# Continuation/Research Progression Projects Form (7)

**Required for projects that are a continuation/progression in the same field of study as a previous project.**

***This form must be accompanied by the previous year's abstract and Research Plan/Project Summary.***

Student's Name(s) Jaekeun Sung

**To be completed by Student Researcher:** List all components of the current project that make it new and different from previous research. The information must be on the form; use an additional form for previous year and earlier projects.

| Components | Current Research Project | Previous Research Project: Year: 2019 |
|---|---|---|
| 1. Title | Hybrid Artificial Muscle Robot(HAMR): Exosuit Building Block | Pneumatic actuator operated by electrolysis of water and fuel-cell inspired water generator: Artificial Muscle Module. |
| 2. Change in goal/ purpose/objective | New Goal:<br>Create HAMR block that can be assembled into any shape for different purposes.<br>Create self-sustainable device. | Previous Goal:<br>Create an artificial muscle that can replace traditional actuators of exoskeletons. Also to create a device that does not require external setup such as battery pack and air pump. |
| 3. Changes in methodology | Most of the fabrication process is done by computer programming (3d printers, and automatic fabric/paper cutters).<br><br>More in depth analysis of visual performance through video cameras at different angles. | 80% of the project was handcrafted |
| 4. Variable studied | HAMR units are studied. | Artificial Muscle Module(AMM) units are studied. |
| 5. Additional changes | | |

Attached are:

☐ Abstract and Research Plan/Project Summary, Year 2019

I hereby certify that the above information is correct and that the current year Abstract & Certification and project display board properly reflect work done only in the current year.

Jaekeun Sung — Student's Printed Name(s)

Jaekeun Sung — Signature

03/19/19 — Date of Signature (mm/dd/yy)

Jaekeun Sung
PHY-774

Title: Pneumatic actuator operated by electrolysis of water and fuel-cell inspired water generator: Artificial Muscle Module.

Abstract:

Our lifespan has increased over the past decades, with the advancement of humanity. However, if our physical ability is limited due to the lowering of muscle activity, our life will be meaningless. Especially in elders, their muscle activities drastically decrease as they age. This lead to limit their movement, possibility of accidents, even worse?  Isolation -- which will lead to depression, eventually lonely end. Shouldn't elders deserve to be happy after retirement? They should be allowed to do whatever they want: start a new career, enjoy leisure activities, study a new topic, or continue their passion in their field and become a mentor of a new generation. All of these can be achieved with aid-technology --artificial muscle. Past artificial muscles require large setups and high energy requirement. Thus, it is not suitable for supporting elders. We developed an artificial muscle module that in near future, it will be assembled into body suits to support elder. Our design is inspired by worm's hydrostatic skeleton mechanism, which use pressurized interconnected segments(coelom) to wriggle and writhe and push its way through the soil. To meet the small setup and low power, we implement a fuel cell inspired membrane between the segments of the module. We used gas instead of fluid for pressuring segments. They were water and air leakage problem, which need to be improved with different fabrication after further research. We measured the prototype's displacement and force. With improvements, it will change the world.

Jaekeun Sung
1/16/19
Research
Dr.Truglio

Research Plan

Project Title: Pneumatic actuator operated by electrolysis of water and fuel-cell inspired water generator: Artificial Muscle Module.

Question/Problem: What can we do to increase the muscle performance of elders, allowing them to move freely like a young adult, so that they can enjoy the rest of their life?

- To improve muscle performances, we can use supportive devices(Wu., et al 2014). These devices are called exoskeletons.
- In the previous studies, exoskeleton was not sufficient due to its limits
  - Limited movement
  - Limit on maximum support weight
- Also, the conventional actuators(pneumatic and hydraulic) used in these devices are insufficient for daily activities(Caldwell et al., 1993).
  - Degree of movements are limited with conventional actuators.
- In order to overcome these limits, researchers have come up with a new idea -- artificial muscle. But these actuators also need large setup and they have low-power efficiency(Li et al,2017).

Goal/Expected Outcomes/Hypothesis:

- Goal: To create an artificial muscle that doesn't require large setup and have high power efficiency.
- Hypothesis: Gas released by electrolysis of water will be able to inflate the bag and withstand the weight. Then using water generator, the module will be returned to its original state.
- Expected outcome: The BOPP film bag with graphite electrode attached to the surface of film will start electrolysis of water and generate hydrogen and oxygen inside the closed system covered by BOPP film. These generated gas will able to inflate the bag and withstand the weight.When controller decide to deflate the bag, hydrogen and oxygen will recombine to form water using water generator. Thus returning to original state.

Design:

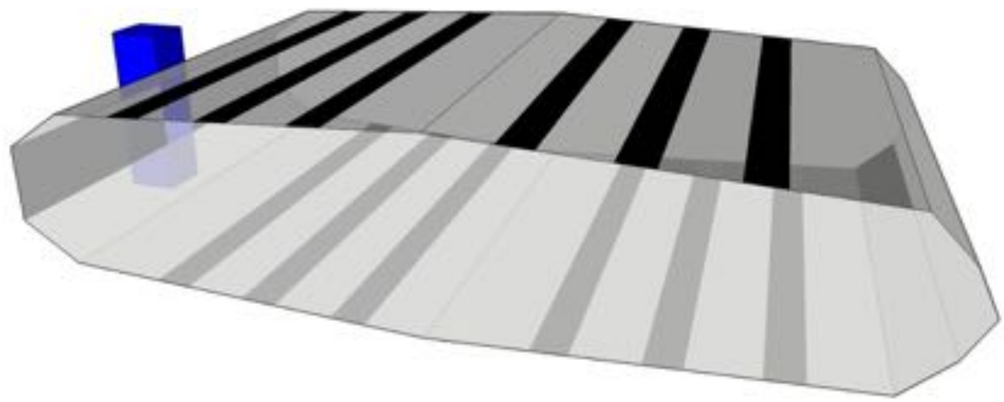

Figure 1: Module when inflated.

- Blue box is water generator.
- Black lines are electrodes

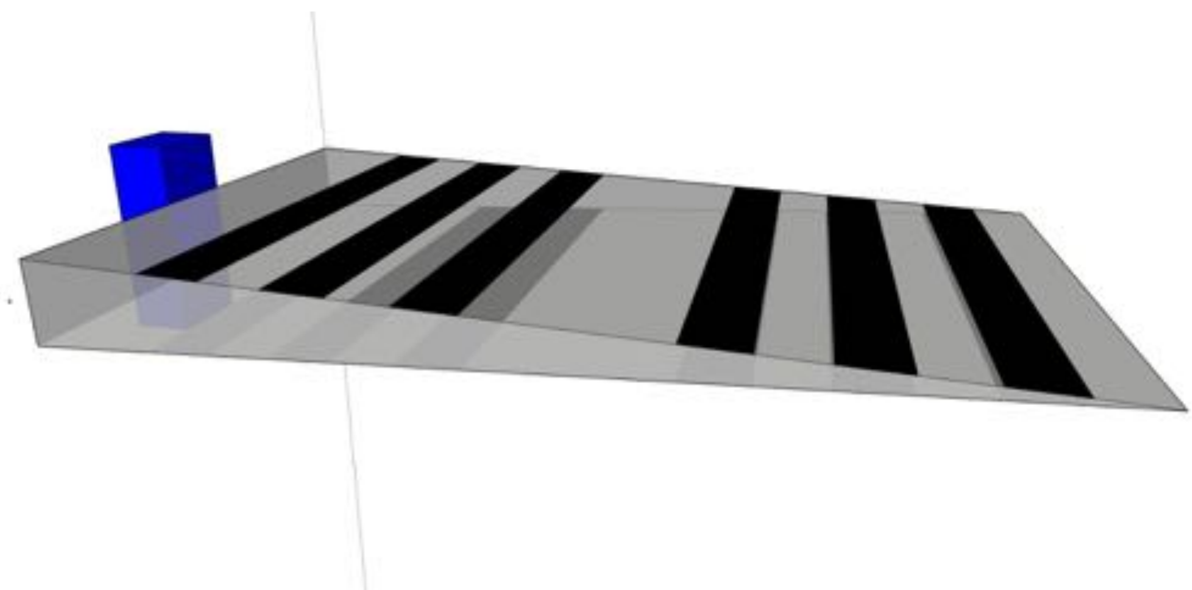

Figure 2: Module when deflated.

Building procedure:

Bag:

1. Preparing electrode layer(Make 2).
    a. Cut out graphite sheet into desired size.
    b. Cut out BOPP film
    c. Layout BOPP film with pen

d. Apply 3M double sided tape to the desired position of Graphite electrode.
e. Place electrode.
f. Turn over the film and solder wire to the graphite electrode.

2. Assembly
    a. Place two electrode layer. Electrode side facing inward.
    b. Use heat plate to fuse the film(on the sides, except opening that will be connected to the water generator).

Water generator(Turn hydrogen and oxygen back to water):

1. Preparing the polymer electrolyte membrane(Spiegel., 2018)
    a. Cut out Nafion 211(PEM) to the desired shape.
    b. For each steps, soak PEM for one hour at 80 celcius
        i. Distilled (DI) water to hydrate the membrane and dissolve surface contaminants.
        ii. Hydrogen peroxide solution to remove organic contaminants from the PEM surface.
        iii. Dilute sulfuric acid to remove metal ion contaminants from the PEM surface and sulfonate the PEM surface.
        iv. DI water to rinse sulfuric acid from the surface and hydrate the PEM.
        v. DI water to rinse and hydrate the PEM again
        vi. DI water for the final rinse and hydration
2. Preparing the electrode layer(Gas diffusion layer)
    a. Cut out “Carbon Cloth Wet Proofed” as GDL
3. Membrane Electrode Assembly
    a. Apply “liquid Nafion solution” to the side of GDL that will be bonding to the PEM using brush.
    b. Dry GDL at room temperature
    c. Place GDL-PEM-GDL order between a heating plate.
    d. Turn on the iron and set temperature to 90 celcius.
    e. Place iron on top of heating plate.
    f. Heat with pressure for one hour to evaporate the solvents from the liquid Nafion coating.
    g. Raise temperature to 130 celsius. And heat with pressure for two minutes
    h. Turn of the iron rod and let them cooled to room temperature.

        i. MEA is assembled.
4. Final assembly of water generator.
    a. Assemble the water generator with these order:
        i. End plate (printed out by 3d printer(pla))(with thermoelectric plate, cool side facing inward)
        ii. Metal electrode(copper tape and Graphite sheet) and gaskets(Mylar Laminate or Graphite sheet).
        iii. Flow field plate(graphite sheet)
        iv. MEA and gaskets
        v. Flow field plate
        vi. Metal plate and gaskets
        vii. End plate with thermoelectric plate(cool side facing inward)
        viii. These will be clamped with bolts and nuts.
    b. Connect anode and cathode to power supply.

Fuel preparation:

1. Make Potassium hydroxide solution
    a. On the beaker, add 10 ml of distilled water.
    b. Add desired amount of KOH on the beaker.
    c. Pour distilled water slowly.
    d. Make 10wt% to 40wt%, test and select the best percentage.
2. Use syringe to transfer fuel on to the bag.

Assembly of module.

1. Connect electrode from bag and water generator to controller and power source.
2. Insert fuel using syringe through the opening.
3. Combine water generator with bag using heat plate and double sided tape.

Procedure for data analysis:

1. Power efficiency:
    a. Setup
        i. On a foam board, place 4 rod around the artificial muscle module.
        ii. Create plate with four circles made out of cardboard, so that cardboard can move up and down along the 4 rod tract vertically.

        iii. Prepare different weight.
    b. Data collecting
        i. Test different weight.
        ii. Measure electricity usage over time in watts.
        iii. Measure displacement
        iv. For each weight, repeat at least 10 times to check for consistency.
    c. Data analysis
        i. Find (weight hold)/(module weight) to find efficiency.
        ii. Compare these data to other actuators that have been previously developed.
2. Test at different conditions.
    a. Create artificial muscle module with different geometry to fit in different task.
    b. Attach one or more modules to create whole system.
    c. Other test methods….etc

Hazardous Chemicals, Activities & Devices:

- Hydrogen Peroxide(3%)
    - Potential Hazards
        - Potential to cause fire or explosion
        - May cause burns to digestive and respiratory tract
        - May cause nausea, vomiting diarrhea, damage to the red blood cell
        - May cause skin and eye burns.
        - May cause central nervous system effects
    - Safety precaution/minimize risk
        - Respirator protection
        - Hand protection
        - Eye protection
        - Skin and Body Protection
        - Store at the tightly closed in a dry and well-ventilated area.
        - Store away from the combustible materials
    - Disposable method
        - Store it in closed container
        - Then send to the proper waste facility.

- Sulfuric acid(0.02N)
  - Potential Hazards
    - May cause irritation to the respiratory tract.
    - Contact with skin causes burns and irritation.
    - Ingestion may cause permanent damage to the digestive tract.
  - Safety precautions/minimize risk
    - Respiratory protection
    - Hand protection
    - Eye protection
    - Skin and Body protection
    - Keep it away from combustible materials
  - Disposable method
    - Store it in a closed system.
    - Hand it to the proper waste facility.
- Potassium hydroxide flakes
  - Potential Hazards
    - Harmful through inhalation or skin absorption
    - Destructive to tissue or mucous membranes and upper respiratory tract
    - Cause burn to skin and eyes.
    - Toxic through ingestion
  - Safety precautions/minimize risk
    - Respiratory Protection
    - Hand protection
    - Eye protection
    - Skin and body protection
    - Do not let water to get into the container
    - Avoid formation of dust and aerosols
  - Disposable method
    - Store it in closed containers.
    - Send it to the proper waste facility.
- Nafion Dispersion- Alcohol based 1000 EW at 5wt%
  - Potential Hazards
    - May cause skin irritation
    - Contact with eyes might cause cornea opacity

- May cause polymer fume fever
- Safety precautions/minimize risk
  - Respiratory Protection
  - Hand protection
  - Eye protection
  - Skin and body protection
  - Remove source of sparks, flame, impact, friction or electricity
  - Store in a well ventilated area away from heat and sunlight
- Disposable method
  - Let it become solid and dispose on to permitted landfill

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