

PROPOSAL

“Smart” Camera to Measure Coil Diameter

Michigan State University

ECE 480

Senior Design

Team 5

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Introduction

The capstone project for the team members of Group 5 will be to provide a solution for sponsor ArcelorMittal, specifically project owner Carlos Forjan. We will present our finalized solution to be installed at their plant in Indiana Harbor by Design Day on Friday, December 5th.

Customer Needs/Requirements

ArcelorMittal needs a way to more accurately measure the diameter of the steel coil that is on the tension reel at the end of the pickling process. From our visit to ArcelorMittal, the current Programmable Logic Controller estimation of the diameter is not adequate for the following reasons. The current method uses the number of rotations of the mandrel and the gauge (thickness) of the steel to calculate the diameter of the coil. There are many problems with this method causing the calculated diameter to be inaccurate. The diameter of the mandrel is about 24 inches however it varies causing the inner diameter of a coil of steel to vary for each roll formed. One other major flaw of the current calculated value is that it does not account for slippage in the system. These flaws result in a diameter calculation that is vastly more inaccurate (more than an inch) than the actual coil diameter. The final cold-rolled steel coil diameter is not to the specification requested by customers of ArcelorMittal. This results in dissatisfied customers and potential loss of business. Having an accurate system would improve productivity and product yield.

Design Specifications

The coiling area of the pickle line has many moving parts and is a place where a physical sensor would have a high probability of being damaged. Also, every time anything needs to be maintained, repaired, or replaced in the coiler assembly the entire assembly needs to be taken apart by crane. So even if a robust physical sensor could be developed it would add extra complexity to the coiler assembly and cause maintenance on itself or other parts to be more difficult.

Due to the accuracy of an inch needed by the ArcelorMittal pickle line and the complexity of the coiler assembly, a system that could measure the coil diameter without being part of the coiler assembly would be ideal. A sensing mechanism must either sit at a protected location not within the coiler area or placed in an area that is out of the operating range of the gantry crane. Furthermore, it must be safe from accidental damage from said crane or parts being transported by the crane. The location could also be chosen to be an accessible area where very little maintenance is done so the sensing system would also be safe from accidental damage caused by a plant worker.

In order for the sensing system to assist in the accurate sizing of coils of steel it would not only need to be able to take a measurement but it would also need to be able to feed this value back into the system that controls when a cut is made. The system would have to be able to accept, as an input, the state of the coiling process so that the sensor will take measurements at the appropriate times. The sensor will then measure both the diameter of the mandrel at the

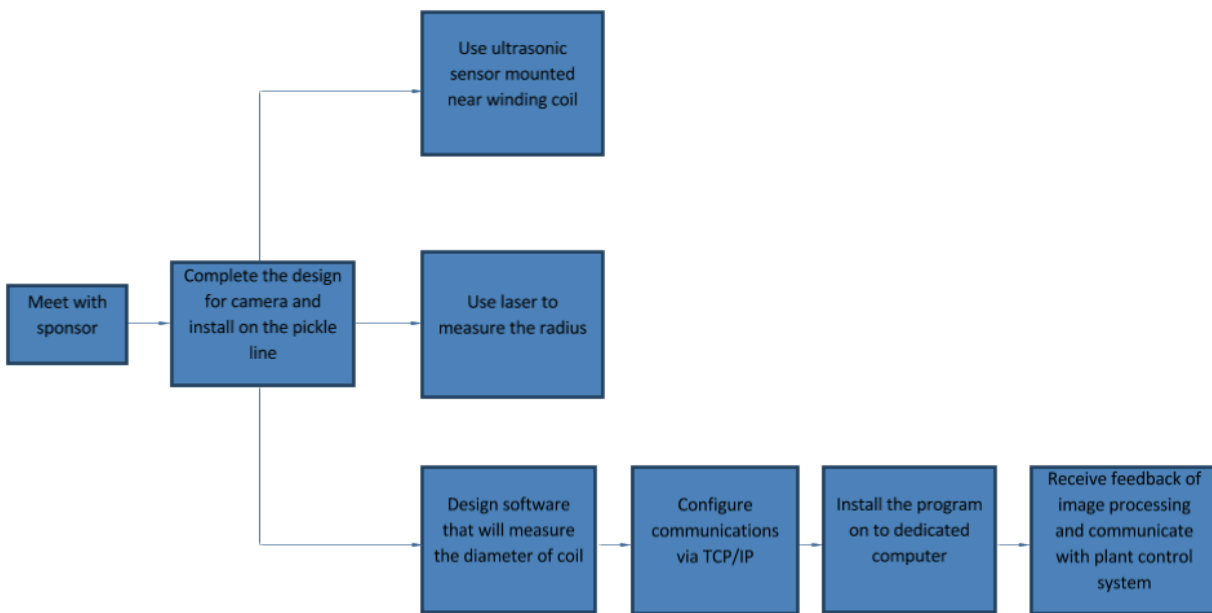
center of the coil of steel and the outer diameter of the steel being wound. The implemented system will then use these numbers to calculate the diameter of steel on the coiler. The system will then output this value to the controls which can then use it to decide when the steel needs to be cut. In order for this to happen the designed system will need to consist of at least two parts, one part to calculate the diameter of the coil and the other to communicate with the current system by TCP/IP Sockets.

The coils of steel in question can reach up to several feet in diameter. At a large diameter the circumference also becomes large and therefore a small error in the diameter calculation corresponds to a large mass of steel. Due to this fact a solution that can measure the diameter of the coil within half an inch of its actual size is necessary. This amount of accuracy will ensure the satisfaction of ArcelorMittal's customers.

Background

The project is to be installed on the tension reel at the end of the #5 Pickle Line. According to ArcelorMittal's description of the line, "The main objective of #5 Pickle Line is to remove scale from hot rolled carbon steel coils. Scale consist of three oxide layers: Fe_2O_3 , Fe_3O_4 , and FeO . Scale is removed by the chemical action of hydrochloric acid. This process is known as pickling. The operation of the line is continuous with the entering hot rolled coils welded head to tail, temper-rolled, pickled, inspected, side-trimmed, oiled and sheared into coils of the desired size at the end of the line." At this point (the end of the line) the tension reel winds cold-rolled steel into coils of a specific diameter based on the needs of customers of ArcelorMittal.

Fast Diagram



Conceptual Design Descriptions

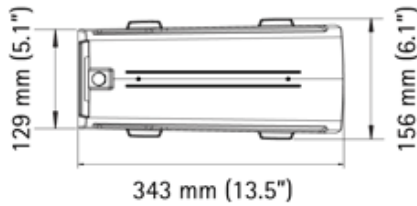
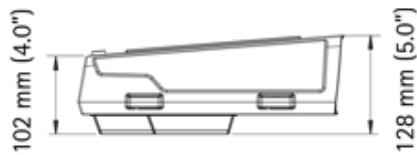
Three different conceptual designs come to mind for a prototype to measure the diameter of a steel coil as it is wound at an ArcelorMittal steel plant. The first design is a “Smart” camera that will use pixel edge detection to create a pixel distance to measure the coil diameter. That pixel distance will then be converted and calibrated to a physical diameter. The camera proposed is the Axis Communications P1355-E Network Camera.



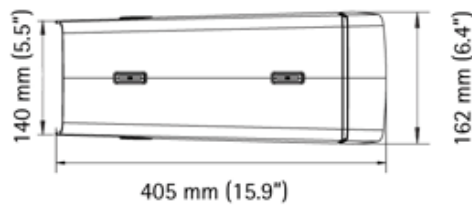
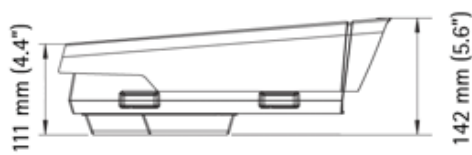
Axis Communications P1355-E Network Camera

This is a high definition 1080p 30fps camera that can be connected to a network to interface with existing software and provide live feed. The Axis camera has the PTZ (pan, tilt and zoom) feature for a wider range of installation area. This is if the camera cannot be installed in a certain position or has to be moved later in life. Another feature of the Axis camera is the day and night functionality. This attribute will help due to possibility of lighting changes in the steel plant. The last aspect that will be utilized of the Axis camera is the wide angle of viewing the camera has. This has to be taken into consideration since the camera will have to be mounted approximately twenty feet away from the coiler and about ten feet off the ground on one of the building supports and may be a few inches off from the center of the coiler in alignment.

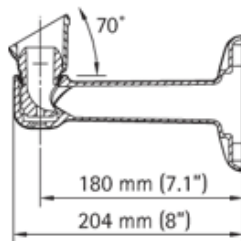
Dimensions



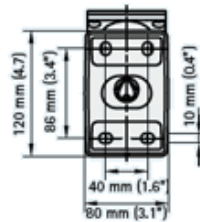
Without sunshield



With sunshield



Wall mount arm



Back side of
wall mount bracket

The next design is to use an ultrasonic sensor mounted near the winding coil. This design may be more accurate than the “Smart” camera because of the close proximity to the coiler and no room for measurement error from its “viewing” angle which can cause small dollar amount losses which could add up to millions of dollars in losses over the year. It will be constantly sending and receiving ultrasonic sounds continuously measuring the radius. This will have to be incorporated near many moving parts and will be prone to physical damage and possible annihilation.

The last design that was thought of was using a laser to measure the radius. This will also have to be mounted near the winding coil which means it will be near many moving parts and will be prone to physical damage and possible annihilation. Another drawback of using a laser would be reflection from the steel coil and a false reading of the radius.

Ranking of Conceptual Designs

Feasibility Criteria	Wt.	Axis "Smart" Camera	Ultrasonic Sensor	Laser Sensor
Operational Feasibility Functionality. A description of to what degree the candidate would benefit the organization and how well the system would work. Political. A description of how well received this solution would be from both user management, user, and organization perspective.	30%	This system will work exceptionally well since it will be away from moving parts and easily accessible. It also has functions to communication with the network and existing software. This system will be user friendly and organized due to its simplicity and standard feature. Score: 30	This system should work moderately well since it will be close to moving parts and a dirty area. This system will not be user friendly and organized because it will be hard to get to and outside noises may cause problems Score: 20	This system will work poorly due to the possible reflection and its vicinity to moving parts. This system will not be user friendly and organized because it will be hard to get to and reflection is an issue. Score: 15
Technical Feasibility Technology. An assessment of the maturity, availability (or ability to acquire), and desirability of the computer technology needed to support this candidate. Expertise. An assessment to the technical expertise needed to develop, operate, and maintain the candidate system.	30%	"State of the art" camera. Easily acquirable. Step by Step guide to interface with networks. Moderately easy to develop. Very easy to operate. Very easy to maintain since it will be installed overhead above a walkway. Score: 27	Old technology with a moderately cheap sensor. Very easily acquirable. May have a few issues communicating with networks due to no pre-developed hardware or software. Moderately easy to develop. Difficult to operate. Difficult to maintain due to installation area near moving parts. Score: 20	Moderately new technology. Moderately available. Easy to acquire. May have a few issues communicating with networks due to no pre-developed hardware or software. Moderately easy to develop. Difficult to operate. Difficult to maintain due to installation area near moving parts. Score: 20
Economic Feasibility Cost to develop: Payback period (discounted): $Payback\ Period = \frac{Initial\ Investment}{Periodic\ Cash\ Flow}$	30%	\$1,000+ Payback period = 7 days Score: 28	\$100+ Payback period = 1.5 days Score: 30	\$200+ Payback period = 2.8 days Score: 29
Schedule Feasibility An assessment of how long the solution will take to design and implement.	10%	3 to 5 weeks Score: 10	4 to 6 weeks Score: 9	5 to 7 weeks Score: 8
Ranking:	100%	95	79	72

Proposed Design Solution

We propose to use the Axis Communications P1355-E Camera to capture a 1080p live video feed of the steel being coiled and a dedicated Windows 7 computer to process the image produced by the Axis camera. The P1355 will be powered by Power Over Ethernet (PoE), using an injector. This will allow for easy installation and minimal wiring. The camera can be mounted approximately twenty feet away from the coiler and about ten feet off the ground on one of the building supports. This area is an ideal place for the Axis camera to be mounted because it will have a clear path to the coiler for the camera to take unobstructed video. An operator or other person walking in the area will not be able to block the image because of the camera's position ten feet above the ground. The camera will also most importantly be out of the way of the moving components of the coiler assembly. The proposed setup will require very little maintenance but in the event that maintenance is necessary there is a catwalk just above the planned location for the Axis camera that provides easy access. Finally, there will no need for any additional lighting since the nearby industrial light pointed at the coiler will provide ample light.

The computer will use the high definition video outputted by the camera to detect the edge of the tensioner and the outer diameter of the coil of steel and use these measurements to calculate the size of the coil. A dedicated Windows 7 computer will also be able to communicate with the existing level 2 (L2) computer over an ethernet network via TCP/IP sockets. It is best to use a dedicated computer because of the significant amount of image processing power. A dedicated computer will provide this computing power without putting additional strain on the current system. The desktop can be positioned in the control room with the other control systems where it will be out of harm's way and easily accessible. The dedicated computer then can be connected to the camera-using network cables routed along building supports. As previously stated the dedicated computer would also be responsible for communicating with the current control systems of the pickle line. The computer will take as inputs the current state of the system and the desired size of a coil. It will use the current state of the system to determine when the camera needs to output video and the computer needs to process it. Only having the system producing data when it is needed will decrease the power consumption of the system. The other input that the computer will accept, the desired size of the coil, will allow the computer to communicate to the existing control system when it needs to slow the steel down and ultimately when it needs to make a cut and finish the coil. The only necessary output of the system is the size of the coil. The dedicated computer will do so by periodically pinging one of the control computers already in place. The computer could also confirm the state of the coiling process communicated to it by the control computer.

The third part of the solution will be the program developed and installed on to the dedicated computer that will do the actual image processing and communicate with the rest of the control system. This program will take the image and using the Sobel method it will convert the image into a three-dimensional contour plot showing the gradient of the image. Looking at the gradient of the image it then becomes apparent where the edges are within the image because the image will have a large derivative at that point resulting in a sharp spike in the gradient. The edge of the steel on the coiler will be readily detected using the Sobel method as the side of the

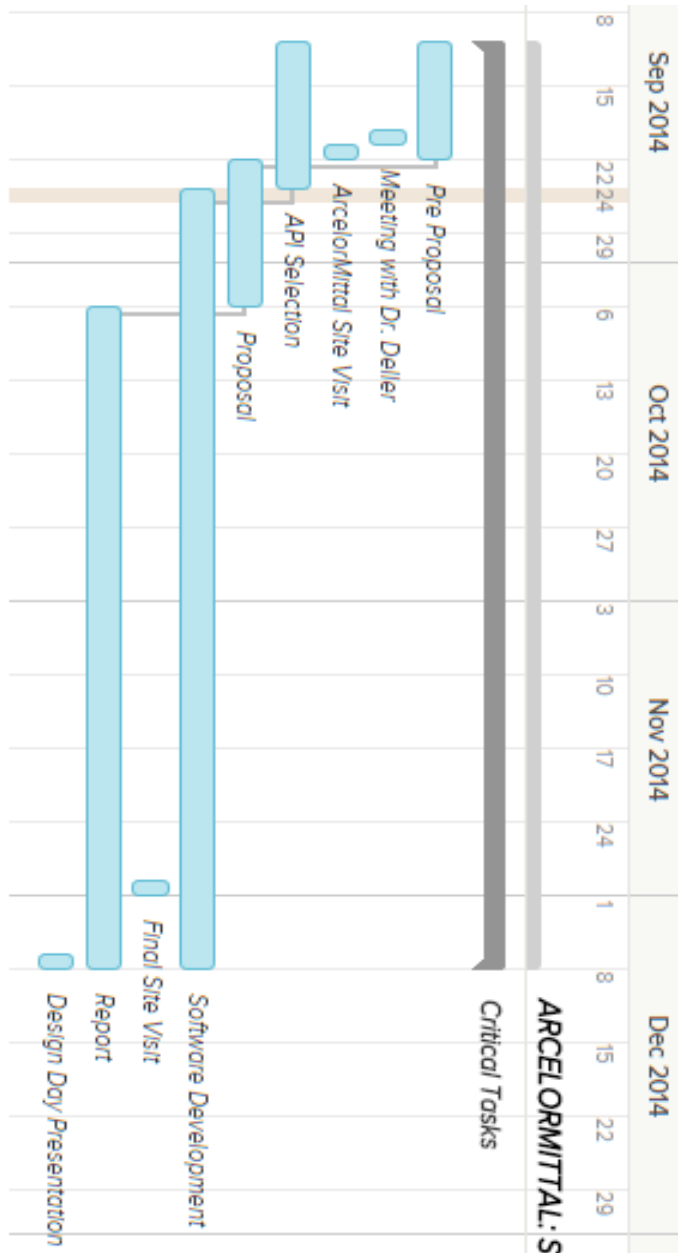
coil will reflect light much more readily reflect light than the much darker colored surroundings. The edge of the inside tensioner will be a much harder edge to determine as there is a shadow created by other parts of the coiling mechanism. The center point of the tensioner is constant so the diameter can be computed using another fixed point in the coiler assembly that shows up well in the Sobel method filtered image and geometry.

The system described in the paragraphs above will provide an effective and robust solution to the current uncertainty in coil size at the end of the ArcelorMittal Pickle line. The camera combined with a dedicated computer is a design that will more than adequately meet the needs of the line. Moreover it is a robust design that will need very little to no maintenance or intervention. The remote nature of the camera will allow it to be placed in an area where it will be unlikely to be damaged. The dedicated computer will also be unlikely to be damaged, as it will be placed in the already active control center. The proposed solution, although requiring some upfront investment, will more than compensate for its cost and provide the best solution to the problem currently facing AcelorMittal.

Risk Analysis

Risk Level	Event	Technical Performance	Cost	Schedule
3 High	The program would relay false data into the computer system, a catastrophic failure could occur down the Steel line endangering other plant line workers	This performance would be highly unacceptable and would greatly increase the chances of an accident occurring	Program budget would be impacted greatly due to insurance liability	The schedule would be forced to be pushed back a maximum of 3 days
2 Moderate	Due to a computer malfunction, the line would be forced to stop due to no steel being produced	This would be unacceptable due to the loss of profit that would be experienced by the sponsor	The budget would be continually impacted for the duration of the line being out of commision	The schedule would be affected until the computer system can be reset and the bug can be fixed
1 Low	During installation of the camera, an issue could occur where a worker could be hurt	The performance would not be affected greatly, but time and profit would be lost	The budget would be impacted no more than the injuries sustained by the worker	The schedule would be pushed back no more than 1 day until the accident is cleared and the camera is properly installed

Project Management Plan



Personnel Breakdown

In order to execute the proposed solution in an effective and timely manner, a project management plan has been created. This plan breaks down the specific task each team member will contribute. The majority of the work required for the “Smart” Camera Project is in the form of intense software development. The tasks of the code can be broken down into five major sections. The responsibilities to develop each section are as follows:

System State Monitor Function: Matt Wesolowski

Output states of the production line, mandrel, steel specifications in real-time.

Variable Input Function: Poyuan Han

Take the specifications of the customer order from host computer control system and input them as variables into the “Smart” Camera” analysis program.

Edge Detection Function: Petros Taskas

Program to recognize and track edges of Axis Camera video output

Edge Detection Calculation and Analysis: James Quaglia

Statistical analysis of detected edge properties (diameter, rad/s frequency, fps, etc) and feedback of that information to host computer control system

TCP/IP Host Communication Function: Joe McAuliffe

Ping IP Address and Port with program outputs from the above routines in order to instruct when reel cuts are to be performed.

Resources

The facilities to complete the necessary steps of the “Smart” Camera Project are all available to us in the Michigan State University Engineering Building. The computers furnished in the laboratories are all equipped with MATLAB Simulink R2014a, Microsoft Visual Studio 2013, ethernet ports for TCP/IP communication, and ample space in order to build and test models emulating the conditions of the proposed solution.

Timeline

All software development is to be completed by October 20th, per the agreement with Carlos Forjan that 1080p footage of the reeling process will be made available to us for testing by that date.

In addition to details concerning the completion of each software development component, Group 5 is committed to reports describing the status of progress. The deliverables schedule is depicted below.

Upcoming Calendar Events

Week 4 (Sept 15th):

Pre Proposal and Gantt Chart Created and Delivered

Week 5 (Sept 22nd):

Group Website Online

Week 6 (Sept 29th):

Fast Diagram Delivered

Week 7 (Oct 6th):

Final Proposal Delivered

Week 9 (Oct 20):

Progress Report, Notebook Photocopy, and Business Canvas Assignment Delivered

Software Development Completed

Week 11 (Nov 3):

Individual Application Notes Delivered

Week 13 (Nov 17):

Design Issues Paper

Progress Report #2

Week 14 (Nov 24):

Professional Assessment Paper

Week 15 (Dec 1):

Final Report Delivered

Budget

Our team was allocated five hundred dollars from the Electrical & Computer Engineering department toward expenses to deliver a final “Smart” Camera system for ArcelorMittal. The system as a whole will cost more than this amount as a result of the hardware and software needed to complete the task. All of the items required for the system were included by either our sponsor or the university. As a result, for the foreseeable future, there will be no need to use our budget of five hundred dollars. Refer to the table below for a breakdown of all the components and approximate cost of the “Smart” Camera system.

Item Description	Approximate Cost / Allocation
Axis Communications P1355-E Network Camera	\$1100
Type 1 PoE Injector	\$50
CAT5e Ethernet Cables	\$50
Windows 7 Desktop Computer	\$700
MATLAB/Simulink Software	\$100
Microsoft Visual Studio Software	\$200
VAPIX (API) - Included with Camera	\$0
Total Cost	\$1,300

References:

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Outdoor-ready, excellent fixed camera for video surveillance with 1080p HDTV quality. (n.d.). Retrieved September 24, 2014, from http://www.axis.com/products/cam_p1355e/index.htm

Payback Period (Payback Period)

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