Summer 2020 Prototype Wash Effectiveness Experiment

*Note: While thorough, this write-up includes many similar yet different topics, and should be cleaned up. This experiment was a failure due to prototype failure. The knowledge gained in this experiment can be used for designing a better experiment to be conducted with both a better prototype and a preliminary design.*

**Experiment Overview**

**Purpose of Experiment**: To test the effectiveness of the washing process in agitating clothing

**Independent Variable:** Number of compression cycles in washing

**Dependent Variable:** Ink darkness (color value of darkest point found on image viewer) and ink spread from origin point (furthest point and average of furthest three points from center).

*Note: Even with this data, the images produced by this experiment should mainly be interpreted through visual analysis of shirts tested.*

**Materials:**

* Crayola Ultra-Clean Washable Markers
* 100% Cotton White T-Shirts with consistent size (one per trial)
* Washing Machine Prototype
* Source of clean water (600 mL of water used per trial)

**Constants:**

* Water characteristics such as temperature and composition (all water is coming from the same source and tested immediately)
* Time in contact with water (5 minutes)
* Amount of water used (600 mL of water)
* Shirt characteristics (Kirkland Crew Neck 100% Cotton Size Medium)
* Ink applied location on shirt (3 in from collar, and 3 in from from the bottom of both sleeves where sewn to shirt)
* Ink type applied to shirt (Crayola Ultra-Clean Washable Markers)
* Amount of ink applied to shirt (.75 in diameter circle about center point)
* Wash process characteristics (Compression time, Same chamber will be used)

**Experiment Procedure:**

1. For each shirt, color in specified area using marker that will be tested with.
2. Select a shirt prepared for the test. Take a picture of this shirt (lighting and viewing angle must be consistent between each picture taken).
3. Ensure the linear actuator is fully contracted, and remove the gasket and cover from the wash chamber.
4. Insert shirt being tested and replace gasket and cover. Ensure the cover is on tight in order to produce a watertight seal.
5. Add water to the wash chamber and perform the necessary compressions and decompressions of the shirt for the trial with linear actuator.
6. Once all compressions and decompressions are complete, wait until the test time has concluded, and then drain water from the washing machine. It is important that water is not removed by compressing the clothing as that may agitate the clothing more than is desired for the experiment.
7. Ensure the linear actuator is fully contracted, and remove the gasket and cover from the wash chamber.
8. Take a picture of the shirt tested (lighting and viewing angle must be consistent between each picture taken).
9. Repeat steps 2 through 8 until experiment has concluded.

*For this experiment, there will be two trials for each tested number of compressions. With a control test, a test with five compressions, and a test with ten compressions, meaning there will be six trials in total. Additionally, the experiment will be conducted at night for consistent lighting for photographs throughout the test.*

**Specific changes made to the experiment to accommodate current prototype:**

Since this prototype was not made to accommodate the specific 500 mL of water requirement of the design challenge and the wash chamber does not have an adjustable volume capacity, a volume of wood cut from 6x6 lumber has been fashioned to take up additional space in the wash chamber. Additionally, with void space being present between the piston and chamber top, water will not be directed through the bypass valve and above the piston. Instead, the water that is displaced is flowing up additional piping added to the end of the dirty water outlet of the system, where gravity will feed it back into the system between compressions. These changes should have no effect on the results of the experiment aside from making the washing machine operate more similarly to how a refined prototype would work.

One change made to accommodate the prototype that will affect the results is the total amount of water that had to be used to conduct the experiment. Even with the volume being used to take up space that would otherwise be water, additional water has to be used to fill the wash chamber completely. As a result, the experiment will be carried out using 600 mL of water for each trial.

**Errors in Experiment:**

While this test could be effective in illustrating a design’s effectiveness or ineffectiveness, it is not very effective in showing measurable data.

Issues with the use of markers to measure the washing capability of the washing machine:

* It is impossible to tell exactly how much ink is being applied to the shirt aside from controlling the area covered (The marker could be running out of ink, the shirt could absorb more ink than others, smearing may occur and skew the results)
* There are no real measurable or concrete numbers that can be generated from the results of these tests
* Visual indications can yield misleading results without possible errors being taken into account
* Washable marker is not necessarily representative of substances that may be present in dirty clothing

Other foreseen issues with the experiment:

* With the frame needing to be partially disassembled in order for clothing to be removed, and then tightly reassembled to avoid leaks for the next trial, times in contact with water may be inconsistent. This difference could be as much as 30 seconds.
* Pictures of clothing could be different despite constant viewing angle and lighting between pictures

**Post Experiment Write Up**

**Unforeseen Sources of Error and Issues in Conducting Experiment:**

Since the shirts were folded together, the marker bled where the surface of the shirt made contact with other locations on the shirt. This made viewing and using the data to extrapolate quantitative data impossible, so the only results worth viewing is the images generated from the experiment.

Additionally, the washing machine prototype was unable to compress the shirt as much as intended. Attempting to solve this issue caused other issues and concerns to transpire. Though this subject will carry into other experiments, the only information pertaining to the results of this experiment is that the piston head could only be moved under a quarter of an inch, resulting in less flow of water through the shirt between compression cycles. This would have adverse effects on the results experiment, and may invalidate the results, as the desired function of the washing machine is.

**Experiment Conclusion:**

While the issue of the piston head failing to move more than a quarter of an inch could invalidate the results of the experiment conducted, the data recorded could still provide some valuable information, and show promising results for the prototype’s ability to agitate clothing. In moving the piston 0.20” (as measured by my digital caliper) during the test, the prototype did prove to agitate the clothing despite operating at only a fraction of what the machine was supposed to be able to do. In only five minutes, in contact with water, the shirts that had been compressed all had lighter spots and more movement of the washable marker. While additional tests need to be conducted with the machine functioning as designed, this is a result that could help to show this machine's effectiveness in agitating clothing.

**Concluding Thoughts on Experiment:**

While this experiment is useful for giving a general idea of how effective the washing process might be for a given machine, all results cannot be interpreted as anything other than qualitative data. Working with markers specifically comes with some challenges:

* It is impossible to know if a consistent amount of ink is being applied to shirts between trials
* Measuring ink within a shirt is not very feasible, and could result in a lot of errors
* Other contaminants are likely to be present in dirty clothing, and testing to find effectiveness for all these prototypes should be done in a more controlled, measurable manner.

All this being said, this experiment should provide a general idea of how effective or ineffective a particular wash process may be by giving a visual indication of how well a clothing item may have been cleaned, which is inferred by ink darkness or spreading from the origin point.

Though preliminary impressions are important for determining potential for viability, other tests should be conducted to determine what specifically a given machine can and cannot do, and to what extent.

**Potential Improvements for Future Experiments:**

Contaminants in clothing could include numerous types of materials. It would be worthwhile to test a machine's ability to remove these contaminants from clothing. Specific types of contaminants and potential anologs for testing includes but is likely not limited to:

* Water-soluble liquids (Corn Syrup)
* Insoluble liquids (Vegetable Oil)
* Water-soluble solids (Table Salt)
* Insoluble solids (Sediment or Sand)

Additionally, with the testing of contaminant removal with a fixed amount of fluid, the cleaning capability of a machine could be measured by taking the water removed after these processes, and filtering out the contaminant being tested with. By knowing how much of a contaminant was added to a clean shirt before the experiment, and then how much was present in the wash water after, it could be determined how much is left in the clothing. This value could be compared with other prototypes to determine their viability.

A potential procedure for this experiment of this using salt would be:

1. Dissolve 50 grams of salt into water.
2. Roll up the shirt being tested, and pour salt solution over the center of the rolled shirt such that nowhere on the shirt is wet.
3. Leave the shirt to dry.
4. Run the desired washing function with the shirt.
5. Remove shirt and collect wash water.
6. Boil wash water until all water is evaporated leaving dissolved salt.
7. Weight the salt from washed water, compared to the mass of salt added initially.
8. Repeat for each trial.

Alongside the washable marker test, a similar experiment should be conducted if the design of this washing machine is to be furthered in the future.