USDOT Tier 1 University Transportation Center Final Report

NURail 2012-MTU-E03

Undergraduate Student Projects

By

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DISCLAIMER

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TECHNICAL SUMMARY

NURail 2012-MTU-E03 Final Report February 22, 2016

Title

Undergraduate Student Projects

Introduction

Michigan Technological University (Michigan Tech) has been involved in rail related undergraduate student projects since the early days of the Rail Transportation Program (RTP). Although many of the projects have been in the civil engineering discipline, RTP has reached out across campus to the mechanical, electrical, and materials science and engineering departments, as well as to the School of Business and the fine arts department. Michigan Tech has completed eight undergraduate student projects since NURail was launched in 2012. Most projects have been funded as a combination of NURail and industry funds. A complete list of undergraduate rail projects is provided in Appendix 1.

Justification and Project Process

One of the best methods to attract future and current university students to a specific field are through active learning related to the field. Active learning is a concept that has existed for long period of time, often in the form of apprenticeships, but more recently attention has been placed into shifting higher education from a lecture-based format to more hands-on approaches. This shift is partially taking place due to a change in the learning preferences of the current student body who have grown up in a digital environment and are accustomed to technology, both in communication and the learning process.

Michigan Tech offers two primary avenues for capstone engineering projects. The senior design option takes a group of students, typically from a single discipline, and assigns them a project to work on. Most senior design projects run two semesters (although some departments do them over a single semester). Project work runs the gamut from development of initial concept(s), to selection of preferred alternative for a more detailed design, and in some cases development of product prototype. The second option is the Enterprise program. In Enterprises, a group of undergraduate students functions as a small company in a thematic area and work on projects in the area. Enterprise and its projects are led by upper class students, while freshman and sophomores concentrate on technical work and gaining experience and skills. Enterprise projects can pull students from many disciplines and projects can extend across academic years, as the students often participate in the Enterprise for multiple years. Table 1 below compares the two programs.

TABLE 1 – Senior Design/ Enterprise Program Comparison

	Senior Design	Enterprise
Time Involved	One or two semesters	One to many semesters
Project Team Makeup	Typically a homogenous group of seniors from a single discipline	Often multidisciplinary groups that can include students from freshman through senior status … and sometimes even grad students. Work on thematic areas (not disciplinary).
Group size	Typically 4-6 students, although some disciplines have groups up to 12-15 members	Can be any size, from a single member to a much larger group. Size can vary as project needs change during execution
Project Costs	Depends on department. Most projects externally funded (normally $15,000 per project team/year). Some supported through student lab fees and department support.	Usually set up, with a set fee (normally $15,000 per project team + fringes and overhead, if under a formal contract)
Project Duration	Two-semester projects (in some cases one semester)	Typically two semesters, but may vary and can include multi-year projects

Finding a proper project can be one of the most challenging parts of the program. A student project typically begins with a discussion within university faculty/staff, or with one or more industry representatives. Sometimes the meeting is a result of the representative seeking out the university as a potential route for investigating an industry problem, or the idea may spur from discussions with industry on the potential benefits a partner can receive. Those benefits include having a group of students dive into a problem with no pre-conceived notions and having relatively low labor costs. A project team may use anywhere between 500-1,000 person-hours into a project. While the students are not yet professional engineers, they are often in the final stages before stepping into the engineering profession and are very open to using new concept/technologies. In addition to attracting students, these projects often turn into recruitment tools for the industry, especially if students get involved prior to their senior year.

Description of Activities

The enterprise/senior design projects fill several purposes. First, they expose our engineering students to the opportunities available in the rail industry, both with the project team and with other students who see the work they are doing. Second, they provide an opportunity for the rail industry sponsors to explore alternatives to problems they have encountered in their programs. Students can be directed to explore a particular option identified by the industry, but more often are left free to explore any alternative they feel might address the problem. This provides a fresh look at many issues and often a novel solution that the industry had either never considered, or may have earlier considered not applicable. Finally, they provide an avenue for students to demonstrate their development as engineers with a project with a real purpose and need.

Figures 1 and 2 illustrate a Mechanical Engineering senior design project that looked at converting a center beam rail car to be used for hauling pods of frac-sand to the North Dakota oil fields. Figures 3 and 4 show an Electrical Engineering senior design project creating a device that can show the status of the shunt developed by a rail signal testing rig in real time … allowing signal maintainers to immediately address shunt problems. Figure 5 shows the site layout for a Civil Engineering project that created a “master plan” for development of a warehouse facility in a rail served facility in the Detroit area for transloading steel from rail to trucks. A NURail News Brief about each project from this contract period is included in the appendices.

Figure 1 - Centerbeam Rail Car Modification Team Tests Prototype

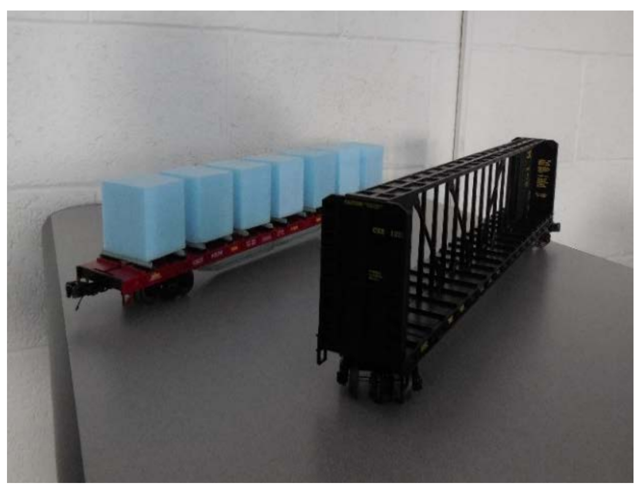
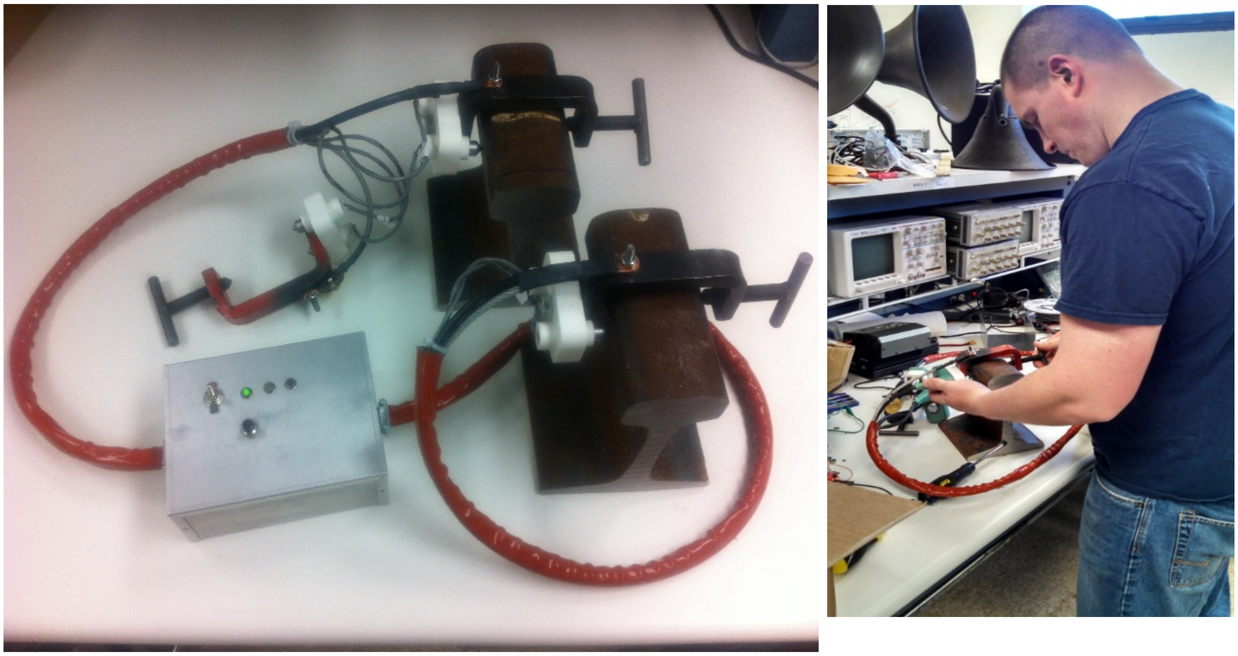


Figure 2 - Centerbeam Rail Car Mock-up



Figures 2 and 4 - Rail shunt testing device (left), Student working the device (right)

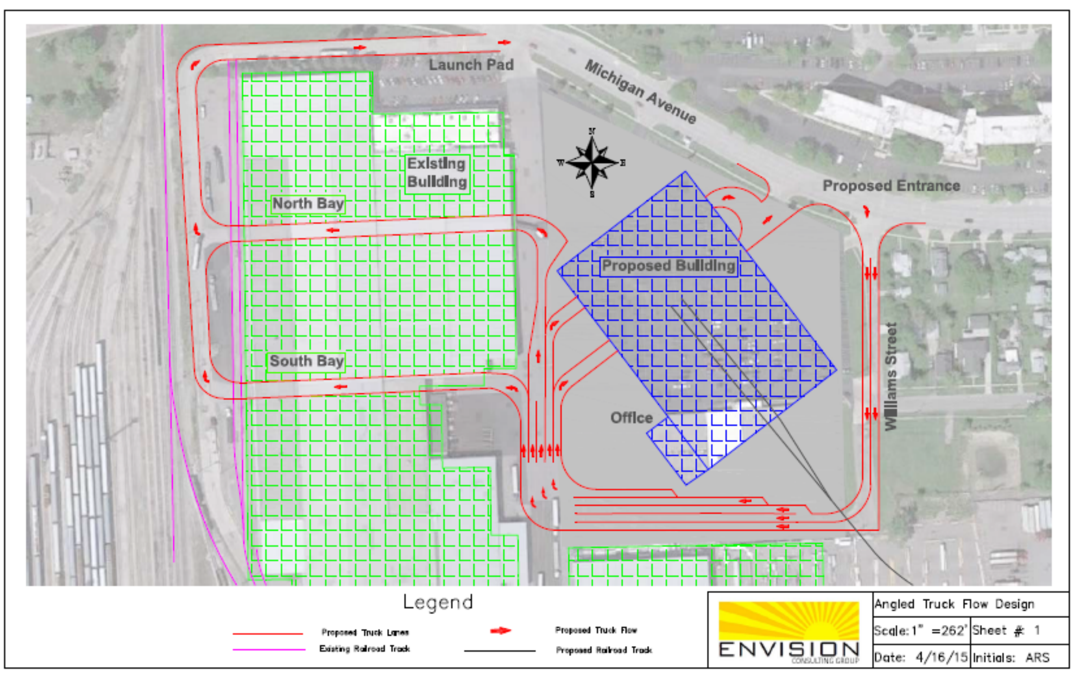


Figure 1 - Wayne Industries Site Development, with Rail Access from Southeast

Outcomes

Since 2012 more than 80 students from seven disciplines and ten industry companies as sponsors and/or technical advisors have worked on rail industry student projects, providing valuable input to the industry and an excellent capstone experience in the engineering field. The projects have been versatile in scope, ranging from railyard and rail served industrial site development to locomotive component development, and items intended to improve safety in the rail environment. We've even worked in a business plan for an investment group with our business students. Seven students who worked on senior design projects have gone on to rail industry internships or full time jobs, but that doesn't tell the whole story. Many students who start these projects are in their final semester at Tech, and already have jobs lined up after they graduate. However, their projects are presented in design expos and other venues on campus and serve to inspire other students to consider the industry as a possible career option. We have also evidence of students who after their graduation have shifted from their initial career selection toward rail industry careers.

We have conducted projects under both senior design and enterprise programs and there are benefits on each. Senior design offers a mature and concentrated group of students, but due to their senior student status, it seems to offer less opportunity for recruitment, as many students have already committed to their first post-graduate position. Enterprise projects provide the benefit of mixing students from earlier grades, allowing the use of students as potential interns in sponsoring companies.

In addition to exposing students to rail transportation, student projects function as an excellent catalyst for increased faculty exposure. There are lots of faculty who are leading experts in their field, but their skills are not taken advantage by the rail industry. These projects involve the faculty with rail industry and encourage direct interaction between them, students and industry, an opportunity often highlighted as one of the key needs by the industry.

While some very interesting ideas have been developed by the students, none of our projects have yet moved on to industrial implementation. Based on our interpretation, one of the main factors causing this are that sponsorship has been provided by the "users" (rail companies) who are not necessarily the entities making manufacturing modifications or directly involved in the development. There has been limited interest from the manufacturing side. Based on discussions with sponsors this may be due to the fact that current technologies are meeting the commercial objectives of the companies, so the motivation for new development is limited.

Recommendations

It is expected that the pace of technology implementation continues to escalate across the industries. Therefore, it is essential that rail industry harnesses as much of the available resources as possible to participate in the development of these new technologies. Exposing the students to rail industry via project activities is a very low cost approach with potential to provide benefits in multiple fronts, namely in recruiting, technology implementation, development of academia interested in rail topics, etc. For these reasons Michigan Tech and other universities should continue to encourage industry to consider undergraduate projects as one of their strategic approaches. In addition to simply getting more projects, both universities and industry need to ensure that these projects are showcased on campus to inspire students to consider the rail industry.

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Appendix 1 – Michigan Tech Undergraduate Student Projects

Completed Student Projects

(2009-2010) Lake Superior & Ishpeming Railroad – Track Design to Improve Train Operations (CE, SU, CM, SBE) - A multidisciplinary team of 13 students completed a track design project to improve capacity of the Lake Superior and Ishpeming Railroad. The team designed two rail sidings, including cost estimates and construction plans, and analyzed the impact of the improvements on the LS&I system.

(2010-2011) CXT / CN Sustainability Assessment (CE, CM) – students from Transportation Enterprise worked with CXT, Inc. and CN Railroad to develop environmental sustainability metrics that can be used in CXT's industrial production facility, and in CN's railroad operations. The project produced a prototype environmental sustainability model to calculate CXT's carbon footprint, and to assess future improvements.

(2010-2011) Lake Superior & Ishpeming Railroad Lubrication Project (CE, CM) - students from Transportation Enterprise worked with Lake Superior and Ishpeming Railroad (LS&I) to assess their existing rail lubrication infrastructure and provide recommendations for updating the system. Students familiarized themselves with not only rail lubrication practices but also rail related terminology and knowledge. During the field visit the student team identified potential problems in the track geometry and added investigation of ideal superelevations to the project.

(2011-2012) Rehabilitation project for the Quincy Mine Hoist Association (QMHA) (CE, CM, SU) - This multidisciplinary group was tasked with restoring the historical track alignments of the mine so that it may serve as a tourist attraction as well as a functional passenger railroad. The team conducted comprehensive topographic surveys, a redesign of the existing track and yard layout around the engine house, crossings between historic and present rail lines, a locomotive run around for maneuvering around passenger cars, and the design of several trestle bridges as part of the final deliverable.

Completed NURail Student Projects

(2012-2013) Locomotive Sand Tank Level Sensor system (EE) – Students developed a sensor system for determining the sand level in locomotive traction sand tanks, and for displaying the level to a remote location.

(2012-2013) Railcar Coupler Redesign (ME, MSE, CE) – Students redesigned the industry standard coupler knuckle to improve durability. The group worked to increase the strength, decrease the weight, and improve the geometric design. The final concept reduces forces in regions known to fail.

(2012-2013) Rail Program Promo Video (HU, SBE) – A student team produced a promotional video for the Rail Transportation Program, including interviews with rail industry leaders and video of active rail operations. The video highlights that the rail industry is a vibrant work place, and that the RTP is a good way to get started with the industry.

(2013-2014) Highway-Rail Grade Crossing Surface Evaluation (CE, CM) – A student group collected available data, conducted site inspections, and analyzed the resulting information to define crossing surface performance. The final report provided Michigan DOT with a criteria set for inspector evaluation of crossing surfaces, and a data collection model for collecting crossing historical data for use in future evaluation of crossing surfaces.

(2013-14) Centerbeam Car Repurposing (ME) – This student group evaluated options for repurposing a centerbeam railcar, and developed a plan for re-using this car type as a frac-sand platform. The plan included removing the existing centerbeam structure, and replacing the lost structural capacity with a redesigned “fish-belly” beam.

(2013-14) Grade Crossing Jumper Cable (EE) – This group investigated the operation of grade crossing signal systems, and the jumper cables used to disable them during maintenance activities. The end result is a redesigned jumper system that can sense the approach of a train and reactivate the crossing even when the jumper is still in place.

(2013-14) Balise and Train Control System Market Study (EE, SBE) – A multidisciplinary team of students provided a client overview of train control systems using balise technology, and the potential market opportunities in that technology area. Ongoing work will look at use of radio frequency tags in the rail industry.

(2014-15) Wayne Industries Site Expansion (CE, ECE)– A group of civil and environmental engineering students worked with Wayne Industries to plan a site expansion for a rail served warehouse. The warehouse receives steel and aluminum by rail, and distributes those materials to the surrounding region by truck. The project involved developing an location plan and preliminary drawings for a 150,000 square foot expansion, plan and profile drawings for rail access to the new expansion, and truck access and parking for the expanded operation.

(2014-15) System to Measure Effectiveness of Rail Shunt – In the rail industry, a shunt merely consists of C-clamps and low resistance wire. This is made in order to simulate the conditions of the track while a train is passing over it as the axles create a very low resistance connection across the tracks which enable various protocols to take place. However, in the simplicity of the design there is a lack of assurance that the shunt is effective in recreating these conditions posing potential threats to calibration and safety of rail workers and equipment. This team developed a clamp system and simple readout that establishes a good shunt and verifies that the shunt operation is being performed adequately.

(2015-16) Lake State Railway Yard Improvements – A team of civil and environmental engineering students are working on developing plans for a portfolio of improvements in the Saginaw Railyard. Improvements include a new covered locomotive wash facility, drainage improvements throughout the yard, re-constructing an abandoned warehouse, track updgrades to support 7 – 9,000 foot unit trains, investigation of road closure and grade separations to support unit train operations, and improvements to the existing locomotive turntable.

(2015-16) Dye penetrants for Rail Defects/Inspection Methods (Materials Science) – Dye penetrants are used in the rail industry to identify rail defects in cut sections of field rail repairs. This ensures that the rail section left in the field after the repair is free from defects. However, dye penetrants do not work well at low temperatures encountered in northern region rail operations. This team is tasked with researching available dye penetrants to find one that will work better than those currently in use, or to find another method of detecting defects that will not be susceptible to cold weather.

(2015-16) Railroad Car Wheel Contaminant Detection (EE, CE) – Wheel contaminants can seriously impact the performance of hump yard retarders. This team developed a system for identifying contaminants on train wheels before they are pushed over the hump, and removing the offending car from the classification stream so that the contaminant can be dealt with.

Appendix 2 – Student Project Newsbriefs

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Center Beam to Frac Sand Railcar Conversion

Alec Bolthouse, William Melcher, Riley Peterson, Nathaniel Scheetz, Becky Schlak, Jocelyn Tervo, Michigan Technological University

The demand for Center Beam railcars has been reduced a great deal with the decline of housing industry in recent years. Many of these cars are either lying idle or being sold for scrap value. Recomissioning the cars for a different function with feasible modification would financially benefit the industry. Mechanical Engineering students at Michigan Tech have found that they can be converted into flat cars that could carry frac-sand for the growing Midwestern oil and natural gas industry.

Introduction

A center Beam railcar is a flatcar with a large truss-like beam down the center of the car. The 'center-beam' provides the structural integrity of the railcar and allows for the loads up to 12 feet high. It is widely used to transport dimensional lumber needed in the construction industry. With reduced demand for the dimensional lumber center beams were designed to carry, many rail car owners are faced with an underutilized, outdated fleet of center beams with few options going forward. Many center beams are held in long term storage, or even sold for scrap value. In the interest of reducing long term cost and capital losses to railcar owners, the team was tasked to develop a proof of concept to convert center beams to another use with a realistic investment of time and resources. Students outlined steps required to convert a center beam railcar into a flatcar specifically tailored to carry seven pods of frac-sand for the growing Midwestern oil and natural gas industry. The conversion requires the removal of the center beam and modification of the center sill underneath the deck to mitigate the structural strengths lost in the removal.

Figure 1. Model center beam car (right) and converted frac sand car with pods (left)

Design/Testing

Students used computer aided drafting and finite element analysis software to design a full scale flatcar with 14 Cross Beam members and an augmented center sill. Two W section beams welded to the center sill running the length of the car make up for load capacity lost when the center beam is removed. An unmodified center beam railcar has an average light weight of 62,400 lb, and a converted flatcar weighs roughly 10,000 pounds more without bulkheads. The proposed modification can support over 2 million pounds of compressive load before buckling, well exceeding AAR regulations. A 3D representation of one end of the car's modified center sill and of the complete sill are shown (in Figure 2a and 2b, respectively). The sill was manufactured in ¼ scale and tested in a laboratory for bending (Figure 3).

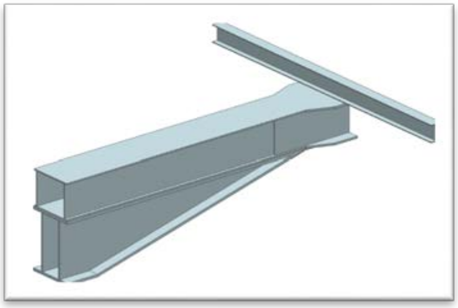

Figure 2(a). representation of one end of center still 3D

Figure 3. ¼ scale prototype testing

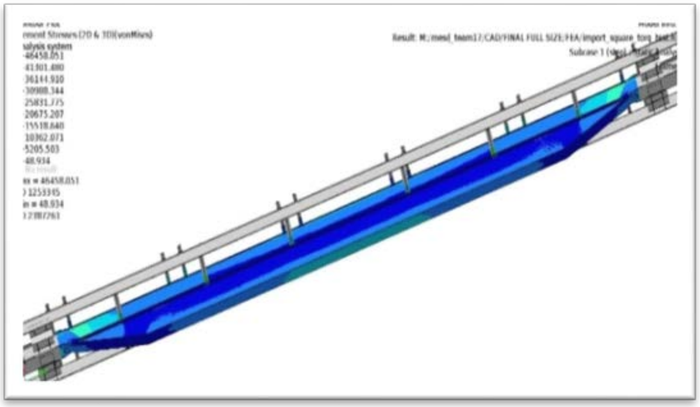

Figure 2(b). 3D representation of complete center still.

Cost

The cost of a frac sand conversion is estimated at $16,793.98 (Figure 4). This number can be compared to the cost of a new flatcar, a minimum of $80,000. A significant portion of the frac sand conversion cost is associated with 28 specially manufactured pod anchors, therefore it stands to reason that converting a car to a different use, perhaps to carry logs, may have equal or lesser cost, making conversion of center beam cars an attractive alternative to both long term storage *and* new car purchase.

Process	Component	Length Needed (ft)	Weight per Length (lb/ft)	Material Weight (lb)	Material Cost, Negative for Scrap ($)	Shop Hours to Complete (hrs)	Shop Rate ($/ hr)	Labor Cost ($)	Total ($)
Materials Added	W Section Beam (Fishbelly)	140	93	13,020	1529.85	25	55	1,375	2,904.85
	Pod Support Beams	140	12	1,680	197.40	30	55	1,650	1,847.40
	Brake Components Repositioning	-	-	-	2200.00	27	55	1,485	3,685.00
	Pod Anchor	-	-	-	6440.00	15	55	825	7,265.00
Materials Removed	Center Beam	73	140	10,200	-1198.50	17	55	935	-263.50
	Bulkhead (2)	-	-	3,800	-446.50	5	55	275	-171.50
								Total ($)	15,267.25
								10% Contingency	1,526.73
								Net Cost ($)	16,793.98

Figure 4: Estimated unit cost

Highway-Rail Grade Crossing Surface Material Performance

NURail Project No. 2010-0295

Student Researchers, Michigan Technological University; Christopher Blessing, Charles Fobbs, Nathanil Jurmu, John Klieber, Alex Summers: Faculty Advisor, Michigan Technological University, Lynn Artman, PE.

Highway-Railroad grade crossings are an integral part of the transportation system and the one location for potential conflict between road and rail traffic. Performance of the surface material at grade crossings is an ongoing challenge. A study, conducted by Michigan Tech's undergraduate students reviewed the literature available on grade crossing surface materials and crossing records available from MDOT in an attempt to determine which surface materials perform best for given traffic levels and site conditions. The study team found that the data currently available was not adequate to perform credible analysis of the situation, and developed a recommendation for a new grade crossing data collection process for MDOT. The team also made recommendations on improving the rating system used by MDOT inspectors for crossing surface condition.

Introduction

Grade crossings are a common theme throughout the United States highway network, in the State of Michigan alone there are over 4,000 documented crossings. These crossings must be maintained to provide a safe environment for both motorist and train traffic. Many high-volume crossings may see thousands of vehicles and 60-80 trains per day. This highlights the need to provide a quality structural design and maintain high safety standards. Federal Highway Administration (FHWA) standards define the required safety devices at a grade crossing, but the structure of the crossing, and the choice of surface material, is normally decided by the railroad company owning the rail line or the responsible roadway agency. The objective of this project was to evaluate different crossing surface materials and determine the one(s) that have had satisfactory performance over time.

Results

The research team selected 107 grade crossings across the state, intended to illustrate the variety of crossing surface materials in use. A visual inspection was performed, and MDOT history files were collected for each of the crossings. The MDOT history files were examined manually, and a spreadsheet was developed including the following data fields: Date of inspection; Crossing surface material; ADT; % Trucks (in ADT); Surface rating; and train speed. The crossings were divided into four categories of Concrete, Asphalt, Timber, and Rubber. A graph of inspection year vs. rating was created for each crossing from the history provided. To avoid scaling issues, the year was graphed horizontally, with each graph showing the same range, from 1994 to 2013, to cover all the data included in the history. The graphs included a vertical scale of 1-5, with integer values only, to correspond to the possible rating values.

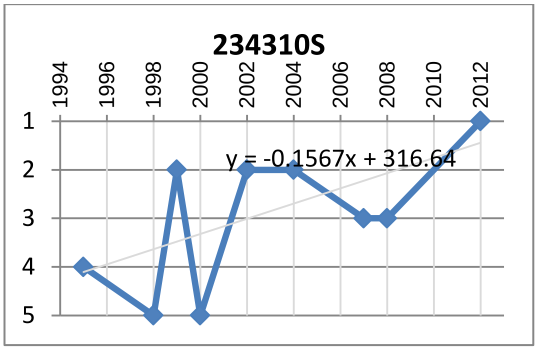

Figure 1, Inspection Rating Graph for Asphalt Crossing 234310S

The evaluation of the data and graphs led to the following conclusions:

- Very few historical records included a complete crossing life cycle from one reconstruction to the next
- Although graphs show changes in ratings, there is no causal data to go with the records, so the reasons for the changes cannot be reliably determined
- It appears that a rating change of one point in either direction for a single rating period may have no real significance. With no rating criteria two different inspectors could rate the same crossing differently on the same day.

The research revealed that shortcomings of data collection and rating process made evaluation of surface performance evaluation impossible. As a result, the team concentrated on improving the process, so institutional knowledge on performance can be improved. They developed a data collection protocol for grade crossing inspections that involves both historical research to find and document techniques during construction and collection of additional data during inspection. The protocol also includes a quantifiable inspection rating to document crossing performance across time, modeled after the PASER system developed by the University of Wisconsin-Madison (Table 1).

Table 1, Crossing Rating System for Concrete Crossings

Concrete
1 - Excellent
New Construction or Recent Reconstruction
No Defects
No Action Required
2 - Very Good
Joints all in good condition
Minor Surface defects - pop outs, map cracks
Light Surface wear
3 - Fair
First signs of crack or joint faulting up to 1/4"
First signs of joint or crack spalling
Moderate to severe scaling or polishing 25-50% of surface
Minor spalling from reinforcement
Multiple corner cracks
Fasteners loose, but not projecting above surface
4 - Poor
Severe cracking or joint faulting up to 1"
Many joints, transverse, meander cracks open, severely spalled
Extensive Patching in poor condition
Occasional holes
Fasteners loose, projecting < ¼" above surface
Loose panels, no vertical displacement
5 - Very Poor
Extensive and severely spalled cracks
Extensive failed patches
Joints failed
Restricted speeds
Loose panels, vertical displacements between panels, > ½"
Loose fasteners, projecting > ¼" above surface

Recommendations

Completing the research originally envisioned in this project will require data collection over an extended period of time. The tools developed in this project could enhance the inspection process and provide a statistically viable data set for future research efforts.

While the available data does not allow a comprehensive analysis of surface material performance, it appears that subsurface preparation impacts surface performance more than the surface material used. Some crossings from each of the categories investigated appeared to perform well over time while others failed relatively quickly.

This work was funded by a National University Rail (NURail) Center, a US DOT---OST Tier 1 University Transportation Center and by the Michigan Department of Transportation. The research team would like to acknowledge the help and advice of:
Dr. Pasi Lautala and David Nelson, Michigan Tech
MDOT Staff
Eric Peterson, CSX (retired)

Intelligent Railroad Crossing Maintenance Jumper

Will Dallmann, Michael Mandalari, Ron Campbell, Katherine May,
Michigan Technological University

During track maintenance, jumper cables are used to disable crossing signals. In rare occasions, the jumper cables may be forgotten due to human error, and the disabled crossing signals pose a risk to human life. The goal of this project is to Design a device with jumper cables or signal crossing devices to lessen the impact of human error during and after maintenance.

Introduction

Maintenance crews use jumper cables to disable crossing signals while working as maintenance vehicles will activate crossing signals if not disabled. However, maintenance crews on rare occasions forget the jumper cables. This allows trains to pass through the disabled crossing without activating the signals. The team has designed a device that monitors a voltage on a GCP-3000, HXP-3 or PMD-3, which measures changing impedance on the tracks. As a train approaches the crossing, the train shunts the RL circuit used by a crossing predictor. The track resistance decreases as the train approaches the crossing. Since voltage is proportional to resistance, the voltage corresponds to position. Position data can then be used to find the velocity of the approaching vehicle. This design solution uses voltage to distinguish between trains and maintenance vehicles. The tool reactivates the crossing signals if a train is detected but keeps the crossing disabled while maintenance vehicles are detected. After a predetermined time period, an optimal timer in the device will turn the jumper off, regardless of the presence or absence of a train.

Prototype

A prototype of the Intelligent Jumper cable was created and tested. This prototype combines software to detect trains with switching hardware that opens the jumper cable circuit if a train is detected. The software filters voltage and takes the derivative of position to find velocity. Special algorithms use velocity to distinguish between trains and maintenance vehicles. A signal is sent to the switching hardware to open the jumper cable circuit when a train is detected. Then the switching hardware opens the circuit, using a solid state relay connected to the jumper cable circuit. The entire prototype could fit in a hand-sized box with cables for power supply and inputting voltage.

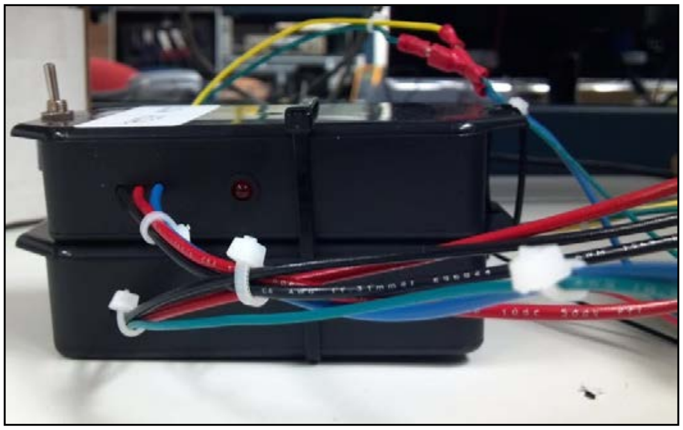

Figure 1. Switching Hardware with LED Indicator and Activation Switch

Results

In simulations, using prerecorded data taken from a crossing, warning times of approximately 20 seconds and greater were achieved. This is not only sufficient for a car to stop, but is also above the required minimum of warning times set by Federal Railroad administration. A live test was conducted in which the prototype successfully deactivated itself with less warning than expected based on simulations. Further testing and calibration could improve the results.This device can be a low cost, effective and robust component in a track maintainers toolkit. Its functionality can be easily integrated into modern crossing predictors in the future, eliminating the need for a separate device.

Cost

A complete Intelligent Jumper Cable unit could be created for under 30 USD. If this device prevented even one railroad accident it would save a railroad company millions of USD in legal fees and damages.

Rail Car Coupler

Francis H. Bremmer, Yidan Lou, Kyle Pepin, Alyssa M. Sahr, Justin D. Tumberg, MichiganTechnological University

The current type E Janney coupler has not been significantly modified since the original patent was filed in 1873. Couplers commonly undergo mechanical failure, knuckle fractures, and the railcars detach while in use and cause major delays costing rail companies and customer's time and money. The main objective of this project was to increase the lifespan of the coupler through design and material changes, without affecting the freight car or train operations.

Introduction

The current Janney railcar coupler has not seen many changes for a long time. An increase in strength, reduction in weight, and improvement in design could yield a more reliable and effective coupler for the industry. Alternative materials are being considered to increase fatigue life and decrease weight. This Senior Design team has researched the current failure modes, potential design modifications and potential changes in materials. In order to be implemented in industry, the coupler needs to be compatible with all current types of the Janney coupler in use and have relatively the same cost. The main stakeholders in the project are the design team, National University Rail Transportation Center (NURail), Michigan Technological University, private railroad companies, coupler manufacturers and railroad workers. There is little incentive for innovation within private industry due to the requirement that designs are compatible, forcing new designs to be shared. Once a year, the three major coupler manufacturers meet to test components for compatibility between couplers produced by all manufacturers. Railroad workers stand to benefit from potential maintenance reduction and increased ease of use. Railroad companies would benefit from a decrease in time lost due to trains that stop to replace broken knuckles. NURail is a transportation consortium that focuses on rail related research and hopes to promote innovation within the industry through promoting projects like the railcar coupler.

Figure 1. Type E Janney Coupler

Design/Modification

The final concept focuses on geometric and material changes to maximize service life. Material is added to the coupling face of the knuckle to reduce the amount of slack that exists between knuckles. Material changes are were considered and evaluated in an effort to increase the lifespan of the coupler. The knuckle was reverse engineered based on interior cavity and exterior geometry. The final design was validated with finite element analysis (FEA) and MAGMA5 software. The interior cavities were adapted from the current material to Austempered Ductile Iron, requiring changes to ensure similar strength and fatigue properties. A mold pattern with draft angles for casting purposes was then created. The final cast results from the Michigan Tech foundry still had minor material issues, such as porosity, and hot tearing. These are currently unresolved due to the team's lack of experience casting, as well as the limitations of the Michigan Tech foundry. Future work will also need to consider that the knuckles provide a safety feature to the coupling system. Knuckles should be designed to fail before reaching levels that would damage the draft gear or other car components to which they are attached

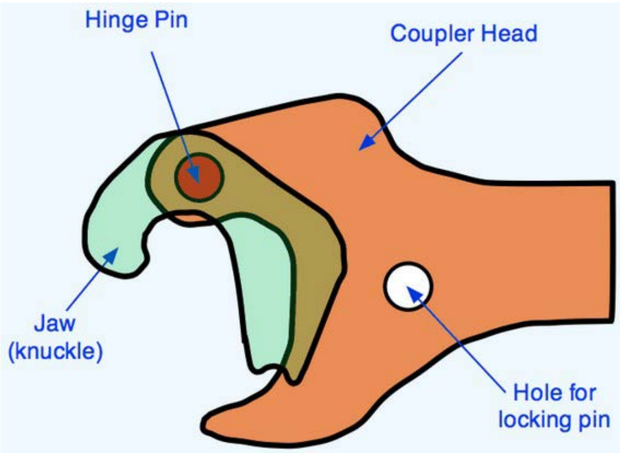

Figure 2. Components of a couples

Results

To implement a material change, the static stresses in Austempered Ductile Iron (ADI) need to be less than or equal to Grade E steel. Due to the lower yield strength of ADI, trial and error was used to adapt material reductions within the knuckle. The simulations were run under two conditions, with and without the hinge pin as a fixture. By design, the pulling lugs should be the only fixture, as that is where the applied force on the face of the knuckle is transferred. However, Amsted Rail found the hinge pin does act as a fixture when the knuckle is close to failure. The FEA shows what happens in normal use (no hinge pin) and when the knuckle is close to failure (hinge pin as a fixture).

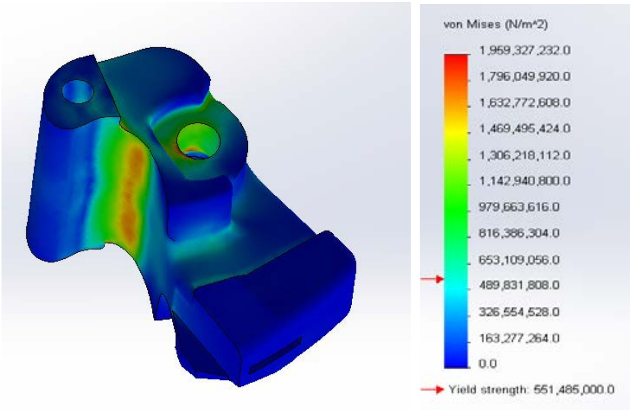

Figure 2(a). FEA of Model with Hinge pin

Material: ADI
Fixtures: Hinge Pin and Pulling Lugs
Load: 650,000 lbf
Result: Highest stresses occur near hinge pin. Failures will occur in this location. (Desired result)

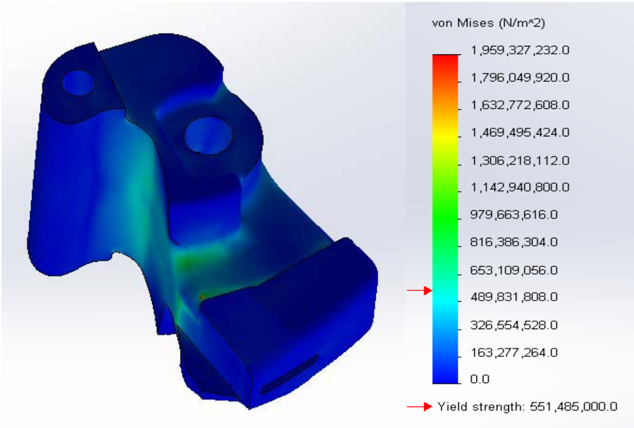

Figure 2(b). FEA of Model without Hinge pin

Material: ADI
Fixtures: Pulling Lugs
Load: 650,000 lbf
Result: Highest stresses occur near hinge pin and pulling lugs. Failures will occur in either location. (Not ideal).

Rail Shunt Connection Test System

Samuel Scott, Frank BeFay, Sean Massey, Alexander Pate, Michigan Technological University

In the rail industry, a shunt merely consists of C-clamps and low resistance wire. This is made in order to simulate the conditions of the track while a train is passing over it whe the axles create a very low resistance connection across the tracks. This enables various signal protocols to take place. However, in the simplicity of the design there is a lack of assurance that the shunt connection is effective in recreating these conditions, posing potential threats to calibration and safety of rail workers and equipment.

Introduction

This project explored the key features and practical implications of a device by which the effectiveness of a rail shunt can be measured. Prompted by Union Pacific Railroad Corporation, the project was built around ensuring the safety of the thousands of linemen who work for Union Pacific on the rail system every day. Consider a situation where workers are out on a track repairing tracks, calibrating equipment, or performing general maintenance on the tracks. In order to ensure that the workers are safe, a shunt is used to mirror the conditions which the track can see when a train is passing through a powered section. This tells the dispatch office that something is on the tracks within that section. It is irrelevant whether that something is a train, equipment, or workers as dispatch isn't able to tell the difference. However, what the shunt does is inform them that something is on the tracks at that location. This allows them to divert trains from entering the area, reducing the danger to equipment and personnel, and preventing interference with whatever operations may be ongoing. Without an adequate shunt, these precautions fall short and the people and equipment which may be in the location in question could be in danger.

A rail shunt is defined as a low-resistance wire apparatus, which, when clamped to the parallel tracks, will create a short-circuit between them. This is done to mimic the conditions present when a locomotive or rail car is shorting a section of powered rail. In order to be an "effective" shunt, the total resistance between the rails at the location of the shunt must be less than or equal to 0.06Ω.Due to inadequate clamping force, corrosion on the rail and/or clamps, or other on site conditions, an "effective" shunt is not necessarily always achieved. The task provided was to design and develop a system which will both measure the shunt effectiveness and communicate the success or failure of the shunt given the shunt criteria above while not interfering with already present track signals being transmitted through the railways.

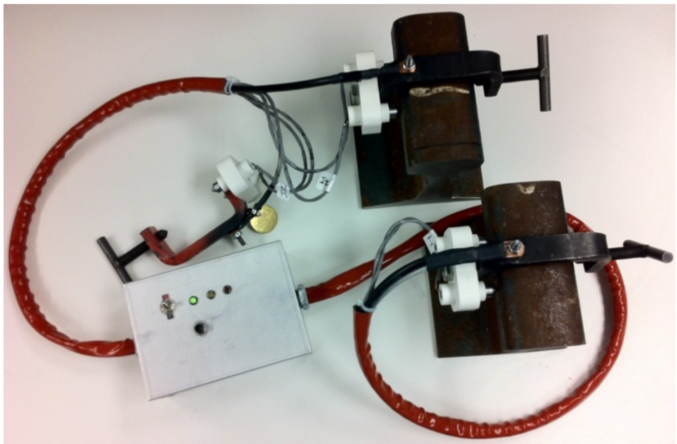

Figure 1. Rail Shunt connection test system

Design

Given that there are many signals present in railways depending on the region of operation, it is important to create a system that is generalized enough to work on any set of tracks regardless of signals present without interfering. Provided by Union Pacific, the current state of track signals can range from:

1. Frequencies between 40 Hz – 20kHz
2. DC Voltages up to 3V

Due to a variety of operating regions, the weather conditions of different areas can affect the operation of the shunt. It is important to design a system that will operate under the temperature extremes of all environments it will experience. In the initial stages of the design, a decision matrix was used in order to come up with ways to complete the project given the importance of various aspects of the system. The microcontroller option with the existing shunt was the best option given the criteria and weighting applied. This provides simple operation at low costs with a light-weight system and small form-factor.

The proposed solution included multiple point clamps, a custom electric circuit, a microcontroller and an instant feedback and status display. The primary source of measurement selected was a Kelvin Bridge. Shown in Figure 1, conceptually the Kelvin Bridge pushes power, in this case current, through a resistor of unknown value and then measures the resulting voltage and current. With that information, the unknown resistance can be calculated.

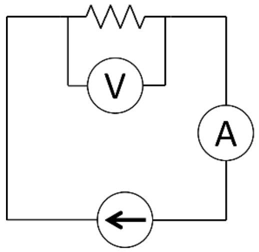

Figure 1: Kelvin Bridge

The core component of this design is a microcontroller which will turn on the current source and push current through the shunt. An amplifier will amplify the signal so that it can be filtered, using a band pass filter (BPF), and input into the ADC module for examination. As we push a sinusoidal current through the shunt, it may interact with other signals present through harmonics, interference, or DC voltage offsets. The amplifier bumps the voltage signal from the shunt to a large enough value to push through the band pass filter. This isolates the frequency that we are using and eliminates the interference from the signal, resulting in an accurate reading of the shunt signal.

Results

The lab results showed success in creating a working prototype. An algorithm built into the device works with the sensors to measure the accuracy of the device and compare it to the required resistance. From these we can determine if the shunt creates a good connection or a bad connection. These results are then fed into a user interface consisting of LEDs to give feedback to the user. The user will have instant feedback if the connection was achieved and if it was good enough to satisfy the job requirements.The accuracy of the device will depend upon the current sensing resistor and the ability of the microcontroller to read and average the voltage measurements correctly and symmetrically.

Build Time and Integration

The time to integrate this system onto existing shunts in the field can vary depending on how much the system can be simplified. The current prototype is built into modules. This form factor however is not ideal. An ideal system would consist of a single system board with all buttons, chips, and power supply all integrated into one. With the existing modular system we estimate a user can build this device in 1 to 2 hours depending upon skill level and familiarity of system. A more efficient single board and all in one unit this could lead to major reductions in assembly time.

Costs

We estimate the cost to build the existing prototype at approximately $200. This estimate uses materials bought in single quantities, cost reduction from buying bulk parts is not included in this estimate. The production level cost should be much less than this.

Conclusion

Following extensive experimentation on rails provided by Union Pacific, the retrofitted clamps and electronics were able to confirm shunt status. It was able to do this consistently and repeatedly. We also tested for long time durations, far exceeding those normally experienced in the field. With further development and testing, this unit could be easily retrofitted to any and all standard shunt units for a very low cost, especially when weighed against the cost of equipment and lives.

RFID in Railway Operations

Kevin Heras, Daniel Holmberg, Frank Kampe, Min Li, Michigan Technological University

The purpose of the Radio Frequency Identification (RFID) technology research project is to prepare a comprehensive report covering RFID technology and current use in the rail industry.

Introduction

The Rail Transportation Systems in today's competitive environment face complex economical and operational challenges. RFID applications have helped the rail transportation industry by improving efficiencies in operations, maintenance, asset utilization, and capacity management. Ultimately, the RFID applications have contributed to improved revenue growth by reducing costs in these areas. The team consisted of Wireless Communication Enterprise engineers and Business Development students that studied both technological aspects of RFID technology, as well as an assessment of the market. The comprehensive report includes an overview of the RFID technology, market assessment, technical specifications, programming information, deployment and installation remarks, and RFID testing and vulnerabilities. The information in this report has been collected from global rail sources. The team also used its own research by utilizing web and vendor product literature in order to have a fully comprehensive report covering RFID technology.

Figure 1. RFID tag on a railcar

History of RFID in Rail

The idea of Radio-Frequency Identification (RFID) in rail had been around for quite some time before the technology began to fall in place in the late 1970s. Several inventions enabled the development of RFID technology including the personal computer, complementary metal oxide semiconductor (CMOS) integrated circuits, electrically erasable programmable read-only memory (EEPROM), and efficient, inexpensive microwave diodes. In the 1960's, there had been attempts to implement a barcode system, however, it failed to satisfy needs due to reliability issues and the fact that it was easily disrupted by bad weather. Transcore was the primary manufacturer of RFID, they made the first prototype in 1984. The technology was designed specifically for demanding transportation applications including rail, intermodal and motor vehicles. Widespread use of RFID started in the 1990's. Having competition from barcode systems, infrared solutions, and optical character recognition, RFID has emerged as the superior technology. It has seen continued development through the years and its long range, robustness, ability to operate in all weather, and the fact that it does not require line of sight has separated RFID from its competition.

Market

There are several types of RFID systems, classified by radio frequencies used. Low frequencies range from 100 kHz to tens of mHZ, and have ranges of less than a metre. Communication distances for several tens of metres use frequencies from 400 mHz to 6 GHZ. RFID systems for rail in North America use frequencies near 915 mHz. RFID technology in China is one of several industries that the central government significantly supports. The goal is to improve the industry's reliability and performance in the country's railway system. The system used in China, known as ATIS (Automatic Train Identification System), is designed to identify railroad cars arriving at or departing from railway stations. It is being widely used in all railway bureaus in China. The ATIS system is mainly used to identify cargo trains whose speed is less than 100 kph, which is a current issue preventing wider use. Once this problem is solved, it could open up a tremendous potential for RFID technology in high-speed rail operations. The global smart railways market is estimated to grow from $12.3 billion in 2013 to $39.2 billion by 2018. This means new railway projects, new technologies, and additional opportunities to utilize RFID technology could arise.

Risks and Vulnerabilities

One of the most common of these limitations is the fact that fast moving tags are hard for sensors or readers to detect. According to our research, the speed limitations on the RFID tags today is approximately 167 kilometers per hour. This represents a huge limitation for the technology with the enormous push for high speed rail in the United States as well as other parts of the world. In order for a company to enter the market of RFID technology for the rail industry and obtain a competitive advantage, they must find a way to increase the capability of the technology to read tags at high speed. Another limitation is the fact that it is very difficult to ensure that each railcar is tagged. Since these tags are added to many cars after their manufacturing process, it is very difficult to ensure uniformity between each car. The tags pose a security risk because essentially anyone who has an RFID tag reader can gain access to the information that is store on each tag. While this information normally includes only information like the age of the train, their ultimate destination, and the contents of the train car, it is a major setback for the technology because it does not allow rail companies to keep their information confidential.

Recommendations

RFID technology has proven to provide railway companies with a wide range of benefits including determination of train conditions, inventory management, location control, traffic and Passeger information management etc. In order to make RFID technology an integral part of a country's railway system and to get the full benefit of the technology, the process has to begin with tagging locomotives, carriages, train stations etc. and distributing tag readers along the tracks. All equipment should be integrated into the main system. The second recommendation involves solving the speed limitation issue. The speed limitation right now is 167.7 kph when reading a fast-moving RFID tag. The reliability of the information being read is obviously of significant importance and as speed increases the technology seems to face more challenges. This would be a major issue when trying to implement RFID technology into high-speed passenger lines. There would be endless potential for RFID if it could gain widespread use in high-speed environments.

Wayne Industries Site Expansion

David Nelson and Pasi Lautala, Michigan Technological University

Wayne Industries approached the Michigan Tech Rail Transportation Program with a request to develop alternatives for expanding their steel warehousing operation in Wayne, MI to better handle changing operational needs.

Project Background

Wayne Industries provides warehousing and transportation of steel coils and aluminum primarily for the automotive industry. Their warehouse in Wayne, MI receives coil cars directly by rail, currently served by Norfolk Southern. They have on site storage for rail cars, and receive unit trains three times per week. The owners anticipate a shift towards more use of aluminum in the automotive industry, and would like to expand their existing facility to handle more aluminum product without compromising existing coil steel operations. Wayne Industries asked a Michigan Tech student team to provide some alternative analysis for options meeting their expansion needs.

Figure 1 - Wayne Industries Steel Facility with rail access

The Michigan Tech team divided itself into three teams to tackle the project. Envision worked on site development factors, JART developed the required rail access for the facility, and Keweenaw Building Solutions provided structural facility design for the new warehouse facility.

Envision

The site development team goals were to successfully manage and create a master plan for the future growth of Wayne Industries. The criteria used to evaluate the possible design alternatives were selected after a site visit to Wayne Industries in order to gain an understanding for the critical areas of operation. Among the most crucial criteria were rail geometry, semi-truck flow, future expansion, and cost of the project. The proposed warehouse required rail access to deliver both steel coils and aluminum blanks, the rail access is essential to Wayne Industries' operations. Transferring product on truck from the warehouse to the customer is equally is also vital which made truck traffic on site just important. Future expansion of the designed site is also vital to allow ongoing development at the site.

Three site design alternatives were explored including warehouses oriented lengthwise in a north/south fashion, east/west manner and angled approach. After further investigation into the logistics of each design, constrained rail geometry for the north/south and east/west designs left the angled option as the preferred alternative.

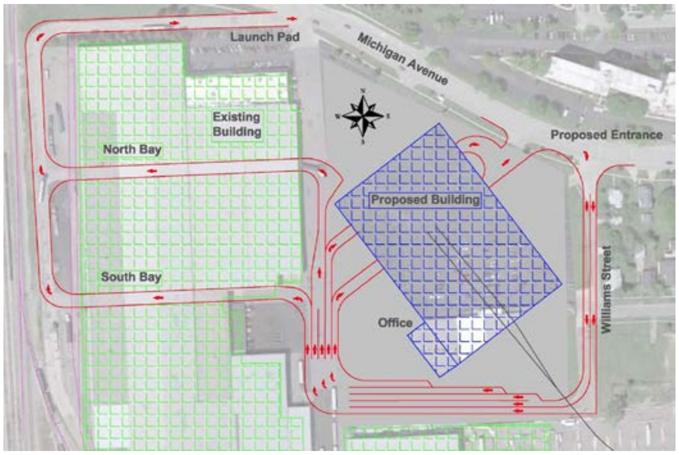

Figure 2 - Angled building site plan

An improved storm water system was designed with new sewer lines beneath the proposed site that tie into the existing city sewer main lines to the east. To prevent flooding inside the warehouse, trench drains are planned along the railroad track at level grade. Truck operations are optimized for each building orientation to improve efficiency. The addition of another exit and one central site entrance will provide a more direct traffic pattern on the site. In addition, local utilities on the site were identified for relocation to compensate for the new building.

JART

JART was tasked with identifying and solving the problems associated with rail access for the new building expansion project. Rapid rail car turnover is key to Wayne Industries position as the steel and aluminum supplier for most of Michigan. Based on discussions with the client it was determined that the operations of the new warehouse would be similar to the existing one, with rail entering on the long axis and truck lanes perpendicular to them.
Rail alternatives were developed for the three building options chosen by the site team. A satisfactory rail geometry was best provided in the angled alternative. Development of final horizontal and vertical alignments required some creative license with the guidelines for industrial yard design. The assumptions for operation included use of a rail car mover within the yard, and 60’ design cars being driven at low speeds. This allowed for the elimination of tangent sections of track before and after curves, saving space.

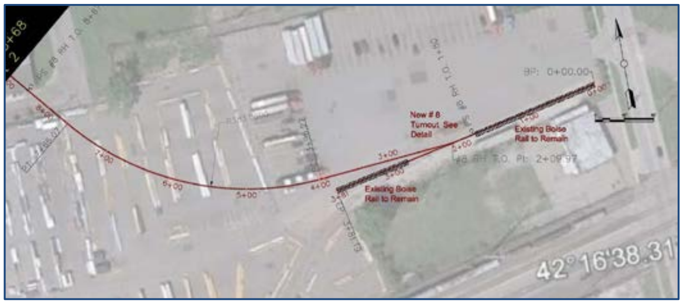

Figure 3 - Horizontal curve to new warehouse site

Shorter #8 turnouts were used to save space. Vertical alignment was a challenge, with a drop of more than five feet required across the constrained access route. The team also used a tighter curve radius than normally included in an industrial site.

Keweenaw Building Solutions

Keweenaw Building Solutions developed a plan that fit Wayne Industry’s criteria for the site expansion.
The new building will support perpendicular rail and truck access with storage for aluminum and steel.
The warehouse function is to store aluminum with the future option of steel storage, thus storage capacity is the primary concern. The preferred design has two-25 foot truck lanes supported by a double track rail configuration down the center of the building. Each track will support four box cars, however the east track will be curved for the first 20 feet into the building. The building includes an option to install two overhead crane bays to support handling of both steel coils and aluminum blanks in the future.
Design constraints for the site included a 50 foot setback from Michigan Avenue and maximizing the length of straight track inside the building. This set the dimensions for the warehouse to 460 feet long by 300 feet wide with an office area extending out from southern corner of the warehouse.

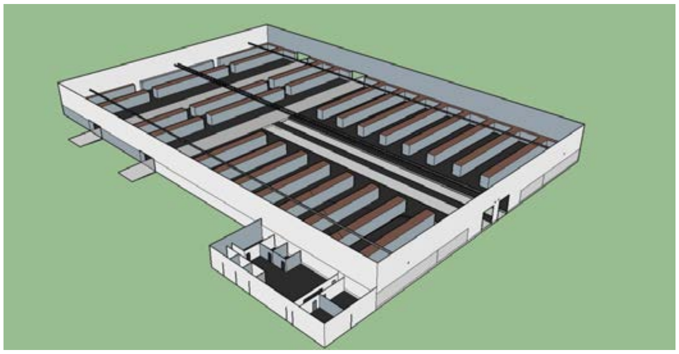

Figure 4 - Warehouse layout with rail access at center

The warehouse floor was designed as an 18 inch thick concrete slab with steel reinforcement meeting the requirements for storing and moving aluminum pallets in the building, forklift operations, and the option to store and handle steel coils in the future.

Recommendations

The Wayne Industries project provided an excellent introduction to the civil design and construction fields for this group of students. Components involving rail activity, highway and site design, combined with facility design and structural analysis offered a wide selection of project activities. Working through the interactions between all of these components was an eye-opening experience for this group! Future capstone projects should include a similar variety of content.

Lake State Railway Company, Saginaw Yard Improvements

Fall 2015: Chris Blessing, Jason Cattelino, Jordan Chartier, Nick Dulak, Chase Elliott, Alexander Fletcher, Jace Fritzler, Jon Hamilton, Michael Hart, Carl Ingalls, Lacey Kaare, Kyle Kent, Robert Prell, Trent Rajala, James Roath, Valerie Sidock

Spring 2016: Tyler Arends, Mikalah Blomquist, Adam Danielson, Allen Eizember, Jacob Logan, Jed Mattmiller, Joe Meemken, Nicole Phillips, Sam Pilla, Zach Scalzo, Alec Sturos, Luke Tolkinen, Kris Turunen, Jacob Wood

Rail industry senior design projects are an excellent way to provide students with an initial experience working with industry and the public to develop plans for future project work. Civil engineering projects can be accomplished on a wide variety of projects, with clients that range from Class 1 railroads to local municipalities. They provide an excellent opportunity for communities to explore "what if" scenarios with only a small economic investment.

Introduction

Michigan Technological University has been involved in rail related undergraduate student projects since the earliest days of the Rail Transportation Program (RTP). Although many of the projects have been in the civil engineering discipline, RTP has reached out across campus to the mechanical and electrical departments as well as the School of Business, and the fine arts department. Since 2012 these projects have often been at least partially funded from the NURail grant, and in 2014 and 2015 supplemental funding was provided by MDOT.

During the 2015-16 school year, 32 senior civil and environmental engineering students conducted "*Planning and Design Services for Improvements to the Lake State Railway Company (LSRC) Saginaw Yard*" as their senior design project.

Background

The project was divided to two semesters and each group worked for a single semester. In general, the fall groups were responsible for conceptual designs while the spring groups concentrated on providing more detail to the preferred alternatives. The yard is a facility inherited from CSX, and has long suffered from drainage issues that make track maintenance and operations difficult. The yard has a locomotive wash facility, but that facility is an open air operation, which creates operational issues during the winter months. While the yard is quite large, it is constrained on the west by Washington Ave, on the east by N. 23rd St, and on the south by Lapeer and Janes Avenues. LSRC is following the industry trend towards longer unit trains, but the constrained yard layout lacks a lead track long enough to build a unit train. The student project provided a "first look" at some alternatives for improving the track layout, creating an enclosed wash facility, and improving the drainage across the site. The four objectives for student work included:

- improvements to the rail system to allow storage of a 9,000-foot unit train in the yard;
- drainage improvements throughout the yard complex;
- design of a covered locomotive wash facility; and site work in the rail yard and the neighboring communities to improve yard access and allow LSRC to park the previously mentioned unit train

Scope Changes

As the work progressed the student team discovered that a 9,000-foot lead track would not be possible, so the scope was altered to look for the longest possible lead track within the confines of the existing yard. Closure of grade crossings at Lapeer Ave and N. 23rd St were investigated as alternatives to provide a longer lead.

The initial site visits confirmed the scope outlined in the project description. In addition, LSRC asked the team to look for potential to reuse the floor slab of an old warehouse facility on site, and to take a preliminary look at improvements to the locomotive turntable.

The following paragraphs summarize project activities and final outcomes of each team's work. Complete technical reports have been submitted to LSRC to be used at their discretion. It must be remembered that the work was done by students and the main objective was to allow them to apply their engineering education to a real world project. Thus, the findings and outcomes should not be considered as professional documents, but rather information provide a solid foundation for LSRC in the continuing development of their project.

Track Improvements

After investigation of the site and available options, it was recognized that a 9,000-foot storage track was not possible without closing either N. Washington Ave or Janes Ave, leading into revision of scope that attempted to maximize the length of storage track within the remaining yard area. During the conceptual phase, the best option provided 7,600 feet of storage in the East Yard between Janes Ave and Washington Ave after track modifications, but this was reduced to 7,300 feet during the detailed design phase. 7,300 feet meets the current LSRC needs, and allows them to handle over 110 car trains, while providing room for storage of two trains. The plan also allows for continuous rail operations, even during construction. A schematic drawing was developed to illustrate the East and Receiving yard tracks and operations (Figure 1). Total project costs for rail work were estimated at $1.4 million during the conceptual phase and later revised to $1.6 million. The final report includes cost estimates for the planned work, and a phasing plan showing how the work could be accomplished over an extended period of time if necessary.

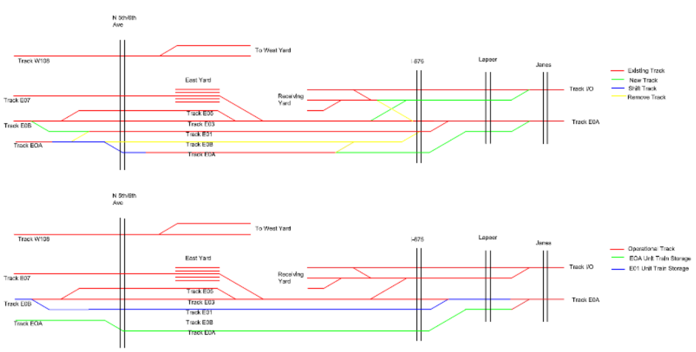

Figure 1: East Yard Rail Schematic

Structural Improvements

This group investigated several options for the wash facility, including pre-engineered steel buildings and individual design/construction packages. They found that a pre-engineered facility would be the preferred option. As preliminary design efforts progressed the LSRC staff expressed an interest in including several improvements, including an inspection pit for minor maintenance activities and an elevated wash platform to provide access to the upper sides and top of the locomotive during the wash operations. The preliminary plan that included the layout for a basic wash facility was estimated to cost nearly $1 million, constructed over two or more years. The final plan increased the cost to just over $2 million, but included inspection pits for both tracks in the wash bay, drainage improvements to support the inspection pits, heating, and the wash platform and associated wash equipment. It also included costs for providing more separation between the tracks which allowed better access to the locomotives during the wash process (Figure 2).

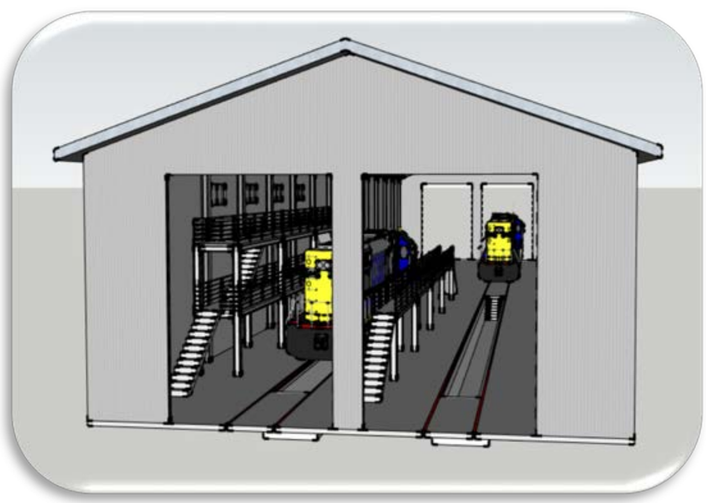

Figure 2: Locomotive Wash Facility Rendering

The preliminary analysis of the old warehouse determined the facility's current condition was beyond repair and recommended that the building and floor slab be demolished, crushed, and used as fill inside the existing foundation walls. A floor cap on top of this would allow use as a loading dock for rail operations and addition of a pre-engineered steel warehouse could provide covered storage. Conceptual level costs indicated a total cost for a pre-engineered warehouse on the slab would run nearly $1 million.

Drainage Improvements

The drainage group investigated ways to remove the standing water that collects on the site after major rain events, and during the spring snow melt. They devised a preliminary plan that would provide surface drainage to catch basins established within the yard. The catch basins would be connected to the existing Saginaw combined sewer system at points around the perimeter of the yard. Surface drainage would take place on the existing access roads within the yard that would be regraded to improve surface flow. Preliminary costs for this work ran approximately $400,000 (maintained in final cost estimate) and could be phased over a period of years to gradually improve the drainage with a reduced annual capital expenditure. Final plans included directional boring from the street side to minimize operational impacts in the yard, grading and drainage for a new access route between the two unit train tracks, and installation of under-drains where possible (Figure 3). A phasing plan was provided that would allow construction over a period of years with recognition that costs would increase as project length was extended.

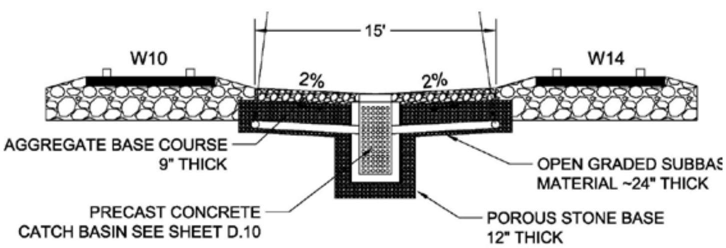

Figure 3: Proposed Drainage Detail

Site Improvements

This team focused on improvements to yard access, and to work required to support the proposed unit train operation. Early on the rail and site teams recognized that the rail crossing at either Lapeer or N. 23rd street would need to be closed to allow a parked unit train operation. They conducted traffic counts during the field trip, reviewed traffic data from the City and Michigan DOT (MDOT), and concluded that one or both could be closed with minimal impact on current traffic operations as both crossings have low traffic volumes. As MDOT provides a payment to communities that close rail crossings, with a bonus for closing more than one, the team recommended closing both crossings. Their preliminary design work focused on the infrastructure changes needed to successfully close either location. They also proposed a set of local infrastructure improvements that might help secure support for the closures from the local community. Conceptual level costs for the work associated with the crossing closures was a little over $400,000, which could be offset somewhat by the MDOT incentives that could be as much as $300,000. As plans were refined the team also reviewed safety issues related to the existing crossings, the crossing closure areas, and local pedestrian traffic. This team recommended closure of two crossings, the first at Lapeer St, the second at N. 23rd St. Although only the Lapeer St closure is required for the current unit train proposal, the N. 23rd closure would allow more flexibility in the yard operations and advancing both in a single public process may save time and resources. The team's work also revealed a level of trespassing activity in the yard area which could be addressed through infrastructure changes, combined with coordination with local police and stepped up law enforcement. Proposed infrastructure improvements include fencing like that illustrated by the red line in Figure 4, vegetative barriers at crossing closure locations, creation of park areas with parking on some of the abandoned street pavement, and installation of vehicle gates at yard entrances. Final estimated costs for the site work associated with the crossing closures is a little over $300,000.

The fall structures and spring site teams also took a preliminary look at the work required to rehab the existing locomotive turntable. They recommended a two-phase approach that would allow continued access to at least two stalls in the round house during construction. Turntable work should take place after the construction of the new locomotive wash and inspection facility, as that facility could be used for some locomotive maintenance activities during rehab of the turntable.

Figure 4: Proposed Site Security Upgrades

In conclusion, the students provided a first look toward various improvements at the LSRC property. Overall, the project would be dependent on the closing of the Lapeer St crossing, which would require a public process to get buy in from the City of Saginaw. The student work could be provided as a starting point to an engineering firm for final design work, and eventual construction if LSRC and the City agree, and if funding is available.

Conclusion and Statement by the Lake State Railway Company on project outcomes

Overall, this project was considered a win-win situation. LSRC got a valuable first look at some alternatives for yard improvements and the students got an excellent opportunity to work through the issues associated with developing a project "from the ground up". The following is a statement by the LSRC on their perspective to the project outcomes.

"*The collaboration with Michigan Tech student teams encouraged our company to put serious consideration for the planned improvements. While the company didn't proceed with all recommendations, an immediate outcome was to use the work as a foundation for detailed analysis on improvement needs and opportunities with an engineering consultant. This analysis resulted in an approximately $2 million investment that concentrates on track modifications and improvements and results in significantly better track utilization and operational efficiencies in the yard. The project is in progress and may continue in the form of drainage improvements, as also recommended by the students.*"

Acknowledgements

The Michigan Tech student teams would like to acknowledge several individuals and organizations for their support and assistance for this project. Mr John Rickoff and his staff at LSRC provided access tho their site, and valuable information during site visits. Dr. Pasi Lautala was always supportive with his constructive criticisms. Kris Foondle and other staff members from MDOT provided insight into the planning process required for crossing closures. The City of Saginaw and especially the City Engineer and her staff provided valuable support, and access to historical drawings.

National University Rail Center - NURail
University Transportation Center Research Brief

Canadian National Railway Cold Weather Defect Detection

John LaLonde, Katherine Tigges, Theodor Smith
Michigan Technological University

In order to maintain rail integrity and safety, railways constantly test for and repair internal rail defects. Modern railways use ultrasonic trucks to locate these defects for removal. Once the defect has been removed, Canadian National (CN) Railway goes one step further to insure that the entire defect was removed with the use of dye penetrant on the cross sections at the ends of the rail. Unfortunately, this process has its limitations due to adverse weather. This project looks at other detection options and ways to make improvements to the current one.

Introduction

This report summarizes the Canadian National Railway study conducted by Advanced Metalworks Enterprise (AME) at Michigan Technological University for Canadian National Railway entitled Canadian National Railway Cold Weather Defect Detection.

In the rail industry profit comes down to a train's average car velocity. Defects can cause this velocity to be reduced, with slow orders or as a train is stopped, waiting for a repair. The goal of this project was to create a process that could be completed reliably, in all weather, in a shorter period of time.

CN's current process is to use a SpotCheck® dye penetrant to further test each rail cross section. The current process can be adversely affected by weather. Cold and wet conditions can cause SpotCheck® tests to fail.

Background

A liquid dye penetrant relies largely on the penetrant's wettability, shown below as Figure 1, on the tested surface. There are many factors that can affect wettability, but a material's wettability is strongly dependent upon its surface tension. Unfortunately, the surface tension of a liquid increases with a reduction of temperature, thus lowering the materials wettability.

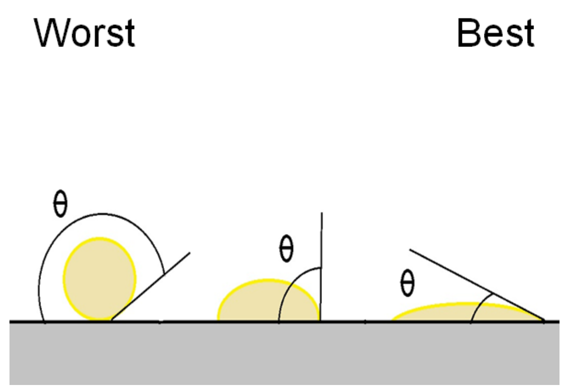

Figure 1: Demonstration of how wettability is determined in a liquid

Magnetic particle inspection relies on the flux created by field lines being forced to bend around a defect in a magnetized piece of material. The magnetic viewing film uses this same flux to manipulate a nickel flake inside of the film, as shown in Figure 2. The flake (purple line in the below image) will reflect light at certain orientations and will display defects as a white line on green film.

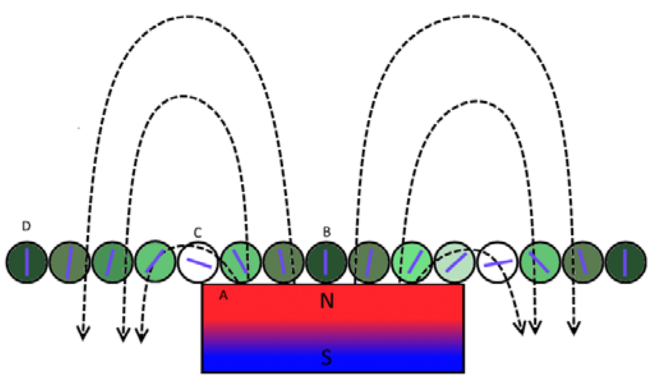

Figure 2: Demonstration of how a magnetic field effects the magnetic viewing film

Hypothesis

Two hypothesis were generated to guide the analysis. They are summarized here:

1. Substituting an alcohol based penetrant for SpotCheck® will allow for colder operating conditions as the lower freezing point of alcohol allows for better wettability at low temperatures.
2. Substituting the entire process for one using a magnetic film inspection will allow for a faster and more reliable test at lower temperatures, as the magnetic field should experience no negative affects based on cold temperatures.

Methods

In order to test both hypothesis, 11 samples containing defects were tested at temperatures ranging between -30°F and 40°F as well as at room temperature. The total time and temperature was recorded for all testing and the dwell time was noted for all penetrant tests.

Conclusion

Hypothesis 1 was rejected, while hypothesis 2 was accepted.

1. There is no perceived increase in reliability of the alcohol based penetrant at reduced temperatures. It also has issues caused by it 'running' off of the cross section.
2. Magnetic viewing film inspection offers a fast and reliable alternative to liquid dye penetrants

In conclusion, this project has successfully created a proof of concept for magnetic viewing film in the detection of defects in rail cross sections. It is suggested that the process and product be further refined before implementation.

Recommendations

- SpotCheck® penetrant is reliable and sufficiently fast at temperatures above 40°F
- A magnetic particle/viewing film inspection can produce reliable tests down to -30°F
  - Further testing is suggested for the magnetic viewing film before implementation

Costs

Figure 3 estimates the cost of implementing a magnetic film process over 3, 5, and 8 years compared to the cost of continued SpotCheck® usage. It can be seen that, even with the high startup cost, over time (4-6 years) magnetic film usage will become lower than continued use of liquid penetrant.

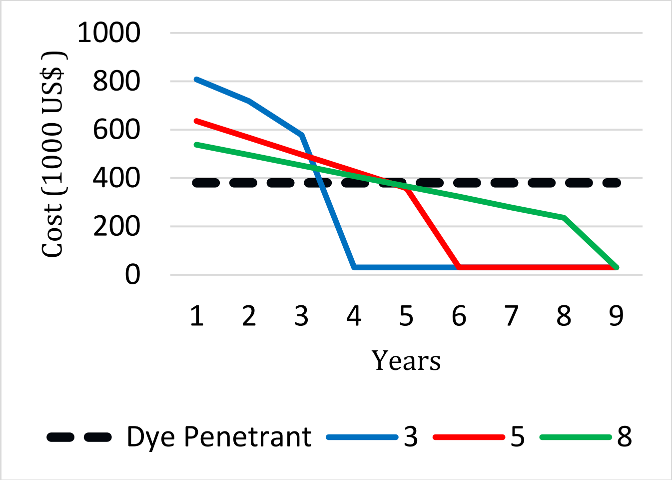

Figure 3: Cost estimate of integrating the magnetic film over time

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Railroad Car Wheel Contamination Detection

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If contaminants are present on the train wheels during car classification, the retarders won't operate effectively and the cars can blow apart couplers or even derail the train. The goal of this project is to detect contaminants on the train wheels in order to avoid damage during the recoupling process. A test stand was designed and built to measure the coefficient of friction for various contaminants at varying levels of application. It was found that even a very thin film of any contaminant had a significant impact on the coefficient of friction. Machine Learning methods were used to classify contamination state with 70% test accuracy.

Background

In the rail industry, gravity classification yards—colloquially referred to as "hump yards"—are used to separate railroad cars from a single incoming train to different outgoing trains. This is done by pushing the train up a small hill, or hump, releasing the cars one by one at the top, and using a combination of special brakes, called retarders (see Figure 1), and switches to control the cars' descent down the hill and direct them to the right outgoing trains. The retarders brake the cars by grabbing onto the rims of their wheels, a surface which is not used by the cars' internal braking systems.

Problem

Often, railroad car wheels are either contaminated when entering classification yards, or become contaminated from their contents leaking while they sit in the yards prior to the classification process. These contaminants sometimes include fats and oils from food and animal products, mechanical greases, and metal dust and shavings. If contaminants are present on the wheel rims, the retarders may not effectively slow the cars during the classification process. Fast moving cars can damage mechanisms when coupling with outgoing trains, and in extreme circumstances, derail.

Figure 1. Hump yard group retarder

The goal of the project is to develop a reliable method for detecting contaminants present on the railroad cars' wheels prior to the cars decoupling at the top of the hump during the classification process. In order to determine the specifications for the detection system, it is necessary to know which substances cause problems during retardation, and in what quantities. Therefore, an intermediate goal for the project was created; namely, to measure the coefficients of friction between a railroad car wheel and the retarder that result from the presence of various quantities of contaminants on the wheel, and to assess potential detection methods based on the findings. A test stand was designed for the purpose of spinning a railroad car wheel, applying a braking force using a brake shoe made of the same material as the retarders, and measuring the forces in the braking process in order to calculate a coefficient of friction.

Design

Figure 2 shows the initial CAD model of the contaminant testing table. The CAD model was done modeled, assembled, and rendered in UGNX. The wheel and motor displayed in our concept model were used from an open source CAD repository, while everything else was created from scratch. This design was handed off to an outside contractor to construct the physical table.

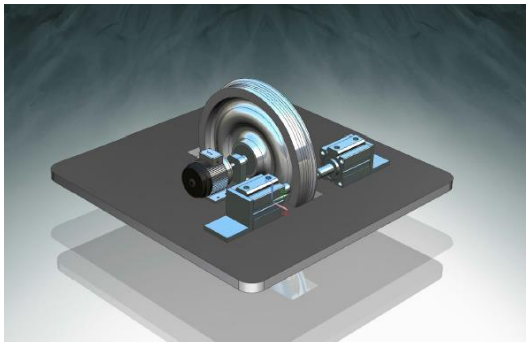

Figure 2. Dungeon Grey

Our realized test stand can be seen in Figure 3. It has slight changes from the initial draft, such as only braking on a single surface of the wheel instead of both sides. The brake box installed on the stand utilizes two load cells to measure the forces need to calculate the coefficient of friction.

Figure 3. Realized Test Stand

Four different contaminants were chosen in order to maximize the variety of viscosities tested within the time constraints of the testing period. The contaminants were:

- 10W30 motor oil
- Vegetable oil
- Corn oil
- Multi-purpose auto grease

Results

Figure 4 shows the mean coefficient of friction displayed from the different tests. By looking at Figure 4, it becomes quite apparent that the coefficient of friction drops dramatically for each of the contaminants, regardless of their respective quantities. In the case of a thick application of motor oil, the coefficient of friction was reduced to approximately 16% of the uncontaminated mean. For a thin film of motor oil approximately 28%. Although the thin film does change the coefficient of friction, the percent difference is not nearly as significant as the difference between the uncontaminated and the contaminated thin film registers. Overall, auto grease expectedly worked as the "best" contaminant, which again makes sense considering it was designed to perform in this manner.

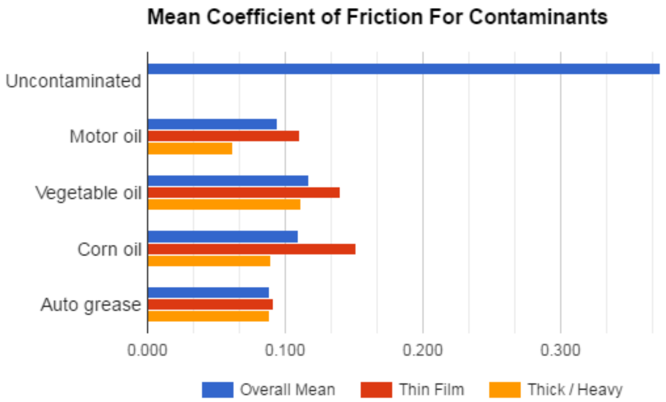

Figure 4. Contamination coefficient results

Analysis

The biggest surprise from the test results was the fact that even a thin film of contaminant (not visible) dropped the coefficient of friction by a factor of 3. This result rules out any type of visual contamination detection method due to the fact that the visual precision required to detect these thin films cannot be achieved in the hump yard environment.

It was noticed that the velocity profile of the wheel as detected by the encoder differed significantly for a clean wheel than a contaminated wheel. A Support Vector Machine (SVM), a commonly used machine learning classifier, was fed frequency data from the encoder. In preliminary testing, leave-one-out cross validation found 70% accuracy in detection (test accuracy).

Recommendations

Fusing the encoder data with sound and/or thermal data could increase the accuracy of the classification. This allows sensor-fusion machine learning methods to be investigated.

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