IPRO 331:
Machine Vibration Monitoring & Control Solutions for A. Finkl & Sons

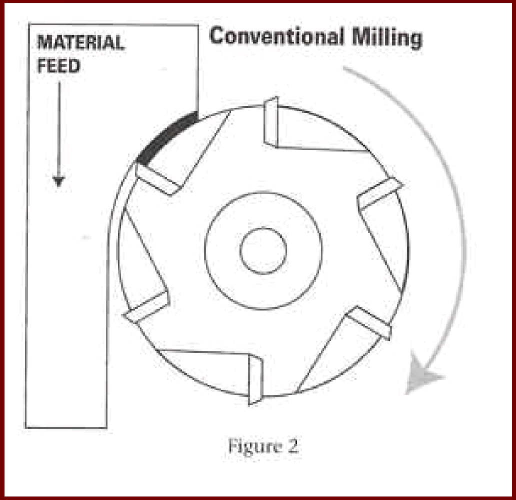
May 5, 2006

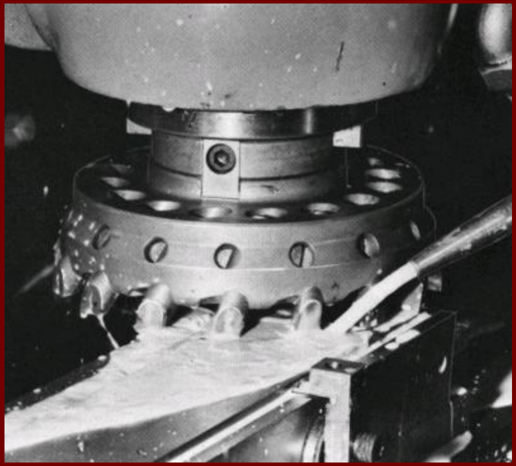
Purpose

- Develop a system to automatically detect the occurrence of an irregularity, such as a broken tooth, on a mill at A. Finkl Steel.
- This will be done by monitoring vibration, noise, and power consumption.
- Automatically sound an alarm or turn off the mill when the system detects an irregularity

Milling

- Milling is the process of cutting away material by feeding a workpiece past a rotating multiple tooth cutter.
- The tungsten carbide teeth are very hard, but also brittle.
- A chipped or broken tooth results in an increase in cutting force and temperature, and a decrease in the quality of the surface finish.





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Mill Specifications

- The mill of interest is used to finish flat steel parts with a hardness of 120-220 HB
- maximum 750 rpm
- 14 in diameter
- 14 tungsten carbide teeth
- 75 hp

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Mill Monitoring Techniques

- Monitoring:
  - Power Consumption
  - Vibration
  - Noise
- Fiber Optic Interferometry
  - Detects ultrasonic vibrations
- Acoustic Emission (AE)
  - Continuous AE detects plastic deformation
  - Burst AE detects chip formation and breakage
- Statistical Force Measurement
  - Monitors the force on each tooth

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Techniques Investigated

- Vibration
  - Increased system vibration occurs when a broken tooth is present
  - In addition, vibration occurs as each tooth engages the material. If a tooth has broken off, the peak vibration it should have caused will be missed.
  - Two vibration monitoring systems were used. A. Finkl & Sons previously purchased a vibration sensor and software that has a maximum sampling rate of 1 Hz. A second system from Illinois Institute of Technology with a maximum sampling rate of 10 kHz was also used.
- Noise
  - A loud "pop" occurs when a tooth breaks, which can be recorded using a microphone.
  - Behringer ECM8000 Microphone is plugged into the microphone jack on a web camera and streamed online along with the video
  - Linear Frequency Response 15Hz-20kHz
  - Data will be obtained during normal use, and during a tooth breakage and compared to determine the signal due to breakage
- Power Consumption
  - More power is required to mill with a broken tooth
  - Brunel PTM-3 continuously monitors power consumption

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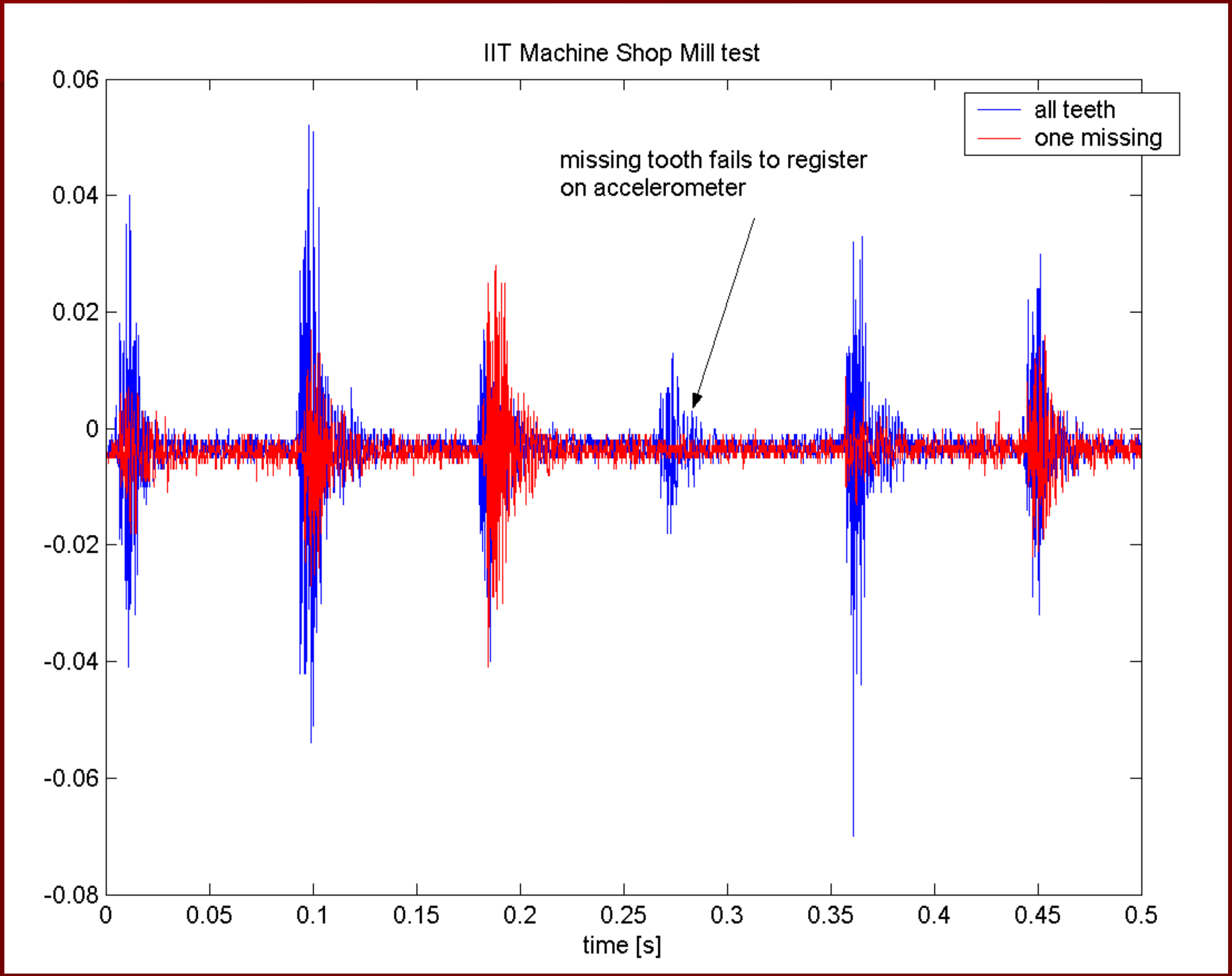
Vibration Data from a Mill at IIT



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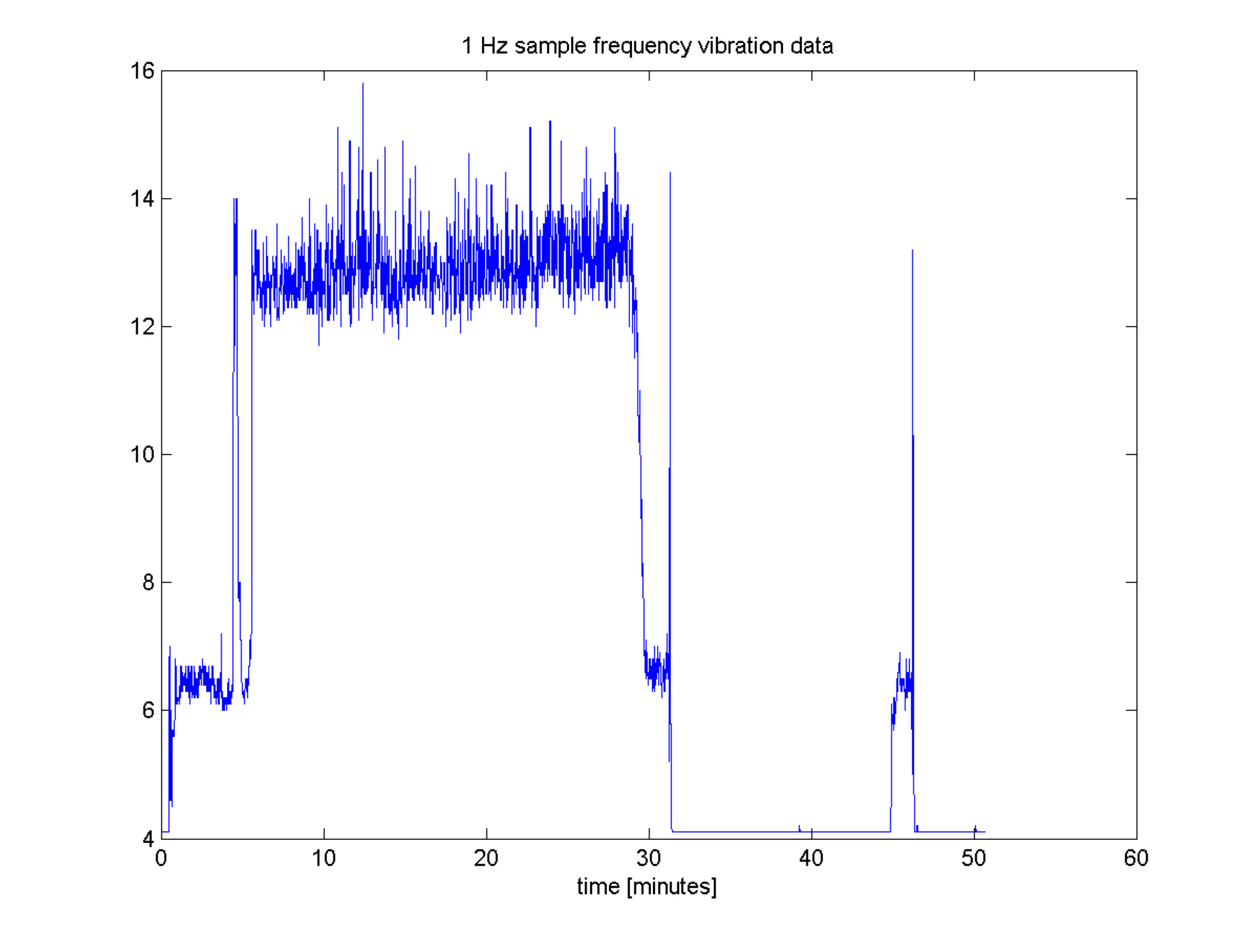
Vibration Data from A. Finkl & Sons



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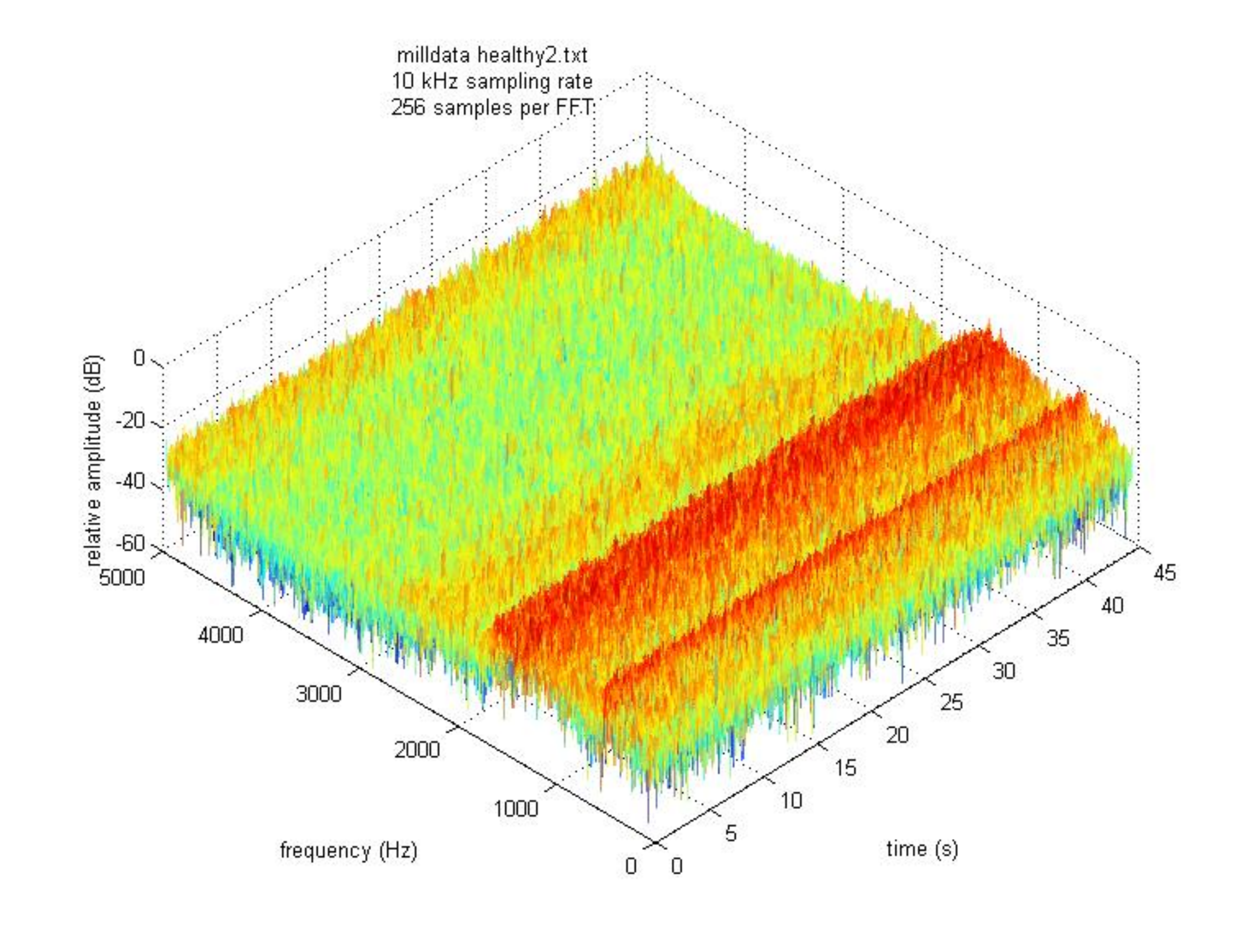
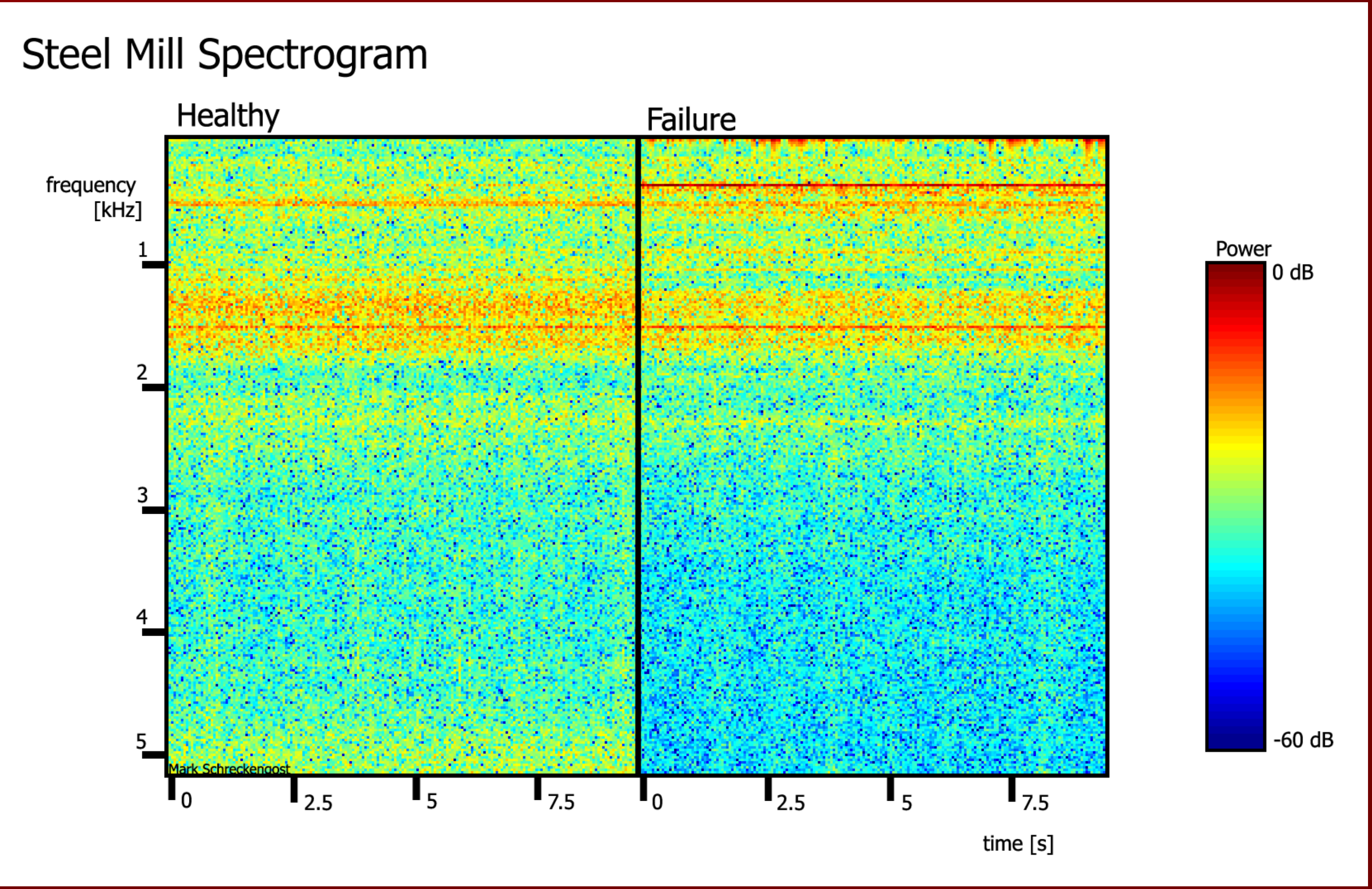
Vibration Data from A. Finkl & Sons



Analysis of 10 kHz Data



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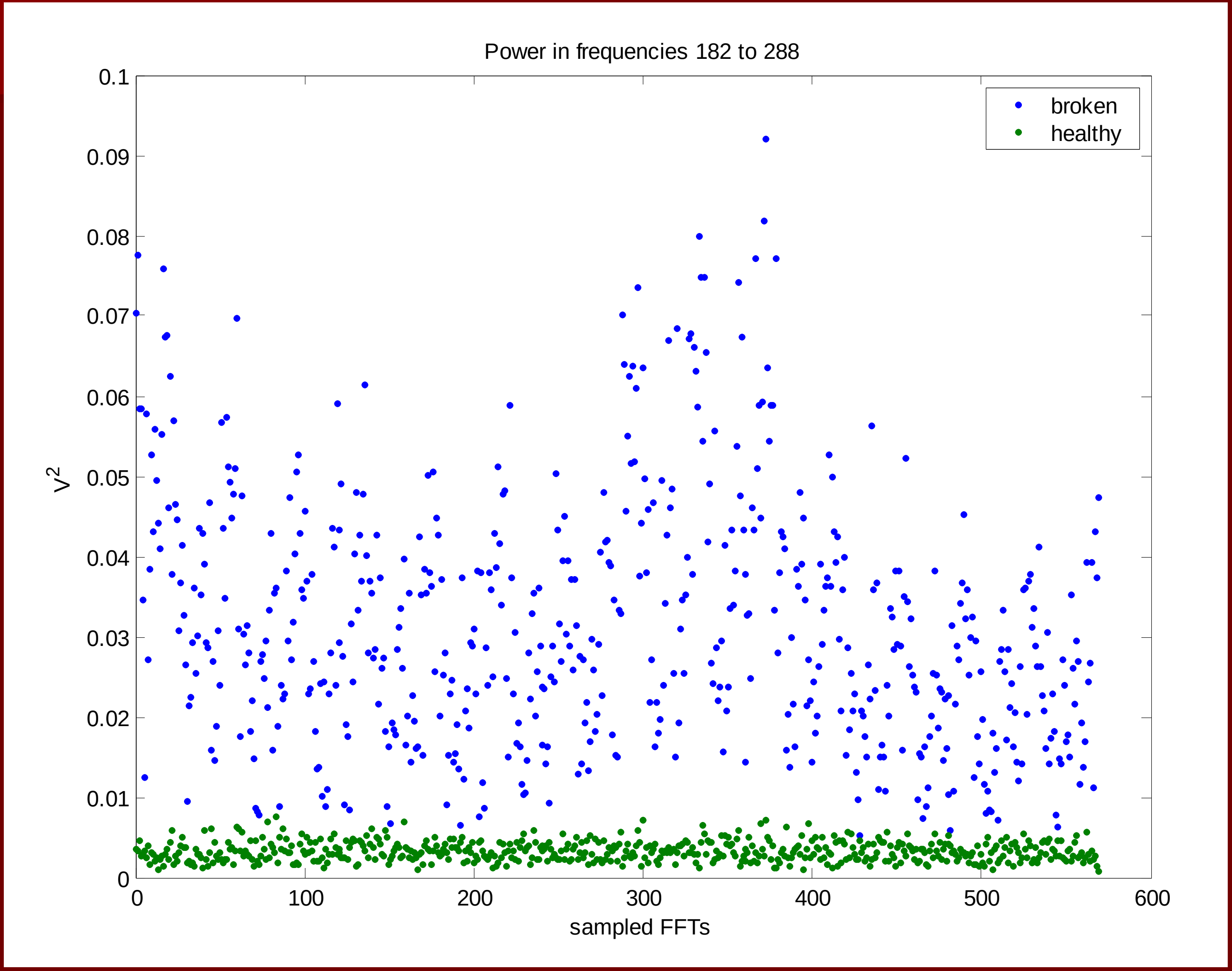
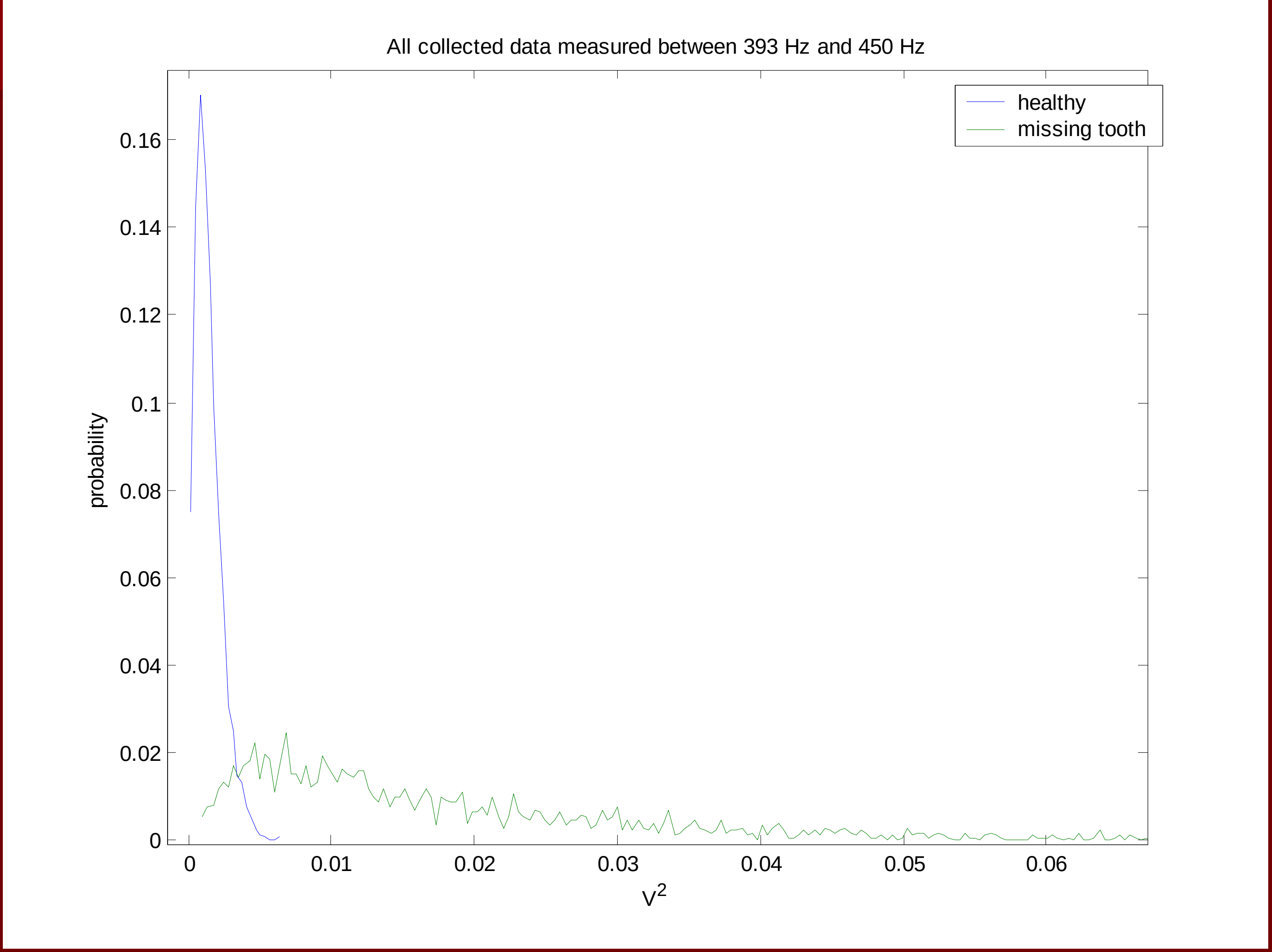
Analysis of 3.6 kHz Data



Analysis of 3.6 kHz Data



Data Analysis Summary

- The preliminary data from the mill at Illinois Institute of Technology shows a clear difference between a mill with all healthy teeth, and one with a broken or missing tooth.
- The 1 Hz data from the mill at A. Finkl Steel is not useful because the sampling rate is too slow.
- The 10 kHz sampling rate data reveals a significant increase in vibration when a failed tooth is present.

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Data Analysis Conclusions

- The accelerometer output at 210 Hz responds markedly to a broken tooth.
- 3.6 kHz is an acceptable sampling rate.
- A 128 sample FFT is able to resolve the frequencies of interest.
- This technique appears promising but will require testing and adjustment before it can perform autonomously.

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Obstacles

- Cooperating with an outside company presented several challenges and impeded the progress of this IPRO.
- For the first month of the semester, the mill was not operational.
- There were times when our inquiries went unanswered for several weeks.
- It took several weeks to obtain approval to buy the new equipment, such as the microphone and power meter.
- To date, the power meter and microphone have not been installed at A. Finkl & Sons.

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Conclusions

- Monitoring the vibration of the mill is a promising method.
- The vibration system currently at A. Finkl Steel does not have a fast enough sampling rate to be of use.
- Noise and power consumption data has not yet been collected.

Future Work

- Collect and analyze additional vibration data to develop a threshold
- Collect and analyze data from the microphone and power meter
- Determine which method or methods to implement
- Create a system to sound an alarm when the mill is out of normal operating parameters for validation.
- Once validated, create a system to automatically turn off the mill

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Questions?

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