**WAVE DRIVEN ELECTRONIC PROPULSION TECHNOLOGY: A NOVEL APPROACH TO INCREASING THRUST EFFICIENCY USING SOUND**

**PART 2, OF A CONTINUING SERIES**

*Simulating Electronic Propulsion: Using Sound to Accelerate Particle Velocity*

**Undergraduate Research 294**

Winter 2018 Quarter Research Proposal (ENGINEERING REVISION 1)

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1. **Introduction:**

Increasing thruster performance while reducing dependency on chemical fuel is essential to future spaceflight applications. (1) Research projects goals for Spring 2018 consist of investigations using harmonic oscillation resonance of a 9” dual coil wave driver to create kinetic energy in Lycopodium (a substance used to simulate gas). Spring quarter will be dedicated towards increasing particle velocity in our lycopodium while attaining a stable geometric pattern in our oscillation chamber using sound.

**NEW RESEARCH**

Currently, increasing electric propulsion propellant velocity in devices during the pre-exhaust stage is done through the use of thermal and electromagnetic energy. Current methods for increasing thruster performance include manipulation of cathode shape (2), wall materials (3), anode geometry (4), channel length (5), magnetic field strength (6) and column configuration (7).

Methods of increasing electronic propulsion velocity using sound add to the body of scientific knowledge associated with aerospace engineering, space travel, and electronic propulsion. These investigations provide both scientists and engineers with new and alternative methods for increasing efficiency in propulsion systems which are used in satellites, space stations, deep space expeditions and the future of manned spaceflight. If successful, this project will extend the range of chemical fuel restricted missions by creating additional thrust via energy which is converted to exhaust velocity through sound waves. Successful results also yield the ability to cut down travel time during transport via electronic propulsion systems, which also lightens mass loads associated with supplies needed for life support requirements (such as food, water, etc).

**II. Research Question:**

**“Can an embedded wave driver be used to increase kinetic energy in electronic propulsion devices?”**

**ADRESSING BIG PICTURE**

This research is being done to address the issue of both space transportation efficiency and thruster performance during future spaceflight missions. The hypothesis of this experiment is that “using sound as a method to transfer stored electrical power into usable exhaust velocity provides a means of reducing overall dependence on chemical fuel and its associated mass during space flight.” During Spring quarter, the research is geared toward showing through scientific method that “Higher Velocities can be attained while maintaining a greater inertia during long voyages by increasing kinetic energy of propellant gases during pre-ejection stages.”

Harmonic oscillation of propellant gases using an embedded wave driver is a novel method for increasing thrust efficiency during spaceflight. This experiment looks for qualitative and quantitative results during oscillation of Lycopodium (8); a gas like particle used in physics, in an effort to produce spherical vortex formations which can be guided down the exhaust column using standard electronic propulsion methods to create increased exhaust velocity. Size and shape of vortex formations can be increased and decreased through tuning of amplitude and frequency during calibration. During early testing and experimentation during spring break, geometric formations and an increase in velocity was found at 47 Hz when using various amplitudes. This shows that our hypothesis has some truth and brings this project very close attaining proof of concept which will in hope, assist in attaining expert analysis and additional funding for further experimentation.

**III. Methods:**

**Investigation of Lycopodium oscillated by sound wave**

**in a cylindric column with 9” diameter and adjustable length**

During Spring quarter 2018, we will use a 9” dual channel wave driver to observe geometric patterns in soundwaves created using a software synthesizer.

Qualitative observations will be used to determine at which frequencies sound in a column will create geometric patterns in Lycopodium. These observational methods will be used as a “Calibration of Frequencies”, which can be used to find which combinations of (frequency, amplitude, and wave type) allow for the best transformation of energy into the Lycopodium powder.

While observing Lycopodium during oscillation, frequencies which produce repeating patterns and geometric formations will be recorded. Recorded frequencies will then be observed under varying amplitudes to determine amplitudes which offer the best structural stability under high amplitude vibration. Higher amplitudes of oscillation within our vortex pattern will give us a higher transfer of energy into particle velocity, from our wave driver.

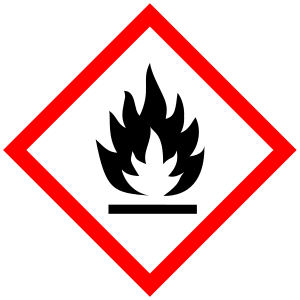
Acceleration of Lycopodium powder will be used as a proof of concept for acceleration of particles via sound. The method of accelerating particle velocity via sound will be used in future research involving gases. Acceleration of chemical fuel in can be used during during pre-exhaust stages to allow for higher exhaust velocities in experimental electronic propulsion devices.

**Safety Protocols**

The group has been aware of a specific safety concern involving this experiment, related to the reagent “Lycopodium Powder” which the project has chosen for oscillation.

1. Lycopodium is classified as a category 1 combustible dust.

While lycopodium is rated as a combustible dust, it is less dangerous than common wood sawdust which can be found in any campus workshop. Sawdust has the following classifications associated with it:

* HEALTH – Carcinogen Category 1A 
* HEALTH – Skin Iritation Category 2 
* Specific Target Organ Toxicity Single Exposure Category 3
* Eye Irritation Category 2B
* Combustible Dust 

During oscillation of Lycopodium powder safety protocols the experiment will follow the following GHS precautionary statements which are assigned to lycopodium as well as taking extra safety precautions by following heavier recommendations used for sawdust.

**GHS Precautionary Statements:**

P210: Keep away from heat/sparks/open flames/hot surfaces. - No smoking.

P243: Take precautionary measures against static discharge.

P260: Do not breathe dust/fume/gas/mist/vapours/spray.

P261: Avoid breathing dust/fume/gas/mist/vapours/spray.

P280: Wear protective gloves/protective clothing/eye protection/face protection.

P362: Take off contaminated clothing and wash before reuse.

P363: Wash contaminated clothing before reuse.

**GHS Response Statements:**

P304 + P340: IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.

P308 + P313: IF exposed or concerned: Get medical advice/attention.

P352: If on skin, Wash with plenty of soap and water.

P351: If in eyes, Rinse cautiously with water for several minutes.

Additional safety protocols for this experiment are outlined in attached Lycopodium Safety Data Sheet “S25396.pdf” from Fisher Scientific as well as “Wood\_and\_Wood\_Dust\_Untreated\_Lumber\_Logs\_Chips\_and\_Sawdust.pdf” from Weyerhaeuser.

**IV. Equipment, Reagents, Supplies and Other Needs:**

For equipment list used in this experiment, please see attached excel spreadsheet “ Hardware.xlsx”.

For this experiment, a standard speakerbox has been outfitted with a cardboard tube, attached perpendicular to the speaker, for oscillation of Lycopodium powder. Signals used for oscillation of Lycopodium will be generated using a laptop and computer software. The wave driver for this experiment is a 9” dual coil car audio speaker which is powered by a 300-watt dual channel car amplifier and +12VDC Power Supply.

The combination of “laptop + car audio electrical equipment” over “EET Department Signal Generation Electrical Equipment” was chosen from a need for a mobile soundwave research platform which would not rely on expensive lab equipment from the North Seattle Electronical Engineering Department.

The current lab environment consists of a standard midrange-subwoofer in a speakerbox with an audio input connected to a laptop running professional audio-acoustical engineering software. The addition of a cardboard column to the speaker allows for controlled oscillation of the Lycopodium powder. Resonance shaping will be investigated using a cork type of device which will be inserted at different lengths as a stopper for harmonic resonance testing at specific wavelengths.

**V. Project Timeline:**

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| --- | --- |
| **Week** | **Goals** |
| 1 (4/2 – 4/6) |  |
| 2 (4/9 – 4/13) | Final Proposal Due  Rocket Club! |
| 3 (4/16 – 4/20) | Poster Intro and Layout Due  Rocket Club! |
| 4 (4/23 – 4/27) | Poster Methods Draft Due  Rocket Club! |
| 5 (4/30 – 5/4) | Poster Results Draft Due  Rocket Club! |
| 6 (5/7 – 5/11) | Complete Poster Draft Due  Rocket Club! |
| 7 (5/14 – 5/18) | PRINT POSTER  5/18 Research Symposium @ UW  Rocket Club! |
| 8 (5/21 – 5/25) | Improve Presentation for NSC Expo  Rocket Club! |
| 9 (5/28 – 6/1) | 5/31 Research Symposium @ NSC  Start Propulsion Research Portfolio  Rocket Club! |
| 10 (6/4 – 6/8) | Complete S18 notebook  Rocket Club! |
| 11 (6/11 – 6/15) | Rocket Club! |

**Conclusion:**

Simplifying research into a clear, step-by-step process is helping this project progress to a point where on campus labwork can be accomplished through shop resources in The North Seattle College Rocketclub Workshop. The NSC rocket club is managed by Engineering and Physics faculty member Traci Furutani, which is also the lab equipment supervisor for the physics department. Traci has shown great interest and knowledge of my field and project goals and has provided positive support and acted as an educational resource since this project was first proposed.

This experiment would most likely remain unfeasible for on-campus lab work without the NSC rocket-club, who’s members are all involved in some type on engineering, many who are in the field of space propulsion and aerospace. The shop area, students and faculty involved within the rocket club are also prepared to deal with the dangers and safety precautions involved with working around sawdust and other combustible materials from both wood, glue and plastics and have very supportive of my project’s involvement within the rocket-club workshop.

As the rocketclub is also a privately funded school project, it has shown the project’s value as being a privately funded research project. All materials and hardware used for this project are student owned by researchers, which allows for easy transport for outside testing and demonstration.

This quarter will be dedicated to further establishing a research portfolio in Electronic Propulsion research as well as preparations for the research symposium at University of Washington. Safety concerns and budgeting issues from previous proposals have been addressed and active research has been started in an exciting field which has gained on campus support and project help from students and faculty involved in the Rocket Club.

**References**:

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