Propellant Formulation of an M-Class Rocket Motor

A Study of Mysore Rocketry and British Colonial Attitudes

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By
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

The goal of my capstone is to research into the technical and STS aspects of solid propellant rocketry. My technical project will focus on my work on the propellant formulation of a student-built rocket designed to reach 5,000 feet. My proposed STS project will be a study of the Mysorean rockets and British colonialism.

Rocket propulsion is an important part of modern life. Rockets deliver into orbit satellites that handle modern navigation, television, and internet services. Rockets also serve important purposes in propelling scientific and humanity-furthering missions into space. The most important component of a rocket is the fuel that enables it to reach the heights of the atmosphere. Although liquid fuels are more commonly used in large rockets, solid fuels are a less expensive, simpler, and safer way to power a rocket (Pradhan, Kedia, and Kour, 2020). Developing those fuels for the safest possible production and use is of vital importance as we continue to send tons of material into space now and into the future.

Our technical project explores the challenging task of designing, manufacturing, and testing a student researched and developed (SRAD) M-Class solid propulsion system. Solid rocket motors are separated into several different classes, with M-Class motors having large total impulses (total impulse is the amount of thrusting output by the rocket over the period of its engine burn) – ranging from 5120-10240 N*s. The solid propulsion system that we are developing will use an Ammonium Perchlorate Composite Propellant (APCP) formula based on Massachusetts Institute of Technology's (MIT) Cherry Limeade. The engine will launch a rocket holding a glider as its payload to a target altitude of 5,000 feet above ground level. The capstone project represents a significant leap in rocketry capabilities at the University of Virginia. Beyond offering invaluable hands-on experience for undergraduate students, this project has the potential to fill crucial gaps, laying the groundwork for future advancements and enhancing the university's standing in the field of aerospace engineering.

Mysorean rockets are an important steppingstone in the development of today’s functional solid propellant rockets. In the late 1700s, Mysorean Rockets were first used by the Mysore people of India as the first successful rocket artillery in military history against British invaders (DeLuca, 2016). These rockets had more advanced and durable black powder propellant and a stronger iron casing than previous attempts at rocket artillery, combining to make them quite deadly to the British. The British appropriated this technology, spread it to Europe, and made it an important part of contemporary European and North American warfare under the name of the Congreve rocket. For my STS project, I propose that I study the portrayal of the British improvements to Mysorean rockets and how they reflected European colonial attitudes in the late 18th and early 19th centuries. I propose doing this by doing an extensive literature review on the technical aspects of Mysorean and Congreve rockets, the anthropology of the colonial relations between the Mysore and the British, and the methods used by the British to adapt the rockets to their own uses.

Technical Project

The goal of our team’s design is to improve upon the design of a SRAD rocket. Specifically, this section will address the question of how my group – the propellant formulation sub-team of the propulsion group– will improve upon existing propellants to maximize rocket performance while minimizing risk during both the manufacturing process and the rocket launch. Propellant is a chemical mass that is burned and exhausted out of the back of a rocket (Braeunig, 2008). The exhaust follows Newton’s Second Law and creates thrust in the opposite direction to the exhaust vector (Hall, 2021). Solid propellant refers to the category of propellants that are composed of solids and exhausted out of a more basic nozzle. They are generally less efficient than liquid propellant engines, but they are much safer to use and simpler to construct.

After a selection process designed to find a solid rocket propellant that was safe, efficient, and made of ingredients that the group could feasibly obtain, the sub-team decided to manufacture a compound based on variant of APCP, supplemented with epoxy and powdered aluminum and called 'Cherry Limeade'. Cherry Limeade was developed by the MIT Rocket Team (Fallon and Senstrom, 2021) and is notable for being easy to manufacture and pour while maintaining high performance.

Our group's aim is to improve Cherry Limeade further from what MIT and later groups have managed. There are three ways in which this goal can be met or exceeded. The first is by making it safer. This will be tested constantly throughout creation and use. There have been no known safety incidents involving Cherry Limeade. If the group makes it through with no incidents, then that will be considered a success. The group could also improve the current formula by finding a way to speed up the manufacturing process at some point or increase the yield of the product without increasing inputs. This seems unlikely for a few reasons, mainly being that we have limited time, money, and resources, giving us a small margin of error. This can be tested by comparing the percentage yield of the ingredients against the products and the time to manufacture to previous iteration in literature.

The third option is to improve the performance of the fuel – specifically, increasing the specific impulse. Our group will slightly alter the original Cherry Limeade formula to achieve this. By changing from used ammonium perchlorate powder of a uniform 200-micron size to a mix of 90- and 200-micron powders, we hope to achieve a denser pack and a more aggressive burn, resulting in a higher measured specific impulse. This will be measured in two separate ways: a static firing test and the actual launch. The static firing test will directly measure the amount thrust produced by the motor by recording the force pushing against a scale during a horizontal firing. This can then be divided by the mass to find the specific impulse. During the test, we can also record the mass of the rocket before and after launch, the mass of the propellant, and the height of the launch – optimally over 5,000 feet, as is the goal of the overall project – and calculate the specific impulse experimentally.

Now that a propellant recipe has been decided upon and an estimate of how much fuel will be needed to take the rocket to the target height of 5,000 feet, the remaining steps are simple. Over the rest of the semester, we will acquire ingredients to make the propellant and a place to mix it. Then, we will make small batches and test them at the beginning of next semester. Once we have an ideal batch made, we will create a final mix for the launch at the end of the spring semester.

STS Project

The British spent three decades attempting to conquer the Mysore Kingdom in India, facing more difficulty than any other kingdom they ran into on the Indian subcontinent. Before finally succeeding with their conquest in 1799, Lord Cornwallis referred to the Mysore leader, Tipu, as the only serious obstacle to British rule of India (Jaim and Jaim, 2011). The kingdom was considered the most militarily competent and best led in India, and it held out longer against British and Mughal rule than any other neighboring kingdom in Southern India.

Although Europe had military rocketry before 1800, it was ineffective. The Mysore, while fighting the British East India Company in the late 1700s, began using Mysorean rockets that reached their targets and did damage much more often than their European counterparts (Naik and Patil, 2015). Their superior performance was due to black powder that was less susceptible to humid conditions than the kinds used in other weapons and a stronger iron case. This allowed for higher pressures to be generated in the rocket body, an increase in thrust, and ultimately better projectile range and velocity. After facing heavy losses to the rocket, British forces purchased some Mysorean rockets from local artisans and brought them to Britain. There, William Congreve of the Royal Society worked over a period of years to standardize and perfect the rockets as a military weapon (Werrett, 2009).

Congreve rockets were eventually used to great effect in the Napoleonic Wars and the War of 1812. They are an example of how the scientific method and Industrial revolution were applied to an innovative piece of technology into a mass produced good. This would be repeated with dozens of other items, from garments to guns, over the coming century, and would spell the end of the artisan class. This also showed colonial disdain for the Mysore, as Congreve claimed that the Mysore were incapable of such scientific and industrial improvements to their rockets.

Jaim (2011) also states that while the British feared the rockets used by the Mysore, they stuck up their noses at the ‘barbarous tactics’ of using ambushes instead of more traditional European warfare techniques. The British, despite the technological prowess of the Mysore, continued to treat them as a racial underclass, applying to them the doctrine that would later become known as The White Man’s Burden. This doctrine promoted reeducating the Mysore people to be more ‘civilized’ and European at the expensive of traditional Indian culture. These racist and patronizing attitudes were typical of British colonialism at that time, even if they were unearned.

I will carry out this project out by literature review. I will use sources from trusted journals that focus on the science of rocketry, propellant, and materials science for the technical side of the research to understand what made the Mysorean rockets superior to their European contemporaries. For the colonialism aspect of my research, I will lean on anthropology papers that describe the interactions of the Mysoreans and the British, as well as how the British treated other similar colonial conquests. I will also study documents from the time to understand how Congreve developed the rockets and what attitudes about rocket warfare were at the time. I will try to gather these resources from a range of sources, focusing on balancing the number of papers I use that are written by authors of Eastern and Western societies. Eastern civilizations like China and India are responsible for most of the early development of solid rocket propellants (Narashima, 1999), but I found few articles sourced from these locations in my research.

The main STS theory I will use for my research will be the concept that all artifacts have politics (Winner, 1980). Winner argues in his paper that all artifacts and inventions have either an implicit or explicit political purpose. Through that lens, I will look at how the Mysorean and Congreve rockets were politicized by the users and foes of both states. I will also use the concept of technological determinism, which is the belief that technology exerts a greater force on society than any other factor (Smith, 1994). In his paper, Smith critiques technological determinism, stating that it led to parts of American several unpleasant parts of history, like aggressive westward expansion and the removal of native peoples. That can be applied to the British and Mysorean interaction by examining how the Mysoreans' advanced technology led to social change, and how Britich technological developments led to their desire for colonial expansion.

Conclusion

There will be 2 deliverables for this technical project: 3kg of APCP Cherry Limeade propellant and the rocket launch and static firing test data. The deliverable for the research project will be a study of how colonial attitudes affected how Mysorean Rocketry was viewed and adopted by the British.

Rocketry is vital to modern society, and solid propellant is vital to rocketry. Aerospace companies and other student groups around the world may see our work and understand that solid rocket fuel is viable for many applications with rocket design. Other academics or engineers may read the research paper as an example of how colonial attitudes often discredit the people they conquered, even if those people may have been technologically superior in some respects. The synthesis of that knowledge will hopefully lead to a recognition of solid propellant as a viable fuel for the future and an increased acknowledgment of the Mysore people as integral to how rocketry became so vital, even though their achievements were belittled and stolen by the British colonizers. History, after all, is written by the victors.

Total Word Count: (2,061 words)

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