IPRO 304 – Process Improvement Design

Spring 2011

A. Finkl & Sons

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Executive Summary

A. Finkl and Sons, a steel manufacturer in the Lincoln Park neighborhood of Chicago, IL, approached the Illinois Institute of Technology to find a solution to a problem with their steel milling operations. IPRO 304's goal is to develop a method of detecting broken tungsten carbide inserts on a horizontal milling machine in real time. By doing so, A. Finkl & Sons could reduce the quantity of broken cutting inserts and re-allocate the current operators of the milling machine to other areas of the manufacturing plant.

Fall 2010's conclusion was that a tri-axial accelerometer would provide more information, and therefore more accurately detect broken cutting inserts after having tested a uni-axial accelerometer. As such, Spring 2011's purpose and objective was to collect data and test the hypothesis of Fall 2010 while researching other solutions should the tri-axial accelerometer prove ineffective at detecting broken cutting inserts. This report goes into further detail on the methods used to collect and analyze the data necessary to determine the efficacy of the tri-axial accelerometer.

The Spring 2011 IPRO was partitioned into five subgroups: data analysis, new ideas development, software programming, communications, and IPRO deliverable management. Each subgroup was equally responsible for ensuring the success of the IPRO regardless of the efficacy of the tri-axial accelerometer. The exact responsibilities of each team are discussed later in the report.

Project Background & Objective

A. Finkl & Sons Co. was founded in 1879 and is now the world's leading supplier of forging die steels, plastic mold steels, die casting tool steels and custom open-die forgings, processing 100,000 tons of steel each year. Since their establishment, Finkl has maintained its commitment to manufacture 100 percent of its products in Chicago. Finkl's products are distributed domestically and to more than 18 countries worldwide. Clients include OEM's, plastic processors, die casting companies and closed-die forging plants. With more than 100 patents to its credit, Finkl's steel formulations and steel making technologies have set the standard worldwide. In recognition of Finkl's product quality, A. Finkl & Sons was the first integrated steel manufacturer in America to receive ISO 9000 certification.

The industry requires that all finished steel blocks sent to the customer be of a uniform thickness and without excess scale from production. A. Finkl & Sons utilizes multiple steel milling machines produced during WWII to bring steel blocks up to industry standard. The component of the milling machines we have been asked to improve is the rotating end mill, a structure containing 14 cutting inserts that removes a layer of the material as it rotates. The material being milled moves underneath the rotating face (which remains stationary) on a moving table.

At present, at A. Finkl & Sons a worker detects broken cutting inserts by manually inspecting the cutting inserts one at a time after each pass, and replacing broken ones.

If a cutting insert does in fact break during the milling process and remains undetected, a larger load is applied to the next milling insert to cover the load. Because of the additional stress caused by a broken insert on the remaining blades, the probability of having another insert break increases. As this process continues, the probability of having a cascading breakdown of the cutting inserts increases with each break.

Broken inserts also compromise the surface finish of the piece. If more than one insert in a row is broken, this effect is multiplied.

By devising a way to detect broken inserts (thus allowing the operators to perform other tasks), A. Finkl & Sons could reduce the amount of cutting inserts broken and increase the productivity of the workers, saving time and money. Additionally, such a solution will also enable a higher rate of production and allow for a higher quality product at the end of the milling process.

Fall 2010's research has shown that a tri-axial accelerometer has the possibility of detecting when a cutting insert is broken after using a dual-axis accelerometer. By analyzing the data from the tri-axial accelerometer to detect the vibrations of the milling machine, the objective for Spring 2011 was to test the hypothesis of Fall 2010 and determine whether a tri-axial accelerometer could be used to solve Finkl's problem.

Organization and Approach

IPRO 304's approach to testing the hypothesis of Fall 2010 required the team to split into groups allowing each team member's skill sets to be utilized. As such, the IPRO strategically split into five groups:

1. Communications: The communications team consisted of a team members who ensured proper communication between the management team at Finkl and scheduled groups to visit and collect data from the milling machine.
2. IPRO Deliverables: The IPRO deliverables team was responsible for producing the documents required for the IPRO office. The members here were selected because of their business experience or had other attributes that would allow them to succeed in this task.
3. New Ideas: The New Ideas team was responsible for finding alternative solutions to Finkl's milling problem if the tri-axial accelerometer were to fail.
4. Programming: The programming team was responsible for using the data collected by the Data Analysis team to develop software that would notify the worker on-duty of a broken cutting insert.
5. Data Analysis: The Data Analysis team was responsible for using the data collected to determine whether we could detect when a cutting insert was broken.

Analysis

The programming team first wrote a data collection program for the tri-axial accelerometer. The program collects data from the accelerometer, and then performs Fast Fourier Transforms on it to produce the power spectrum density (PSD). This analysis has been proven by past semesters to be the best way to detect shocks to the system.

A sheet of steel requires multiple passes across it with the cutting head in order to remove a layer from the entire sheet. The program proved to be consistent within the same pass across a piece of steel, but it is not consistent between passes, even on the same piece of steel.

The team then wrote a trigger program, which takes 8 seconds of data before and after a ‘trigger’. The trigger is any acceleration shock to the system, ideally when a cutting tooth breaks, and that threshold is adjustable. The threshold needs to be set such that it triggers when a cutting tooth breaks, and not when a defect is hit within the cut, or something heavy drops in the building. The program then compares the 8 seconds before and after the trigger as a secondary attempt to differentiate between a tooth breaking and a false alarm. If a tooth actually broke, the “after” PSD will be markedly different.

In order to determine the threshold, data collectors needed to observe data where it was known that a tooth broke. To do this, notches were filed into cutting inserts to ensure that they would break during a cutting pass.

New Ideas / Future Work

After researching our current solution and determining that future work is needed using our current testing method, we have also decided to research other methods of detecting broken inserts, and we started experimenting with prototypes.

The most developed prototype has to do with Radiation Detection. This idea relies on the principles used in ionization smoke detectors. There is a positive and negative electrode with a radiation dot under the negative side. The dot ionizes air particles to create a small current, which in turn closes the circuit. The radiation emitted is only alpha particles, which cannot penetrate skin and therefore are harmless. By placing a dot on the carbide we could potentially complete the circuit as it passes through or near the electrode, which could potentially detect when the radiation is not there anymore, and therefore an insert has broken. An advantage of this method is that it would give a more accurate reading without the need for complex analysis. Potential challenges include the possibility of the dot falling off the carbide when the carbide hasn't broken.

The second idea being developed involves using a piezoelectric transducer as a pressure sensor. If one places a piezoelectric between the carbide and the mounting wall you could potentially pick up variations in force acting on the carbide. Using some simple circuitry it is possible to make a triggering device that triggers with an increase of force. The triggering event could either be the increase of force on the carbide following the broken one, or the reduction in force on the broken carbide. This method would give a positive or negative reading without any extra analysis of data. It is simple and cheap to make. The challenges of this method are that we would need to find a way to power the circuit on the spindle head. One possible solution is a magnetic induction type power source.

The third idea being developed uses phosphor paint. This idea is fairly similar to the radiation one. The carbide could be painted with a phosphor paint. When a UV emitter hits the paint it will glow, allowing a light sensing device to pick it up. If the carbide is broken, the sensor will not see it and declare a broken insert. This idea would be fairly easy to install, and provides a simple yes/no output without need for complex analysis. It may be difficult, however, to find a way to keep the paint on the intsert while it's cutting steel. The high temperatures involved with milling may also play a part.

Conclusion

After performing this semester's work, the Data Analysis team determined that the tri-axial accelerometer is a viable option to solving A. Finkl & Sons problem. However, to create a program capable of notifying the on-duty operator of a broken insert would require additional data from the Fall 2011 semester.

Extensive research was done creating alternative approaches to detecting broken cutting inserts that may be used next semester in addition to the accelerometer.

Appendix

A. Budget

We used previous semesters materials all was available

B. Team Members

Name	Major	Position
Greg Tatkowski	Mechanical Engineering	Team Leader
Bill Watts	Mechanical Engineering	Team Leader Assistant
Tom Kozmel	Materials Science	Communications
Alex Szalko	Business	Deliverables Team
Megan Meeke	Biology	Deliverables Team
Tomasz Chojnacki	Mechanical & Materials Science	New Ideas
Jaimin Ray	INTM	New Ideas
Dorothy Collins	Materials Science	New Ideas
Greg Sparks	Materials Science	Programming
Paul Gal	Electrical Engineering	Programming
Claudius Kuzmicki	Electrical Engineering	Programming
Michael Regacho	Mechanical Engineering	Data Analysis
Sukwon Kim	Electrical Engineering	Data Analysis

YuBo Diao	Aeronautical Engineering	Data Analysis

C. Acknowledgements

We would like to thank the following parties for helping us with any of our questions and giving us advice on how to approach this problem. Since this is our 5th semester, this list continues to grow, so in addition to the following people, we would like to extend our thanks to anyone who has helped us and is not listed below.

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