Capstone Project: String Wound Cartridge Filter Restoration Project

Jeffery M. Plumblee, Salvatore Coluccio, Donald Price, Emily Bierman, and Jason Howison
The Citadel

Abstract

Access to clean water is a challenge in many developing contexts. Cartridge filters, paired with chlorine tablets, are commonly used as a water treatment solution in small, rural communities. These cartridge filters are often imported, are relatively expensive, and after their useful life, regularly end up as litter due to lack of waste management system. This paper discusses a capstone design project intended to create a viable solution to extend the usable life of string wound cartridge filters. It also discusses how the project is being planned and executed in the capstone class, including a description of the proposed solution, testing protocol, preliminary results, and a path forward for more thorough testing and iteration.

Keywords

Water treatment, senior design, capstone, humanitarian design, sustainability

Introduction

According to the World Health Organization, 780 million people across the world do not have access to a safe water source.[1] Oftentimes, these water sources are contaminated and can cause users to become ill. The United Nations has repeatedly identified clean water as a pressing global issue, delineating "Clean Water and Sanitation" as one of their sustainable development goals.[2] Water treatment generally consists of four steps: coagulation and flocculation, sedimentation, filtration, and disinfection.[3] This capstone project, and the work presented in this paper, focuses primarily on the filtration phase of the process.

Water filtration can occur in a variety of different ways, depending on context. For decentralized, small-scale developing communities, the relatively low flow, unreliable electricity, and need for inexpensive solutions lends itself to sand filtration or cartridge filtration. Cartridge filtration is particularly attractive when the user would like to implement a modular system that can be placed in-line. These cartridge filters range in maximum passing particle size from 0.5 micron to 150 micron, and include string wound cartridge filters, melt-blown cartridge filters, activated carbon cartridge filters, and pleated cartridge filters.[4] String wound cartridge filters are the most versatile among these options, as they provide a range from 0.5 to 150 microns and are appropriate under a wide range of turbidities and flow rates. These may also be placed in series for progressively finer filtration.

Unfortunately, the filters often must be imported. Furthermore, insufficient waste management systems lead to these filters littering the area surrounding the water systems. This research explores methods to extend the usable life of string wound cartridge filters, which could reduce waste, reduce import costs associated with new filters, and improve developing economies by creating a mechanism for locals to support the maintenance of their water systems. The research project takes place within the context of a mechanical engineering capstone course and is led by an undergraduate team of five students. The following sections detail the capstone course, as well as how this project has progressed along its timeline.

Design Process

The mechanical engineering capstone course at The Citadel takes place during both semesters of the senior year. During the first semester, students focus on understanding their project needs, developing designs, and planning for execution. The second semester primarily consists of constructing and testing a fully-functional prototype. The goal of the capstone process is to coach students through the engineering process with a focus on design, innovation, and economics, as detailed in Figure 1. This is reflected through assignments like participating in the Baker Business Bowl, a "Shark Tank"-like pitch competition that lasts two semesters with a grand prize of $10,000, and crafting elevator pitches for the product. The semester is broken up into five three-week periods, with each period having a different team member act as team leader.[5]

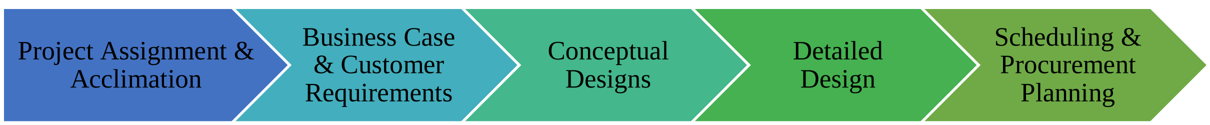

Figure 1: First Semester ME Capstone Process

Project Assignment & Acclimation

Brief project scopes are submitted by local companies and industry partners, as well as faculty across multiple departments on campus.[6] These are submitted early during the spring semester of the junior year so that the projects will initiate and are vetted by mechanical engineering faculty for suitability as capstone projects. Later that semester mechanical engineering students rank the projects by preference. Over the summer, teams are assigned to projects and meet with their advisor to discuss and clarify the project scope.

Business Case & Customer Requirements

During the Business Case & Customer Requirements phase, the String-Wound Cartridge Filter (SWCF) Team generated a more detailed scope of their project, created a project concept, identified relevant stakeholders and targeted customers, and surveyed potential customers to determine customer requirements. The team determined that the primary customer requirements included cost, complexity, ease of use, portability, repairability, time requirements for use, and durability. The target audience was determined to be prospective business owners in developing communities who may sell the reprocessed filters, and the end user would be heads of household or community leaders in small developing communities. The SWCF team also developed the following elevator pitch:

"Every day, members of third world countries use string wound water filters to clean the sediment out of their water. These filters are used daily but are not replaced often due to the poor economy. The product that we have here allows for local businesses to reuse these high demand filters by simply unwinding the string, cleaning it and rewinding it. Doing so allows for

the local villages to have access to cleaner water which will help improve the quality of life which in turn improves the local economy. A small, sellable, machine can make a large impact in the world and we need your help to fund this project. Let's seize the opportunity and change the world."

Conceptual Design

During the Conceptual Design Phase, teams create hand sketches or 3D models of different design permutations for major subsystems. Then they determine the criteria by which their preliminary conceptual designs will be compared. The teams then select a final design concept to move forward to the next phase. The SWCF Team broke their design into three major assemblies: the cleaning section, winding section, and crank section. The team used a Pugh Chart to determine that a bicycle sprocket and chain would be the most appropriate cranking mechanism when compared to an electric motor, a belt and pulley system, and a direct crank system.

Detailed Design

The detailed design phase is dedicated to refining the designs created in the conceptual design phase. After selecting the conceptual designs that best meet the established criteria, teams work to create accurate models, prototypes, and manufacturing plans for their design. This stage requires a full CAD model of the prototype to give students, instructors, and stakeholders a visual representation of what the team will produce in the spring semester. The CAD model, shown in Figure 2, also drove development of the bill of materials for ordering parts in future phases. In Figure 2, the dirty filter is shown in brown, beveled rollers in green, the brush cleaning mechanism in red, the grooved roller in tan, the cleaned filter in dark grey, and the PVC frame and crank assembly in light grey.

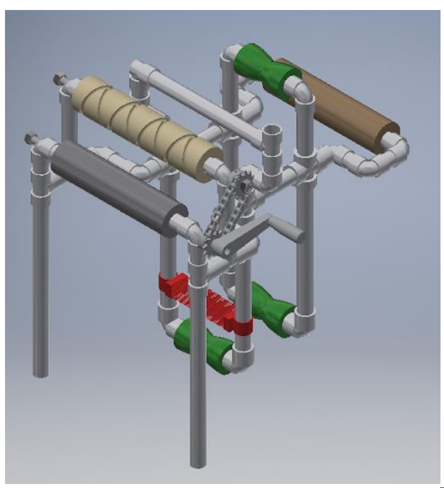

Figure 2: SWCF CAD model

Scheduling & Procurement Planning

The last phase of the semester focuses on preparing each team for the second semester of the capstone course. Each team submits and revises a detailed bill of materials, which is used to place orders over winter break. Students also present their semester report to classmates, faculty, and other advisors. To create a roadmap for the following semester, students develop a project plan and Gantt chart.

Conclusions

The SWCF Team has completed the detailed design, developed a bill of materials, ordered parts, and is ready to begin construction and testing during the Spring 2020 semester.

To ensure that the rewound filters meet the same filtrations specifications as new filters, The Citadel Humanitarian Development Club is constructing a testing system that includes a large tank and pumping system following ASTM's[7] guidelines in "Standard Practice for Determining the Performance of a Filter Medium Employing a Multipass, Constant-Rate Liquid Test." Pre-treatment and post-treatment results will be compared to one another for both new and rewound filters, primarily analyzing post-treatment particle size distribution, turbidity, and filter life span.

In a broader context, if this project is successful and the rewound filters meet pre-use specifications, further research should be conducted to field test the product for reliability, quality control, and site-specific challenges. The product should undergo further iteration based on these results, including potentially modifying materials based on local availability. Additionally, if the product becomes viable for widespread adoption, surveys should be conducted in target markets to determine the best go-to-market strategy and business model for implementation.

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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.

Salvatore Coluccio, The Citadel

Salvatore Coluccio is a senior in Mechanical Engineering at The Citadel.

Donald Price, The Citadel

Donald Price is a senior in Mechanical Engineering at The Citadel.

Dr. Emily 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.

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.