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

Introduction

The purpose of IPRO 331 is to 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.

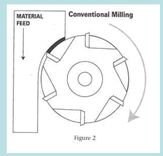
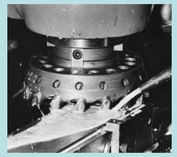


Figure 2



Background

- 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.
- A number of different methods are used to monitor mills, including:
  - Fiber Optic Interferometry - Detects ultrasonic vibrations
  - Acoustic Emission
    - Continuous AE detects plastic deformation
    - Burst AE detects chip formation and breakage
  - Statistical Force Measurement - Monitors the force on each tooth
  - Monitoring:
    - Power Consumption
    - Vibration
    - Noise

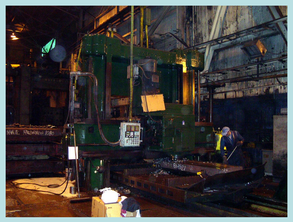
Techniques Investigated

IPRO 331 utilized several of the abovementioned mill monitoring techniques: Vibration, Noise, and Power Consumption

- 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 Steel previously purchased a vibration sensor and software that has a maximum sampling rate of 1 Hz. Therefore, 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 webcam 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

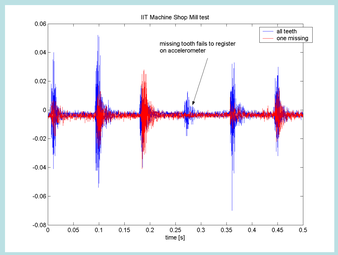
Mill Specifications

- 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 carbide teeth
- 75 hp



Data

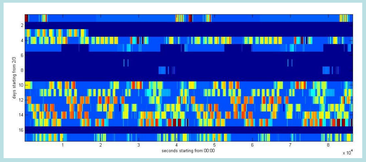
- Preliminary data on a mill at Illinois Institute of Technology

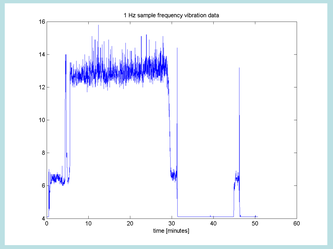


Voltage vs. Time With and Without a Missing Tooth

- Mills use interrupted cutting, which means part of each pass overlaps the previous one, so not all the teeth are contacting the material at once.
- Each peak is due to a new tooth contacting the edge of the material. When a tooth is broken off or missing, so is the peak.

- Data on the mill at A. Finkl Steel
  - 1 Hz Sampling Rate

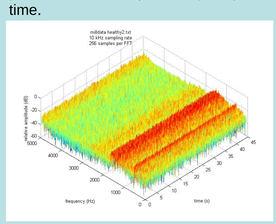

Summary of Two Weeks of Vibration Data

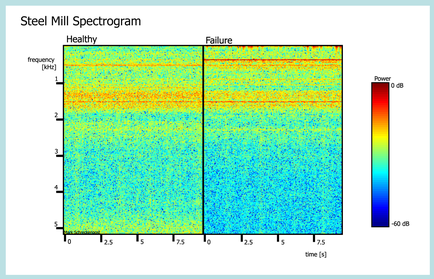


Voltage vs. Time Data for Mill Operation at Finkl

  - 10 kHz Sampling Rate

Data analysis identifies frequency ranges of interest. The figure below shows the power content of a given frequency over time.


Relationship between Amplitude, Frequency, and Time



Comparison of Healthy and Broken Teeth

Discussion

- 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.

Obstacles

- Cooperating with an outside company presented several challenges and impeded the progress of this IPRO.
- There were times when our inquiries went unanswered for several weeks.
- For the first month of the semester, the mill was not operational.
- 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 still not been installed at A. Finkl Steel.

Conclusions

- Monitoring the vibration of the mill is a promising method, but the 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

- Determine the ideal sampling frequency for vibration monitoring
  - Too low and the signal is not detected, too high and the system will require a large amount of memory.
- Further data analysis to determine 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