The Hybrid Train
Sponsor: GE

EDSGN 100: Introduction to Engineering Design

Section 010, Team 2
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Abstract

This project report will cover Team 2’s solution to GE’s problem: smog levels in Pittsburgh. The report contains: table of contents, an introduction, a description of the design task, the design process and approach of Team 2, pictures of the prototype, an analysis, a summary and the team’s PowerPoint presentation.
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Introduction

Pittsadelphia was facing an environment pollution problem as a result of Tier 2 locomotive, engine-emitted NOx. To meet EPA (Tier 3 or higher) requirements, Pittsadelphia was looking for the design of a cost-effective freight shipping system that reduced smog and met EPA requirements. At the same time, the freight capacity into and out of city should be maintained or increased.

This report presents the steps taken by our team to design and develop a system for the city that met all of the criteria. The approach to each design, final design, prototype and the engineering analysis of the chosen design are documented in this report.

Description of Design Task

Problem Statement:

The problem is that the city of Pittsdelphia has a severe smog problem which needs to be addressed in order to meet EPA requirements.

Mission Statement:

The mission was to produce a cost effective system for Pittsdelphia that exceeded or met EPA requirements for NOx and PM without decreasing the volume of freight.

Design Specifications:

The team’s focus for this design project was to create the best possible solution to Pittsdelphia’s smog problem, all while keeping the costs at a reasonable level. Therefore, the team decided to sell the current fleet of tier 2 locomotives and use the money to purchase fewer, more expensive, yet more eco-friendly hybrid trains.
Design Approach

Gantt chart

Table 1. Gantt chart

Concept Generation
FIG. 1. Tier 2 Train with Summary

Tier 2 locomotives, however, are cost-effective but do not meet EPA requirements. Additionally, locomotives are a relatively fast method of shipping.

We would transfer our freight shipping from trains to ships. We would ship large ships to port and from there we would have trains (tier 4) to transport the freight locally. This would be very...
FIG. 2. Cargo Ships with Summary

Aftertreatment system.

Mixing section: \( NO + CO = \frac{1}{2} N_2 + CO_2 \)

\[
\begin{align*}
\text{SCR} & \quad \text{n}_2 \\
\text{n}_2 & \rightarrow \text{SCR} \\
\text{SCR} & \rightarrow \text{NH}_3 \\
\text{O}_2 & \rightarrow \text{H}_2 \text{O}
\end{align*}
\]

\[
\begin{align*}
4\text{NO} + 4\text{NH}_3 + \text{O}_2 & = 4\text{N}_2 + 6\text{H}_2 \text{O} \\
6\text{NO}_2 + 8\text{NH}_3 & = 7\text{H}_2 \text{O} + 12\text{H}_2 \text{O} \\
\text{NO} + \text{NO}_3 + 2\text{NH}_3 & = 2\text{N}_2 + 3\text{H}_2 \text{O}
\end{align*}
\]

Aftertreatment system use Ammonia for NOx Reduction. With above chemical reactions and also improved durability.

FIG. 3. After Treatment System with Summary

Freight by air: have the freight be moved by plane rather than by rail. Flight would be extremely expensive, not energy efficient, and will not hold as much as a train or boat.
Summary of Hybrid

The Hybrid train includes a large battery, inverter/ converter and an AC induction motor with generators in the wheels. We will sell our prior tier 2 trains and upgrade them all to the 30% more efficient hybrid systems.

Design Concept Selection
Table 2. Design Matrix Part One

<table>
<thead>
<tr>
<th>Selection Criteria</th>
<th>After Treatment System</th>
<th>Hybrid</th>
<th>Reference (Tier 2-Tier 3)</th>
<th>Shipping the Freight</th>
<th>Flight</th>
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<td>Cost</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Public Opinion</td>
<td>-</td>
<td>+</td>
<td>0</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Emissions</td>
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<td>+</td>
<td>-</td>
</tr>
<tr>
<td>On time delivery</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Capacity</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Sum of +'s</td>
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<td>2</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Sum of 0's</td>
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<td>2</td>
<td>5</td>
<td>0</td>
<td>1</td>
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<tr>
<td>Sum of -'s</td>
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<td>1</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
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<td>0</td>
<td>1</td>
<td>-2</td>
</tr>
<tr>
<td>Rank</td>
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<td>3</td>
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<td>Continue?</td>
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<td>No</td>
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</table>

Table 3. Design Matrix Part Two

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<th>Rating</th>
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<th>Rating</th>
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<th>Weighted Score</th>
</tr>
</thead>
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<td>3</td>
<td>0.75</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Public Opinion</td>
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<td>5</td>
<td>0.45</td>
<td>3</td>
<td>0.27</td>
<td>1</td>
<td>0.09</td>
</tr>
<tr>
<td>Emissions</td>
<td>40%</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>1.2</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>On time delivery</td>
<td>15%</td>
<td>3</td>
<td>0.45</td>
<td>3</td>
<td>0.45</td>
<td>1</td>
<td>0.15</td>
</tr>
<tr>
<td>Capacity</td>
<td>11%</td>
<td>3</td>
<td>0.33</td>
<td>3</td>
<td>0.33</td>
<td>4</td>
<td>0.44</td>
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<tr>
<td>Total Score</td>
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<td></td>
<td>3</td>
<td></td>
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<td>3.68</td>
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<tr>
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<tr>
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<td></td>
<td></td>
<td>No</td>
<td></td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>

Description of the best design selected

The best design selected is a Hybrid train. Its parts that make it Hybrid include a lithium-ion battery, an Inverter/converter, an AC induction Motor, and wheels with a motor/generator inside.

Prototype

Design Drawings
FIG. 6. Final Train Assembly Drawing
FIG. 8. Engine Detail Drawing
FIG. 9. Inverter Detail Drawing
FIG. 10. Train Base Detail Drawing

Prototype

FIG. 11. Prototype Picture
Design Features

The design includes wheels that cause the converter to charge the battery to power the locomotive. The engine is smaller and uses less diesel fuel. The battery is small and can get the train up to speed so it does not use as much fuel when fuel consumption is at its worst.

Analysis

Rationale

The design selected exceeds expectations of an average Tier 4 train. These is a 70% reduction in PM and NOx, immensely decreasing the amount of smog and emissions in the atmosphere. This is also shown by the 30% reduction in fuel. A Hybrid train is ran by a battery, but this battery will last for twenty years. Although the current Tier 2 trains are sold, no freight is lost due to the purchase of all Tier 4 trains. This may sound expensive, but a Hybrid train is actually saving over $600,000 daily, which is $40 billion over the span of two years.

Concept of Operation

The goal of the Hybrid train is to meet EPA requirements of PM and NOx standards without decreasing the volume of freight. The Hybrid train includes wheels that will set off the converter to charge the battery that powers the train. This battery will last longer than regular fuel or coal lasts in a locomotive, saving time and money. Responsibilities of keeping a Hybrid train delegated includes making sure the battery is changed every twenty years.

Life Cycle Analysis

FIG. 12. Life Cycle Analysis
Feasibility Assessment

An important aspect of the Hybrid train includes the necessity of the wheels. Not only is this a source of movement for the train, but the wheels create power that cause the converter to charge the battery. These wheels can work with the converter to power the battery for twenty years.

Economic Viability

45 Tier 2 trains cost $67.5 million in total revenue. The total revenue divided by the cost of a Tier 4 train yields 15 Tier 4 Hybrid locomotives. This costs a total of $202.5 million. Hybrids save 30% in fuel, so $607,500 is saved daily, saving 40 billion dollars within two years.

Summary/Conclusions

The hybrid locomotive system is one of the best ways to solve Pittsadelphia environment pollution problem. The Hybrid system will not only save up to 30% fuel consumption, but also reduce the NOx and PM emissions by up to 70%. Overall, the team was satisfied with the final design because it meets the design requirements and includes ideas from each member. During this project, members gradually became familiar with the standard engineering design process, learned where to find material resources, and practiced problem-solving skills. In short, creativity and participation of every single member on the team lead to the success of getting the final design and prototype done.
**Tier 2 and Tier 4**

It takes $450,000/day to move 15 freight trains (7000 tons) into the city and 15 freight trains (5000 tons) out of the city.

**Tier 2:**
Extreme amounts of NOx and PM produced
- 22,275mg of NOx and 810,000,000mg of PM produced per day by 45 trains

**Tier 4:**
The amount of NOx and PM produced is significantly decreased from Tier 2
- 12,175mg of NOx and 162,000,000mg of PM produced per day by 45 trains

How can a system meet EPA standards for NOx and PM without decreasing the volume of freight?

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**Mission Statement**

To produce a system for Pittsdelphia that meets or exceeds EPA standards for NOx and PM at the lowest possible cost, without decreasing the volume of freight.
What's our plan?

Sell our current fleet of tier 2 trains ($67.5M revenue)

Purchase trains that have the hybrid system implemented to meet tier 4 emission requirements

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**Monetary**

45 (current tier 2 trains) * $1.5 million sales price = $67.5 million total revenue

67.5 (total revenue)/ $4.5 million hybrid tier 4 cost = 15 tier 4 hybrid locomotives

45 (tier 4 trains) * 4.5 (million per train) = 202.5 million total

135 million in costs

Hybrids save 30% fuel

2,025,000 (cost of diesel per day) * .3 (efficiency) = 607,500$ saved daily

1478250000 (cost of fuel currently) - 1034775000 (hybrid cost of fuel) = 40 billion dollars saved in 2 years
Conclusion

Advantages:
1. Saving up to 30% fuel consumption.
2. Reducing 70% NOx and PM emissions.

Disadvantage:
1. Increasing cost.

References


"Coal Prices and Charts - Data from Quandl." Coal Prices and Charts - Data from Quandl. N.p., n.d. Web. 10 Dec. 2015.

