EDSGN100 Design Project #2
Final Design Report

Recycling of Advanced High Strength Steel

Introduction to Engineering Design
EDGSN 100 Section 02

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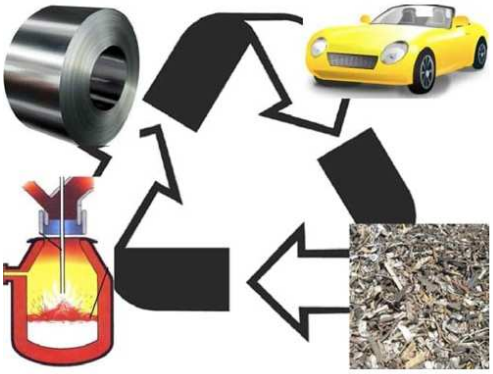

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Executive Summary

For this project we were required to design a process that could effectively recycle Advanced High Strength Steel from the automotive market back into the basic oxygen furnace steel production cycle. We were required to avoid causing any off-chemistry heat and also to utilize the alloys in the recycled steel to reduce the use and cost of new alloying elements. After generating as many possible solutions as possible and comparing them we were able to develop three solutions to improve four problematic areas of the current process. By implementing community steel recycling days, manufacturer labels, and adding an extra shredder to the recycling line, ArcelorMittal's current recycling process would be improved overall.

Recycling of Advanced High Strength Steel

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1.0 Introduction

For this project we were asked to design a process that could effectively recycle Advanced High Strength Steel from the automotive market back into the basic oxygen furnace steel production cycle. We were required to avoid causing any off-chemistry heat and also to utilize the alloys in the recycled steel to reduce the use and cost of new alloying elements.

Our team decided to tackle the entire steel-recycling process. First we found the four areas which needed most improvement: extra non-metal materials from cars making it through the recycling process, lack of information shared between partner companies, low percentage of steel re-entered into the recycling process, and producing desired alloy contents from other steels and scrap.

Following the engineering design process our team then developed as many possible solutions as possible for each problem. Through a scanning and scoring approach we were able to narrow down our solutions and chose the most efficient and practical solutions for our formulated problems.

2.0 Project Background

Our project and results were to reflect the current process used by ArcelorMittal USA. ArcelorMittal USA is the largest steel producer in North America and the largest integrated steel producer in the United States. They are the leader in all major global steel markets, including automotive, construction, household appliances, and packaging. It is the world's largest and most global steel company by both revenue and production, with over 285,000 employees in 60 countries.

Steel is one of the most common materials used by modern societies, with large, known, finite reserves. Because steel is very common it most often ends up disposed of in a landfill rather than recycled. Therefore it's process is linear and referred to as "cradle-to-grave". Repeated recycling greatly reduces the strain on resources and waste disposal. Currently only 30% of total new steel is made of recycled content. Most recycled scrap metal comes from trucks and automobiles which are torn apart and shredded. However, cars with high alloy steels are beginning to emerge in the scrap stream causing higher unwanted alloys in steel producing.

3.0 Project Objectives

Our objectives for this project were first, to change the current, linear “cradle-to-grave” process into a cyclical “cradle-to-cradle” process. For this we had to generate a way to increase the current amount of steel recycled by common users and households. Another objective was to be able to separate out the highest alloyed steel from the automotive scrap and keep it separate throughout the process. We found two areas which could aid in this process. First we wanted to improve the communication so that the dealers would know what metals were in the cars when they arrived at the lot. We also wanted to add another step into the current recycling process to increase the efficiency of later steps designed to separate AHSS from scrap metal. Finally, we were also asked to calculate how much of this high alloyed steel could be added to low carbon aluminum killed (LCAK) steel without causing an off chemistry.

During our problem formulation and concept selection we had to keep in mind cost, time consumption, efficiency, and practicality. Since this process is to reduce costs by increasing recycling implementing expensive and tedious machinery and regulations would counteract the point of the entire project.

4.0 Conceptual Designs

To generate and select solutions we followed the steps taught to us in the engineering design process, specifically the step 3, concept generation. A product concept is an approximate description of the technology, working principles, and a form of the product. It is a concise description of how the product will satisfy the customer needs. Our goal was to generate as many concepts as possible and later use a screening and scoring process to choose the best.

4.1 Descriptions

Since we chose to improve the entire recycling process we chose four problems and developed concepts then chose the best solution for four different problems.

Our first problem was that too little steel was being recycled. To improve this we generated possible solutions that would entice common steel users to recycle. Our possible solutions were community recycling days, scrap recycling stations and bins, a point system, and government incentives. Community recycling days would be advertised around the town before the event and would be held at high schools or community buildings. There would be large dumpsters or similar containers to collect the recycled scrap that would later be hauled to a scrap dealership. This concept is modeled after community computer and paint recycling days. Scrap recycling stations and bins would either be implemented in common areas where one would find a public trash can, or delivered separately to households and collected weekly just as plastic and newspaper recycling is. Our point system would work similar to programs for frequent buyers. When individuals went and recycled their steel to scrap yards they would receive point which could later be exchanged for gift cards or something similar. Finally our last concept was government incentives such as receiving tax breaks for recycling certain amounts of steel.

Our second problem was the lack of information exchanged between companies (car manufacturers, scrap dealers, ArcelorMittal). The possible solutions we generated were a systematic approach and a backwards assembly line. The systematic approach would include an auto manufacturer label, government implemented laws, and certified inspectors. The label would include information about the typed of steel (specifically AHSS) found in the car and their specific locations. The label would either be found as a sticker inside of the car or as an extra informational booklet, similar to an owner's manual. With this information the recycler would know the amount and location of AHSS to expect from each they disassemble. The government would oversee the entire process by passing laws requiring the sticker or booklet as well as by sending out certified inspectors to different agencies. The other concept was to implement a disassembly line before a vehicle entered the recycling process. This way all separate parts of the car could be analyzed and detected for AHSS.

To improve the current actual recycling process we developed the concepts of a human disassembly line, a claw concept, and an extra shredder. We noticed that a great amount of non metal material is left in the metal chunks after the process began. The first solution was to simply insert a human disassembly line to take apart the automobiles and dispose of all non-metal materials. The claw concept consists of a large mechanized claw which would tear out all of the inside non-metal materials

inside of the cars. The additional shredder would be placed in the middle of the process. The shredder would be used to cut the metal chunks into smaller pieces which would increase the efficiency of the other machines (such as the magnet) and aid in removing smaller non metallic pieces stuck inside of the crushed metal chunks.

Finally, when it came to calculating how much high alloyed steel could be added to LCAK without causing off chemistry we experimented with open steel in combinations with pure elements, AHSS in combination with open steel, LCAK in combination with open steel, and AHSS in combination with LCAK and open steel. The different types of steel were analyzed based on different element percentages and expense. Elements and steels could either be added into the BOF where some of the elements would be reduced due to reaction with oxygen then dissipation, or after the BOF process to a tap. For this portion of the project we focused on creating a LCAK heat composition.

4.2 Research and Analysis

Throughout this process a multitude of literature was made available to us regarding the current steel recycling process, different types of furnaces and machinery, ArcelorMittal USA, current company problems, and chemical compositions of different types of steel.

This information helped us in determining our problems. For example we were given a project statement that mentioned only 30% of new steel is made from recycled materials. Articles explained to us that ArcelorMittal would receive a short report on the composition on the scrap metal they were receiving, however these numbers were never verified. Animations were able to pictorially explain how the current recycling process separates different types of metals and steels. We also were given reports on off-chemistry and how to effectively avoid it. Off-chemistry is when the element composition exceeds maximum values and therefore alters the value of steel.

The information provided to us about the composition of steels and BOF reduction rates proved to be the most helpful because it was the topic that we had least knowledge about. For example, we were able to create these two tables about composition and reduction due to the information.

Element Composition of Steel

	Open Steel	LCAK	AHSS
C	0.04%	0.04%	0.17%
Mn	0.1%	0.2%	1.5%
Cr	0.01%	0.1% max	0.2%
Cb	0%	0.004% max	0.02%
Al	0%	0.04%	1.2%

BOF Reduction Rates

Element	Reduction Rate
Cr	50%
Mn	33.3%
Cr	100%
Al	100%
Si	100%
Ca	100%

All of these materials were given to us by our professor and were accessible by Penn State's Angel website.

4.3 Concept Selection

Again, following the engineering design process provided to us we used evaluation, comparison, screening, and scoring as described in step four, Concept Selection. We prepared a selection matrix for each specific problem, rated the concepts, ranked the concepts, improved the concepts, and finally chose the best solution.

For each solution we created a table comparing all possible solutions using a simple +, 0, -, compared to a reference system. Tables are included on next page.

Problem: Low Rates of Recycling

	Current Recycling Process	Scrap Recycling Stations and Bins	Point System	Government Incentives	Community Recycling Days
Feasibility	0	+	0	-	+
Cost	0	+	+	-	+
Time Consumption	0	0	+	0	0
Awareness	0	-	0	+	+
Net Sum	0	+1	+2	-1	+3
Rank	4	3	2	5	1

Community Recycling days was chosen as the best solution to be implemented because of it's low cost, potential awareness, and feasibility/effectiveness.

Problem: Lack of Information Shared Between Companies

	Backwards Assembly Line	System Approach
Cost	0	0
Time Consumption	0	+
Feasibility	0	+
Net Sum	0	+2
Rank	2	1

The systematic approach was chosen because it would be the most effective while also being feasible and have low time consumption.

Problem: Non-metal Materials in Recycling Process

	Current Recycling Assembly	Claw Concept	Extra Shredder	Human Disassembly Line
Cost	0	-	-	-
Time Consumption	0	-	0	-
Practicality	0	0	+	0
Effectiveness	0	+	+	+
Net Sum	0	-1	+1	-1
Rank	2	3	1	3

The additional shredder was chosen as the best solution because it's practicality and effectiveness outweighs the initial cost of installment.

Problem: Making LCAK Without Causing Off-Chemistry

	LCAK + Open Steel	AHSS + Open Steel	LCAK + AHSS + Open Steel	Open Steel + Pure Elements
Off-Chemistry	0	-	-	+
Cost	0	0	0	-
Difficulty of Calculations	0	-	-	+
Net Sum	0	-2	-2	+1
Rank	2	3	3	1

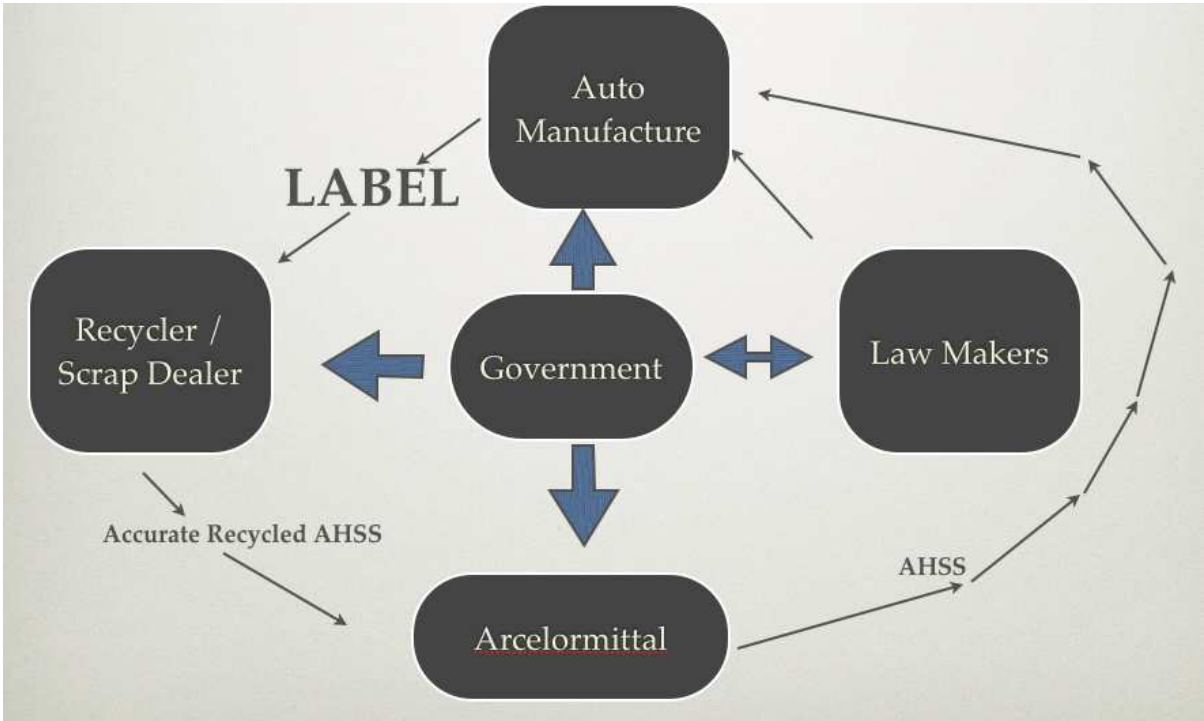
Although the combination of open steel and pure elements had the highest overall score we could not chose this as the best solution. The price of using pure elements is extremely high and counteracts the point of this project - to recycle. The calculations were extremely tricky and we were unable to figure them out. However with further calculation and experimenting with different percentages, someone with more experience and expertise in mathematics and chemistry may be able to come to a more precise solution.

5.0 Detailed Design

Because we chose to improve the entire recycling process from the beginning to end we have more than one design. Our first design is our community recycling days. This would require advertisement, organization, and transportation. First the community would need to decide the date and location of the event. Because this is modeled after the computer and paint recycling days we envision that they would be held either once a month, or once every two months. The location would vary each time to the parking lots off different high schools in the community. This information could either be decided at township meetings, or possibly by the school board or PTA. Once the location and date is decided flyers would be made up and distributed around town and sent home with school children. On the day of the event and entrance and exit would be labeled and the traffic would flow through the parking lots. Volunteers would unload the steel from the trucks and automobiles that arrive. Scrap dealers would arrive after the event was finished to collect the steel. We believe this would be most efficient because it would make it easier for families and residents to drop their steel off at the local high school than take trips to the scrap dealers. Also, we believe in the success of this solution due to the success of computer and paint recycling days.

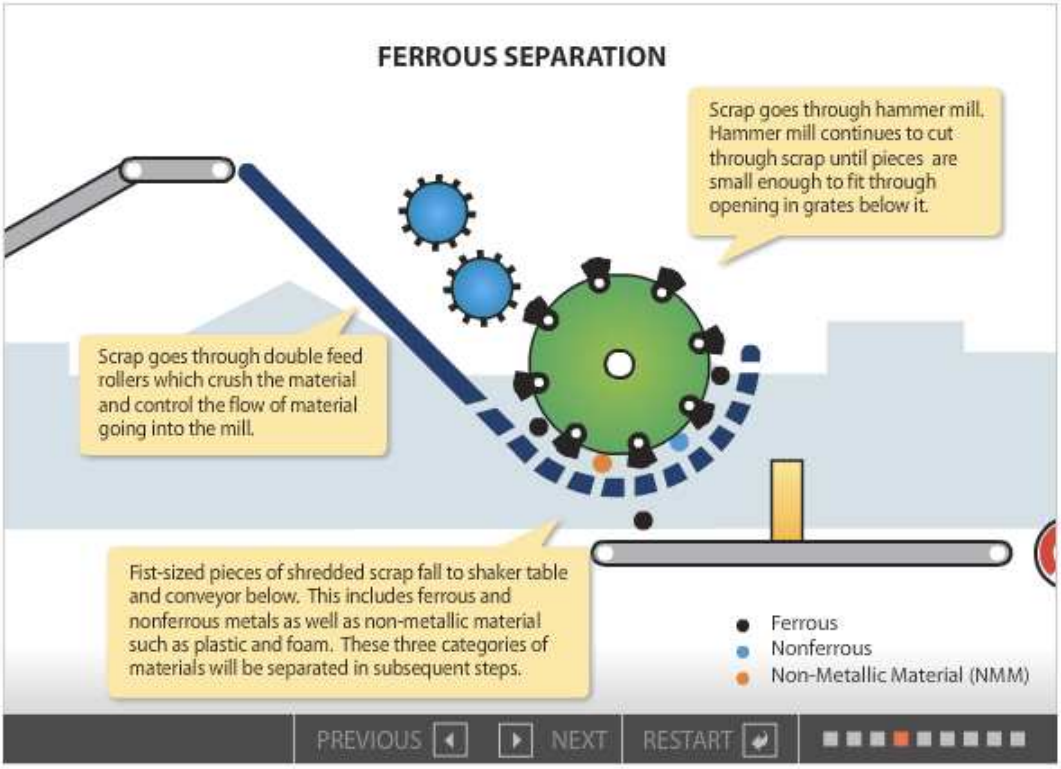
The second solution we developed was a systematic approach to the fixing the lack of communication between companies. We developed a flow chart to display the interactions we hope to instate.

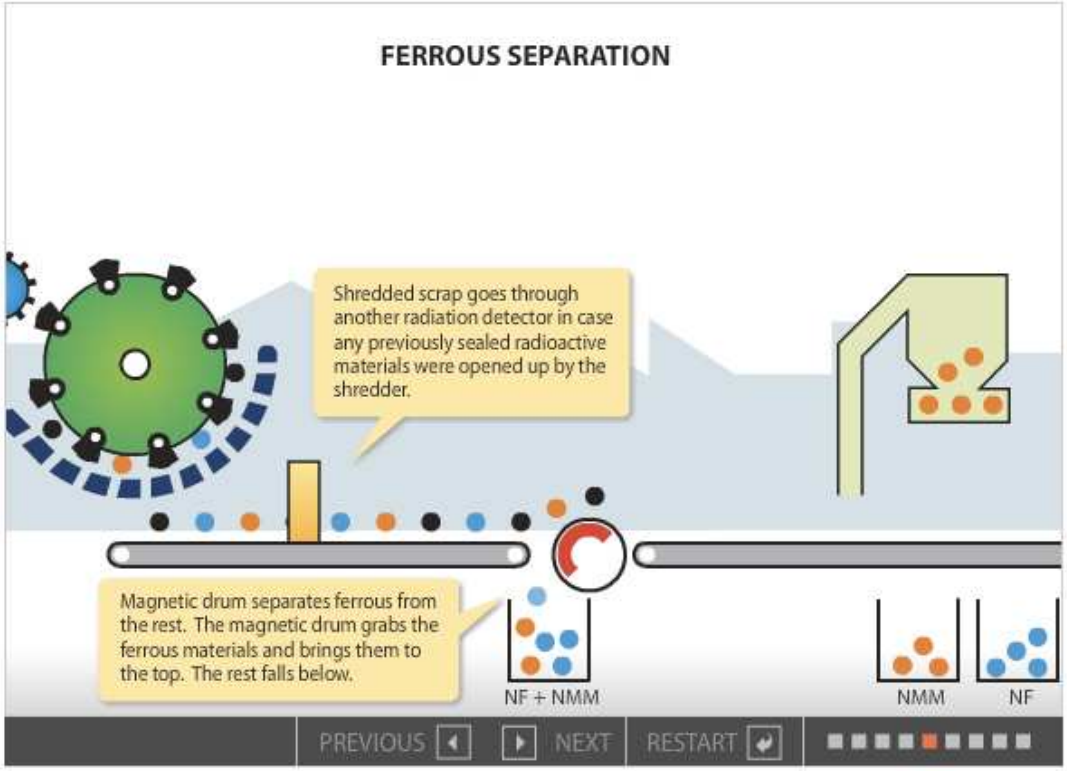
Our solution to the lack of communication states that automakers by law would be required to provide a label or informational booklet (similar to an

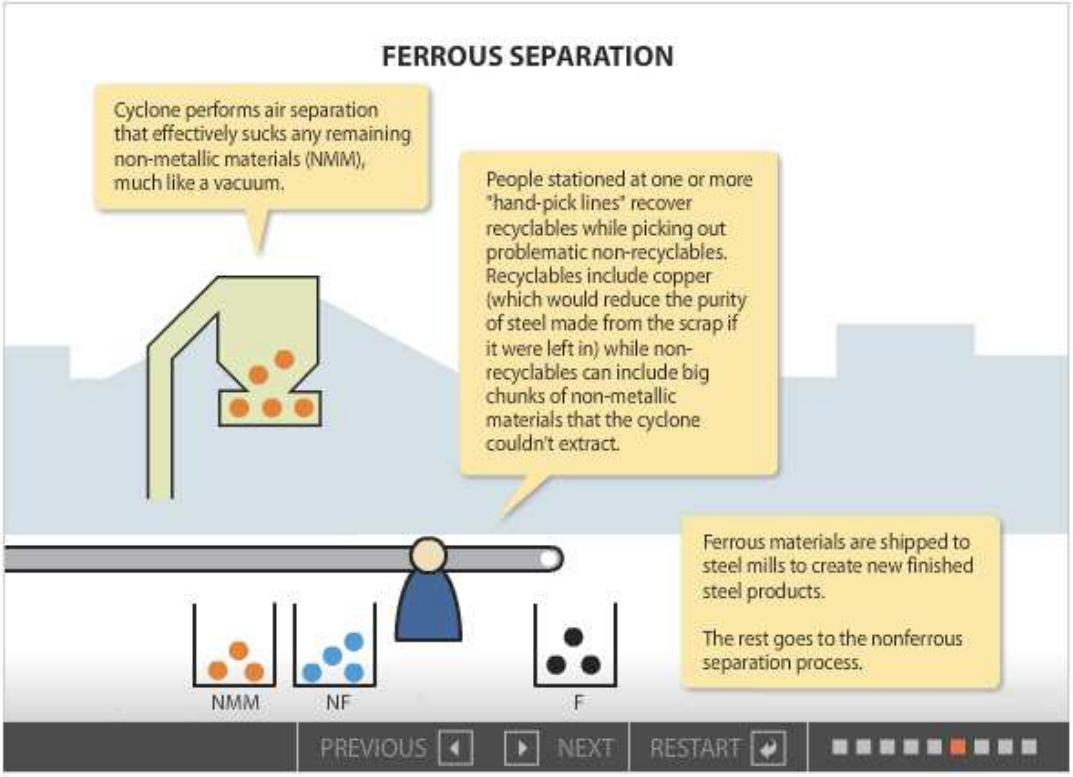


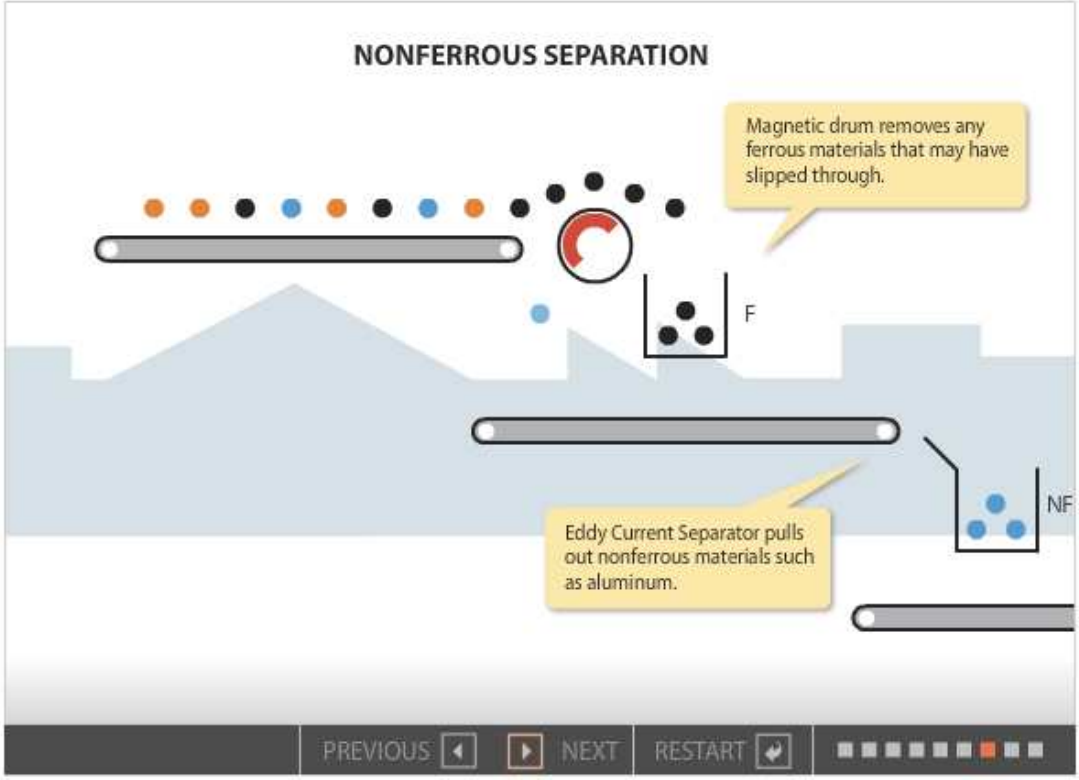
owner's manual) with facts about the specific amount and location of AHSS used on every model of car produced. This new information will allow the recycler to know what to expect from each vehicle they disassemble and turn into scrap. If the location of AHSS is known before the car enters the recycling process it will be much easier to separate it from the rest of the steel. The government will oversee the whole system by sending out certified inspectors to make sure there is no fraud when it comes to the material report. The law will also require car owners to update their labels or booklets if they make any changes to their car that would change the type or location of steels.

The additional shredder that we chose would be inserted into the middle of the current recycling process. After watching an animation made available to us by our professor we realized that the metals passed through three radiation detectors, two magnets, and three stations that separate out non metallic materials. However, the scrap only goes through one shredder which also has the potential to crush the pieces, therefore lodging the non metallic materials inside the pieces of metal scrap. These still-shots are included from the animation we studied.




FERROUS SEPARATION
Shredded scrap goes through another radiation detector in case any previously sealed radioactive materials were opened up by the shredder.
Magnetic drum separates ferrous from the rest. The magnetic drum grabs the ferrous materials and brings them to the top. The rest falls below.
NF + NMM
NMM
NF
PREVIOUS
NEXT
RESTART


FERROUS SEPARATION
Cyclone performs air separation that effectively sucks any remaining non-metallic materials (NMM), much like a vacuum.
People stationed at one or more "hand-pick lines" recover recyclables while picking out problematic non-recyclables. Recyclables include copper (which would reduce the purity of steel made from the scrap if it were left in) while non-recyclables can include big chunks of non-metallic materials that the cyclone couldn't extract.
Ferrous materials are shipped to steel mills to create new finished steel products.
The rest goes to the nonferrous separation process.
NMM
NF
F
PREVIOUS
NEXT
RESTART



We realized if the pieces were again shredded after their first cutting/crushing the magnets and cyclone would be more effective. This additional shredder would be added after the cyclone and could possibly eliminate the dangerous job of the “hand-pickers” described in the still shots. Eliminating the hand-pickers would save the company money and therefore possibly cancel out the cost of purchasing and installing the shredder.

Unfortunately, we could not come to a concise solution for the final problem of using alloyed steel to improve the quality of open steel while utilizing the BOF and avoiding off-chemistry heat. Although we experimented with different amounts of steel, different types of steel, and adding the steel to the tap after the BOF to minimize reduction we could not calculate an appropriate a sufficient amount of AHSS to add without causing off chemistry due to it’s high percentages of elements within. However, we believe that if the problem is further investigated with more allotted time and by someone with more expertise that a solution is in fact possible.

6.0 Conclusion

After the completion of this project our team was able to find successful solutions worth implementing for three of the four problems we initially addressed. Although we were not able to fully answer our final problem we believe our project to be overall successful. We saw many areas for improvement in the entire system and we attempted to fix all of

them, while we discovered other teams chose to only address one issue. Through this process we learned how to address problems appropriately. By creating proper customer need statements we successfully found the flaws present in the current overall steel recycling process. Also, by following the engineering design process we learned to create an operational scoring process to decide upon optimum solutions. Our final solutions of creating community steel recycling days, taking a systematic approach to the lack of communication issue, and adding and extra shredder to the current recycling process would prove to be very effective and attainable if implemented. We believe our project results should be seriously considered and possibly enforced for the better of ArcelorMittal USA.

7.0 Resources

"Big Picture of Recycling Process." Lecture.

"Recycling of Advanced High Strength Steel." *ArcelorMittal*.

ArcelorMittal, Apr. 2012. Web.

"Schnitzer Steel Industries, Inc." *Schnitzer Steel Â» Recycling Process*.

Web.

<http://www.schnitzersteel.com/metals_recycling_process.aspx>

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"Steel Making Basics and Overview." Lecture.