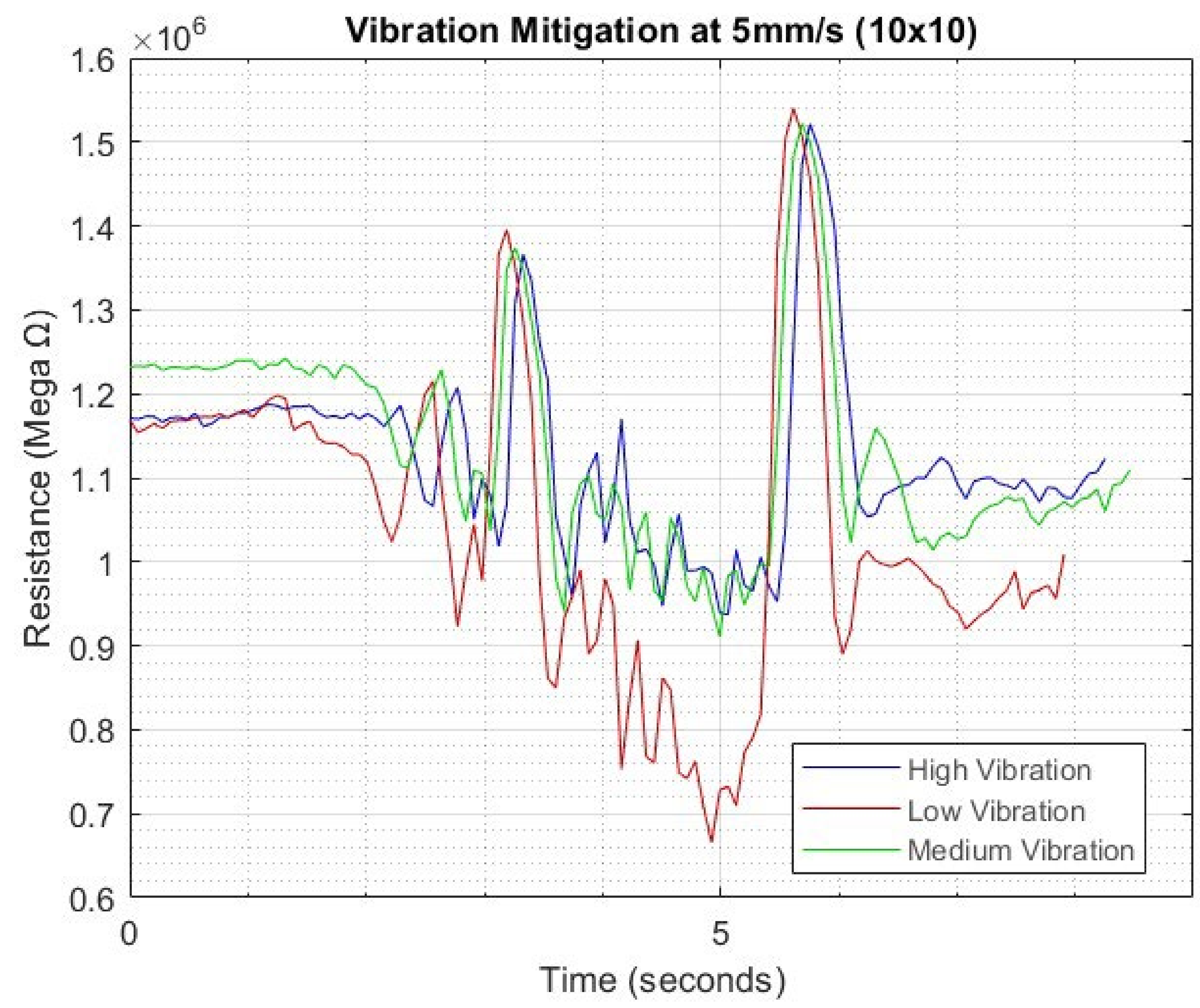

Vibrational Comparison at 5mm/s (10x10)
×10^6
Resistance (Mega Ω)
Time (seconds)
High Vibration
Low Vibration
Medium Vibration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Time (seconds)
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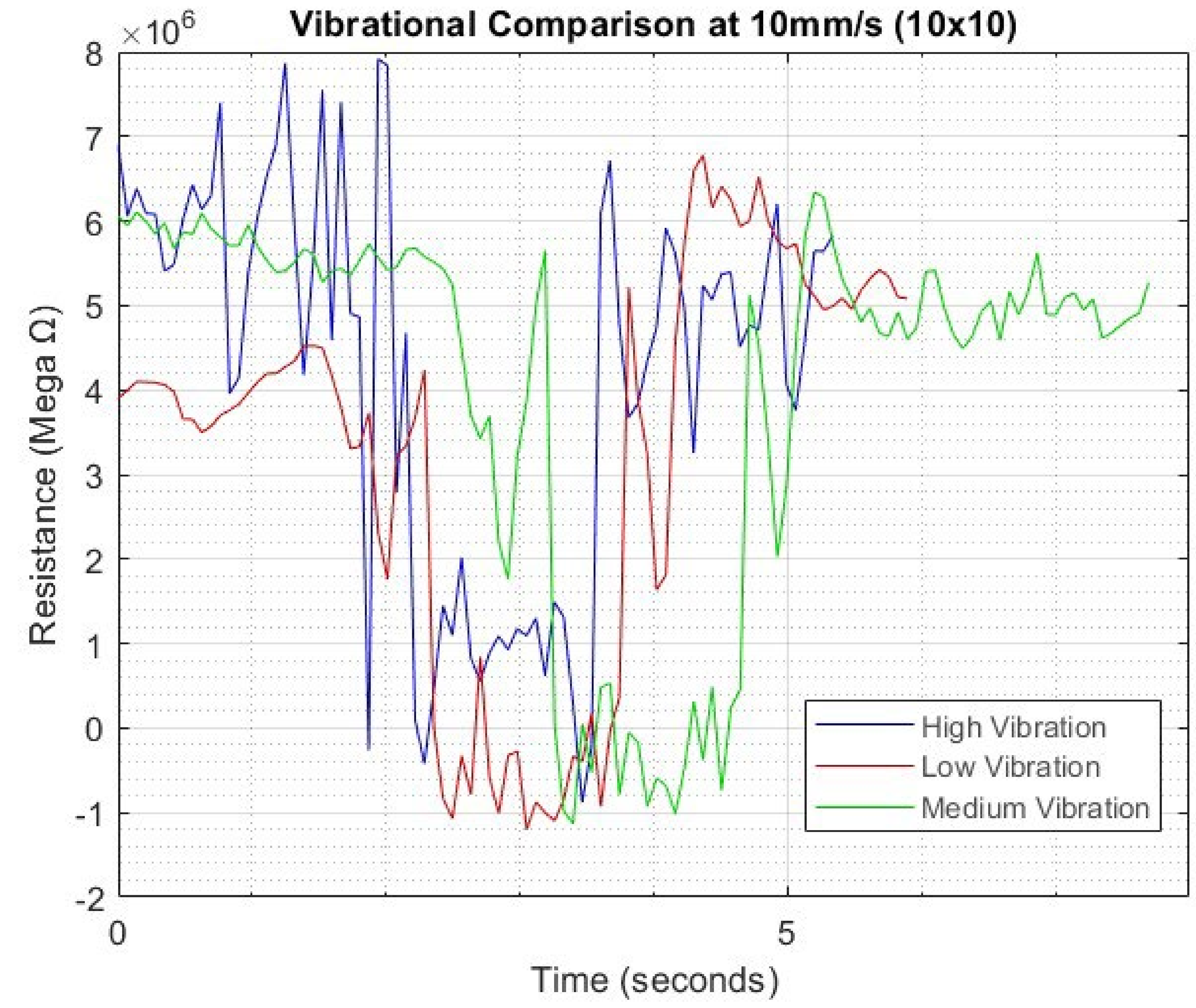
Vibrational Comparison at 10mm/s (10x10)
×10^6
Resistance (Mega Ω)
Time (seconds)
High Vibration
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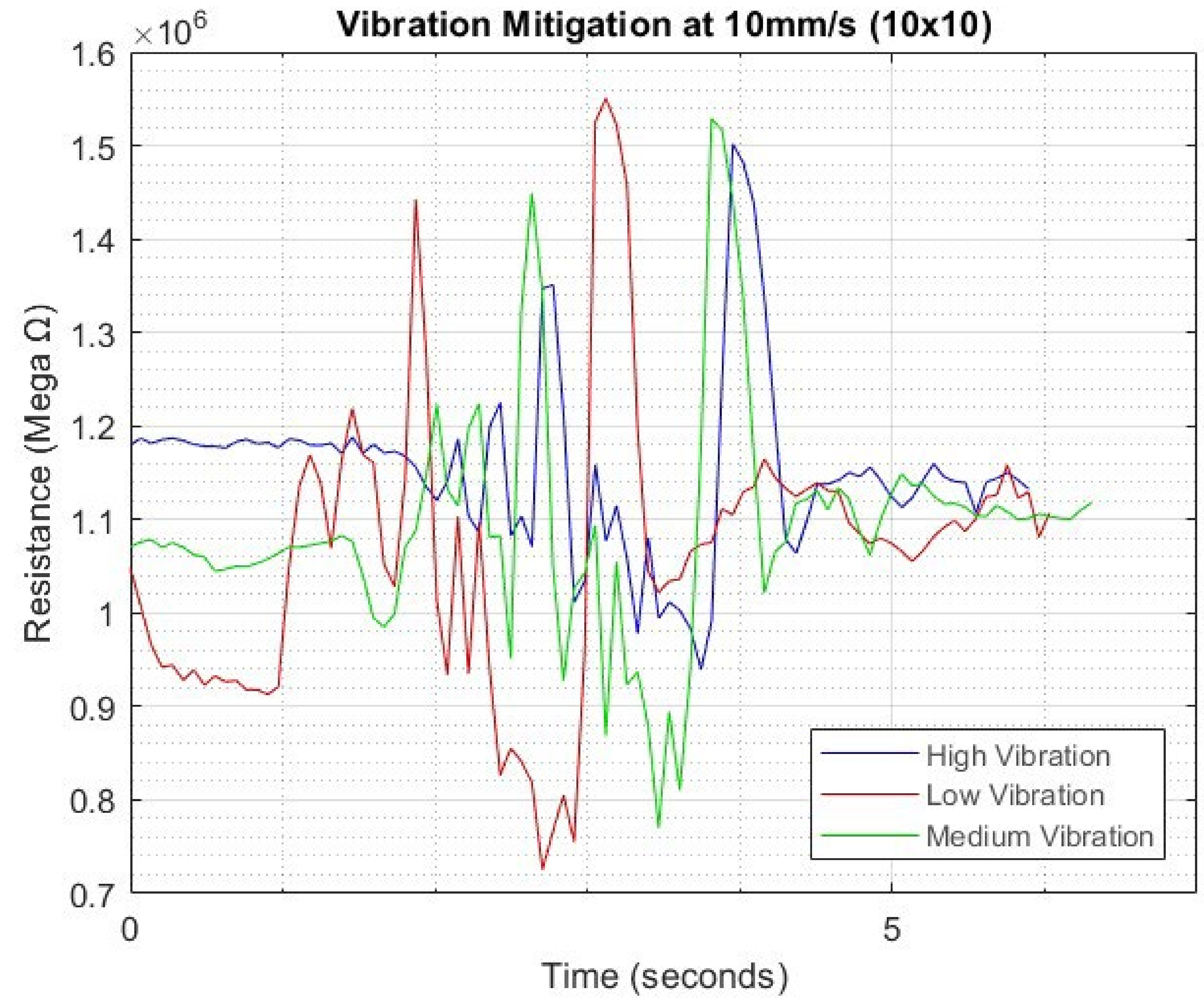
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Resistance (Mega Ω)
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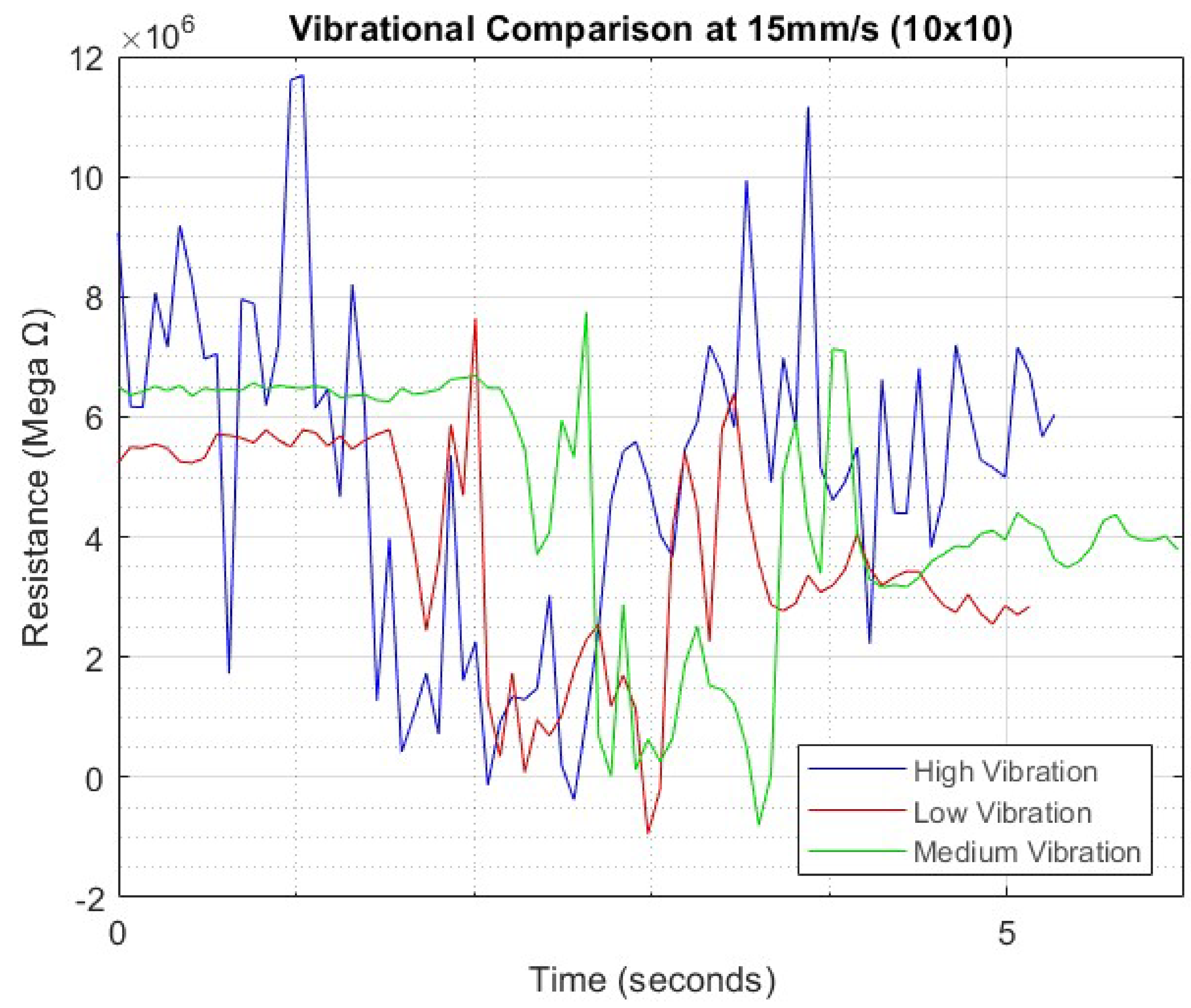
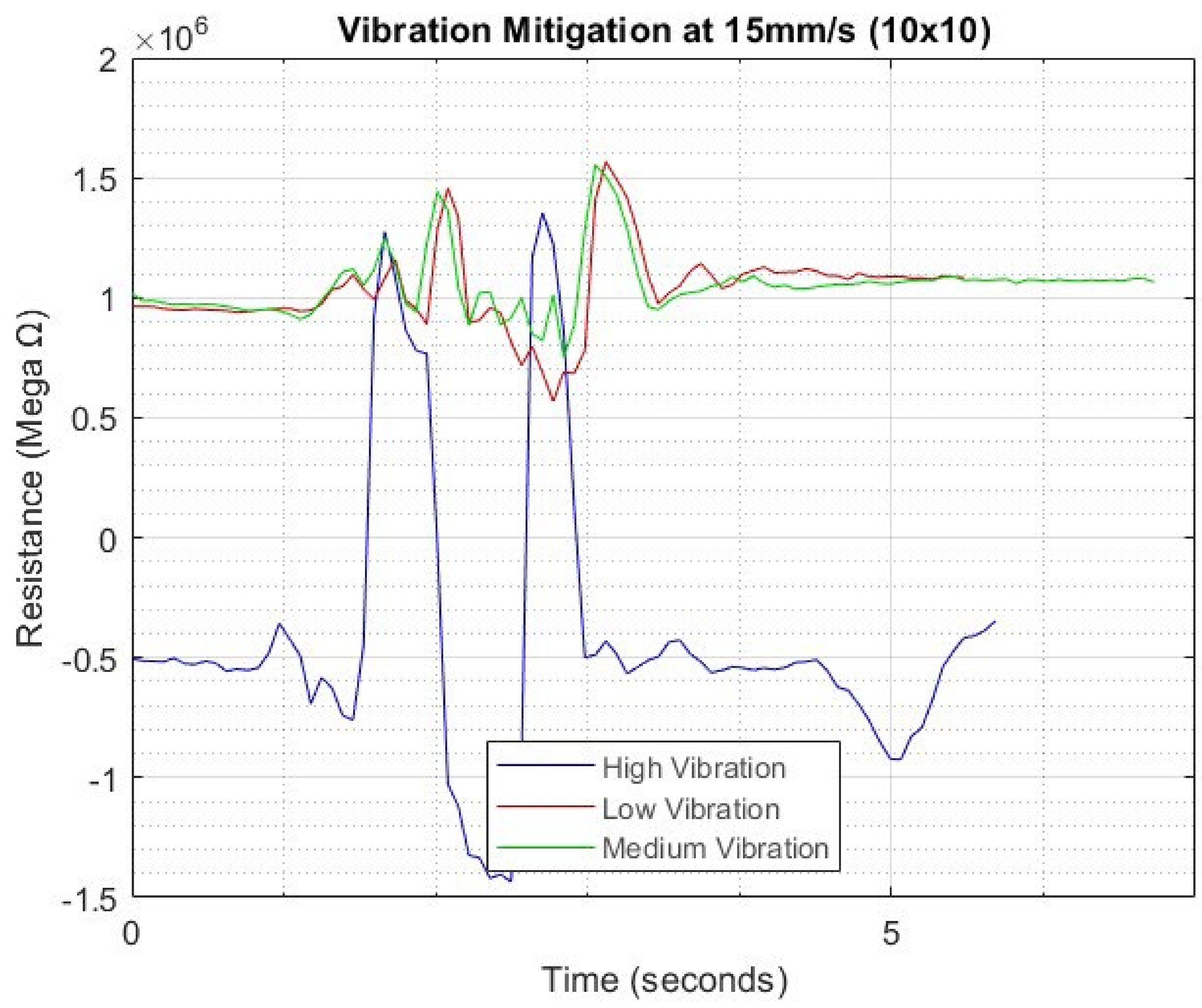
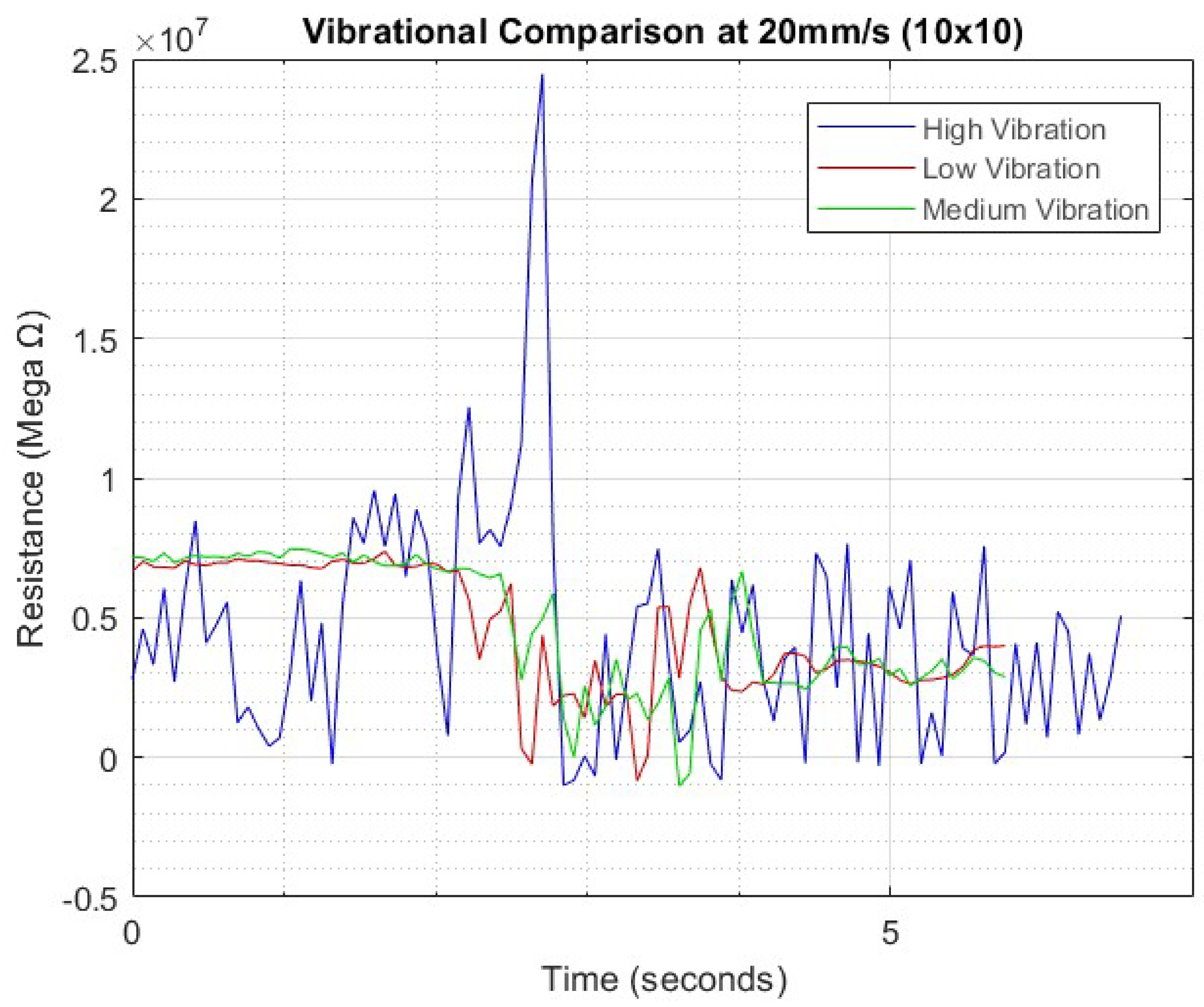
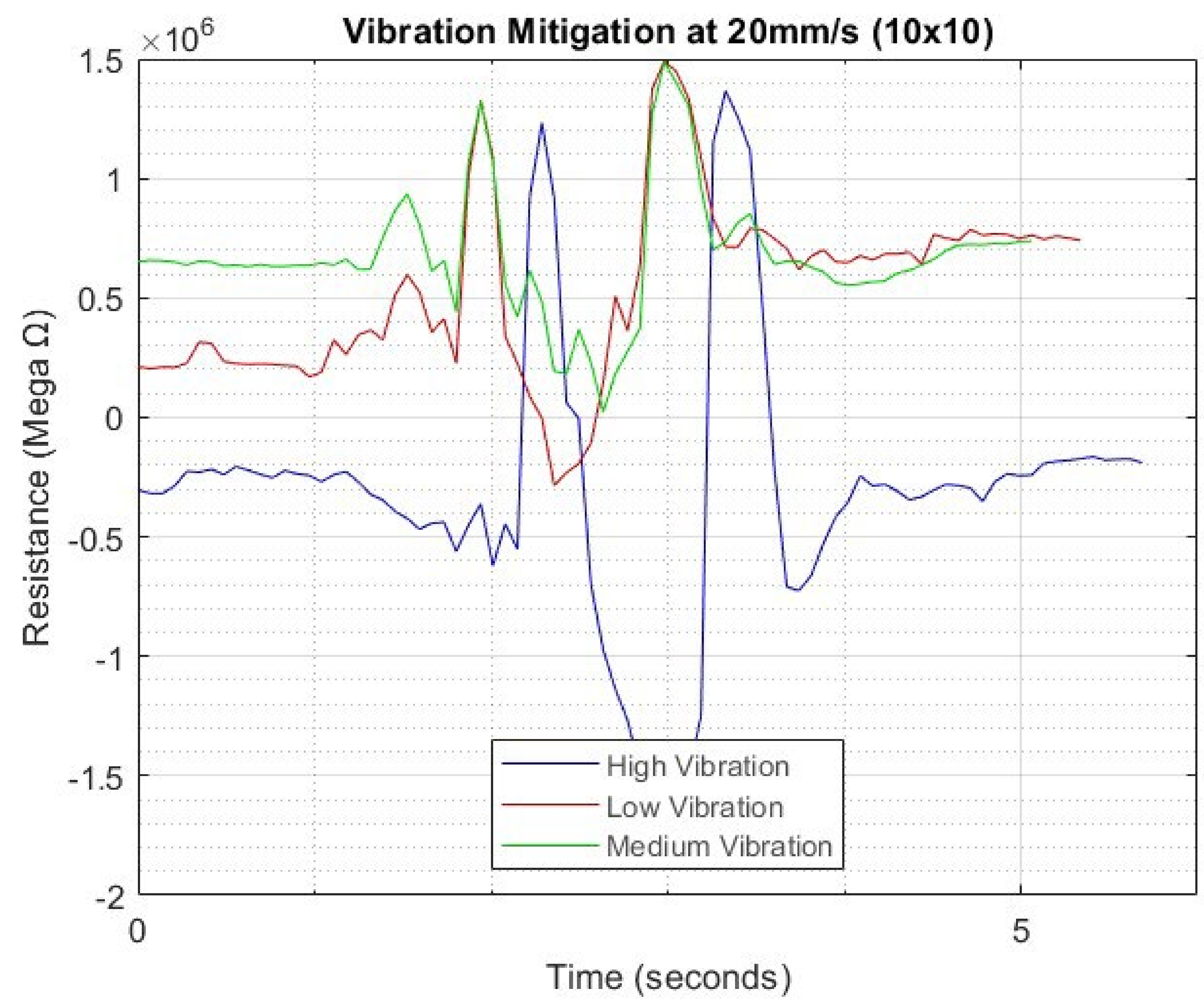

Vibrational Comparison at 15mm/s (10x10)
×10^6
Resistance (Mega Ω)
Time (seconds)
High Vibration
Low Vibration
Medium Vibration


Vibration Mitigation at 15mm/s (10x10)
×10^6
Resistance (Mega Ω)
Time (seconds)
High Vibration
Low Vibration
Medium Vibration


Vibrational Comparison at 20mm/s (10x10)
×10^7
Resistance (Mega Ω)
Time (seconds)
High Vibration
Low Vibration
Medium Vibration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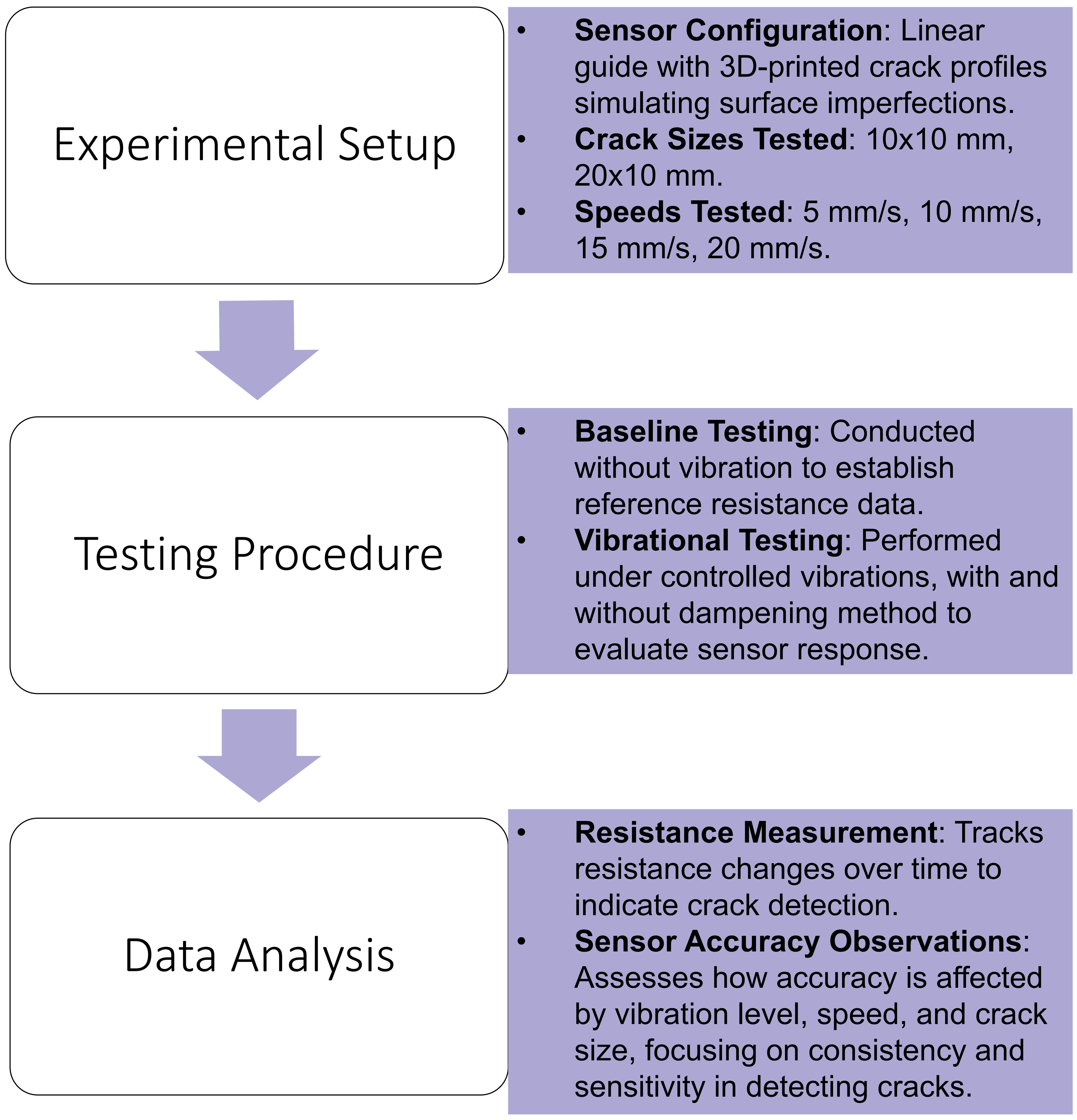
Experimental Setup
Sensor Configuration: Linear guide with 3D-printed crack profiles simulating surface imperfections.
Crack Sizes Tested: 10x10 mm, 20x10 mm.
Speeds Tested: 5 mm/s, 10 mm/s, 15 mm/s, 20 mm/s.
Testing Procedure
Baseline Testing: Conducted without vibration to establish reference resistance data.
Vibrational Testing: Performed under controlled vibrations, with and without dampening method to evaluate sensor response.
Data Analysis
Resistance Measurement: Tracks resistance changes over time to indicate crack detection.
Sensor Accuracy Observations: Assesses how accuracy is affected by vibration level, speed, and crack size, focusing on consistency and sensitivity in detecting cracks.