Operation Elevation

Engineering Design 100
Section 016
Team 4
Submitted to Wallace Catanach on December 15, 2013

Mike Roszkowski  Yasemin Yaker  Asher Jabalon  Joaquin Hidalgo
Myr5401@psu.edu  yyy5174@psu.edu  Ahj5045@psu.edu  jyh5638@psu.edu
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Executive Summary

Alcoa Incorporated has a need to improve the energy efficiency, and increase sustainability on the Penn State campus and surrounding areas. The campus typically uses a variety of different materials in the construction of buildings. The need to increase the energy efficiency on campus is needed, to create a more sustainable environment and a more cost efficient model for the future. In order to do this Alcoa a manufacturer of aluminum parts has given us the task of increase the energy efficiency on campus by implementing aluminum parts in different areas around campus. The goal of the John Smith Agency is to implement the use of aluminum part by replacing elevator parts with new lightweight aluminum parts, making the elevator lighter and therefore requiring less energy to operate.

We encountered many options during the design process. After examining various aspects on campus that could be changed to utilize aluminum and brainstorming to come up with possible designs to make the campus more energy efficient; the best ideas seemed to be the ones that involved improving the already in place structures with new aluminum parts in order to make them more energy efficient and sustainable. After analyzing the company’s requirements, scoring and ranking our concepts we selected the best design, according to their needs.

This project presents us with many different types of problems. The main objective of the project is to make the campus and surrounding areas more energy efficient and sustainable by implement aluminum on campus. The only problem present in our designs is that our aluminum replacements would not perform as good as the replaced parts in terms of durability and resistance creating catastrophic consequences. This will be solved by running tests to make sure that the aluminum piece can hold the load that the non-aluminum piece could. Other smaller risk exist, such as making sure that the people who are installing the new pieces are trained in installing them can be fixed by training the maintenance staff to work with the new pieces. The final design produced by the john smith agency will be present to Alcoa Inc. on Thursday Dec. 5th, 2013.

Introduction

A team of four members was commissioned by Alcoa Inc., with the intention of finding ways to utilize aluminum a product that Alcoa produces. The group set out to find ways to utilize Aluminum on campus and find a way to implement it. Individually we went around campus and looked for different ways to implement aluminum around campus. We came together with our individual ideas, and selected the best ones. Customer needs were taken into account, while designing the prototypes. The prototypes were reviewed and the best ones were selected for further development. Research was done on: the different types of elevators, how elevators work, the durability of aluminum, and if aluminum would be able to be used in the system. Once the research was complete we selected the best idea and continued to develop that product. After the completion of the research we designed
an elevator that would utilize the many versatile properties of aluminum. A model was created and presented to Alcoa Inc. for approval.

**Mission Statement**

Our mission is to design a product that utilizes the multiply different properties of aluminum, while increasing the sustainability and efficiency of a product on either the Penn State Campus, or the State College Area.

**Needs Statement Analysis**

After determining that we would be designing an elevator we made a list of required things that we knew the elevator must be able to do. We made sure that the elevator would be able to work to the same ability as a traditional steel car elevator. The elevator was studied and a list of what an elevator needs to do was complied and ranked based off of which needs were the most important.

<table>
<thead>
<tr>
<th>Need Statements</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>The elevator has to be energy efficient</td>
<td>Kg x</td>
</tr>
<tr>
<td>The elevator has to include aluminum in its design</td>
<td>KW-h x</td>
</tr>
<tr>
<td>The elevator has to be affordable</td>
<td>Sec x</td>
</tr>
<tr>
<td>The elevator has to be durable</td>
<td>ft x</td>
</tr>
<tr>
<td>The elevator has to follow safety regulations</td>
<td>x</td>
</tr>
<tr>
<td>The elevator has to be time efficient</td>
<td>x</td>
</tr>
<tr>
<td>The elevator has to be able to carry at least 2500 pounds</td>
<td>x</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Need Statements Importance</th>
<th>Importance (1-5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The elevator has to be energy efficient</td>
<td>5</td>
</tr>
<tr>
<td>The elevator has to include aluminum in its design</td>
<td>5</td>
</tr>
<tr>
<td>The elevator has to be affordable</td>
<td>3</td>
</tr>
<tr>
<td>The elevator has to be durable</td>
<td>4</td>
</tr>
<tr>
<td>The elevator has to be recyclable</td>
<td>3</td>
</tr>
<tr>
<td>The elevator has to follow safety regulations</td>
<td>5</td>
</tr>
<tr>
<td>The elevator has to be aesthetically pleasing</td>
<td>2</td>
</tr>
<tr>
<td>The elevator has to be a positive improvement to the campus</td>
<td>4</td>
</tr>
<tr>
<td>The elevator has to be time efficient</td>
<td>3</td>
</tr>
<tr>
<td>The elevator has to be compatible</td>
<td>5</td>
</tr>
<tr>
<td>The elevator has to be able to carry at least 2500 pounds</td>
<td>3</td>
</tr>
</tbody>
</table>
External research

Research was done not only on the elevator and elevator requirements, but the company Alcoa and the product Aluminum as well.

ALCOA

ALCOA is the world’s third largest aluminum producer company, after Rio Tinto Alcan and Rusal. Headquarters in New York and it has an operational base in Pittsburgh, Pennsylvania.

WHAT DOES ALCOA DO?

ALCOA is the producer of primary aluminum, fabricated aluminum, and miner of bauxite and refiner of alumina (chemical form of aluminum oxide). Aluminum and alumina represents more than 3/4ths of Alcoa’s revenue. Alcoa is behind major milestones in the aerospace, automotive, packaging, building and construction, commercial transportation, consumer electronics and industrial markets.

Alcoa makes tire rims for cars, buses, vehicles, in addition

At the World Economic Forum in Davos, Switzerland, Alcoa was named one of the top three most sustainable corporations in the world. Employs 61,000 people in 30 countries around the world.

As long as Alcoa making aluminum, they have been recycling aluminum.

FINANCIAL STATUS

Income from continuing operations; 191 million dollars! Revenue of 23.7 billion dollars! Cash from operations of 1.5 billion dollars! Free cash flow of 236 million dollars

ALUMINUM

Aluminum weights about one-third as much as steel or copper. Some of the many uses for aluminum are in transportation (automobiles, airplanes, trucks, railcars, marine vessels, etc.), packaging (cans, foil, etc.), construction (windows, doors, siding, etc), consumer durables (appliances, cooking utensils, etc.), electrical transmission lines, machinery, and many other applications.

Elevators

The last and most important part of our research was on elevators themselves and how elevators work. These were necessary research that needed to
be done in order to improve the average elevator on the Penn State campus.

There are three main types of elevators that are commonly used on the Penn State campus, these include: hydraulic elevators, geared and gearless traction elevators with machine rooms, and Machine-Room-Less elevators. All of these elevators are similar and different at the same time. Mainly, they could all have aluminum implemented in them in many different ways.

The first type of elevator is the hydraulic elevator; a hydraulic elevator uses a large piston to push up an elevator car up to the floor, which is desired. They are typically only used in smaller buildings, with a max speed of about 200 feet per second. The machine room for the elevator is located on the lowest floor adjacent to the elevator shaft.
The Second type of elevator most commonly found on the Penn State Campus is the, geared and gearless traction elevator with machine rooms. These elevators usually have a cart that is guided by a guardrail, and is balanced by a counter weight, which uses a pulley system to move the elevator. The whole system is powered by a machine room, which is powered by a machine located at the top by the pulley system. These elevators can go a lot faster, and are commonly used in larger buildings.
The third and final type of elevator is the Machine-Room-Less elevator, which is similar to the traction elevator. The main difference between the two is that a MRL elevator has no dedicated machine room instead has the motor in the space above elevator shaft where the elevator would never have to go. Like traction elevator a pulley system with a counter weight is used to move the elevator. They use less energy than the standard elevator and are becoming more popular in mid
size building where they are most effectively used.


### Benchmarking

<table>
<thead>
<tr>
<th>Material</th>
<th>Volume of the Car (m3)</th>
<th>Density of the Material (Kg/m3)</th>
<th>Mass of the car (Kg)</th>
<th>Annual Energy Consumption (KW-h)</th>
<th>Annual Cost($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>6.307</td>
<td>7850</td>
<td>2355.0</td>
<td>14157.0</td>
<td>1414.0</td>
</tr>
<tr>
<td>Aluminum</td>
<td>6.307</td>
<td>2712</td>
<td>813.60</td>
<td>9781.8</td>
<td>977.0</td>
</tr>
</tbody>
</table>

We compared both, the traditional design and the aluminum design we proposed and found that the energy consumption and cost has a radical decrease. The proposed cost of an aluminum elevator is only 70% of the cost of the average steel elevator.

### World Market

The elevator market is expected to reach $16.45 billion by 2018.

The major players in this industry include Kone Corporation (Finland), Otis Elevator (U.S.), Schindler (Switzerland), ThyssenKrupp (Germany), and others.

The inflexible regulations being enforced by the governments developed by the increasing need to save operational costs by building manager/owners has enhanced the demand for elevator access controls and security, automation, and modernization.

With elevators being readily used pretty much everywhere in the world today, there are endless opportunities to utilize aluminum in elevators. If elevators made with aluminum are cost efficient and still effective. These elevators could be implemented all around the world in order to save companies money. If designed correctly aluminum could be used in elevators all over the world.
Product Dissection

In designing an elevator that is both sustainable and energy efficient we need to look at what could be done to the elevator in order to make it better. Many parts of the elevator could be replaced with aluminum, but there are many opportunities to create a product that could be dangerous by not using the right material in the right place. We researched the different components of an elevator and examined which could be replaced with aluminum.

There are many components that make up an elevator with many of them
being crucial to pressure and heat. This being said some parts of the elevator should not be redesigned using aluminum, some of these parts include the: machine drive, over speed governor, and Control Cabinet. These pieces are essential to making the elevator run and without redesigning the entire piece would not be good to redesign with aluminum. These pieces are under a lot of pressure and would be better with a strong material than aluminum. These are also the motor pieces that power the elevator and would be better off not being touched.

There are other parts of the elevator system, which wouldn't be good to replace with aluminum. These parts include the counter weight which is traditionally made of steel and since aluminum is less dense than steel, we would just be making the counter weight bigger. The landing doors could be made out of aluminum but since they're really only they're for safety and aesthetic appeal, making them aluminum wouldn't really do anything. Other than this aluminum could be implemented in all other parts of the elevator.

**Concept Generation**

To find the best way to implement aluminum campus we researched different ways aluminum could be used. After researching the multiple uses of Aluminum, we considered aluminum's many different properties and compared their pros and cons.

- **Recyclability**
  - Aluminum is a highly recyclable material which can be reused through collection of unwanted aluminum, and shipping off to a recycling center where the unwanted aluminum is melted down and formed into usable metal.
  - **Pros:**
    - Highly recyclable
    - Easy to collect
    - Valuable in large quantities
  - **Cons:**
    - Many places already have aluminum recycling programs set up.

- **Light Weight**
  - Aluminum is a very lightweight material, and in totals weights about a third of the weight of steel.
  - **Pros:**
    - Makes products lighter
    - Reduces energy required to move an object
    - Reduces dead weight
    - Paired with other materials to make alloys increase strength.
  - **Cons:**
- Is not as strong as some metals on its own
- Can be a safety hazard, if not monitored for load maximum.

- Corrosion Resistance
  - Aluminum is a highly corrosive material and can be exposed to water without rusting.
  - Pros:
    - Creates a protective oxide coating
    - Anodizing, and other processes can improve this property
    - Useful where protection and conservation are required
  - Cons:
    - Many other materials have the same properties when other processes are applied to them.
    - Becomes more expensive the more processes are done to it.

- Reflectivity
  - Aluminum is a highly reflective material, which can reflect many things such as heat, light, etc.
  - Pros:
    - Can be used as insulation for heat
    - Can reflect light
  - Cons:
    - Is heavier than most insulation
    - Is not a great reflector of light.

- Impermeable and odorless
  - Aluminum is great as block visible light and has no odor.
  - Pros:
    - Can be used with light sensitive things
    - Has no odor
  - Cons:
    - Aluminum shares these properties with many different types of materials.

Aluminum has many different properties, which helps to make it one of the most useful materials on earth. After comparing which properties would be useful in the design of an elevator. We quickly eliminated Impermeable and odorless, reflectivity, and corrosion resistance from our list of design points. This left us with high recyclability and lightweight. From these concepts we designed many ideas that would these properties in order to improve the efficiency of an average elevator and improve the sustainability of campus.

After completing our research we narrowed the list of ideas down by using a concept vs. needs statement ranking chart. This allowed use to ranking system to pick the best ideas, and combine some ideas to make better ideas.
In the end we selected two ideas, the aluminum car idea, and combined the aluminum cable and aluminum interior to make a second final idea. From this we took the best ideas, and paired the good ideas to make them better.

Concept Selection

In order to decided which concept would be best we compared the best two concepts and compared them in the same areas. As a group we weighted the areas and then compared to the two concepts, and the concept with the overall highest rating was selected.

<table>
<thead>
<tr>
<th>Need Statements</th>
<th>Weight</th>
<th>Concept (A) Cart</th>
<th>Concept (BC) Wire + Indoor</th>
</tr>
</thead>
<tbody>
<tr>
<td>The elevator has to be energy efficient</td>
<td>25%</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>The elevator has to include aluminum in its design</td>
<td>10%</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>
The elevator has to be affordable | 10% | 3 | 2
---|---|---|---
The elevator has to be durable | 15% | 4 | 4
The elevator has to follow safety regulations | 30% | 5 | 5
The elevator has to be time efficient | 5% | 5 | 4
The elevator has to be able to carry at least 2500 pounds | 5% | 5 | 4

Total | 100% | 32 | 28

From this Concept Selection Chart we were able to decide that the best concept was the Aluminum Cart.

Embodiment Design
Final Design Description

The design of the elevator is a standard geared and gearless traction elevator with machine room. It has the same dimensions as a normal elevator and from the outside appears the same as a regular steel car elevator. The only difference is that the steel, which is normally used to build the car, is replaced with aluminum.
Conclusion

Through the process we were able to design an elevator, which has been modified so that it utilizes the many different properties of aluminum. We started by examining where on campus aluminum could be implemented; from here we generated ideas that would effectively use aluminum on campus. From here we did research on multiple different items eventually deciding to work with elevators since, it appeared that if aluminum were implemented on elevators that the weight reducing would save a good amount of energy required to lift the elevator up to the desired floor. The next step was to decide what part of the elevator could be rebuilt with aluminum. We did some research on the different parts of the elevator and how it works; we then eliminated parts that would be under high pressure eliminating any chance of a system failure. From there we selected the part that would have the largest overall impact if made into aluminum, and we selected the car. At this point in time we started to design models for our prototype. We designed both a solid works model and a real life-working model. Overall if the car of an elevator were switched to aluminum we would reduce the weight of the elevator by around 34.5%, but to provide the same resistance as steel, we switched it to a 20% weight reduction, this would save around 1.2% of the overall energy used to power the elevator, which applied to multiple elevators would save thousands of dollars annually.