IPRO 304

Integration of Process Improvements

Spring 2010

Advisors: Professor W. Maurer and Professor S. Mostovoy

Sponsor: A. Finkl & Sons (Chicago, IL)

Emmanuel Flores

Corey Hawker

Charles Loeppert

Ryan Marx

Richard Pollack

Ricardo Rodriguez

David Snyder

Stefan Stevanovic

Joshua Willett

Table of Contents

I. Team Charter

A. Team Information

Name	Year	Major	Skills	What is Expected from IPRO	Team	Contact Info
Emmanuel Flores	4th year	Materials Science & Engineering	Undergraduate research on Ti alloys and Ni super alloys. Familiar with LabView VI's, programming in C++ and Java	I expect to solve the problem we face by working as a team. I would like to further develop my knowledge of LavVIEW and to learn about accelerometer technology.	Mechanical Testing Team	eflores1@iit.edu
Corey Hawker	4th year	Computer Science	Extensive programming and project management experience.	I hope to gain experience in engineering, project management, basic machining and digital processing, and working in a team.	Mechanical Testing Team	chawker@iit.edu
Charles Loeppert	4th year	Mechanical Engineering	4 years of experience with data acquisition, signal conditioning and destructive testing.	I hope to gain experience in problem solving, as well as customer relations.	Analysis Team	cloepper@iit.edu
Ryan Marx	4th year	Computer Science & Engineering	Wireless Networking Experience, Programming Skills, Electrical Engineering Experience	Experience	Analysis Team	rmarx@iit.edu
Richard Pollack	3rd year	Mechanical & Aerospace Engineering	I have a knack for differential equations, and for finding the source of a problem and solving it. I have some management skills from a job as a building manager, and am pretty quick with computers.	I am hoping to gain experience working on engineering problems, learning about my skills and applying them. Looking to learn and contribute enough so that in my next IPRO I can take on the role of a leader	Mechanical Testing Team	rpollak@iit.edu
Ricardo Rodriguez	4th year	Chemical Engineering / Chemistry	Chemical engineering background, experience in leading small groups, as well as basic programming.	I hope to learn basic mechanical aptitude geared for mechanical engineers, as well as to learn how to work with individuals from other disciplines.	Mechanical Testing & Analysis Teams	rrodrig9@iit.edu
David Snyder	4th year	Materials Science & Engineering	Knowledge of metallurgical principals and testing, as well as basic machining.	I hope to broaden my appreciation for multi-disciplinary teams, and to better understand engineering problem-solving techniques.	Analysis Team	dsnyder2@iit.edu
Stefan Stevanovic	4th year	Mechanical Engineering	Computer programming (Matlab, Maple, Java), data analysis/interpretation, materials and dynamics knowledge	I hope to gain Digital processing knowledge, engineering problem solving experience.	Analysis Team	sstevano@iit.edu
Joshua Willett	4th year	Aerospace Engineering	Experience with CNC machining, MATLAB, Management, Excel	I hope to gain, knowledge of using Labview, digital signal processing, analysis, signal noise reduction.	Mechanical Testing & Analysis Teams	jwillet1@iit.edu

B. Team Identity

The group's logo combines IIT's logo and Finkl's. The group's logo is:

The group's motto: *Breaking Teeth and Taking Names*

C. Team Purpose and Objectives

1. Team Purpose

During the milling operations at an industrial steel producer like A. Finkl & Sons (Chicago, IL), a substantial amount of time and money is lost due to the fact that cutting inserts break catastrophically and without warning. The goal of this project is to devise an effective means by which a cutting insert breakage event can be quickly and reliably detected, thereby minimizing damage to the steel and other cutting inserts, and also freeing technicians to attend multiple machines at a time. This increases the productivity of their operations, and it has the potential to save A. Finkl & Sons substantial costs per year in time lost in rework and prematurely broken cutting inserts.

2. Team Objectives

The core objective is to automate the process by which cutting insert breaks are detected by creating a computer program that interfaces with the milling machinery. To accomplish this, our team will need to isolate a profile of the behavior of each cutting insert on the milling head, establish consistent breakage conditions, identify breakage detection criteria, and produce digital algorithms by which those breaks can be reliably detected. With consistently reliable detection parameters, the team will then need to produce a computer interface by which a technician can be alerted to the breakage.

D. Background

1. Information about the Sponsor

A. Finkl & Sons Co. was founded in 1879. Finkl is 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 the 1800s, Finkl has maintained a commitment to manufacture 100 percent of its products in Chicago. These products are distributed domestically and to more than 18 countries worldwide. They sell their products to other manufacturers, like plastic processors, die casting companies and closed-die forging plants. With more than 100 patents to its credit, Finkl's steel formulations and steelmaking technologies set worldwide standards. Finkl's facilities are on the leading edge of technology, using the most automated processes in the world. In recognition of Finkl's product quality, Finkl was the first integrated steel manufacturer in America to receive ISO 9000 certification.

2. Information about the Problem

As Finkl machines the steel during a milling operation, they rely heavily on the performance of the mill. Each milling machine has an eighteen inch diameter faceplate with eighteen tungsten carbide cutting inserts. The hardness of the steel being milled causes cutting inserts to chip, wear, or at times fail catastrophically. As a result, the surface finish of the steel can be substandard, and more stress will be placed on the remaining cutting inserts, making a systemic failure of all inserts highly probable. This poor surface finish also often forces Finkl to re-machine the part to meet customer specifications, and this leads to the loss of significant amounts of otherwise productive time.

3. Information about the Technology Used

The milling machines operated and owned by Finkl are manually operated. There are no computer based components of the machine; therefore, the solution will have to be implemented externally. Accelerometers, devices which measure acceleration, have been shown to be useful in the isolation of each cutting insert of a milling machine. With a known RPM of the milling machine, software can be designed to isolate each cutting insert from the accelerometer output. The software can be designed to record the history of each insert. In theory, a cutting insert's acceleration will differ if it becomes broken or chipped, allowing the software to display the insert failure to the milling machine operator.

4. Prior Investigations of Machine Tool Failure

The Fall 2009 IPRO was able to isolate individual cutting inserts through accelerometer output. With an established baseline of performance with no broken cutting inserts, the IPRO members were able to see a higher amplitude of acceleration when broken inserts were detected. However, the isolation and detection did not occur in real-time; it was only possible when analyzing the accelerometer data after collection.

E. Ethical Issues

This project aims to reduce human error during the machining process which, in turn, would increase productivity. Finkl has asked IIT to find a reasonable solution to this problem and this team will conduct its research under Finkl's discretion. As sponsor of this project, Finkl rightfully holds that the team's findings are not intended to be shared outside of the IPRO setting, and any company methodologies or technical communications shared will be held in strict confidence.

F. Business Costs

Finkl must spend money to purchase new cutting inserts to continue their milling operations. The money spent per year on these cutting inserts is on the order of several hundred thousand dollars. If a solution is created to detect when an insert fails, the insert can be replaced immediately, reducing the risk of a systemic failure of other inserts. This saves Finkl money, time and productivity.

G. Practical Methodology

The team's current approach to solve the problem of cutting insert failure is through accelerometers. The challenge is to use the information collected from the Fall 2009 IPRO, and the success of the post-machining data analysis, and devise a system for real-time insert monitoring, so an insert failure can be detected immediately.

H. Team Value Statements

1. Team Behavior

IPRO 304 holds a code of ethics as fundamental to maintaining an honorable and respectable presence inside and outside of the classroom. Members of IPRO 304 shall conduct themselves in accordance with the ethics standards stated below:

- Conduct research and classroom discussion in a manner that is consistent with accepted honor and decency. Maintain an awareness of applicable laboratory and industrial safety codes.
- Be civil and respectful in professional and academic interactions, avoiding discrimination of any kind.
- Maintain the highest standards of conduct and integrity when representing IIT and the IPRO program.
- Be constructive and supportive in evaluating the work of other students.
- Encourage the free and open exchange of ideas and information from all students.

2. Problems

Members of this group will address conflicts within applicable group or sub-group settings. If this fails to address the issue, the conflict will be taken up by the team as a whole, in the presence of the advisors to ensure effective resolution and maintain civility.

II. Project Methodology

A. Work Breakdown Structure

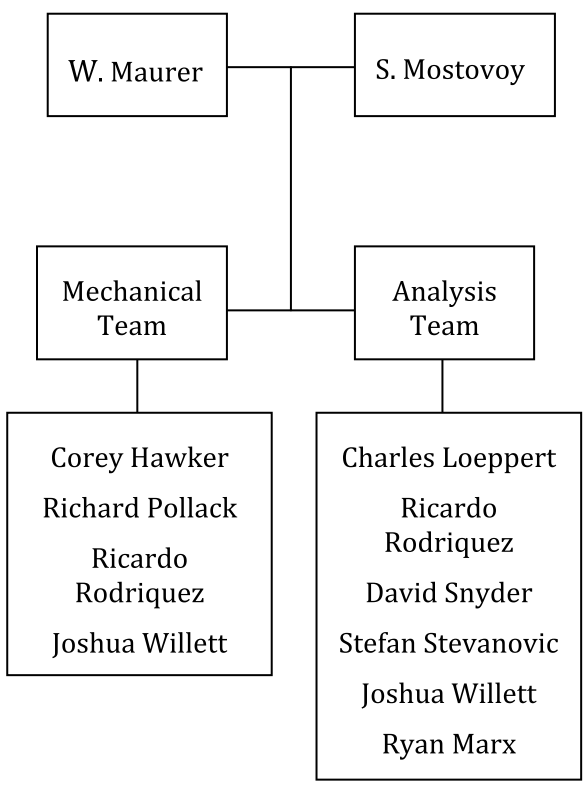
1. Problem Solving Techniques

The overlying focus will be to develop a system of detecting when a cutting insert has broken during a face milling operation. Other main tasks are finding out how to isolate individual cutting inserts to model the behavior of each insert on the milling head, and creating a small-scale solution using IIT facilities that can be modified for use at Finkl. First, the mechanical testing group will establish milling parameters that influence the integrity of the cutting inserts, then devise a method under which data can be collected during an insert breaking event. Concurrently, the analysis team will formulate a means of isolating the behavior of each cutting insert on the milling head from one another, with the intent of reliably detecting and identifying the event of a broken insert. Upon completion of each of these tasks, a comparison of the profiles of broken and unbroken inserts will be established to determine certain criterion for the identification of broken inserts. Completion of these tasks within the timeframe of one semester is obtainable, but to deliver an end product to the sponsor will likely take additional time and resource.

2. Team Structure

The problem has been divided into two core segments: Mechanical Testing and Analysis. The mechanical testing team is responsible for conducting milling test trials, varying parameters to create smooth milling conditions as well as insert breaking events. The analysis team will collect data under the various simulated conditions developed by the mechanical testing team to develop breakage detection criteria.

We have chosen not to assign team leaders and project managers. The nature of our project requires effective communication between all members of the group, and any one task will involve members from each group. As such, we have decided that members will report their own findings to the group as a whole, and subsequent tasks will be determined by the group, under the direction of group advisors.



3. Gantt Chart

ID	Task Name	Duration	Start	Finish	Predecessors	Classification	Involved
Project Tasks							
1	Familiarize with Previous Work	3 weeks	1/12/2010	2/2/2010		All Teams	All
2	Meet with Finkl Contact	1 day	2/4/2010	2/4/2010	1	All Teams	All
4	Identify Breakage Conditions	2 weeks	2/9/2010	2/23/2010	1,2	Mechanical Testing	Mechanical Team
5	Build Test Procedure	2 weeks	2/23/2010	3/9/2010	4	Mechanical Testing	Mechanical Team
6	Identify Milling Head RPM	1 week	3/2/2010	3/9/2010	5	All Teams	All Teams
8	Isolate Cutting Insert Profiles	3 weeks	3/9/2010	3/30/2010	4,5,6	Data Analysis	Analysis Team
9	Synchronize cutting insert profile with RPM	2 weeks	3/16/2010	3/30/2010	6,8	Data Analysis	Analysis Team
10	Identify criteria for breakage event	2 weeks	3/30/2010	4/13/2010	9	Data Analysis	Analysis Team
11	Mid-semester Presentation to Finkl	1 day	late March?		10	All Teams	TBD
12	Onsite Testing at Finkl	3 weeks	4/1/2010	4/20/2010	10	All Teams	All
13	Develop algorithm to evaluate operation and identify breakage based on criteria	2 weeks	4/6/2010	4/20/2010	10	Analysis	Analysis Team
Presentations							
7	Midterm Review	1 day	3/2/2010	3/2/2010	3	Presentation	TBD
16	Final Presentation	1 day	4/23/2010	4/23/2010	14,15	Presentation	TBD
17	IPRO Day	1 day	4/23/2010	4/23/2010	14,15	Presentation	All
18	Finkl Presentation	1 day	4/23/2010	4/23/2010	17	Presentation	TBD
Deliverables							
3	Project Plan	2 days	2/3/2010	2/5/2010	2	Deliverable	David/Ryan/ Stefan
14	Abstract/Brochure	2 days	4/17/2010	4/19/2010	3	Deliverable	TBD
15	Poster	2 days	4/17/2010	4/19/2010	3	Deliverable	TBD
19	Final Project Report	2 days	4/28/2010	4/30/2010	16	Deliverable	TBD

B. Anticipated Results

1. Details on Anticipated Activities

The group will experiment in a lab for the first half of the semester while they test whether they can develop an algorithm to successfully identify when a cutting insert breaks. After the initial testing period, the group will finalize results and present them to the sponsor. After the sponsor approves of the findings, the group will begin the testing phase on-site at Finkl for three weeks. The team hopes to find that the algorithm developed at IIT facilities will function in the same manner and be able to detect cutting insert failures for the Finkl machines. If the group is successful, the next step is to present our success to Finkl again for feedback on subsequent course of action.

2. Anticipated Data and Testing

The team anticipates that accelerometer data combined with the rpm of the milling spindle will allow a time-series profile to be created corresponding to each cutting insert. In addition, LabView will analyze this data from the accelerometers. The group hopes to compare the current profile of each insert to its preceding profiles in real-time. A significant change in an insert's profile would signify that it has failed. The group will present testing results and findings to Finkl and attempt to replicate the results on their machines. It is expected that lab results will match the on-site machinery results, specifically pertaining to the algorithm correctly identifying when an insert breaks. The team will conduct this experiment at each machine and test the system for a few weeks to ensure that the broken cutting inserts can be detected with confidence.

3. Potential Products

The team wishes to develop a system what will increase Finkl machining productivity from this experimentation. It is possible that a streamline version of this system may be a potential product, and it will be the proprietary of A. Finkl & Sons by virtue of their sponsorship status.

4. Potential Outputs from Each Project Task

The potential outputs from the first phase of testing are to create a test plan and obtain analyzed data. The time-series profile of each cutting insert will be identified and exploited to detect insert failures. The output from the second phase of testing is to obtain Finkl's approval of the test plan and the analyzed data corresponding to the first phase testing.

5. Anticipated Results of Deliverables

The group anticipates the experiment, carried out on the milling machines at Finkl, will result in a working program that, when interfaced with the milling machines, effectively detects when the cutting inserts break.

6. Summarize the Challenges, Risks and Assumptions

The initial challenge involves combining milling machine rpm information with accelerometer time-series data to identify the data profile for each cutting insert. The assumption made is that an insert's profile will differ significantly from its previous profiles once it has been broken. Then, the team must face the difficult task of developing an algorithm to identify a profile change and signal that an insert has broken. Once a working prototype program has been developed, the team must then show that it works in the industrial setting of Finkl's machining facilities, which undoubtedly present very different situations than the controlled setting of a laboratory.

As with any heavy machinery, the milling equipment used in this project must be operated with the highest concern for safety. Powerful cutting forces produce high temperature steel chips from the work-piece that are vigorously ejected in all directions, so safety gear such as glasses and appropriate clothing must be used. Improper operation can lead to entanglement of loose clothing or body parts into the milling machine, so machinery will only be operated by trained individuals.

The proposed method for detecting broken cutting inserts during the milling operation requires the assumption that each cutting insert will register a unique profile, and that the profile will only change significantly when the insert breaks. This ignores the possible effects of other various parameters, but it is the intent of this experiment to mitigate the effects of those parameters so as to justify this assumption.

7. How the Expected Results will be Incorporated in Proposed Solution

The first set of testing will be conducted at an IIT laboratory using a scale milling set-up that is similar to that used at Finkl. The results provided by this testing will allow for a better understanding of the difference in cutting insert profiles and help determine if they can potentially be used to detect insert failures. With this information, it will be determined whether the current approach is successful in determining when a cutting insert is broken by means of the output frequencies measured by accelerometers. If the results for the scale testing are found to be successful, testing will proceed at Finkl. Using the milling machines at the Finkl facility, the difference in time series profiles of the cutting inserts will be measured to determine if the assumptions made are valid and whether profiles can be used to detect broken cutting inserts. Given that the results are conclusive with a functional algorithm identified, a procedure and recommendation will be proposed to Finkl regarding the determined process and the desired equipment to perform the given process.

C. Designation of Roles

- **Mechanical Testing Team**

  Corey Hawker

  Richard Pollack

  Ricardo Rodriguez

  Joshua Willett

- **Analysis Team**

  Charles Loeppert

  Ricardo Rodriguez

  David Snyder

  Stefan Stevanovic

  Joshua Willett

  Ryan Marx

- **Team Coordinator**

  Ryan Marx

- **IPRO Office Link**

  Corey Hawker