IPRO 304

Integration of Process Improvements

Presenters:
Ryan Marx – C.S./E.C.E. 4th year
Joshua Willett – A.E. 4th year
Stefan Stevanovic – M.E. 4th year
Background

✔ Sponsored by A. Finkl and Sons.
  ✔ CEO on IIT Board of Trustees
  ✔ IIT alumni employed at A. Finkl and Sons.

✔ Project History
  ✔ Created five semesters ago
  ✔ Attempted many different approaches
Problem Statement

Broken carbide inserts from the machining operation incur significant costs
Previous Approaches

- Lasers, accelerometers, microphones
- Accelerometers proved most promising
Semester Objectives and Ethics

- Time-series is useful visual aid but need to augment it so an algorithm can be developed to detect a failure
  - Combine tachometer with accelerometers to synchronize spindle position with data
  - Revisit Fast Fourier Transform (FFT)

- Ethics
  - Non-Disclosure Agreement.
  - Reduction in Human Error
  - Cost Implications
# Group Organization

<table>
<thead>
<tr>
<th>Name</th>
<th>Year</th>
<th>Major</th>
<th>Team</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emmanuel Flores</td>
<td>4th year</td>
<td>Materials Science &amp; Engineering</td>
<td>Mechanical Testing</td>
</tr>
<tr>
<td>Corey Hawker</td>
<td>4th year</td>
<td>Computer Science &amp; Engineering</td>
<td>Mechanical Testing</td>
</tr>
<tr>
<td>Charles Loeppert</td>
<td>4th year</td>
<td>Mechanical Engineering</td>
<td>Analysis</td>
</tr>
<tr>
<td>Ryan Marx</td>
<td>4th year</td>
<td>Computer Science &amp; Engineering</td>
<td>Analysis</td>
</tr>
<tr>
<td>Ricardo Rodriguez</td>
<td>4th year</td>
<td>Chemical Engineering / Chemistry</td>
<td>Mechanical Testing &amp; Analysis</td>
</tr>
<tr>
<td>David Snyder</td>
<td>4th year</td>
<td>Materials Science &amp; Engineering</td>
<td>Analysis</td>
</tr>
<tr>
<td>Stefan Stevanovic</td>
<td>4th year</td>
<td>Mechanical Engineering</td>
<td>Analysis</td>
</tr>
<tr>
<td>Joshua Willett</td>
<td>4th year</td>
<td>Aerospace Engineering</td>
<td>Mechanical Testing &amp; Analysis</td>
</tr>
</tbody>
</table>
We Own This

- Mechanical Testing Team
- Analysis Team
- Professors
# Project Plan

<table>
<thead>
<tr>
<th>ID</th>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
<th>Predecessors</th>
<th>Classification</th>
<th>Individuals Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Familiarize with Previous Work</td>
<td>3 weeks</td>
<td>1/12/2010</td>
<td>2/2/2010</td>
<td>All Teams</td>
<td>All</td>
<td>All</td>
</tr>
<tr>
<td>2</td>
<td>Meet with Finkl Contact</td>
<td>1 day</td>
<td>2/4/2010</td>
<td>2/4/2010</td>
<td>1</td>
<td>All Teams</td>
<td>All</td>
</tr>
<tr>
<td>4</td>
<td>Identify Breakage Conditions</td>
<td>2 weeks</td>
<td>2/9/2010</td>
<td>2/23/2010</td>
<td>1,2</td>
<td>Mechanical Testing</td>
<td>Mechanical Team</td>
</tr>
<tr>
<td>6</td>
<td>Identify Milling Head RPM</td>
<td>1 week</td>
<td>3/2/2010</td>
<td>3/9/2010</td>
<td>5</td>
<td>All Teams</td>
<td>All</td>
</tr>
<tr>
<td>8</td>
<td>Isolate Cutting Insert Profiles</td>
<td>3 weeks</td>
<td>3/9/2010</td>
<td>3/30/2010</td>
<td>4,5,6</td>
<td>Data Analysis</td>
<td>Analysis Team</td>
</tr>
<tr>
<td>9</td>
<td>Synchronize cutting insert profile with RPM</td>
<td>2 weeks</td>
<td>3/16/2010</td>
<td>3/30/2010</td>
<td>6,8</td>
<td>Data Analysis</td>
<td>Analysis Team</td>
</tr>
<tr>
<td>10</td>
<td>Identify criteria for breakage event</td>
<td>2 weeks</td>
<td>3/30/2010</td>
<td>4/13/2010</td>
<td>9</td>
<td>Data Analysis</td>
<td>Analysis Team</td>
</tr>
<tr>
<td>11</td>
<td>Mid-semester Presentation to Finkl</td>
<td>1 day</td>
<td>late March?</td>
<td>late March?</td>
<td>10</td>
<td>All Teams</td>
<td>David/Chuck</td>
</tr>
<tr>
<td>12</td>
<td>Onsite Testing at Finkl</td>
<td>3 weeks</td>
<td>4/1/2010</td>
<td>4/20/2010</td>
<td>10</td>
<td>All Teams</td>
<td>All</td>
</tr>
<tr>
<td>13</td>
<td>Develop algorithm to evaluate operation and identify breakage based on criteria</td>
<td>2 weeks</td>
<td>4/6/2010</td>
<td>4/20/2010</td>
<td>10</td>
<td>Analysis</td>
<td>Analysis Team</td>
</tr>
</tbody>
</table>

## Presentations

<table>
<thead>
<tr>
<th>ID</th>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
<th>Predecessors</th>
<th>Classification</th>
<th>Individuals Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Midterm Review</td>
<td>1 day</td>
<td>3/2/2010</td>
<td>3/2/2010</td>
<td>3</td>
<td>Presentation</td>
<td>TBD</td>
</tr>
<tr>
<td>17</td>
<td>IPRO Day</td>
<td>1 day</td>
<td>4/23/2010</td>
<td>4/23/2010</td>
<td>14,15</td>
<td>Presentation</td>
<td>All</td>
</tr>
<tr>
<td>18</td>
<td>Finkl Presentation</td>
<td>1 day</td>
<td>4/23/2010</td>
<td>4/23/2010</td>
<td>17</td>
<td>Presentation</td>
<td>TBD</td>
</tr>
</tbody>
</table>

## Deliverables

<table>
<thead>
<tr>
<th>ID</th>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
<th>Predecessors</th>
<th>Classification</th>
<th>Individuals Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Project Plan</td>
<td>2 days</td>
<td>2/3/2010</td>
<td>2/5/2010</td>
<td>2</td>
<td>Deliverable</td>
<td>David/Ryan/Stefan</td>
</tr>
<tr>
<td>14</td>
<td>Abstract/Brochure</td>
<td>2 days</td>
<td>4/17/2010</td>
<td>4/19/2010</td>
<td>3</td>
<td>Deliverable</td>
<td>Ricardo, All</td>
</tr>
<tr>
<td>15</td>
<td>Poster</td>
<td>2 days</td>
<td>4/17/2010</td>
<td>4/19/2010</td>
<td>3</td>
<td>Deliverable</td>
<td>Ricardo, All</td>
</tr>
</tbody>
</table>
The Wishful Thinking

- Study previous work
- Develop testing procedure to build upon results from last semester
- Collect data using Haas CNC Machine at IIT
- Develop technique for detecting failure event
- Repeat testing at A. Finkl and Sons
- Present Data to A. Finkl and Sons
Experimental Setup

- **Components**
  - Two single-axis accelerometers
  - Triaxial accelerometer
  - Laser tachometer

- **Analysis techniques using LabView**
  - Time domain
  - Frequency domain (FFT)
  - Power Spectral Density (PSD)
Laboratory Testing

- Same accelerometer placement as previous semester
  - Spindle
  - Machine

- Milling conditions:
  - Depth of cut: 0.02 – 0.04 in
  - Spindle speeds: 200 – 400 rpm
  - Feed rates: 1.2 – 2.5 in/min
  - Teeth: all good – 3 broken
Challenges

- Producing breakage event unlikely at our facilities
- Differences between Haas and Finkl milling machines
- Timing constraints in analyzing data
Infrared Thermometer Approach

Temperature profile ahead of the milling head

- Ahead of milling head
- 2 inserts
- 4 inserts
- 6 inserts
Analysis of the power carried in the cutting frequencies has shown considerable promise. Real-time comparison would allow for effective failure detection.
Real-Time PSD Analysis

Testing 2-18-10

Tooth Configuration: All good
Cut Depth: 0.02"
Feed Speed: 1.2 in/min
Spindle Speed: 250 RPM
Cut Position: Fully engaged
Material: Soft steel

Tooth Configuration: 2 broken
Cut Depth: 0.02"
Feed Speed: 1.2 in/min
Spindle Speed: 250 RPM
Cut Position: Fully engaged
Material: Soft
Benefits to a PSD System

- From what we’ve seen, it works!
- In theory, a PSD system would work on the initial scale cuts and interrupted cuts
- While testing, other aspects of machine performance can be monitored
Potential Monitoring System

- PSD to monitor gradual tooth wear/failure
- Trigger system to capture catastrophic insert breakage
- Once machine noise frequency range is established, it may be possible to monitor if machine is being operated out of its recommended feed and speed envelope
Accomplishments and Results

- Can successfully detect insert failure on Haas machine
- Initial testing at A. Finkl and Sons. Facility
  - PSD shows promising data
Conclusions

- There are changes in PSD when broken inserts are present on the Haas.
- PSD method works for various cutting conditions (as observed during Haas machine testing).
Future Work

- Streamline analysis methodology
- Continue experimentation at A. Finkl and Sons
- Create working software for real-time analysis
Acknowledgements

A. Finkl & Sons
- Guy Brada – Chief Metallurgist
- Liz Bilitz – Liaison to IIT students

PCB Piezotronics
- Keith Crawford – Field Application Engineer

Illinois Institute of Technology
- Craig Johnson – Machine Shop Supervisor
- Russ Janota – Director of Operations Mechanical Behavior
Questions?