Capstone project – Design an engine dynamometer to provide an Air Pollution Reduction Solution (APRS) in developing communities

Emily K. Bierman, Peyton A. Campbell, Jeffery M. Plumblee, and Jason Howison
The Citadel

Abstract

Air pollution is a global issue, both caused and felt by those in developed and developing communities. This paper will dive into the process and challenges of designing and constructing an engine dynamometer and developing a prototype solution that is economically feasible and technically appropriate for developing countries. Discussion includes how to ensure that students understand cultural and social context of the problem and proposed solutions, challenges and solutions to a multi-year research project largely executed by multiple cohorts of students in single-year capstone experiences, and how to extrapolate these initial successes in real-world global senior design projects at The Citadel and elsewhere.

Keywords

Senior Capstone, Air Pollution, Engine Exhaust, Engine Dynamometer, Humanitarian Project

Introduction

The United States and many other developed countries have laws that regulate the amount of pollutants that on-road and off-road engines may produce. These regulations for engine exhaust pollutants do not exist in every country, or they are not stringently enforced. A capstone project is underway at The Citadel to build an engine dynamometer for single cylinder engines, which will test potential solutions related to air pollution reduction in internal combustion engines. Currently, The Citadel does not have an engine lab; however, it does have three single cylinder diesel engines available for research. The long-term goal for this project is to complete testing with these engines and a variety of fuels and develop a solution to reduce the pollution produced in on-road vehicles that are most commonly operating in Central and South America. Pollution levels in many Central and South American cities have reached an unacceptable level that is harmful to human health, specifically to the respiratory system.[1] In addition to the alarming pollution levels of this region, the decision to initiate this student-centric research in this geographic area is due to accessibility and feasibility for faculty and students to travel.

Capstone Project

Over the course of two semesters, students within a capstone team at The Citadel complete a mechanical engineering project. The first semester is for designing and the second semester is for developing a fully functional prototype. Currently, two capstone teams are within the first semester of the senior design class in which the teams' requirements include many aspects of designing and presenting the project as if it were a startup company. Explicit tasks of the first

semester's part of the course include developing concepts, determining potential customers, analyzing the target market, and distributing surveys to create customer requirements. Following these steps, the students are to develop a final concept. The final concept includes engineering drawings and/or 3D CAD models. The students must then create a functional decomposition of each subsystem. Students must also perform necessary calculations and simulations for an engineering analysis of their projects. A bill of materials each group develops provides parts necessary to build the dynamometer. The parts are ordered between fall and spring semesters.

The goal of the dynamometer capstone teams is to design and develop an engine dynamometer that is cost effective and portable so that it can be used in various facilities. Primarily the target market for the team is smaller, teaching-based universities that like to promote student research and hands on labs for engineering majors, including undergraduate and/or graduate level courses.

Three Yanmar L70-AE engines, shown in Figure 1, were donated by the University of Wisconsin to The Citadel Department of Mechanical Engineering. The Yanmar L70-AE is a single-cylinder, diesel engine that has a variety of uses ranging from powering generators, to running various small engine vehicles. The donated engines are missing some components. The teams will determine which components are missing, order replacement parts, and assemble them. The goal is to assemble two operational engines from the three partial engines. The capstone design project is intended to be suitable for these specific engines.

Figure 1: Yanmar L70-AE Single-Cylinder Diesel Engine

Research in Parallel with Capstone Project

While the engine dynamometer is under construction, research is underway in effort to be able to start testing as soon as the capstone project is complete. A trip to Guatemala will occur on January 4th to 8th, 2020. During this trip, the author will perform field research with the following research questions in mind:

1. What is the primary means of public transport?
2. Where are the vehicles used sourced from?
3. What laws and regulations are in place concerning allowable fuels and vehicles? (both at a local and national level)
4. Do automobiles, buses, and motorcycles require inspections, and if so, what does the inspection process entail?
5. What types of fuel are used? Where is it sourced from?

After the trip, the author will set a target percentage of reduction in particulate matter (PM) from on-road vehicles. PM is mostly black carbon produced from diesel engines exhaust, which is harmful to human health.[2] An engine exhaust filter provides a solution for this goal. The specific filter is what needs to be determined. Research will be underway to find a material that is able to reach the goal. The material of the filter should be as close to a renewable material as possible, as well as be inexpensive and lightweight. The filter will need to be cleaned or replaced after the PM builds up enough to cause a backpressure on the engine. In the U.S. and other developed countries, a filter shown in Figure 2 is used. The PM builds up on the walls of the filter. This prevents the PM from contaminating the environment. This filter is expensive and has a short time in which it needs to be cleaned. A filter that cleans the exhaust this significantly is not a requirement for this current project because there are not a stringent target for the PM levels.

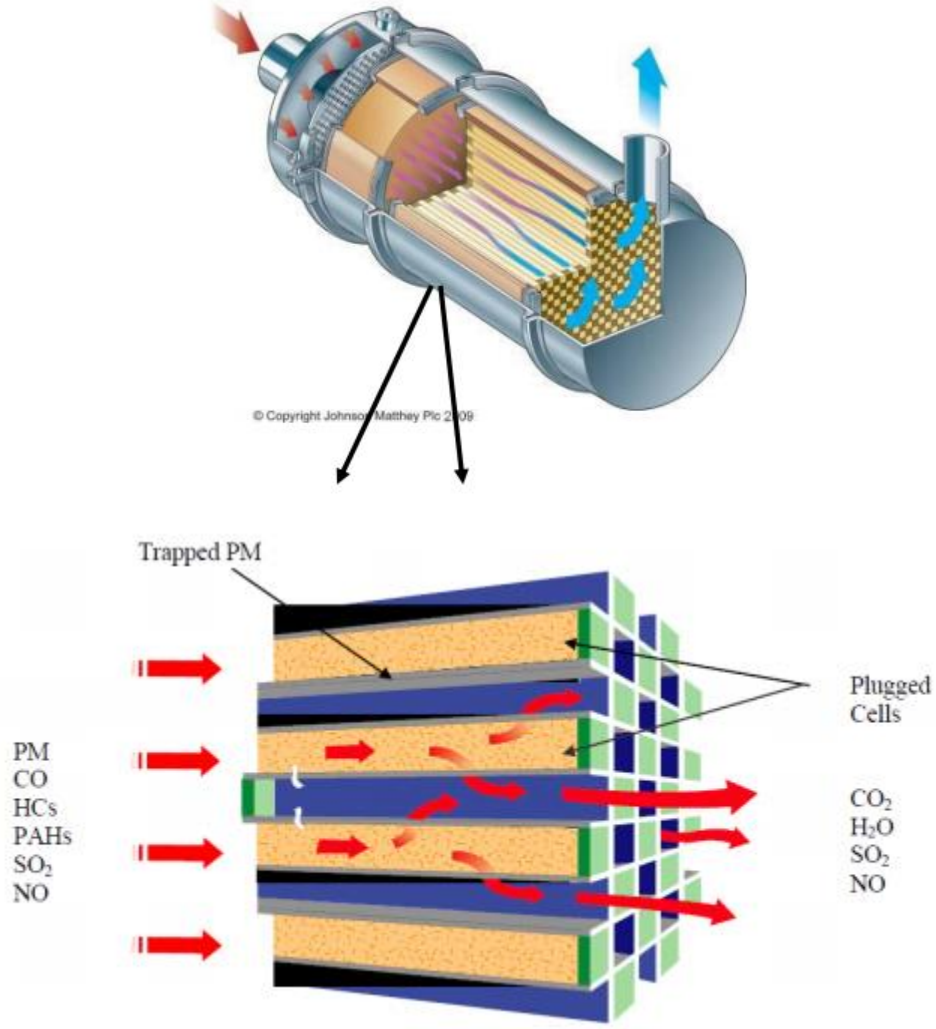

Figure 2: Example of Diesel Particulate Filter in Production in the U.S. [3]

In order to determine the amount of PM in the exhaust, an engine is operated on an engine dynamometer. Part of the exhaust goes through instrumentation that determines the levels of particulate matter in it. An Engine Exhaust Particle Sizer (EEPS) is ideal for the type of testing necessary.[4] This is instrumentation is from TSI.[5] The cost of this equipment may make it necessary to use an alternative instrument. A Micro Aethalometer may be adequate for the type of reduction considered for this testing. Once the engine dyno is complete, the engine will perform a standard test to compare different exhaust filter solutions with fuel that Guatemala uses. This project has many hurdles and it will be challenging to get funding to provide the solution to the developing countries. Ways to enforce and implement the solution are unknown at the time.

Benefits to the Students

Using the capstone project for research development provides additional benefits for the students. The project exposes students to processes necessary to do research. A student who may not think he/she wants to conduct research may discover research is in his/her interests. A capstone project specifically for research exposes the student to the advisor(s) that complete research and the types of research. The opportunity for a research capstone project provides students opportunities to then conduct research once the capstone project is over. In the specific case of the engine dynamometer development, one of the students on the teams asked to do an independent study in parallel with the capstone project specifically on the engines that are tested on the dynamometer.

Working on a project that leads to work in developing countries gives the students the opportunity to learn about the developing countries needs and consider ways that contribute to mitigating the issue. A long-term goal of this type of project is to lead to opportunities where students could visit developing countries and determine if a solution is feasible.

The Citadel currently monitors job placement rate of the graduating students. Because The Citadel is a military college, there is a percentage of students that go directly to the military instead of the workforce. The students involved in this project will be specifically monitored to see if the student gets hired into industry, enters the military or does not get a job within the first three months of graduation. The percentage of the successfully hires will be compared to the overall class average to determine if there is a significant difference.

Future Work and Conclusions

This project is in its infancy and has copious tasks to be completed. The current priorities include providing the two student teams the knowledge of building the engine dynamometer using the outlines provided in the capstone project class and getting the Yanmar engines operational. This project prioritizes providing the students with experience in working on projects that positively affect the global environment. It provides the student the additional benefit of learning about research processes and opportunities, with the possibility of experiencing work done in developing communities.

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Dr. Emily K. Bierman, The Citadel

Emily Bierman received her B.S. in Mechanical Engineering from Purdue University, her M.B.A. from Clarke College, her M.S. in Mechanical Engineering in Engine Systems (MEES) from University of Wisconsin, and her Ph.D. in Mechanical Engineering from North Carolina State University. She completed internships at Caterpillar, Ford and GM. She worked for John Deere in the Construction and Forestry Division as well as the Power Systems Division. She worked for Cummins in the High Horse Power group for two years. She is now an assistant professor in the Mechanical Engineering Department at The College.

Peyton A. Campbell, The Citadel

Peyton Campbell is a senior in Mechanical Engineering at The Citadel.

Dr. Jeffery M. Plumblee, The Citadel

Dr. Jeffery Plumblee is an Assistant Professor in the Department of Engineering Leadership and Program Management (ELPM) in the School of Engineering (SOE) at The Citadel. Dr. Plumblee earned his BS in Civil Engineering at Clemson University (2008), Masters in Civil Engineering at Clemson University (2009), MBA at Clemson University (2013), and PhD in Civil Engineering at Clemson University (2013). Plumblee's research interests focus on building a more resilient society, as well as innovation and entrepreneurship in resource constrained settings (primarily humanitarian technology and delivery). He continues to drive innovation of engineering and entrepreneurship experiential learning through new initiatives at The Citadel.

Dr. Jason Howison, The Citadel

Jason Howison is an Associate Professor in the Department of Mechanical Engineering at The Citadel. He earned a B.S. in Mechanical Engineering at Clemson University, an M.S. in Mechanical and Aerospace Engineering at the University of Virginia and a Ph.D. in Aerospace Engineering at the University of Tennessee. He is a registered professional engineer in South Carolina. His research interests include computational fluid dynamics, aeroelasticity, and engineering education.