OREGON METALS INITIATIVE

2013 - 2014
Annual Report

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MISSION AND GOALS:

The Oregon Metals Initiative, Inc. (OMI) is a consortium of metals industry companies and research institutions that pursue research to improve the long-term competitiveness of the metals industry and the research infrastructure in Oregon. Metals industry firms are involved in a diverse range of activities including primary metal production, manufacturing of fabricated components, designing and building a wide range of specialized machinery and transportation products including trucks, railcars, ships, and aircraft components. In addition to the direct economic impact provided by payrolls, metals firms play an important role in providing demand for products and services produced by other Oregon businesses such as intra-industry sales of metals industry products, business services, energy, and transportation.

OMI was established in 1990 as a mechanism to both support and enhance the competitive position and contribution of the metals industry to Oregon's economy and, more generally, to the national economy. The organization is managed by a 10-member Board of Directors which includes both industry and research (university) representatives. Mark Nelson, Public Affairs Counsel, currently serves as OMI's Executive Director. The following are OMI's objectives:

- Develop new technologies and new applications of existing technologies;
- Increase metals research capacity, accessibility and infrastructure;
- Encourage collaboration on research between the metals industry and Oregon's scientific research institutions; and
- Improve the competitive position of Oregon's metals industry.

The objectives are met through joint industry-academic research projects. Interested companies work with one of four research institutions, currently Portland State University, Oregon State University, George Fox College and the University of Oregon, to develop project proposals. Every July, the OMI Board meets for its annual meeting. At this meeting, the Board reviews the proposals to ensure they meet the criteria established in the by-laws. The Board then determines which projects will be funded up to the level of available matching funds. The Oregon University System provides the matching funds to the industry funds on a 1:1 basis. It is the availability of the matching dollars that renders OMI feasible. With the matching support, the industry has been able to undertake research that would not have been pursued at all or at this time, and research institutions have benefited from the invaluable experience of conducting this research and working with industry.

All funds go to the research institution, with none being earmarked for administrative costs. The Oregon State Board of Higher Education states, "Since 1990, the Oregon Metals Initiative has exemplified the concept of successful private-public partnerships…OMI is the model the Chancellor's Office hopes other industries will emulate in the next biennium." (OSBHE Docket 4/17/98).

PARTNER ORGANIZATIONS:

- George Fox University
- Portland State University
- Oregon State University
- University of Oregon

PARTNER COMPANIES:

- A & K Development
- Benchmade
- Blount (2 projects)
- Boeing
- Cascade Steel
- D W Fritz, Inc.
- DeMarini Sports, Inc.
- ESCO
- EVRAZ North America
- Fought & Company
- Hewlett Packard
- Intel (2 projects)
- PCC Structurals (4 projects)
- Sheldon
- Warn

INVESTMENT:

During fiscal year 2013 – 2014, $681,000 from the industry was matched by $681,000 in state funds to conduct research projects.

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Determination of Input Parameters for a Model-Based Design of a Shaker Feeder

Participating Company: A & K Development

Company Contact: Matt Durbin

Participating University: Oregon State University

OSU Principal Investigator: John Parmigiani and Rob Stone

PROJECT SUMMARY:

A & K Development Company designs and manufactures equipment for the food processing and agricultural industry. Founded in Eugene, Oregon, A & K Development Company also has facilities in Drain, Oregon; Arcadia, Florida; Bangkok, Thailand; and Harbin, China. A & K is the world leader in the production of husking equipment for the sweet and seed corn industries and also manufactures pre-cleaning equipment for carrots, citrus products, potatoes, radishes, beets, garlic and onions.

The overall goal of this project is to apply the techniques of modern engineering computer-based design and validation to the Half Transfer Shaker Feeder, a product of A & K. The Half Transfer Shaker Feeder is a vibratory conveyor table which uses a novel patented drive mechanism to move food products during processing. A & K's current build-test-revise approach, while effective, is slow and is causing delays in new product launches resulting in missed sales.

Year one of this project is complete. Year one consisted of (i) developing computer models of the "spring arm", a key component in the drive mechanism of the machine, (ii) conducting testing of the spring arms and creating the basis for an incoming inspection procedure for them, (iii) installing an A & K shaker feeder at OSU for research, and (iv) designing and installing instrumentation to precisely measure key physical attributes of the operation of the shaker feeder. A & K needed to accelerate their product development cycle to respond to current and new business opportunities. This project begins to apply modern computer-based engineering and manufacturing methods at A & K to accomplish this.

This project won't directly create new products or markets, but will allow A & K to more effectively and rapidly introduce new products and respond to new market opportunities.

The project enhanced both the analytical skills and experimentation skills of the two involved graduate students. Analytical skills were enhanced through conducting computer-based modeling of the load-displacement response of the spring arms and through the dynamic modeling of the shaker-feeder operation. Experimentation skills were enhanced through the need to fabricate custom fixtures and instrumentation for the measurement of spring arm load-displacement response and the dynamic properties of the shaker feeder. A & K personnel have become more familiar with OSU's facilities and personnel. OMI was the deal closer. The availability of matching funds was very helpful in having A & K, which had never before sponsored research at OSU, commit to this project.

No new capital was acquired to execute the testing. OSU does have an A & K shaker feeder installed, however the intent is to return it to A & K at the conclusion of the project. Because of this project, an incoming inspection procedure for spring arms has been developed.

The following papers were delivered:
Foglesong, T., Stone, R., Parmigiani, J.P., "Dynamics Modeling to Inform Design Optimization, *ASME 2014 International Design Engineering Technical Conferences Design Education Conference IDETC/DES,* Buffalo, NY, 2014.

BUSINESS SUMMARY:

The first year of this project has been completed. This focused on OSU becoming familiar with A & K and the vibratory shaker feeder. OSU also worked on developing a computer model for the fiberarm. We have a quarterly update meeting schedule for Wednesday, October 22 at Oregon State.

The problem that was faced by industry was that the machines run 24/7 during the corn processing season, so there was breakage with the fiberarms. The main question is what can be done to mitigate this breakage? We have tried different designs, dimensions, and materials, hoping to find something that will be more durable in the field. With a computer model, we hope OSU can test different parameters and find the ideal material, design, and operating conditions.

There was estimated cost savings (capital, labor and resources): The cost of a fiberarm from the previous vendor: $98.35, cost of a fiberarm from current vendor (See below) $37.50. We have made gains in the resource use and/or re-use, human-hours saved, utilization of lower cost or locally produced materials, impact on the environment, reduced carbon footprint, and other benefits. At a meeting in December, 2013, we noticed material on a robot in a display window at MIME. We asked and found the supplier. After consultations with their engineers and sales staff, we found this material to be superior to the material we were previously using at a lower price.

Our company has not added any new jobs and have not captured any new markets. An improved fiberarm would mean less breakage and more reliability for our machines, enhancing our customer support. At this time, we have not applied for or obtained a patent. We believe we are on the way to simplifying our machinery and how we design and build it.

A Study of Heat Treating Effects on Edged Blade Performance

Participating Company: Benchmade
Company Contact: David Maxey
Participating University: Oregon State University
OSU Principal Investigator: David Kim and Julie Tucker

PROJECT SUMMARY:

In this project the effect of changing heat treating parameters of selected steel alloys used in Benchmade products was to be studied. The project objective is to better understand how blade steel heat treating parameters can be controlled and subsequently optimized to enhance specific knife blade performance dimensions. This project has been completed and the final report draft is in progress.

The problem industry faced was developing a better understanding of how changing alloy heat treat parameters affect blade steel performance and microstructure. This project approached this question experimentally and generated data and data analysis to help develop a better understanding.

Possible new niche products may be developed but more work is required. At this time no new patents have been applied for. Graduate students were trained on using the scanning electron microscope and had exposure to experimental design and statistical analysis.

This is the latest project of an on-going working relationship between Benchmade and OSU. The matching funds made the project feasible. This project was one poster session for an undergraduate student and also it was the basis for a M.S. thesis in materials science. The project is just being completed so more papers may be possible. Students always benefit from being in a real life research project.

BUSINESS SUMMARY:

Knife blade performance is affected by several characteristics including, but not limited to, the cutting edge geometry and surface finish, the bevel geometry, the blade profile, and the parent material properties as well as the heat treat parameters used. This project studied the effect of changing heat treating parameters of selected steel alloys. The project objective was to better understand how blade steel heat treating parameters can be controlled and subsequently optimized to enhance specific knife blade performance features (e.g., edge retention, edge strength, corrosion resistance, etc.). The approach utilized will be experimental and will utilize existing Benchmade knife blade performance tests to characterize alloy performance, as well as scanning electron microscopy (SEM) to characterize the alloy microstructures.

The effect of changing heat treating parameters of selected steel alloys used in Benchmade products was studied. The project objective was to understand how blade steel heat treating parameters can be controlled and subsequently optimized to enhance specific knife blade performance.

Benchmade blade steel performance tests as well as hardness and sharpness tests were utilized to evaluate blade alloy performance. In addition to the blade steel performance tests, scanning electron microscopy images were taken and data related to the alloy microstructure were obtained from the images. From this data various statistics such as average carbide size, and inter-carbide spacing could be obtained.

Summary analysis results and graphs were presented. The results will allow Benchmade to analyze performance results relative to the heat treat variables. Several changes to steel heat treating processes will be incorporated as a result of this project.

Saw Chain Cutting – Mechanics, Experimental Methods and Data Collection, Part 2

Participating Company:	Blount
Company Contact:	Jamie Munn
Participating University:	Oregon State University
OSU Principal Investigator:	John Parmigiani

PROJECT SUMMARY:

The project (the companion to the project "Saw Chain Cutting – Mechanics, Test Device Design and Fabrication Part 2") has been completed. The purpose of the project may be summarized as follows: to develop initial test procedures for use with the device created in the companion project and to use these procedures to collect meaningful data. Both of these tasks have been accomplished.

Use of the device created in "…Test Device Design and Fabrication Part 2" has not proved trivial. While it is expected that the development of procedures to test various aspects of saw chain will be ongoing work for years to come, the data collecting methods devised through this project have provided an important framework in establishing basic testing procedures and in determining the machine's precision.

Though no new markets have been captured or new patent applications or patents have resulted from this project, it will enable effective use of the device created in "…Test Device Design and Fabrication Part 2."

Moreover, this project has enhanced the research and data collection skills of the graduate student and team responsible for the development and testing of the test procedures. This graduate student also gained interpersonal skills through his interaction with Blount engineers to establish the machine's testing procedures as well as presentation skills through his presentations of his findings. In conjunction with this project, two journal articles are currently being written, and this project was a significant portion of a graduate student's (Andrew Otto's) master's degree studies.

This project ultimately resulted in the development of new test procedures and the ability to use these procedures to test previously untestable aspects of saw chain.

BUSINESS SUMMARY:

This project is complete. The student has completed making and validating the test fixture and the data has been analyzed to confirm cutting efficiencies of current and new chain saw chain designed. This data will be used frequently by the Oregon saw chain design & development teams.

Within a prior OSU/Blount project through OMI the OSU research team developed a chain saw test apparatus to measure cutting efficiency specifically for the 2 hp and less power level. With the increasing market of cordless chain saws we need to develop a chain for that market, but the 10 hp test apparatus in our lab is too powerful and doesn't measure efficiency down at the respective power range. We need a test apparatus to test those new classes of products. Now with the apparatus complete, we needed to confirm the concordance to our 10 hp rig and ensure that the data is correct and representative of the saw chain's performance. This was a large study to use the test apparatus, conduct a Measurement System Analysis (MSA) to ensure the data is accurate and are repeatable, and a concordance study to show that it is representative of output data similar to Blount's larger test apparatus all within a /design of Experiment (DOE).

Estimated savings is $200,000 USD, approximately one full engineer's labor & overhead to design, develop, build & validate. This project will allow us to expand our product range and remain competitive within the global market. With the increasing market-share of cordless lawn & garden tools the exhaust emissions will be reduced. It's difficult to quantify how much. For reference in 1 year a gas lawnmower emissions equal the emissions from 4 cars. As we increase the market share of cordless tools from 6-7% presently to 10% as projected by 2018 there will be substantial emissions reduction.

No new additional jobs or increase in skill level. An increase in accessible knowledge was gained through this project. We can now develop and test new products for the cordless and corded chain saw market. That would have been impossible without this test apparatus. There have not been any patents or patent applications sought.

We have been so pleased with the test apparatus that we will be using it to further our research and depth of knowledge on other aspects of chain saw chain and bars. Also we have been so pleased with the quality of work produced from Dr. Parmigiani's lab we have committed to fund research with him for the next 5 years and created a Blount Fellowship. We have also been encouraged by the work of OMI to take an active role within the board, and participate with the Northwest Collaboratory for Sustainable Manufacturing as well.

Saw Chain Cutting – Mechanics, Test Device Design and Fabrication Part 2

Participating Company: Blount
Company Contact: Jamie Munn
Participating University: Oregon State University
OSU Principal Investigator: John Parmigiani

PROJECT SUMMARY:

The intent behind this project concerns the design and construction of a laboratory test device for testing the performance of the project chain saw.

The project has been completed; the machine has been built and is currently being used to conduct research on a saw chain for Blount at OSU. The machine proved so useful that a second machine (a virtually identical copy) was built and is located in the Blount test lab for their internal use.

Industry faced the following problem before the initiation of this project: existing chain saw test machines in the sponsor's lab either were not the correct size (i.e. were too large) or did not have the measurement and control capabilities needed to develop certain new products and product features. This project attempted to solve this problem, and the machine developed will add to these capabilities.

Regarding future use, the two machines (one at Blount and one at OSU) created by this project will be used in various ways for product development. The Blount machine is envisioned to serve as a development tool to be used on a regular basis to test relatively large amounts of saw chain. The machine stationed at OSU is envisioned to serve as more of a research tool for exploratory longer-term projects.

No new patent applications, patents, or markets have been captured following the development of this product. It is expected, however, that use of these machines will lead to the development of new products and product features.

The graduate student who saw to this project's completion experienced an enhancement of design creation, component fabrication, software programming, and machine assembly abilities. The project's results proved exceptionally impressive for two years of master's degree work.

Furthermore, this industry-research partnership has resulted in the graduate student's gain of interpersonal skills through interaction with Blount engineers to establish requirements for the machine as well as presentation skills in numerous design review meetings.

A conference paper was written and presented at the 2013 International Mechanical Engineering Congress and Exposition in conjunction to this project. The project overall was a significant piece of a master's thesis and was the basis for two senior projects. The students' and supervising faculty's skills and knowledge were enhanced by their participation in this project.

BUSINESS SUMMARY:

This project has been completed. The student has completed making the test fixture and the duplicate is now being used frequently by the Oregon saw chain design & development teams.

Blount has two chain saw cutting test machines in our laboratory – a 30 hp version to replicate a mechanized tree harvester machine and a 10 hp machine to replicate large gas engine hand-held chainsaws to allow us to test for cutting efficiency of new and competitive saw chains. With the increasing market of cordless chain saws we need to develop a chain for that market, but the 10 hp test rig is too powerful and doesn't measure cutting efficiency down at that respective 2 hp and less power range. We needed a test apparatus to test those new classes of products.

The savings industry will experience is approximately one full engineer's labor & overhead to design, develop, build & validate. Assume approximately $200,000 USD. This project will allow us to expand our product range and remain competitive within the global market. With the increasing market-share of cordless lawn & garden tools the exhaust emissions will be reduced. It's difficult to quantify how much. For reference, in one year a gas lawnmower will exhaust emissions equal to the emissions from 4 cars. As we increase the market share of cordless tools from 6-7%, presently to 10%, as projected by 2018, there will be substantial emissions reduction.

No new additional jobs or increase in skill level was experienced through this project. An increase in accessible knowledge was gained through this project. We can now develop and test new products for the cordless and corded chain saw market, which would have been impossible without this test apparatus.

We have been so pleased with the test apparatus that we will be using it to further our research and depth of knowledge on other aspects of chain saw chain and bars. Also, we have been so pleased with the quality of work produced from Dr. Parmigiani's lab we have committed to fund research with him for the next 5 years and created a Blount Fellowship. We have also been encouraged by the work of OMI to take an active role within the board, and participate with the Northwest Collaboratory for Sustainable Manufacturing.

Development of a Sustainability Assessment Method and Tool for Metal Aircraft Component Manufacturing and Assembly (Phase 3)

Participating Company: Boeing

Company Contact: Matthew D. Carter

Participating University: Oregon State University

OSU Principal Investigator: Karl Haapala

PROJECT SUMMARY:

In summary, this project developed a methodology for assessing the sustainability of an aircraft assembly at the manufacturing process level, and continued development of a software tool initiated in earlier phases to facilitate sustainability assessment. This phase (Phase 3) incorporated additional processes to the tool and applied these processes using an example of aircraft assembly.

This project (Phase 3) was completed on June 30, 2014. The tasks of developing a sustainability assessment method for an aircraft assembly of assemblies and of creating a software tool were completed during this phase of the project. The additional processes were also incorporated into the tool.

Industry is striving for sustainable goals by manufacturing products with reduced costs, energy consumption, emissions, wastes, and ensuring the well-being of their employees, communities, and consumers. There is a current lack of knowledge for assessing the sustainability of a product at the manufacturing level, which could greatly help engineers in making designs and manufacturing processes more sustainable. This project has succeeded in producing a methodology and software tool to facilitate such assessments to aid engineers in sustainable decision-making.

Though research has not led to new patent applications or patents, the software tool has the potential to become a product following further development. No aircraft parts were developed under this project.

This project has greatly enhanced the research skills of the team and students. Communication and research skills were developed by conducting teleconferences and onsite visits with the industry partner throughout the course of the project to collect data and obtain a better understanding of the project and its goals. Research skills were enhanced by conducting scientific and technical literature searches, studying actual manufactured products and manufacturing processes, working with software tools, and recording and documenting progress and results in presentations, reports, and peer-reviewed technical publications.

Benefits from this industry-research partnership include an expansion of the team and students' knowledge on several manufacturing processes, as well as learning how the processes add value to the product, what resources are used, and how the processes work and function. The partnership has resulted in peer-reviewed scientific publications for the team, with this work also forming the basis of the M.S. thesis of one of the students involved. An undergraduate research assistant was able to become involved in the project. Phase 3 has also led to the faculty advisor's invitation to participate in related scientific meetings, as well as receiving a grant from a U.S. government agency (the National Institute of Standards and Technology) to pursue related research.

Furthermore, new manufacturing process models were developed as a part of the work to evaluate sustainability-related performance. A conference publication was presented at the 2015 ASME Design for Manufacturing and the Life Cycle Conference based on this work. The ASME conference paper is being extended to a journal quality version. Two journal articles were submitted and accepted, one to the Journal of Cleaner Production and one to the International Journal of Advanced Manufacturing Technology.

The research conducted under this project forms the basis of forthcoming M.S. thesis work for one graduate student and has encompassed the thesis work of an M.S. thesis completed in June 2014. The one faculty member involved with this project gained knowledge in addition to previous research focused on related work for component manufacturing. By extending this work to include assembly of components, new skills and knowledge have been gained in terms of manufacturing processes and methods, process modeling, and the development and application of new software tools.

BUSINESS SUMMARY:

This project developed thought leadership for sustainability metrics in manufacturing. Further, the project implemented those metrics and analysis, tested in the real world and refined. The developed software tools were critical to testing methodologies in a real manufacturing environment. The project is currently in third of four development cycle phases.

The analysis of sustainability metrics has led to some re-thinking of several key business approaches, for example work place safety. While still in the prototype phase, it is expected that significant competitive advantages will be produced by being able to drive to sustainability.

The benefit we experienced is that by leading this development, we are in a position to act rather than re-act to coming requirements.

Warehouse Logistics

Participating Company: Cascade Steel
Company Contact: Bob Harder
Participating University: George Fox
GF Principal Investigator: Jonathan Ostling

PROJECT SUMMARY:

The final scope of this project focused on increasing the safety and efficiency of moving bundled rebar from a discharge area to flatbed railcar. The final design recommendations were completed and submitted to Cascade Steel at the end of April 2014.

Cascade Steel sought to minimize/eliminate the need for workers to be in close proximity to rebar that had recently been hot rolled. Currently, workers approach the bundles of hot rebar and place a hook through the wire ties. The hooks are chained to a spreader bar which is attached to an overhead crane. The crane moves the rebar either to a railcar or a limited storage area where workers need to again approach the hot rebar to help dislodge the hooks. The temperature of the rebar, sharp ends of tie wire, and height of storage piles where all ongoing potential safety hazards.

The solution of installing an automated conveyor system to move the rebar bundles from the discharge area to the flatbed railcar eliminates all of the immediate safety concerns. In addition, the conveyor system uses existing technologies which Cascade is familiar with, and it can easily keep up with production rates. The proposed conveyor system can move hot rebar from a discharge area to flatbed railcar with no human contact.

No new markets were created and the project has not led to a new patent application.

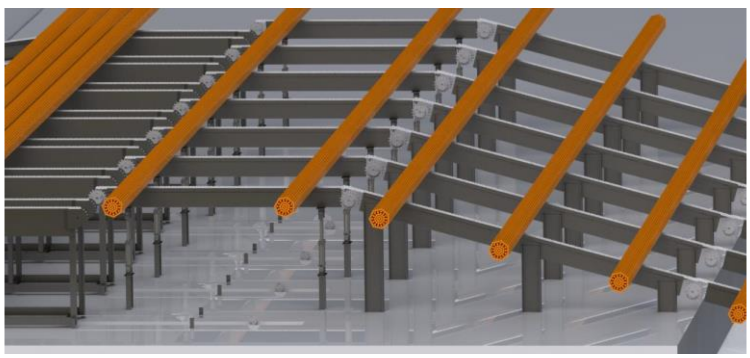
Students learned about the steel rolling industry, working under deadlines, industrial safety concerns and standards, the importance of both maintenance and production viewpoints on material flow, and carefully understanding the client's needs. Cascade Steel regularly hires George Fox engineering students as interns and has hired several alumni as full-time employees. This project has strengthened existing relationships between George Fox University and Cascade Steel Rolling Mills.

OMI's funding enabled the George Fox University Engineering Program to support student design and build projects. No new capital was required for this project. This project fulfilled the Senior Design requirement for six students. The university staff that advised this student project gained additional experience in managing and understanding both student and client expectations. They also gained practical experience with the steel manufacturing industry, as well as appreciating the logistical challenges of material handling.

BUSINESS SUMMARY:

Cascade Steel Mill produces rebar from the steel billets it makes (Fig. 1). They currently transport the rebar around their facilities by bundles attached to the overhead crane with hooks. The hot rebar and height of the storage stacks make working conditions harsh for the processing line employees. Cascade Steel Mill would like to convert to using only magnet cranes to prevent workers from coming into direct contact with the rebar. Because the transition to using magnet cranes will not be immediate, they would like another method to provide improved conditions for workers.

There are many parts to the rebar storage and transportation processes. Our team explored these different areas for alterations and improvements before focusing on a specific section, the point where the rebar is discharged off the processing line to storage. The purpose of our study of the discharge area was to develop an automated system to transport rebar from the line to the transfer car.



(Side view of discharge conveyors)

Deliverables:

•Project Report

•Technical Report

•Operator’s Manual

•Budget cost estimates with Bill of Materials

•Plan and elevation drawings with key components

Automatic Detection of Visual Defects in the Metal Parts

Participating Company: D W Fritz, Inc.

Company Contact: Michael Tanguay

Participating University: Oregon State University

OSU Principal Investigator: Bill Smart

PROJECT SUMMARY:

This project will design and develop automated systems that will detect and classify small defects (such as scratches) on assembled small consumer devices (such as smartphones and computer tablets). The project has just started. We have been waiting for the start of the academic year at Oregon State, and the arrival of the graduate student who will work on this project. We are currently setting up the kickoff meeting with DW Fritz and OSU staff, and expect to make material progress on the project in the coming weeks.

When a consumer first takes a new small consumer electronic device, such as a smartphone, out of the box, any cosmetic defects significantly impact their impression of both the product and the company. These defects, which are typically shallow scratches and abrasions on the metal parts of the device, are checked for by a human inspector. Given the volumes of devices produced, this is both labor-intensive and prone to errors. The project seeks to automate at least part of the inspection process, identifying and classifying defects as automatically as possible, while still optionally using human assistance for hard-to-classify and borderline cases.

The results of this project will be integrated into DW Fritz' assembly automation, potentially increasing throughput, and raising the overall quality of the final devices. We have no significant potential for new consumer products or markets. At this time, the project has not led to any new patent applications or new patents.

The OMI contribution allowed us to assign a full-time graduate student to this project, rather than using (less qualified) undergraduate students. This will allow us to make much faster progress. This project did not require any new capital, no new tests or techniques were developed as a result of this project.

BUSINESS SUMMARY:

Using commercially available representative samples with known surface defects, develop methods and machine based vision detection equipment to acquire, analyze defect images, and classify on specific feature characteristics. Representative samples provided with preliminary detection methods demonstrated for basic approach. Follow-on technical discussions and reviews necessary to establish theory of operation and specific actions. Next team meeting planned at DW Fritz location for lab based evaluation.

A solution was not found, additional actions are necessary. If we can find a successful solution, the proposed discoveries would classify defects for root cause analysis which would lead to product yield improvements. Existing human based inspection methods and classification is non-uniform and widely varies from person to person, machine vision will significantly be more consistent for defect detection and classification, accelerating defect reductions. Implementation of defect classification enables rapid yield loss reductions, which will result in higher equipment utilizations, less direct material loss, and human-hours saved with less scrap material handling.

Through this project, there has been an improved understanding of Robotics program at OSU and additional applications in the near future.

Aluminum Bat Performance

Participating Company: DeMarini Sports, Inc.

Company Contact: Ed VanderPol

Participating University: Portland State University

PSU Principal Investigator: Dr. David Turcic

PROJECT SUMMARY:

DeMarini Sports is a world leader in development of high performance softball bats and baseball bats. These high performing bats can be manufactured from high-strength aluminum, in contrast to solid wood bats used in professional baseball. In order to improve bat design, DeMarini seeks a basic understanding of the factors that affect bat performance. The proposed continuing study will refine the softball and baseball bat high speed test apparatus and experimental methods to further improve the reliability and precession of the measurement of the impact mechanics of aluminum bats and the effects of material properties and bat structure on the bats' response characteristics.

The project is ongoing. To maintain as the leader in high performance softball and baseball bats, DeMarini needs to test and understand materials behavior under test conditions to provide input into the design and construction of a softball or baseball bats. Based on the results of this effort, we are able to analyze various constructions and the impact on bat performance. These new capabilities will provide input into new designs. New patents are possible.

The research skills of the team and students were enhanced in the areas of machine design considering high speed impact, creative and innovative solution to challenging engineering problems, use of various high performance sensors, and use of high performance data collection systems. Graduate students learn to apply the theory and methods that they learn in classes to real world industrial applications. OMI matching funds helped to support faculty and students and also the purchase of equipment. This project was used as part of an MS degree. The skill levels of all participants have been raised.

BUSINESS SUMMARY:

This project has allowed DeMarini to perform testing in-house at a lower cost with a faster turn-around. Whereas, if the product was sent outside the testing would have about a month turn-around. Skill levels have been raised. New capabilities will provide input into new designs. Future patents are possible. Graduate students learn to apply the theory and methods that they learn in classes to real world industrial applications.

Assessment of Stress Distribution in Steel Castings

Participating Company: ESCO

Company Contact: Daniel Widlund

Participating University: Portland State University

PSU Principal Investigator: Bill Wood

PROJECT SUMMARY:

This project is continuing to assess the use of computational simulation methods to assess critical stress situations relevant to ESCO manufacturing technologies. PSU will use DEFORM-HT as the computational simulation tool and will develop procedures to import a generic geometry from ESCO. The effort will focus on determining the ability to simulate and assess the influence of inhomogeneous composition stress distribution. PSU' efforts in this project fit within a major national initiative to adopt integrated computational materials engineering in the U.S. metals manufacturing infrastructure.

The project work is complete. The results formed the basis for a continuing effort during the 2014-15 OMI research year.

Empirical based learning in a production environment is hugely expensive and requires years of effort. The costs and times associated with shop floor trials minimize the likelihood of significant technology advancements and can negatively impact global competitiveness. The integration of computational materials engineering process simulation has the potential to greatly reduce costs, times, and technology development risks. This project is directed at accelerating manufacturing process technology development implementation.

Incorporation of computational simulation into the engineering learning environment has become a core learning activity in Materials Science and Engineering. It is a major basis for stimulating research and a major skill set for the student transitioning into the work place. This project has broadened and strengthened the role of the university in partnering with Oregon's metals industry.

Analytical research simulation capabilities directly applicable to castings, heat treatment and residual stress formation metals manufacturing were developed. Technical presentations were delivered to internal R&D and Engineering personnel. Undergraduate students earned research credits towards their degree. The development of computational analysis of metals manufacturing processes was significantly enhanced and created opportunities for PSU to pursue new and continuing research activities with Oregon industry.

BUSINESS SUMMARY:

This project assesses the stress distribution during quenching of a cast product. The use of computational simulation tools has the potential to reduce costly trials to mitigate quench cracking due to non-optimal design. This project is complete and has proven the possibility and benefit of using simulation tools. The results form the basis of continued research during the OMI research year of 2014-2015.

The problem faced by industry was that localized stresses in a part during quenching may exceed the flow stresses of the material causing quench cracking or contribute to delayed, hydrogen assisted cracking. This project has shown how a simulation tool, in this case DEFORM-HT, can be used to identify areas of high stresses and thus be a tool for helping problem solving and avoid or minimize the need for expensive production trials.

Industry will save money by cost avoidance with reduced or eliminated production trials corresponding to approximately $5,000-$10,000 per occasion (depending on trial heat size and assigned process route). Each avoided production trial means savings in energy, reduced carbon footprint, less man-hours. No new jobs were created and no new markets were captured or new products developed by this project. This project did not lead to a new patent or patent application.

This project has continued to strengthen the partnership between ESCO and the university.

Modeling of Mechanical Property Shifts Resulting From Flattening of Ring Samples of Steel Pipe

Participating Company: EVRAZ North America
Company Contact: Laurie Collins
Participating University: Portland State University
PSU Principal Investigator: Lemmy Meekisho

PROJECT SUMMARY:

The main objective of this project was to use numerical modeling methods to investigate mechanical property changes that occur when transverse samples harvested from pipe sections were flattened then machined into dog-bone tensile test coupons and tested in accordance with the ASTM standard E8. It has been observed that the multi-step forming process from the pipe forming and hydro testing, followed by harvesting and flattening pipe sections to the fabrication of tensile coupons resulted in the reduction of the yield strength measured from tensile tests. In the absence of a reliable methodology to determine the cause and extent of this property shift, the quick fix (but costly) solution for this problem was to use higher alloy content in the plate rolling mill in order to compensate for the property reduction post pipe forming.

The procedure for pipe making for the pipe type used in this study involved multi-step forming of plate material from a flat shape into a U-shape then into an O-shape followed by a longitudinal weld down the length of the pipe to complete the pipe forming process. Tensile test coupons harvested from a typical pipe section involve a multi-step flattening and machining process which induces a state of stress into the eventual tensile coupons, one that undermines the mechanical properties. A Finite Element Analysis (FEA) modeling procedure was initiated to attempt to quantify the state of stress induced into coupons following multi-step forming processes. Prior to tensile pulling, the pipe sections were subjected to a series of four-point bend forming processes until the curved specimens were nominally flat, after which they were machined into standard dog-bone test coupons before being pulled to failure in standard tensile test equipment.

As a starting point for modeling considerations there was the need to establish the approximate bounds of the range of forming loads that would be required to flatten a steel coupon of known tensile strength and dimensions. A closed-form strength of materials formulation based on the bending characteristics of beams was used to determine the range of forming loads that would be required to flatten resultant coupons. To this end, FEA models of a 24 inch diameter pipe, 0.5 in wall thickness for a mid-range Carbon steel were developed. Illustrations are shown in figures 1 and 2.

Initial FEA model for nonlinear structural analysis

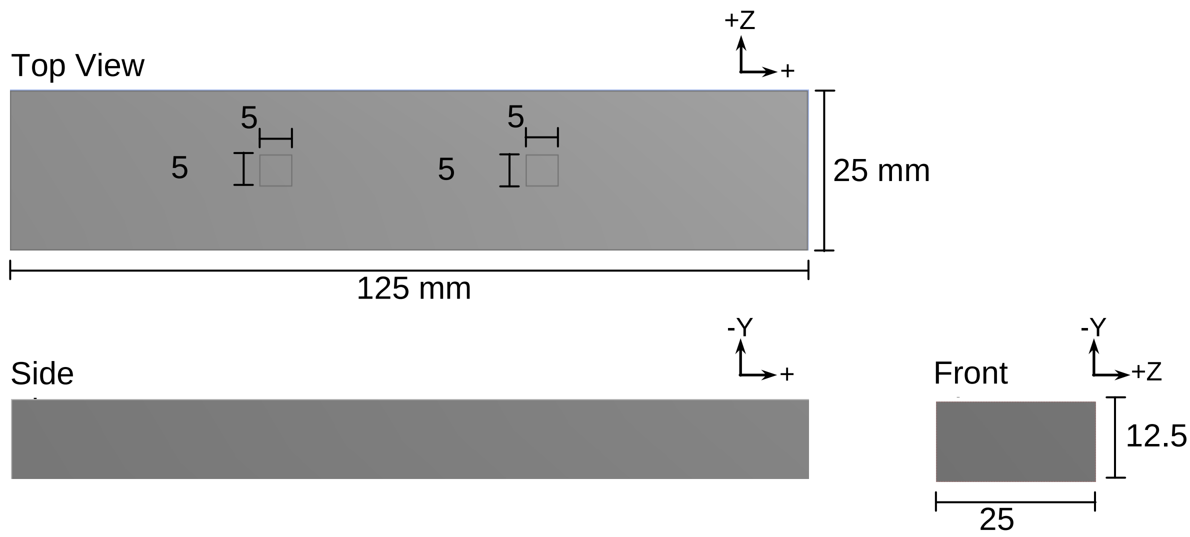


Fig. 1 Geometric details

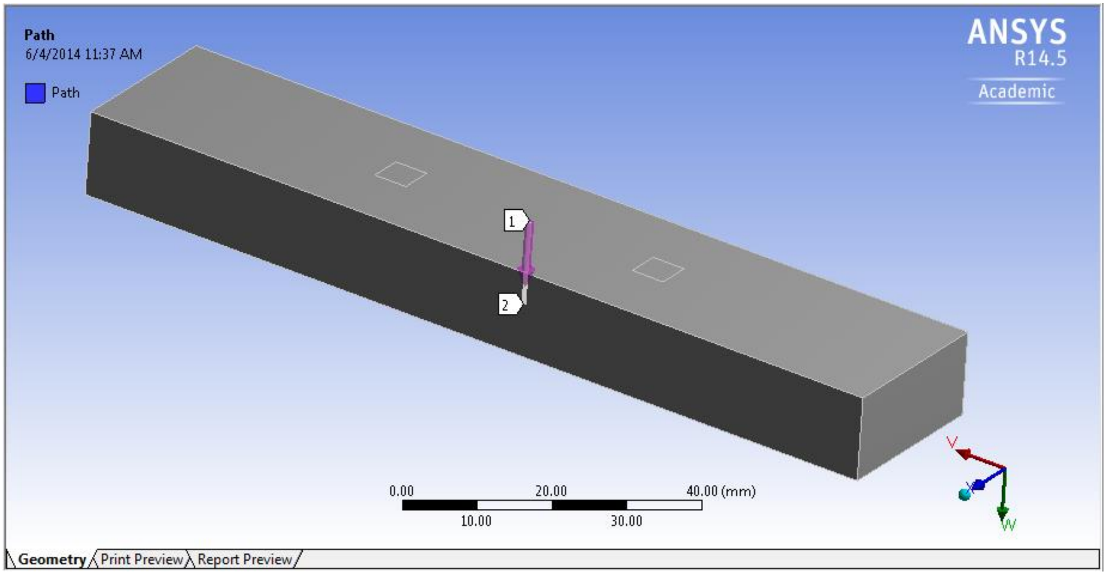


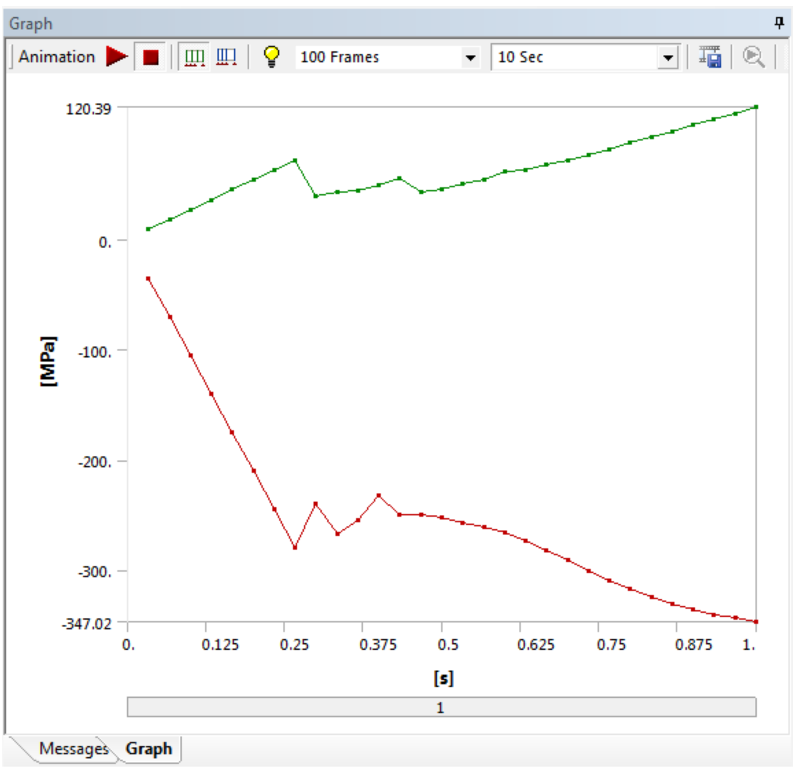
Figure 2. 3D solid model in Ansys showing the through-thickness path for mapping key solution information

Boundary conditions applied for the four-point bend simulation in the solid beam shown in Fig. 2 include concentrated pressure loads (in the w-direction) on the two squares on the top face of the beam and the two short horizontal edges (25 mm long) were fully constrained. A nonlinear Finite

Element analysis was conducted explore the characteristics of mechanical properties for mid-range Carbon steel of the pipe section under study.

Results obtained from this study showed that upper side of the beam which was subjected to the compressive loads remained in compression (negative stresses) whereas the bottom face of the plate was in tension (positive stresses). It was also noteworthy that tensile loads indicate that parts of the wall area have undergone plastic deformation for the applied compressive loads.

Fig. 3 shows a trace of the normal stresses mapped to the path across the wall of the plate. The horizontal axis labeled as **[s]** ranges from 0 (the top face of the beam) to 1 (the bottom of the beam, Fig. 2). This summary gives an excellent indicator of the locus of the tension-compression map through the wall thickness.



Tabular Data

	Time [s]	Minimum [MPa]	Maximum [MPa]
1	3.3333e-002	-34.911	9.0103
2	6.6667e-002	-69.83	18.024
3	0.1	-104.76	27.042
4	0.13333	-139.69	36.064
5	0.16667	-174.63	45.09
6	0.2	-209.58	54.119
7	0.23333	-244.54	63.153
8	0.26667	-279.5	72.19
9	0.3	-239.55	39.216
10	0.33333	-266.74	43.429
11	0.36667	-254.77	43.865
12	0.4	-232.07	49.35
13	0.43333	-249.38	55.118
14	0.46667	-249.75	43.06
15	0.5	-252.16	46.096
16	0.53333	-256.83	50.087
17	0.56667	-260.93	54.252
18	0.6	-265.39	61.588
19	0.63333	-273.63	62.963
20	0.66667	-282.29	67.544
21	0.7	-291.53	72.315
22	0.73333	-301.2	77.238
23	0.76667	-309.56	82.321
24	0.8	-317.62	87.528
25	0.83333	-324.76	92.822
26	0.86667	-330.97	98.187
27	0.9	-336.33	103.63
28	0.93333	-340.32	109.17
29	0.96667	-343.8	114.76
30	1.	-347.02	120.39

Fig. 3. Normal stress mapped to the through thickness path

The practical implication of the results in Fig. 3 certainly indicates that multiple four-point bending operations would lead to a complex stress distribution through the wall thickness, one that required many iterative FEA models. Several generations of FEA models were thus analyzed based on the scope that was presented and approved by the sponsor. Detailed results and recommendations of technology transfer specifics that are of interest to the industry sponsor were submitted to the industry sponsor, Evraz.

Economical Eccentrically Braced Frame – Stiffener Detailing

Participating Company: Fought & Company
Company Contact: Steve Fugate
Participating University: Portland State University
PSU Principal Investigator: Peter Dusicka

PROJECT SUMMARY:

Structural steel system for buildings called eccentrically braced frame was shown to perform extremely well in New Zealand's recent earthquakes. Yet, this system is often not chosen to be used in the US due to fabrication costs. This project looks to experimentally investigate more economic detailing options by examining the stiffener requirements for a critical piece of the frame.

Numerical models of the critical component had been developed and initial analyses conducted. After an initial delay in getting the fabrication of the test setup sorted, the laboratory setup had now been constructed and the instrumentation as well as hydraulic equipment installed in the laboratory. Initial set of 4 specimens had been constructed and are ready to be tested.

The issue is that the economic detailing and fabrication requirement for this type of frame limits adoption of this type of steel system in building construction. By potentially easing the stiffener requirements, the building frame would become easier to fabricate and thereby become more cost effective to adopt.

By providing a more cost competitive option for the building industry, the eccentrically braced frames would bring a high performing structural system when subjected to large earthquake demands. This would provide a higher degree of satisfaction to the building owner, increase the viability of steel as a building structural system choice and have an overall societal benefit of reducing post-earthquake damage in these types of buildings.

The students learned critical thinking and advanced analysis techniques. The team of graduate and undergraduate students has developed analysis skills that would not have been gained through traditional instruction. Furthermore, the practical nature of designing and physically testing the design has made the students appreciate the need for communication with the fabricators in order to attain not only a functional design but also a practical design.

The industry-research partnership on this project has resulted in discussion of a pursuit of other potential ideas, in the area of steel bridge component fabrication. Furthermore, the research partner made a presentation of ongoing research to the fabricators in the Pacific Northwest and thereby increasing the potential industry-research impact beyond this single partnership.

OMI matching funds were crucial in getting this project off the ground. The potential benefit for fabrication of these structural components along with the match potential of OMI attracted funding from American Institute of Steel Construction and together results in the viability of the project moving forward. Research is being conducted with existing equipment and facilities at Portland State University.

A conference paper was presented at a national conference on structural design of earthquake resistant structures; 10th US National Conference on Earthquake Engineering, held in Anchorage Alaska. The research is being used as part of dissertation for PhD degree for one student. In addition to the training of the PhD student, the project provides hands on exposure to several undergraduate students who help out with the laboratory test setup. This is invaluable experience for the undergraduate students who get exposed directly to structural steel fabrication and steel structural performance that will significantly enhance their ability to obtain a job in the engineering industry.

BUSINESS SUMMARY:

The project is about providing cost savings in the fabrication of structural components that are expected to perform under extreme earthquake conditions. The costs savings are expected to translate to additional steel frame buildings being designed and fabricated. With the Pacific Northwest having a high threat of earthquake action, this project also provides a leadership style in the industry nationwide. The potential is for this structural system competing for high performance structural systems that are not proprietary and are able to be fabricated locally.

Reliability and Adhesion Layer Studies of MEMS Actuators

Participating Company: Hewlett Packard

Company Contact: James Abbott

Participating University: Oregon State University

OSU Principal Investigator: Brady Gibbons

PROJECT SUMMARY:

The project is focused on the implementation of environmentally benign materials in piezoelectric applications and devices, where a piezoelectric material is defined as one that changes its shape upon application of a voltage. It also deals with integrating these materials in thin layer embodiments on substrates developed by the industry partner (Hewlett-Packard) and studying the reliability of devices over time. The project is complete, although the PIs maintain an active relationship with the industry sponsor.

The most common material used in piezoelectric applications is lead zirconate titanate, which contains lead as a major constituent. Lead is one of the substances listed in the Reductions of Hazardous Substances (RoHS) directive, which aims to eliminate hazardous materials worldwide. This project aimed to take suitable replacement materials previously developed by the PIs and incorporate them into devices and study their reliability, as it was unknown. Devices were fabricated and tested and showed good responses over time. It also assisted HP in leveraging some of their existing intellectual property into new areas for potential use.

There is significant potential for new markets, as leveraging HP's existing intellectual properties in new areas could be very lucrative moving forward. This project has led to new patent applications. Several graduate and undergraduate students participated in this project from a research/thesis perspective. One undergraduate student was a co-inventor on the patent that resulted from this work. The relationship between HP and the PI's continues today. Some of the PI's students have gone on to internships with HP in Corvallis.

OMI's support was critical to the success of the project, by providing support in terms of salary and materials and supplies. There was no new capital acquired to execute the work done on this project. There were papers delivered at technical meetings relating to this project. This project was part of a degree for the student involved in the project.

BUSINESS SUMMARY:

Our project with OSU focused on leveraging our existing intellectual properties in amorphous oxide semiconductors as substrates for piezoelectric thin films and our previously developed intellectual properties (with the PI's) in lead free piezoelectric materials for use in real devices. Although the materials appear promising, we did not achieve reliable data portraying their use in actual devices.

This particular project is complete, although we maintain an active relationship with the PIs.

At a fundamental level we want to have a lead free piezoelectric material available for us in our products at such time as there is a customer driven or regulatory driven business need for the new material. In previous collaborations with the PI's we developed new piezoelectric materials that did not contain lead. These materials showed very promising behavior, but had not been implemented in actual devices thus the commercialization potential was unknown. Additionally, an opportunity was apparent to leverage our existing intellectual property by integrating these new materials in a thin layer embodiment with amorphous oxide semiconductors. Both goals were addressed in completing this project.

It is difficult to estimate any cost savings since the materials are still in an early phase of development towards product. However, our collaboration with the PIs certainly impacted our bottom line in terms of cost/benefit analysis in and aiding in our ability to make rapid business decisions. The impact of future licensing of intellectual properties developed in this project as well as possible application in product is hard to quantify at this point in time. The impact on the environment could be significant, as we are moving towards removing a toxic element from devices that are ubiquitous in our lives. This will have significant impact at all stages of the manufacturing supply chain – from raw materials through completed final devices. The controls necessary to safely work with Pb based materials in a manufacturing environment are significant.

No additional permanent jobs were created, but through this collaboration HP has benefitted from the PI's students coming to HP for internships. The understanding this project has provided to our internal research teams has been invaluable. The work of these interns has allowed us to further verify the value of these materials leading to our investment in securing relevant patents and investing man hours to investigate the licensing opportunity. There is great potential for new products and markets. This is especially true as worldwide restrictions on the use of toxic elements like lead are implemented. The IP we've developed with the PIs is expected to be of significant value.

This project has led to an application for a patent. HP has benefitted from the excellent technical work provided by the various interns from the PIs' groups. We have also greatly benefited from the collaboration with the PIs and have come to rely on their technical depth of knowledge and insight in this high value materials area.

Fabrication of High Quality Graphene for the Development of Carbon Interconnects

Participating Company: Intel
Company Contact: Roman Caudillo
Participating University: Portland State University
OSU Principal Investigator: Jun Jiao

PROJECT SUMMARY:

This OMI supported joint project between Intel and Portland State University (PSU) has the primary goal of developing an inductively coupled plasma chemical vapor deposition (ICP-CVD) system to fabricate high quality graphene and graphene-metal composites that are beneficial to both semiconductor and metal industries.

The design and assembling of the ICP-CVD system is nearly completed. We are in the process of optimizing the system and are doing the growth of 4" wafer graphene. Overall, the project is on schedule and will meet the deliverable goals as outlined in the OMI proposal.

One problem industry faced was uniform and repeatable production means of wafer-scale graphene and other metal composite thin films. During the course of the project, Intel and PSU have developed dedicated equipment for producing wafer-scale graphene (4") and graphene-metal composites. The developed equipment allows for automated control of process parameters, which will enable the growth of thin film materials with high repeatability. Additionally, the system possesses the flexibility to grow metal or metal oxide based thin films with sequential deposition of designated materials while maintaining vacuum. This system is very unique and is the only one of this type in the greater Portland area and will be very useful for university and industrial collaborative projects.

The second problem faced by industry was transferring the as-grown graphene onto arbitrary surfaces for utilization in electronic devices and various other applications. While developing strategies for growth of graphene and graphene-metal composites, the Intel/PSU collaboration also developed highly effective transfer methods that are cleaner and simpler than previously used methods.

The developments made within this project will be used to fabricate wafer-scale high quality graphene for new electronic devices and lightweight graphene-metal composites for the research and development of metal industries. With the development of a novel means of producing wafer-scale graphene, it is anticipated the process can be scaled to the industry level for electronic devices and graphene-metal composites. Additionally, the developed system combines low-temperature processes coupled with sequential metals deposition without breaking vacuum for creating high quality and lightweight graphene-metal composites. These composites have a large range of applications with one being the aerospace industry.

There is no new patent application at this time. The research skills of the university team have grown in three principle ways as a result of this project: (1) Since the project requires a large range of analytical techniques that span nearly the entire array of instrumentation readily available at PSU, students have the opportunities to become skillful for all the analytical techniques (2) the development of a scalable manufacturing technology allowed the student team insight into considerations and limitations in place within the environment at Intel and related facilities, and (3) the PSU team operated with a dual academic/industry working style, which requires strict adherence to deliverables, proposed timelines, and the creation of several mid-quarter and quarterly reports. These industry-type skills are important not only for integration of a student into an industrial environment, they also promote success in time management and pursuance of goals.

While meeting the deliverables outlined by the Intel/PSU research partnership, high quality graphene has been made available to the research teams at both Intel and PSU. Graphene belongs to a large family of other 2D materials, which are important for the future of electronics and lightweight composites. By developing procedures and capabilities for manufacturing and handling graphene, the Intel/PSU research partnership has created new possibilities with other 2D materials that will be essential for developing new technologies.

Participation in OMI has largely benefited this project through the purchase of critical components required for the dedicated graphene and graphene-metal composites system. This system enabled the project to meet the milestone of producing 4" wafer-scale graphene for prototyping new electronic materials with scalable manufacturing means and allows the PSU research team to explore the growth of lightweight metal composites as well as initiating research with local metal industries.

There was no new capital expended for this project. The development of the dedicated graphene and graphene-metal composite system has enabled the availability of consistent, high quality, and wafer-scale graphene. Additionally, new and improved methods for handling graphene have been developed for creation of electronic devices and graphene-metal composites. Several publications are anticipated from this project with two currently being developed. Additionally, a conference proceeding paper is prepared to be presented at the upcoming 2015 Microscopy & Microanalysis conference. This project is a part of a Ph.D. research thesis that is carrying out by the Ph.D. candidate, Lester Lampert in the Physics Department of PSU. Both the faculty and staff involved in this project have benefited from this project.

BUSINESS SUMMARY:

This project was aimed at producing large-area, high-quality CVD graphene on metal catalyst thin films and developing a reliable graphene transfer process from the catalytic metal onto insulating substrates without degrading the properties of the as-grown graphene. Overall, the project is on track to meet its deliverables.

Graphene is a potentially interesting material for the semiconductor industry. However, for it to be relevant, large area and high quality graphene growth and transfer techniques still need to be developed and improved. This project explores ICP-CVD growth methods to produce high quality graphene over large areas at potentially lower temperatures than the predominantly used thermal

CVD growth methods used by the graphene research community. The project also explores cleaner and more reliable transfer methods to improve the overall properties of the transferred graphene films.

As a research project into an exploratory material, it is difficult to gauge any estimated cost savings or estimated gains in resource use at this time. No additional jobs were created. Research engineers at the sponsor company working with graphene and other 2D materials were affected positively through knowledge sharing of improvements made to relevant growth and transfer techniques.

No new markets or products were developed. As a research project into an exploratory material, it is difficult to gauge the potential for new products or markets at this time. No new patents or patent applications are being pursued. A major benefit to this project was good communication and collaborative learning thus having resulted in a strengthened relationship between industry and university.

Study of Fatigue Life of Lead-Free Solder Joints of Ball Grid Array Packages

Participating Company:	Intel
Company Contact:	Dr. Phil Geng
Participating University:	Portland State University
OSU Principal Investigator:	Sun Yi

PROJECT SUMMARY:

In the present study, the fatigue life of solder joints of ball grid array packages (BGA) under thermal cycling conditions is evaluated using the finite element method. It is very time consuming to measure thermal fatigue life of solder joints of PBGAs. The matrix dislocation mechanism and grain boundary sliding model for solders are employed. Damage parameters are obtained from the finite element analysis (FEA) results and are used to estimate the thermal fatigue life of lead-free solder balls. The findings of this study can be used to improve the reliability of the Intel's PBGA package.

PSU research team broadens their experience and gains the knowledge on fatigue failures of solders. It is a great challenge to develop an accurate model. The student will be trained by solving the real world problem. This type of project also increases the employment opportunities for the students involved.

BUSINESS SUMMARY:

In the present study, a numerical simulation method for the prediction of fatigue life of solders of a plastic ball grid array package (PBGA) is developed. The fatigue life of solder joints of PBGAs under thermal cycling conditions is evaluated using the finite element method. The project was finished successfully.

Recently, chip density, die size, electric functionality and geometric complexity have increased. As a result, microelectronic devices have become more susceptible to defects and internal residual stresses during packaging processes as well as service conditions. In this study, modelling and numerical simulation is used to guide development activities to the right direction by finding optimum thermo-mechanical properties of the IC packaging material to enhance the reliability of solder joints.

The findings of this study can be used to predict the reliability of solder joints of a PBGA package and as its general design guidelines. For Intel, this partnership provides access to expertise they did not have.

Analysis of the Precision and Accuracy of the Aspex Explorer SEM for Inclusion Analysis

Participating Company: PCC Structurals
Company Contact: David Brayshaw
Participating University: Oregon State University
OSU Principal Investigator: Jamie Kruzic

PROJECT SUMMARY:

The accuracy and precision of the Aspex Explorer SEM with automated feature analysis was assessed for a typical nickel base super alloy of interest to PCC. The current OMI project has been completed.

PCC wanted to determine if using the Aspex Explorer SEM with automated feature analysis would be a valuable tool for the company to acquire and use for analyzing their metal castings. This project collected the data needed for PCC to make their assessment of the technology. PCC was able to assess a new technology and make an informed business decision about whether to adopt the technology.

The research student involved learned valuable materials characterization research skills and used this research to help them complete their M.S. degree in Materials Science.

OMI's financial contribution helped employ a student, Michelle Jennings, who gained valuable research skills and obtained an M.S. degree. No new capital was acquired and no new tests or analytical techniques were developed. This research was used for Michelle Jennings' M.S. degree in Materials Science.

BUSINESS SUMMARY:

Non-metallic inclusions are detrimental to the manufacturing of castings, causing reduced mechanical properties and requiring additional labor to remove these inclusions prior to shipping of the castings. The Aspex Metal Quality Analyzer tool was investigated as a tool to identify and quantify non-metallic inclusions as a means to reduce inclusions in castings. This project is complete. OSU analyzed roughly 300 samples for non-metallic inclusions and provided the analysis to PCC.

Non-metallic inclusions in castings are undesirable and are required to be removed prior to shipping of the casting. Throughout the investment casting process, multiple sources of non-metallic inclusions exist. This project was aimed at using a new analysis tool to help analyze and quantify the type of inclusions from multiple samples throughout the investment casting process to direct focus on reduction of non-metallic inclusions in the final product.

The reduction of non-metallic inclusions in castings would result in a substantial cost savings for PCC in reduced scrap and re-work. This project was aimed at evaluating a piece of equipment for purchase to achieve this reduction. Although technically successful, the cost justification for purchase of equipment was not achieved. Reduction of non-metallic inclusions would greatly reduce labor required to grind out and repair castings prior to shipping. No additional jobs were created.   At this time, no new markets or projects have been developed.

This project helped to sponsor a graduate student at OSU. This student was able to train PCC employees and analyze samples on equipment provided by PCC. Without the assistance of the OSU student, the analysis of the samples and equipment would have taken much longer due to resource constraints at PCC.

Electrochemical Machining, Data Collection and Analysis

Participating Company: PCC Structurals

Company Contact: David Brayshaw

Participating University: Oregon State University

OSU Principal Investigator: John Parmigiani

PROJECT SUMMARY:

This project is the companion to the 2012-2013 project "Electrochemical Machining Test Apparatus." The companion project resulted in the creation of a device that in this project was used to remove metal protrusions from manufactured parts. The 2013-2014 project has been completed. The resulting device was used, with specifically designed fixturing, to effectively remove metal protrusions from parts as an alternative to mechanical grinding.

Before the completion of this project, industry faced inefficient, expensive, and potentially dangerous (due to repetitive stress injury) means of protrusion removal by mechanical grinding. This project offers an alternative method through the use of electrochemical machining.

Though no new markets or products are anticipated following the development of this machining device, the outcome of this project is the improved manufacture of existing projects. The research compiled in the process of completing this project has led to the filing of a patent application for the fixturing creation methods and the fixturing itself.

Benefits of this project include the involved graduate student's immense gain of metals fabrication skills, experimental techniques and electrochemistry knowledge, and management abilities in order to complete such a complex technical project. Furthermore, this project's success has helped launch other projects with PCC and OSU.

In conjunction with this project, the following two conference papers (listed below) as well as one journal article were presented at technical meetings:

- Bingham, B. and Parmigiani, J.P. "The Effect of Electrolyte Flow Slots in Tooling Electrodes on Final Anode Surface in Electrochemical Machining", Proceedings of the COMSOL Conference 2013, Boston, MA 2013
- Bingham, B. and Parmigiani, J.P. "The Design and Fabrication of an Electrochemical Machining Test Apparatus", Proceedings of ASME 2013 International Mechanical Engineering Congress & Exposition, San Diego, CA

Graduate student, Bruce Bingham, used the research resultant of this project as part of his master's degree studies. This student gained significant knowledge regarding metals fabrication and experimental technique.

BUSINESS SUMMARY:

The manufacture of large metal components at PCC Structurals requires the removal of gate contacts from castings. Currently this work requires extensive grinding. PCC is interested in exploring ECM (electrochemical machining) as an alternative to grinding. ECM can be thought of as highly-accelerated and controlled corrosion or also as reverse electroplating. ECM consists of a pressurized electrolyte fluid being injected onto the surface to be machined. Electrical current flowing through the fluid causes metal from the work piece to be dissolved. Fluid motion carries debris away. This project consists of the use of the apparatus to conduct a statistical design-of-experiments study to identify optimum methods for machining PCC parts.

The project is complete. OSU has provided data analysis for optimum methods for the ECM process. This project involves looking at an alternative method for metal removal, a process which PCC Structurals, Inc. currently invests a large amount of money in consumables for this process and this process is very labor intensive.

Although this project did not fully develop ECM capabilities for production, the apparatus and learning will help to determine the feasibility of implementing this technology, which could open up the possibility to $M's in cost savings for reduced purchasing of consumables for metal removal.
ECM implementation will drastically reduce the number of labor intensive human hours needed to remove metal in the grinding processes at PCC.

PCC and Oregon State University have conducted several OMI funded projects. Through this relationship, communication and project scoping has evolved and this is evident in the quality of projects that are now being conducted.

Image and Chemical Analysis of Inclusions and Defects in Castings

Participating Company: PCC Structurals
Company Contact: Justin Clews
Participating University: Portland State University
PSU Principal Investigator: Bill Wood

PROJECT SUMMARY:

Elimination of inclusions and defects in castings requires the complex integration of design and manufacturing practices. In order to understand the origin of inclusion and defects and how to then adjust design and manufacturing practices imaging and chemical analysis of inclusions and defect play an important role in first understanding the factors leading to their formation and then modifying designs and practices to eliminate their formation. This project was designed to have PCC select inclusions and defects for chemical and image analysis by PSU. Based on these results, PCC would be able to avoid defect formation in their casting processing.

Materials received from PCC have been evaluated. The project is completed. PSU will work with PCC to provide any supplemental analysis relating to these efforts as need arises. During this project time frame PSU has added powerful additional state of the art compositional analysis tools capable of depth profiling, structural as well as chemical composition. This capability further enhances PSU's characterization capabilities for the metals industry.

The challenge is to eliminate the formation of defects in castings. Key to eliminating them is to understand their origin and the relationship to advanced casting technologies. One way to understand their evolution is to determine their chemistry and morphology. The project was directed to determine the chemistry and the size/morphology of defects to enable PCC to determine what elements in their manufacturing practices contributed to their formation.

The results will be used to optimize PCC investment casting variables. The data are immediately useful for current manufacturing process optimization and for forward looking computer simulation optimization of processes and practices for next generation applications. Elimination of inclusions and defects is an essential step in developing new products that can expand markets. Understanding the factors that lead to defect formation can be applied to development of a wide range of new products. No new patents or patents applications have been applied for.

This project was a continuation of prior materials characterization research. Advanced characterization of materials is a core learning skill for materials scientists and engineers.
A continuing research partnership greatly helps enhance undergraduate and graduate students awareness of very high level of advanced materials engineering driving Oregon's metals manufacturing industry. It provides exposure to opportunities in Oregon for these graduating

engineers. OMI is a catalyst mechanism that triggers collaboration. Its long standing presence permits both organizations to proactively explore collaboration opportunities.

PSU was fully equipped to conduct this research so did not have any capital expended. Added capabilities during this research period further expand future advanced research potential. PSU materials research projects all involve advanced materials characterization, manufacturing simulation both physically and computationally. The integration of all the research projects technical activities continuously advance PSU's analytical techniques and capabilities and expose graduate and undergraduate students to advanced technologies and manufacturing practices.

Technical presentations are routinely delivered to PCC R/D and engineering personnel on an ongoing basis. This project was not part of a degree or capstone project. Maintaining and advancing skill sets require ongoing hands on laboratory research. All research projects directly contribute towards enhancing the skills and knowledge of PSU faculty and research staff.

BUSINESS SUMMARY:

PCC uses the investment casting process to manufacture metal castings for its customers. Non-metallic materials are used throughout the investment casting process to produce the castings and are sources for non-metallic inclusions in the final product, which are undesirable. This project is aimed at providing a chemical signature for the non-metallic sources to enhance and expedite future defect investigations. PSU has provided image and chemical analysis for 33 samples from PCC. PCC is currently gathering an additional 20 samples for image and chemical analysis over the next 6 months.

Non-metallic inclusions in metal castings are a source for costly re-work in order to ship the final product. By providing a chemical "fingerprint" for various sources of non-metallic inclusions, PCC will be better aligned to expeditiously find the root cause for these inclusions.

Reduction of non-metallic inclusions is a constant issue within the investment casting industry. The potential cost savings in using this data to identify and reduce these inclusions is substantial ($M) with regards to scrap and re-work labor. The data provided in this project will help drive reduced labor needed to re-work castings with non-metallic inclusions. No additional jobs were created. No new markets or products were developed, but the analysis completed during this project will assist in the development and time to market of new products in the future. At this time, there have been no new patents or patent applications.

This project continues a partnership between industry and the university to utilize analysis tools at the university for root cause investigations in industry.

Thermophysical and Thermal-Mechanical Property Characterization of Materials Used in Investment Casting Process

Participating Company: PCC Structurals
Company Contact: Justin Clews
Participating University: Portland State University
PSU Principal Investigator: Bill Woods

PROJECT SUMMARY:

This project represents the continuation of a multi-year research effort to determine the temperature dependent thermal and physical properties of materials integral to the manufacturing technology of the investment casting process. In the materials lab, PSU is replicating the thermal cycle associated with production casting technology and determining the temperature dependent properties to enable PCC to make optimal materials selection for their manufacturing technology.

Large investment cast components experience a long complicated thermal cycle after the investment mold is filled with metal. During this process the metal is subjected to thermal and solidification induced stresses that can result in cracking. The selection of the best high temperature materials used in developing an investment shell system requires knowledge of high temperature properties. PSU's high temperature instrumented lab furnaces were used at temperatures over 2400^{o}F to evaluate PCC's materials selection possibilities. PSU will also test insulating materials for thermophysical characteristics for improved simulation capability as well as for investigating potential replacement materials.

The results will be used to optimize PCC investment casting variables. The data are immediately useful for current manufacturing process optimization and for computer simulations of processes for next generation applications.

New product development is usually accompanied by increasingly complex alloys and part configurations. This is accompanied by increased cracking susceptibility. Understanding the high temperature properties of materials used in the manufacturing process allows optimization of the manufacturing technologies to avoid cracking. Eliminating cracking reduces repair costs and delivery times and leads to increased productivity, manufacturing competitiveness and affords the opportunities to efficiently develop new products. New lower cost and more environment friendly materials can also be evaluated for use in current and future processes.

This project did not lead to any new patents or patent applications. This project was a continuation of prior research. During the course of this research, PSU developed new lab capabilities and skills for determining high temperature materials properties.

The continuing research partnership greatly helps enhance undergraduate and graduate students awareness of very high level of advanced materials engineering driving Oregon's metals manufacturing industry. It provides exposure to opportunities in Oregon for these graduating engineers. OMI is a catalyst mechanism that triggers collaboration. Its long standing presence permits both organizations to proactively explore collaboration opportunities. No new capital was expended as PSU is fully equipped to conduct this research.

PSU has developed the ability to determine materials properties at very high temperatures. The capability can be applied to a broad spectrum of materials and provides experimental data that can be fundamentally important for computational simulation as well. Technical presentations were delivered to PCC R/D and Engineering personnel and will continue to be delivered after testing of the materials delivered in 2015 is complete. The development of PSU's capabilities for very high temperature physical simulation and data acquisition of conditions present during the investment casting process significantly enhanced the knowledge and skills of PSU research personnel.

BUSINESS SUMMARY:

This project aims to provide material property data that can be used in the simulating of the investment casting process more accurately, thereby providing engineers the best possible chance of minimizing defects in addition to optimizing the process. New materials can also be tested for use in PCC's process – these materials could be of lower cost or have a lower environmental impact. PSU has tested all the materials provided to them and has submitted summary reports to PCC of their work performed in 2013. No materials were provided to PSU in 2014, PCC will be delivering materials in 2015 to complete the testing.

Material properties are a key input into the simulations that help industry predict defects and help optimize their processes. This project provides data that can be used as inputs into the simulations that more realistically represent the actual material's properties, thereby representing the process more accurately.

Data from this project will be used as inputs into future simulations to better represent the process. In addition to simulation inputs, the data will also be used to evaluate new materials and compare them to currently used materials. New materials need to be equivalent to current ones and this data will be used to benchmark those materials prior to production use. The data will also be used to modify or improve a process should it be determined that the new materials are a better fit for that process. New environment friendly materials could be compared to current materials in order to reduce PCC's impact on the environment.

At this time, the cost savings is not calculable, however, it is expected that the data provided will allow for improved process design and therefore decrease the number of defects in a part thereby reducing the overall cost of making a part. In addition, the data will also be used to compare materials from different vendors, both for reducing cost and for selecting improved materials that may be value-added. The data will help the selection of materials with similar thermophysical properties, but have a reduced environmental impact.

No additional jobs were created nor was the skill level of employees raised. This research will allow PCC to better understand the current materials in use in addition to understanding new products that could replace the current material for various reasons, including but not limited to safety, environmental impact, ease of use and cost. No new patents have been acquired or applied for.

Using Process and System Modeling to Understand Manufacturing Costs, Part 1

Participating Company: Sheldon
Company Contact: Jeff Mason
Participating University: Oregon State University
OSU Principal Investigator: Karl Haapala

PROJECT SUMMARY:

This project was ultimately designed for the university research team to assist the industry partner in identifying and quantifying sources of time and of resource inefficiency in production as they related to material and energy flows, as well as to production schedules.

This project is complete and a final presentation was provided to the industry partner in May 2014.

Entering this project, industry faced a lack of an accurate understanding of production cost on a per-unit-product basis. This project worked toward a functional cost model for Sheldon's production system and to provide a certain analysis of labor, material, and energy costs. This model has helped company personnel better understand their manufacturing system and identify potential improvements.

Results of this project can assist the company decision makers in making more informed production planning, scheduling, and costing decisions.

Neither new products nor new markets were captured by this project; the research entailed by this project has not led to new patent applications or patents. Nevertheless, this project has contributed to a Ph.D. dissertation, four capstone projects (of which two are unique), and one B.S. honors thesis. Regarding the Ph.D. student specifically, support from OMI directly assisted the student in devoting the necessary time for collecting data and developing the cost model for Sheldon as well as developing cost modeling theory for his dissertation. Two undergraduate researchers benefited from this project, as well, by participating in data collection and modeling.

This project has furthermore resulted in two conference papers, with one undergraduate attending the IIE Industrial and Systems Engineering Research Conference (ISERC), and one attending the American Society of Engineering Management (ASEM) conference, in addition to one of the project investigators and the Ph.D. student. Details of these two technical papers are as follows:

- Girod, O.J., Zhang, H., Calvo-Amodio, J., Haapala, K.R., Mason, J., 2014. "A Hybrid-Dynamic Transition Phase for High Mix Low Volume Manufacturers," Industrial and Systems Engineering Research Conference. May 31-June 3, 2014. Montreal, Canada.

- Zhang, H., Flynn, A., 2014. "A Systemic Cost Model for High Mix Low Volume SME Metal Manufacturers," in: Proceedings of American Society for Engineering Management International Annual Conference. October 15-18, 2014. Virginia Beach, VA.

The research team gained knowledge of production scheduling, production costing, and sustainable manufacturing. One additional benefit from this industry-research partnership includes the fact that this collaboration has resulted in a proposal to the U.S. National Science Foundation requesting approximately $300,000 for development of the fundamental theory for full cost modeling.

As a result of this research, a deeper understanding of cost factor relations in the manufacturing system has been achieved. Further research topics have been identified to move this understanding to another level. Initial work developed simulation models and system dynamics models that will provide groundwork for and be expanded by future research.

BUSINESS SUMMARY:

The model/template was developed and validated with live product information. Our previous costing methodology was incomplete and inaccurate leading to both under and over pricing of product. This model provides a more complete depiction of product costs and helps identify key areas for improvement.

Understanding our costs more completely and accurately is the first step in identifying areas for improvement. We will not have any direct cost savings, but we expect this project will aid in our continuous improvement efforts by identifying focus areas. The model will be further refined to allow scenario analyses – to identify potential savings/improvements through alternate materials, labor reduction, etc. We also recently pursued a new paint line to reduce our biggest energy consumer of natural gas by 50% (Energy Trust award will be $93k). Sheldon did not create any additional jobs at this time. The biggest driver is trying to remain competitive with new overseas competition. There are some markets in which we cannot compete on price, although we hope to gain entry into through cost reduction.

This project helped our industry give fresh eyes on factory operations which helps to develop ideas for improvement and also energizes the existing workforce by exposure to good work practices and methods. I believe that the research participants benefit in the same way.

Evaluation of Technical Articles Applicable to the Replacement of Steel Cable with Synthetic Rope

Participating Company:	Warn
Company Contact:	Ian Wendler
Participating University:	Oregon State University
OSU Principal Investigator:	John Parmigiani

PROJECT SUMMARY:

The goal of this project is to provide Warn with a written summary of existing technical literature relevant to the replacement of steel cable in winch applications with synthetic rope. It is projected that from this summary, topics for future OMI projects will emerge.

As of mid-December 2014, this project has not been completed. This completion status attributes to delays in starting the project following the graduation of the graduate student working on this project. Another student, however, is making progress on the project, and project completion is expected in winter of 2015.

As far as an industry problem this project is dedicated to solving, Warn is exploring the replacement of steel cable with synthetic rope for several winch applications. Identifying, obtaining, and reading relevant academic technical literature and then extracting relevant information and creating a useful summary thereof are not trivial.

This project will be used to inform Warn of current content relating to published technical information on the replacement of steel cable with synthetic rope relevant to winch applications. It is anticipated that some of this information will be of immediate use to Warn and that the project will identify compelling related research that may be of value to Warn if extended specifically to winch applications.

No direct new markets, products, patent applications, or patents have been captured by the working summary of this project. So far, however, this project has enhanced the research skills of the team and students assigned to it; creating summaries of academic technical literature has certainly enhanced the involved students' research skills.

There have not been any new tests, analytical techniques, or research capabilities developed as a result of this pending project. This project is not part of a degree or capstone project and papers in conjunction with this project have not been delivered at technical meetings. Nevertheless, greatly enhanced literature review skills would not have come to fruition had OMI not matched state funds for this first project for Warn.