EDSGN100 Design Project #2
Final Design Report

Recycling of Advanced High Strength Steel

Introduction to Engineering Design

EDSGN 100 section: 002

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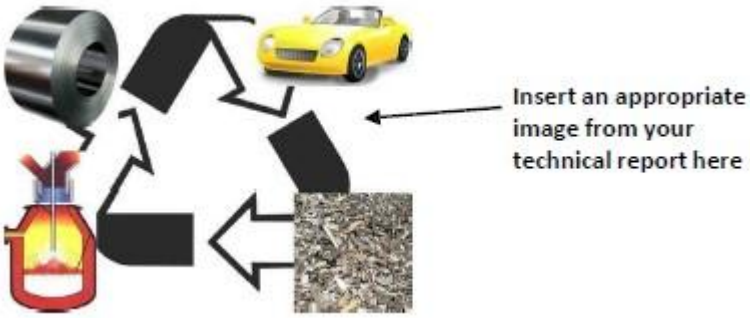

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Executive Summary

In EDSGN 100 design project 2, we will create a new system which can separate AHSS and Fe from trash. The whole system includes seven parts. They are edge mill, magnetic system, spray paint system, density system, high pressure washing down system, transmission system and recycle system. First, we will put cars into edge mill which will cut large pieces of objects get into pieces. Second, in magnetic system, magnet will only attract with Fe, Co and Ni, therefore we can remove nonmetal from trash. Third, we will spray paint on the surface of each pieces to protect them do not react with anything, because we will use a strong acid in nest system. Forth, we create a solution which the density of solution is between AHSS and Fe, Co, and Ni. Therefore, when we put all metal into density system, AHSS float on the surface of this solution and Fe, Co and Ni will be immersed in solution. As a result, we can separate AHSS at here. After, we will use same method to separate Fe. Fifth, we will use high pressure of water to wash down the paint which is covered on the surface of metal. After all these, we can use transmission system to put AHSS or Fe into BOF and recycle the solution for the next system cycle.

Recycling of Advanced High Strength Steel

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1.0 Introduction:

Now, the resources of ion is more and more scarce, so ArcelorMittal want to create a system to highly recycle ion resources especially AHSS. Therefore, in EDSGN 100 design project 2, we will create a new system which can separate AHSS and Fe from trash. In these report, it has 7 parts: introduction, project background, project objectives, conceptual designs, detailed design, conclusions and reference. In project background, you now know the information of ArcelorMittal and the function of BOF. In project objective, you will know our objective with more details and the challenge in this whole process. In conceptual design, you will now the whole system which we build. In detailed design, you will see how to find a solution and use the density of this solution to separate AHSS and Fe from trash. In the end we will get our conclusions and show our references.

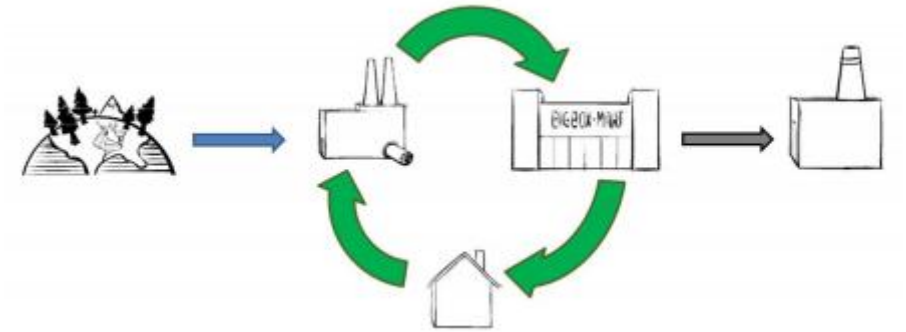
2.0 Project Background:

The purpose for the project is to improve the recycle of Advanced High Strength (high alloy) Steel from the automotive market back into the basic oxygen furnace (BOF) steel. For this project the partner is ArcelorMittal USA, one of the largest steel producers in the United States. ArcelorMittal products are used not only in the automotive industry, but also in construction, household appliances and packaging, making ArcelorMittal, one of the leaders in North American steel market. The company also operates outside the USA; it currently operates in over 60 countries, with about 285,000 employees.

"Steel is one of the most common materials used by modern societies". The steel use in the automotive industry has outstanding properties that have been achieved with technological edge processes. It is one of the resources that are known for having large finite reserves. Meaning that although the reserves are large the amount one can obtain from them is limited. The large reserves have created a system called 'Cradle-to-grave' (depicted below) that operates amongst companies like ArcelorMittal. The 'Cradle-to-grave' is just a term given to the linear production cycle of certain products, products that go from extraction directly to the landfill.

One of the purposes of the project is to change the 'Cradle-to-grave' system by recycling, therefore making it a cyclical "cradle-to-cradle" process (depicted below). By recycling most, if not all of the materials the waste disposal will diminish significantly. Although ever since the 19th century companies have been trying to

recycle steel, they have had little success in doing so. Today, “only about 30% of total new steel is recycled content”. With new high strength (high alloy) steels being incorporated to cars the process of recycling has become more complicated because they usually cause higher residuals or unknown alloys.



Currently, the steel making industry is implementing a process called Basic Oxygen Furnace or BOF. BOF is a process in which the scraps parts of autos are feed into a BOF and from there convert into steel. The following chemical reactions are taken from an article titled *Schematic Illustration of Iron making and Steelmaking Process*.

Chemical Reactions in BOF

1. Decarburization
    a. $2C + O_2 \Rightarrow 2CO$ (reaction occurs in bath, CO to off gas)
    b. $2CO + O_2 \Rightarrow 2CO_2$ (reaction occurs above bath, CO_2 to off gas)
2. Silicon Oxidation
    a. $Si + O_2 \Rightarrow SiO_2$ (reaction occurs in bath, SiO_2 to slag)
3. Manganese Oxidation
    a. $Mn + O_2 \Rightarrow MnO$
4. Aluminum Oxidation
    a. $4Al + 3O_2 \Rightarrow 2Al_2O_3$ + HEAT!

This is a process in which the largest heat in the process sinks in the furnace and balances the required steel temperature.

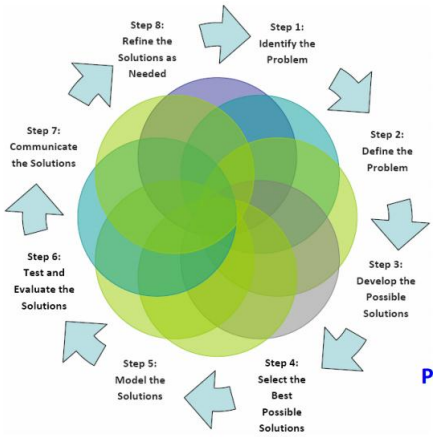
3.0 Project Objectives:

The main goal is to design a process or system to recycle Advanced High Strength (high alloy) Steel or AHSS. The two main points or criteria for this project were one, no off Chemistry and two, cost savings. With the eight steps of the engineering design process the final concept was the ideal solution to the problem of recycling AHSS.

1. Problem Identification, the difficulty of the steel producers to recycle AHSS and also the high cost of recycling it.
2. Defining the problem. By looking at the current recycling process the team decided that the incertitude and inefficiency of the scrap dealers to separate AHSS was the main problem.

3. Development of Possible Solutions. Throughout the first two steps of the process there were many solutions offered such as, magnetism to separate the ferrous from the non-ferrous, heat to melt of the alloys and then separate them, and finally to use density to separate AHSS.
4. Selecting the best possible solution. After much thought and charts comparing the pros and cons of the different ideas, the best possible solution came up to be the one that used density.
5. Modeling the solution. Perhaps the biggest challenge of the team. It was challenging because there was too much information that needed to be gathered such as density levels of AHSS, Fe, Co, and Ni. Then the search for the perfect solutions that would enable AHSS and the other materials to separate easily and cost-efficiently. When the solutions were found, there were considered too harmful for the environment and the workers (the solution would contain mercury and other toxic materials) for that reason the team decided to implement a series of steps to wash off all of the solution.
6. Steps 6-8 were done with the charts and research. At the end the density solution proved to be the most effective solution.

Engineering design Process



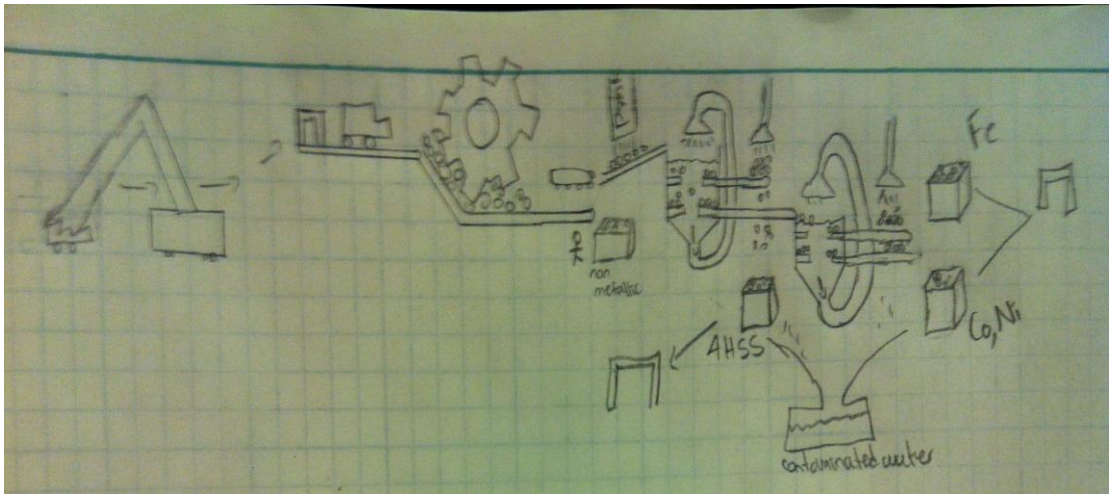
The density solution is the best strategy to fulfill the team objective of recycling AHSS with the efficiently, without causing off chemistry and cost efficiently.

4.0 Conceptual Designs

I. Description

The basic idea of our design was a to create a solution in which we would place the metals into and based on the different densities of the metals they would either sink or float. In this process we decided to create 2 tanks with solutions. In the first tank we would separate AHSS from the other metals in the cars, such as steel, iron, aluminum, etc. The second tank would be used to separate those metals into their own divisions. The solution that we would use would be recycled after the metals were separated

from it in order to eliminate any chances of making mistakes in creating the complex solution.



II. Research and Analysis.

Metal Research

Types of metals	Density (g/cm^3)	Melting Point (degree C)
Steel	7.85	1300
Iron	7.87	1500
Aluminum	2.7	1200
Titanium	4.51	1660
Platinum	21.45	1800
Palladium	12.02	
1500		
Rhodium	12.41	2000
AHSS	(roughly 1/3 of steel)	varies depending on % of

each metal used

Solution Research

To create our solutions we made calculation based on which densities we wanted to float and which ones we wanted to sink:

–Density of AHSS: 7.794g/cm3

–Density of Fe, Ni, Co: ~ 7.874 g/cm3

We found our **solution (a)** to be of a density of 7.83g/cm3

We then did the same calculations to determine the density for our second solution:

–Density of Fe is 7.874

–Density of Ni, Co is 8.9

After calculations, our ideal solution for our first tank**,** will be made with 48.5% Aqua regia dissolved with 51.5% liquid mercury and our second tank will be made with 43.7% Aqua Regia dissolved in 56.3% liquid mercury.

Alloy Research

1. Components of open steal and LCAK.

	Elements in Alloy (%)					
	C	Cr	Cb	Mn	Al	Fe
Open Steel	0.040	0.010	0.000	0.100	0.000	99.850
LCAK	0.040	0.100	0.004	0.200	0.040	99.616

2. Calculate how much alloys that we need to put in open steel to make LCAK.

	Elements in Alloy (%)					
	C	Cr	Cb	Mn	Al	Fe
Aim	0.040	0.100	0.004	0.200	0.040	99.616
Already in steel	0.040	0.010	0.000	0.100	0.000	99.850
Needed alloy	0.000	0.090	0.004	0.100	0.040	0.000
Heat size (lb)	440,000	440,000	440,000	440,000	440,000	440,000
Result (lb)	0.000	44,000	1956	48889	19556	0.000

Formula of calculation:

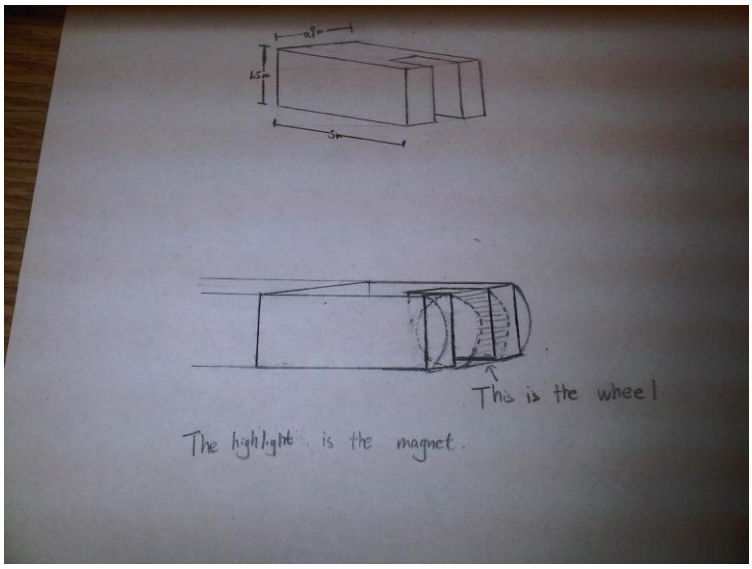
$$\frac{(\textbf{percentage of needed alloy} * 440,000)}{\textbf{90\% recovery}} = \text{Result}$$

III. Concept Selection

The method we chose was the one discussed above with a few more advancements. We intend to keep the two-tank system with the two solutions as defined above. A conveyer belt will be used transport the metals from tank to tank and a net contraption will be placed at the end of the tanks so the metals that float in the solution will be separated and cleaned off, while at the same time the ones that sink will continue on to the next solution tank where Keeping the idea of preserving the metals in mind we felt that if we were to place the naked metals into the solutions described above the acidity of it would begin to deteriorate the metals so we came up with the idea of applying a layer of paint over the metals, which would defend the metals from the acidic solution. By adding this painting step to our process we also needed to add a process that would deal with eliminating the paint from the metals after they were taking out of the solution, which was as simple as applying water to the paint through a high-pressured valve.

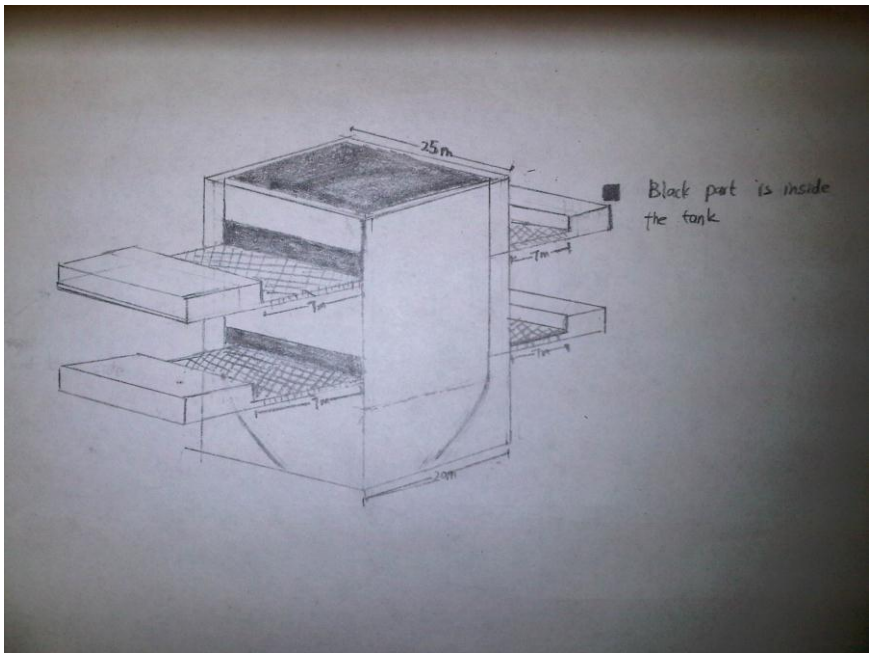
5.0 Detailed Design

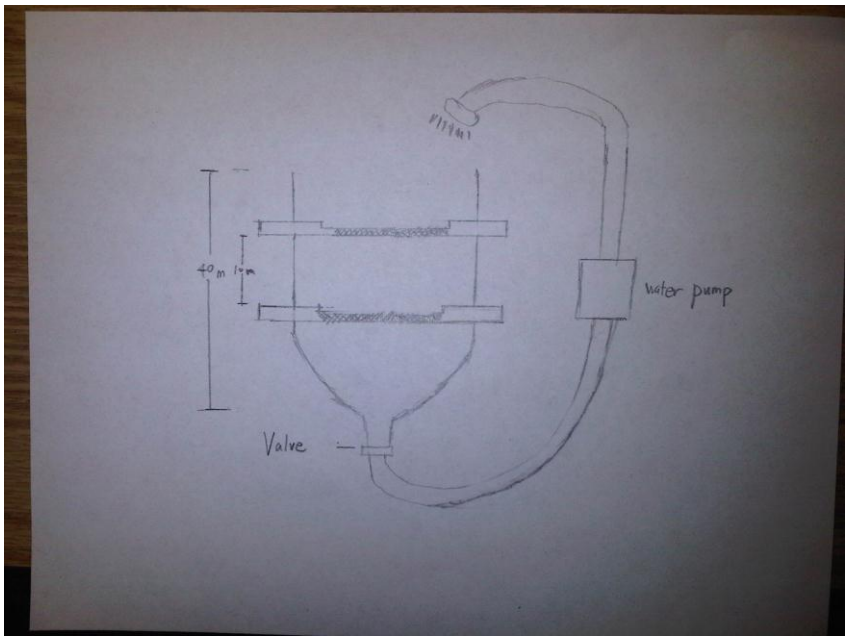
After get our car fragment stayed on a conveyor belt with width 1 m (all the same size), the conveyor belt will lead to a thinly slice machine operated by a worker. The machine will grind the car fragment into box shape. Then the sharp knife edge attach inside the machine with strong power will slice our car boxes into car pieces with about 5 cm* 1 cm each.



Car pieces will be dropped onto another conveyor belt with a strong magnet inside. The magnet is designed about 5m*0.9m*1.5m with semicircle shape gap (for wheel) at one end, and be fixed at one end of the belt. The inner height of the belt will be about 1.7m with (1.6m diameter 0.5m width) wheel attached at two ends. After the car pieces moved to the end with the belt, car pieces with material other than Fe, Co, Ni will fall onto the floor due to gravity and can be collected to continue with other separation process. Car pieces with material Fe, Co and Ni will be attracted by the strong magnet and will keep moving with the belt until the magnet does not make any magnetic force upon them.

After they fell onto another conveyor belt due to gravity, a cover is made for all iron pieces by using a spray head with anti-erosion protection paint. All the iron pieces will be collected after first paint and go through with the paint process again in order to make sure every pieces of iron are fully covered by the paint.





Following the paint process, iron pieces will move with conveyor belt to separation tank A which is designed to separate AHSS and Fe, Co and Ni.

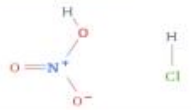
Input interpretation:

aqua regia

Chemical names and formulas:

formula	$3HNO_3 \cdot HCl$
compound formula	ClH_2NO_3
name	aqua regia
IUPAC name	nitric acid hydrochloride

Structure diagram:



Basic properties:

molecular weight	99.474 g/mol
density	1.76 g/cm^3
solubility	miscible in water

In order to use density to separate AHSS and Fe, Ni , Co. Density of our proposed solution is need at the range of 7.794g/cm3 (Density of AHSS) to 7.874 g/cm3 (Density of Fe, Ni, Co).Therefore, We defined our ideal solution a to have a density of 7.83g/cm3. In order to make our ideal solution a has a density of 7.83g/cm3, we use a solution has density below 7.83g/cm3 and a solution above 7.83g/cm3 which are mutually soluble. In other words, 'miscible'. Our first solution is liquid mercury (13.546g/cm3) , because it is above 7.83g/cm3 and it is in liquid form. A lot of research has been done in order to find a solution to be miscible with liquid mercury. Finally Aqua regia(lit. “royal water”) (1.76 g/cm3) was chosen. After calculation, our ideal solution a will be made with 48.5% Aqua regia dissolves with 51.5% liquid mercury. Following the step,Our ideal solution b which can separate Fe (7..874g/cm3)from Ni Co (8.9g/cm3) is defined has a density of 8.39g/cm3. After calculation, our ideal solutionb will be made with 43.7% Aqua Regia dissolves with 56.3% liquid mercury.Aqua regia(lit. “royal water”), or nitro-hydrochloric acid is a hghly-corrosive mixture of acids, a fuming yellow or red solution. The mixture is easily to be prepared by freshly mixing concentrated nitric acid and hydrochloric acid, usually in a volume ratio of 1:3.

6.0 Conclusions:

Our method is very successful and it is totally satisfy the project objectives. We use the 7 Systems (edge mill, magnetic system, spray paint system, density system, high pressure washing down system, transmission system and recycle system.) to help us separate Fe and AHSS from trash. The most important part is our density system. Different metal has different densities, so we use density to separate AHSS and Fe from trash. The result can be found very clearly, because the metal with lower density will float on the surface of the solution and the metal with higher density will be immersed in solution. The challenge of this method is how to find a solution which has a density between Fe and AHSS. Most of groups don't get the answer. However, we find it. Aqua regia (1.76 g/cm3) can be miscible with liquid mercury (13.546g/cm3). We can use these two solutions to create an idea solution which the density is between the Fe and AHSS (this technology has been talked in Section 5). Therefore, we can separate AHSS and Fe from trash and finish our project objectives successfully.

7.0 References:

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