EDSGN100 Final Report Project #2
Final Design Report

Recycling of Advanced High Strength Steel

Introduction to Engineering Design
EDSGN 100 Section 020

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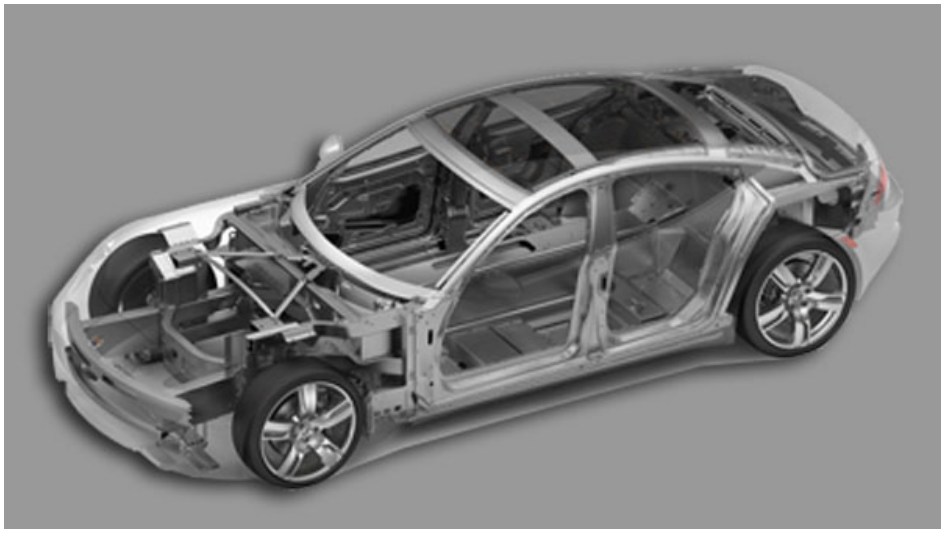

Submitted to : Prof. Correll
Date : 04/30/2012

Executive Summary

Our objective as a team was to find a way to effectively recycle AHSS (Advanced High Strength Steel). The primary restraint was to maintain ArcelorMittal's outstanding steel quality, while also making the process cost effective. In order to meet the requirements our team designed a process where the steel makeup of every make and model of car is put into a database and can be accessed by both scrap dealers and ArcelorMittal. The main reason we decided on this solution is because it did not affect the manufacturing process at all, and was also the most accurate of our concepts.

Recycling of Advanced High Strength Steel

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1.0 Introduction

This project is sponsored by ArcelorMittal, the largest steel producer in the world and an integrated steel producer in the United States. The purpose of this project is to design a process to effectively recycle Advanced High Strength steel from the automotive market back into the basic oxygen furnace steel production cycle. First of all, the reason to design this project relates closely to the background of steel. Steel is one of the most common materials used in the modern world. The steel resources on the earth are known to be finite. Most industries have initially developed a linear production cycle which is "cradle-to-grave" when utilizing finite resources like steel. In this project, we are going to change the cradle-to-grave process, into cradle-to-cradle process by making it circular instead of linear. Therefore, by recycling materials over and over again, we can increase the efficiency of the steel-making process.

To solve this problem, we are going to follow the steps in the design process. The first part is to define the problem and identify customer needs. We initially understood that ArcelorMittal's primary constraint on the project was to maintain the company's current steel quality. This constraint was kept in mind throughout the whole design process as something of utmost importance. After reading over the problem statement from ArcelorMittal, as a group, we realized research needed to be one. With no background knowledge of steel manufacturing, scrapping, or recycling processes, our most important task was to fully research the entire steel manufacturing process. Then, after completely understanding the problem, we developed eight solutions. These solutions were judged on a developed selection criteria using a concept screening matrix to narrow our concepts to three. These three were fully researched and developed.

The first was to develop a barcoding system that would be put into place on the assembly line of the vehicle manufacturer. This barcode would be scanned by a scrap dealer and reveal the chemical makeup of the steel including all of the alloying elements. The second concept required all car owners to return their vehicle to the car manufacturer or to a disassembler that separates the steel according to alloying elements. The third concept would consist of the vehicle manufacturer determining the total chemical steel makeup of each make

and model of car. This information would then be put into a database that would be made available to both the scrap dealer and ArcelorMital. Sketches and SolidWorks visuals were created to specifically show the concepts components. A concept scoring matrix lead us to a final refined concept: the vehicle steel-content database.

In order to keep organized and ensure that our group remained on track with our progress, we developed a Gantt Chart. As seen in **Table 1.1,** we allotted an appropriate amount of time to accomplish each task in order to finish the project by the deadline. This chart proved to be surprisingly helpful in the middle of the design process to let us know whether we were behind or ahead with the design process.

Table 1.1- Gantt Chart showing project timeline requirements.

	Week 1			Week 2			Week 3			Week 4			Week 5			Week6			Week 7		
	3/12-3/16			3/19-3/23			3/26-3/30			4/2-4/6			4/9-4/13			4/16-4/20			4/23-4/27		
Define Problem																					
Design Research																					
Concept Design																					
Concept Dev.																					
CAD Solidworks																					
Comm. Res.																					
Final Report																					
Presentation																					

2.0 Problem Statement

Design a process to effectively recycle high quality steel by separating it based on what alloys the steel contains. To further clarify the given problem statement we modified it slightly to help fit into the steel making process by not modifying the actual car at all. Specifically, we need to determine exactly how much AHSS and LCAK steel needs to be added to the 15% scrap charge that is added to the 85% hot metal charge. This must be done accurately to avoid off chemistry (caused by too much AHSS or LCAK).

3.0 Customer Needs, Research and Project Objectives

3.1 Customer Needs

After defining and researching the problem, we developed a list of important criteria that our final design would need to satisfy. We compared each concept on *cost, process's time required, human labor, time to implement, uniform to all cars, accuracy, and feasibility*. Of course when solving any problem, minimizing *cost* is a key component in the design. The incentive for a company to pick a design that saves them money is much greater than that for a design that would be more expensive.

The *process's time required* is crucial to the efficiency of the steel recycling process. A solution may be extremely accurate and even inexpensive, but if it takes several weeks to sort through the different types of steel and separate them, it would slow down the steel recycling and production tremendously. ArcelorMittal is known for impeccable steel quality using an efficient system. As the largest steel producer in the world, slowing down their steel-making process would adversely affect the company immensely. Our third customer need*, human labor*, ties in with this. A process that minimizes the amount of excess *human labor* necessary would decrease the time required and cost. We wouldn't want to design something that would require a group of workers to sort through tons of steel on a daily basis. Our fourth customer need is *time to implement*. ArcelorMittal has a problem and the sooner it can be solved, the better. A process that can be enacted within several weeks has a definite edge over a process that would take years to be put into place.

We determined that our most important three criteria are *uniform to all cars, feasibility, and accuracy* using an AHP Chart. **Table 3.1** displays each of our customer needs compared with one another.

Table 3.1 – AHP chart weighing design criteria

AHP Chart	Cost	P.T.R.	H.L.	U.T.A.C.	Feas.	Acc.	T.T.I.	Total	Weight
Cost	1.00	0.33	0.50	0.25	0.25	0.20	0.33	2.86	0.04
Process's Time Required	3.00	1.00	2.00	0.33	0.33	0.25	0.33	7.24	0.09
Human Labor	2.00	0.50	1.00	0.33	0.33	0.25	0.33	4.74	0.06
Uniform to All Cars	4.00	3.00	3.00	1.00	0.50	0.33	2.00	13.83	0.18
Feasibility	4.00	3.00	3.00	2.00	1.00	0.50	3.00	16.50	0.21
Accuracy	5.00	4.00	4.00	3.00	2.00	1.00	2.00	21.00	0.27
Time to Implement	3.00	3.00	3.00	0.50	0.33	0.50	1.00	11.33	0.15
						Grand Total:		77.50	

The design clearly must accommodate *all types of vehicles*. If the process only separates steel from certain vehicles, it would not be very valuable. Especially because ArcelorMittal is the largest steel producer in the world, any process created needs to be universal. *Feasibility* is our second most important customer need. In our design process, we aimed to develop a solution that would not require new technologies. Maybe in the future, magnets or traceable paints could be developed, but again, we want to develop something that can be put into action soon. Finally, *accuracy* proved to be the most important of criteria. ArcelorMittal's main requirement is to maintain their steel quality, so the accuracy of our proposed process is crucial. The current process for steel production is already exceptionally precise, but our process needs to be accurate to the small percentages of alloying elements in the steel.

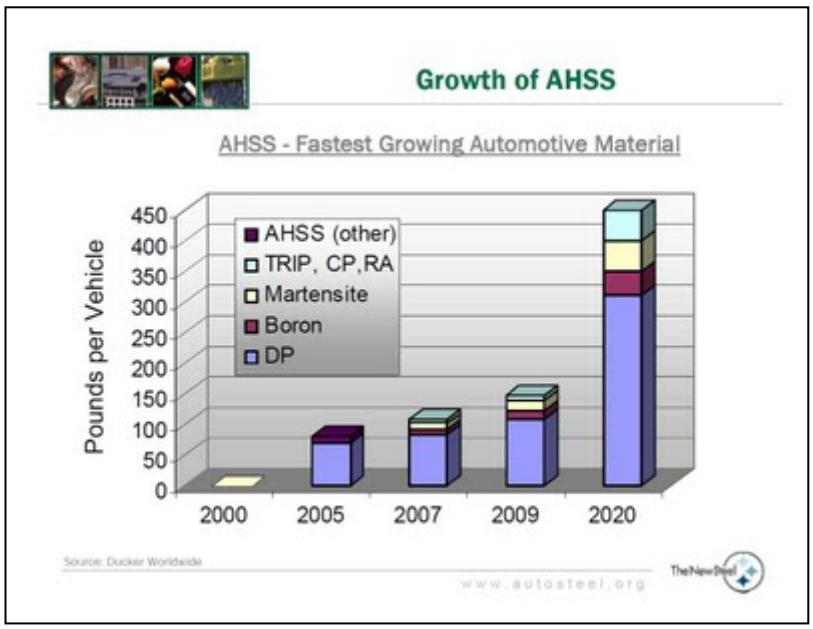
The public, environment, consumers, design team, and financiers were all taken into conceptual account also. Although we did not include each of these groups on our AHP chart, we discussed that none of our top three concepts to be developed would have a significant negative impact on the environment, steel consumers, or people paying for the policy. Environmentally speaking, none of our three top concepts would increase emissions or fuels used in the steel manufacturing process. If anything, our concepts would benefit the

environment because steel is being recycled more efficiently, leading to less metals such as iron that would be needed to produce steel.

3.2 Research

For preliminary research, our group was required to explore the differences between AHSS and LCAK steel. It was the most important research for the project because our objective was to design a process to separate these types of steel. Only by knowing exactly what AHSS and LCAK were could we produce something to separate them. We discovered that "Aluminum Killed" meant that the LCAK steel contained the element aluminum. The aluminum stabilizes the steel and makes it softer and more pliable than regular steel. LCAK is primarily used in automotive parts, power tools, and packaging parts. We are concerned with the automotive industry, so after looking more into the automotive uses of LCAK, we found it often used for small flat parts such as brackets but also large deep drawn parts such as floor pans. The LCAK steel is used for both exposed and unexposed parts of every vehicle. Advanced High Strength Steel differs from Low Carbon Aluminum Killed steel in that it's stronger and more lightweight. AHSS improves vehicles fuel efficiency and crashworthiness, and reduces greenhouse gas emissions. **Figure 3.2** shows the projected growth or AHSS in the automotive industry.

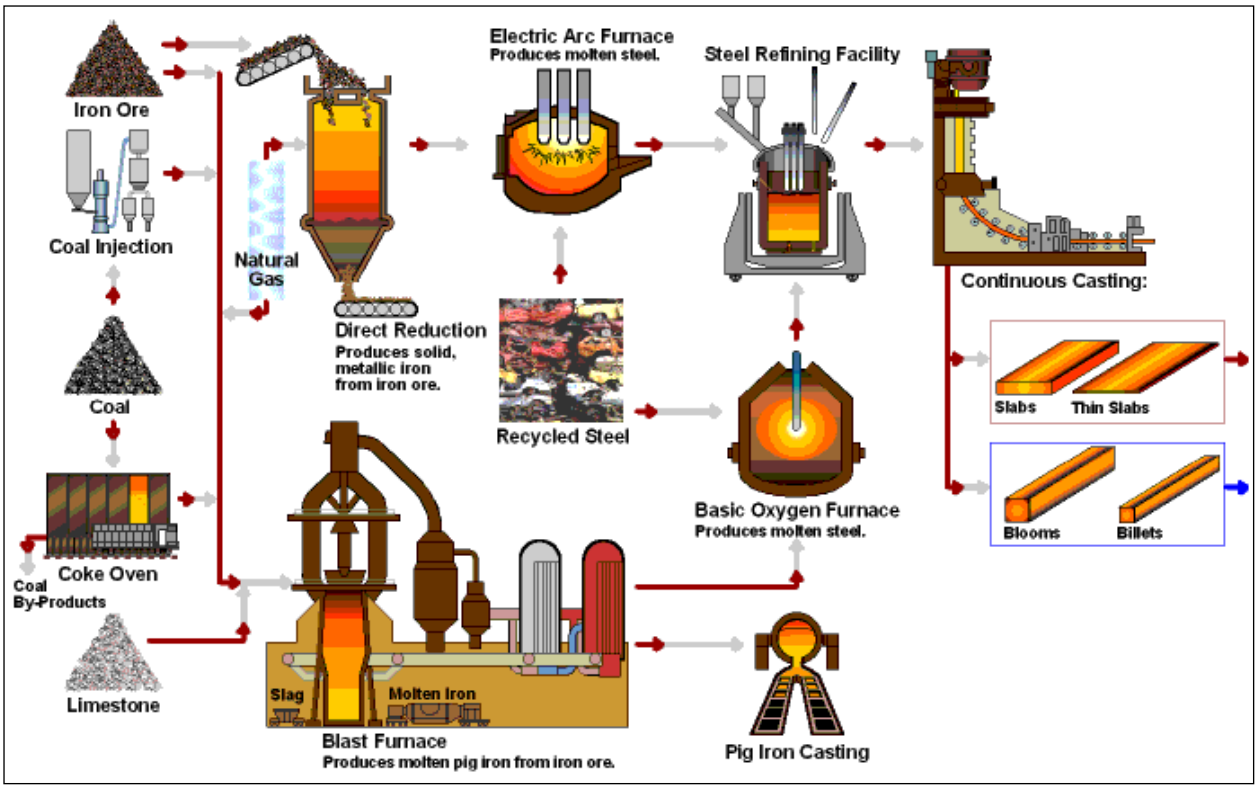
Figure 3.2 – Projected AHSS Growth
http://boronextrication.com/tag/ahss/



The differences in AHSS and LCAK are miniscule percentages of the alloying elements carbon, chromium, manganese, aluminum, and several others. With such a negligible difference physically, any separating process would need to differentiate between the two on a chemical level.

Research from other groups included that of alloying elements, the scrapping process, and the ArcelorMittal steel-making process. Utilizing this information and further researching the resources the groups provided, we were able to develop an understanding of the full course of steel production. The scrap steel that ArcelorMittal receives makes up 15% of a mixture with 85% hot metal charge made of molten iron ore. This "batch" is melted in a basic oxygen furnace that results in a tapped steel product. Once steel is tapped, the composition is fixed. The details of the steel manufacturing process are outlined in **Figure 3.3.**

Figure 3.3 - Basic Steel-Making Process
http://www.asgco.com/industries/steel-conveyors/steel



3.3 Project Objectives

Through researching the current ArcelorMittal steelmaking process, we were able to develop several objectives that our process needed to either improve or not adversely affect. Firstly, we did not want to cause any alterations to the vehicle assembly line. Designing an extra step in the car manufacturing process would require every car manufacturer that ArcelorMittal receives cars from to change their assembling process. Because ArcelorMittal is such a large company, this is virtually every vehicle producer. Modifying the production of all of these vehicles would be costly and time-consuming. We also strived to accomplish our design without developing any new technology or procedures. Using a component in our design that would require further development would also increase the time it takes for our design to be implemented as well as cost. Basically, our goal is to design a process to accurately identify steels chemical content while keeping the process feasible. Optimistically, this would be done without changing the production of vehicles or creating any expensive technological advances.

4.0 Conceptual Designs

4.1 Concept Generation

After gaining an understanding on the project, problem statement, and objectives, we generated concepts as a group. This was accomplished in a classroom activity in which each group member developed one concept. After four concepts were generated, we each read one another's concepts and either refined it or started a new concept. At the end of this activity, we had eight concepts that we were able to move ahead with. A short summary of each concept can be seen in **Table 4.1**.

Table 4.1 – All preliminary concepts with explanations

	Concept	Explanation
A	Database	The steel make up of every make and model of car is put into a database. Scrap dealers and ArcelorMittal would have access to it. (see more in Detailed Design)
B	Filter	Use a type of filter to separate the different steels according to physical properties such as density and strength.
C	European union recycling	When a car is done its life cycle it's taken back to the manufacturer where trained technicians would take the car apart and separate it according to the steel process.
D	Engrave parts with alloys contained in the steel.	Mark each individual part with the steels chemical makeup engraved on the part. This could be done by an automated machine such as a CNC machine.
E	Separate cars into sections	Mark large sections of the vehicle that have a similar steel makeup. Separate the vehicles steel into 4 or 5 categories and simply mark each one A, B, C, D, or E. This would make the "marking process" much easier and make it easy to interpret for the scrap dealer. It would also leave a small percent error though, because we are generalizing the steel into categories.
F	Engrave parts with barcode	On each piece of steel, a barcode would be engraved. This concept would require some complicated computer programming, but the scrap dealer would just have to scan the barcode of the part and immediately know the exact chemical makeup of the part.
G	Electric arc furnace	Melt all the scrap into a uniform substance using the electric-arc furnace, then "lollipop" test it. After that different alloys can be added depending on the customer specifications.
H	Magnetic separation	One of the main chemical differences between AHSS and LCAK is the difference in aluminum content. If a powerful enough magnet that picks up on the aluminum could be developed, then this magnet could separate steel with different aluminum content. The magnet would need to be accurate enough to pick up on differences as small as 1%.

4.2 Concept Screening

In order for us to screen down our initial concepts to three or four that we were going to continue through the design process with we put our concepts into a concept screening matrix. We graded all of our concepts on the selection criteria we came up with as a group on a plus, minus, neutral scale. After, the concepts were ranked based on their net score and the top concepts moved on to be further developed. **Table 4.2** shows the Concept Screening Matrix and which concepts continued to move through the design process.

Table 4.2 – Concept Screening Matrix

	CONCEPT VARIANTS								
SELECTION CRITERIA	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	REF.
Cost	0	-	0	-	-	-	-	-	0
Process's Time Required	+	0	-	-	-	0	-	0	0
Human Labor	-	0	-	0	0	+	0	0	0
Uniform to all Cars	+	-	+	0	0	+	+	-	0
Feasibility	+	-	+	+	+	+	+	-	0
Accuracy	0	0	+	+	0	+	+	0	0
Time to Implement	+	-	0	0	0	-	0	-	0
Pluses	4	0	4	2	1	4	3	0	
Neutral	2	3	1	4	4	1	3	3	
Minuses	1	4	2	1	2	2	2	4	
Net	3	-4	2	1	-1	2	1	-4	
Rank	1	7	2	4	6	2	4	7	
Continue?	**YES**	NO	**YES**	NO	NO	**YES**	NO	NO	

4.3 Concept Development

After putting the concepts through the concept screening matrix we continued development with only three of our original eight concepts. The concepts we moved forward with were A, C, and F. These three clearly outweighed the other concepts when judging them all against our selection criteria.

Concept A is the Steel-Content Database. This process would require all vehicle manufacturers to determine the total steel makeup of each make and model of car. Nobody

knows what the exact chemical steel content of the steels are better than the producers of the vehicles. This information would then be placed into a database that would be made available to both the scrap dealers and ArcelorMittal. Scrap dealers would record each vehicle that is shredded into a truckload and therefore the total weights and percent's of the alloying elements would be available to ArcelorMittal. The current steel process would then be conducted with increased accuracy due to the knowledge of all alloying elements.

Concept C was to implement a process similar to the European Union's vehicle recycling program. Between eight and nine million cars are discarded annually in the EU. In Germany, automobile manufacturers have the responsibility to recycle the car by law. Germany has made the recycling efficiency to be 86.8% in total and 73.6% in metal recycling. The German government does not give the money to vehicle dismantlers. **Figure 4.1** shows the current European Union vehicle recycling process. Although this concept would prove to be extremely accurate, it would require a great amount of human labor to dismantle each car and separate it according to its individual parts. It would also require some type of government legislation and subsidy mandating that every car owner return their car and giving them compensation for it. The time to implement this process would be three to five years at the best.

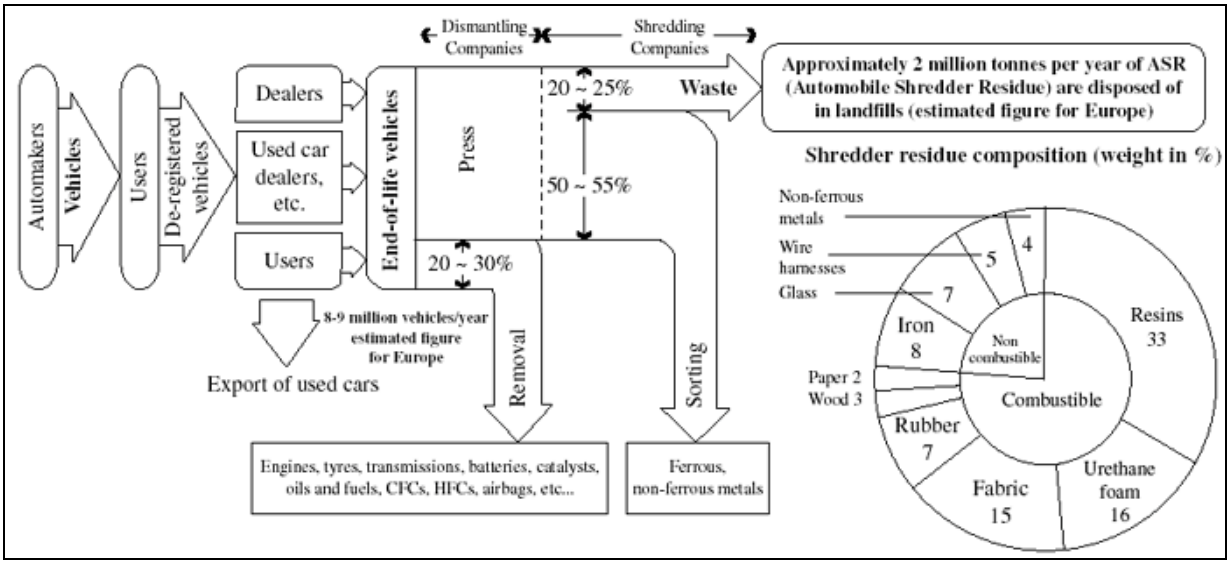


Figure 4.1 – European Union Vehicle Recycling System

Concept F is a barcoding system to be implemented in the manufacturing of all vehicles. Similar to concept A, the total chemical steel makeup would be calculated by the vehicle producer, but instead of being placed in a database, this information would be shared through

a barcode engraved on each car. This barcode would be on the inside of the door panel, as seen in **Figure 4.2**.

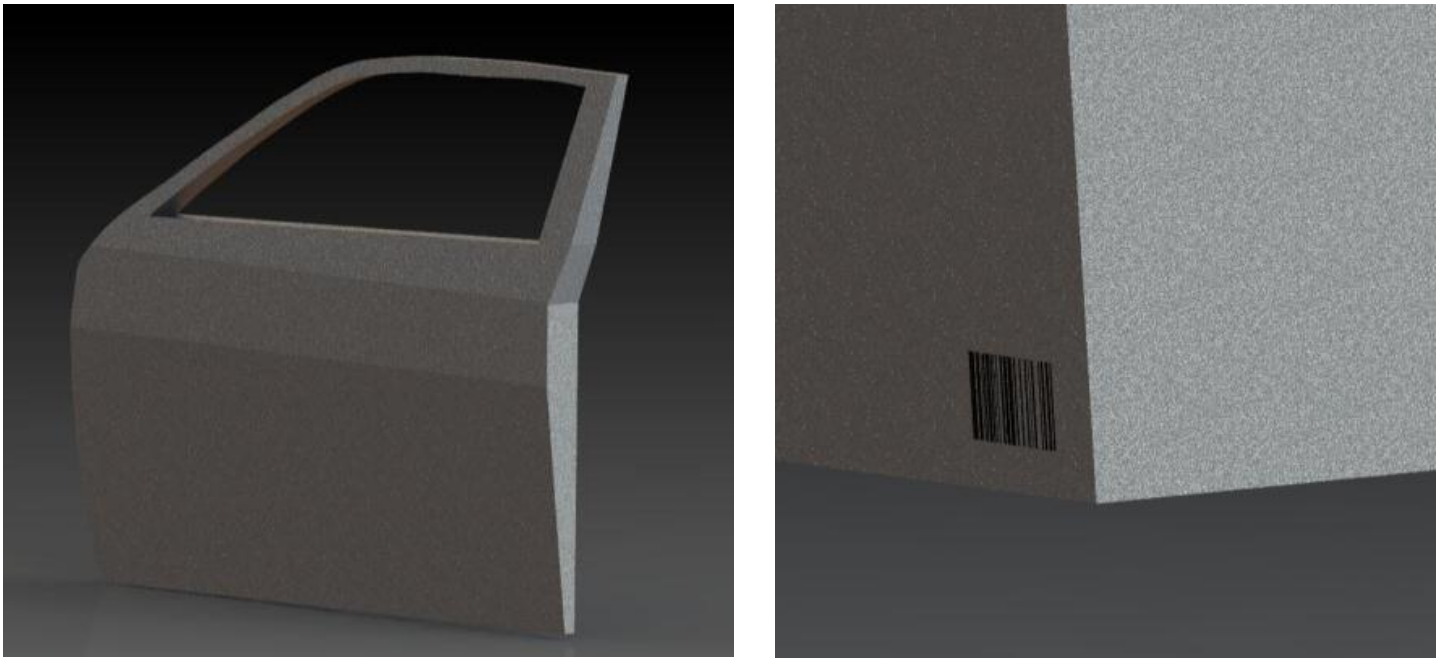


Figure 4.2 – Barcoding Location

In order to maintain durability, the barcode would need to actually engraved in the steel, not simply painted or marked by a sticker. This process would involve milling, or engraving the surface. It would use a high-average-power switched diode pumped solid state laser to locally change the surface roughness. The scrap dealer would use a scanner to read each barcode and determine the amount of alloying elements in each vehicle. This would then be totaled for a railcar load of shredded steel and this information would be readily available to ArcelorMittal. A barcoding system that could accomplish this is a BAI barcode system, totaling $12,000 to $15,000 in cost. Aside from the problems of cost, this process would require ArcelorMittal to intervene in the production of all vehicles that they receive.

4.4 Concept Selection

In our Concept Scoring Matrix (**Table 4.3**) we rated our final three concepts on a scale of 1-5 based on how well we thought each concept perform in that category. After that the rating was multiplied by the weight (derived from the AHP Chart, Table 3.1) of the piece of criteria it was being graded on. The sum of each concepts weighted scores were ranked and the concept

with the highest total score was developed. Concept A (Database) was developed specifically because it was uniform to all cars, it was accurate and it was a feasible option.

Table 4.3 – Concept Scoring Matrix

		Concepts					
		A		**C**		**F**	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Cost	4%	4	0.16	3	0.12	2	0.08
Process's Time Required	9%	3	0.27	3	0.27	3	0.27
Human Labor	6%	4	0.24	2	0.12	3	0.18
Uniform To All Cars	18%	4	0.72	3	0.54	3	0.54
Feasibility	21%	5	1.05	5	1.05	3	0.63
Accuracy	27%	4	1.08	3	0.81	5	1.35
Time To Implement	15%	3	0.45	3	0.45	2	0.30
Total Score		3.97		3.36		3.35	
Rank		1		2		3	
Continue?		DEVELOP		NO		NO	

5.0 Detailed Design

This Vehicle Steel-Content Database will smoothly integrate into the vehicle manufacturing, steel scrapping, and steel producing process. In the first step, the steel makeup of the car is determined by the manufacturer and submitted to the database for both scrap dealers and ArcelorMittal to access. It will take some time for the database to fill up due to how many different cars there are out there. Once the database is complete, it will be the scrap dealer's job to keep track of what cars they shred and put into shipments for ArcelorMittal. Every shipment they make will be given a serial number that will tell ArcelorMittal exactly what kind of scrap is coming into them. **Figure 5.1** is a flow diagram displaying the three different places that our process will target and **Table 5.1** displays an example of the Steel-Content Database.

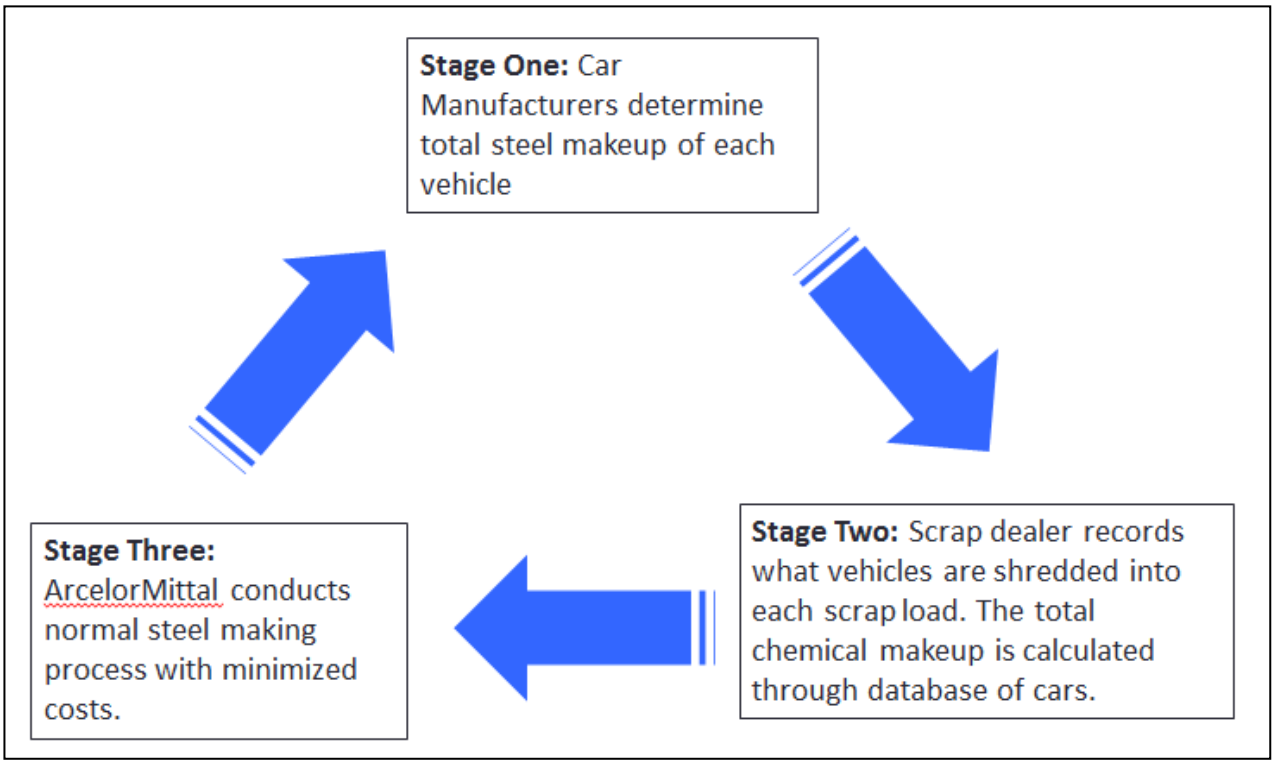


Figure 5.1 – Concept Flow Diagram

Table 5.1 – Example Steel- Content Database

Honda Civic 2001			
Alloying Element	Alloy Percent	Vehicle Weight (lbs)	Alloy Weight (lbs)
Carbon	0.02%	2564	0.5128
Chromium	0.08%	2564	1.923
Columbium	0.00%	2564	0.10256
Manganese	0.15%	2564	3.846
Aluminum	0.05%	2564	1.282
Ford F-150 2002			
Alloying Element	Alloy Percent	Vehicle Weight (lbs)	Alloy Weight
Carbon	0.05%	4800	2.448
Chromium	0.02%	4800	0.96
Columbium	0.00%	4800	0.096
Manganese	0.13%	4800	6.24
Aluminum	0.03%	4800	1.44

Once the scrap arrives at ArcelorMittal, whoever is receiving the shipment will simply read what the chemical makeup of the load is and add whatever alloys needed for that particular batch of steel. We have included only the main elements in our database, but ArcelorMittal can easily add alloying element categories at any point during the design process. The total amount of each alloy will be calculated as a percent of the complete weight of the shipment. ArcelorMittal can conduct their steel-making process as they normally would, but knowing how much of each element is in the steel will increase the accuracy of the produced steel. ArcelorMittal can know, to hundredths of a percent precision, exactly what is in the steel so they know what to add or what they can omit. This will also lower costs associated with using more alloys.

6.0 Conclusions

Initially we were given a problem with a primary and secondary constraint. We were required to efficiently separate steel according to its alloying elements. Our primary constraint was that the quality of the steel must not be adversely affected. As a secondary restriction, we were asked to minimize costs. Keeping this in mind throughout the design process, we added several other key objectives that our design would aim to satisfy. These included avoiding alterations to vehicle manufacturers, and refraining from the use of undeveloped expensive technologies. Our final design meets all criteria from ArcelorMittal, our AHP matrix, and our added objectives. The database would only require an upfront initial cost for the vehicle manufacturers to determine the steel makeup of vehicles. It would only slightly increase the amount of time that the scrap dealer takes to shred the steel. The database would create an accurate means to record *exactly* what alloys are in each railcar load of shredded steel arriving at ArcelorMittal without compromising the existing unparalleled steel quality. Although our design is simple, it satisfies the needs of feasibility, cost, and time to implement more fully than any elaborate change in ArcelorMittal's, scrap dealer's, or vehicle manufacturer's current process. Our proposed design would absolutely satisfy ArcelorMittal's needs and solve the problem statement in a more precise, practicable, and timely approach than any other process.

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