Microgravity Press Washing Machine Preliminary Agitation Effectiveness Test

Tommy Rohmann

04/06/2022

Background Information

Currently, there is no way to wash clothing in space. Astronauts on the ISS today actually wear clothing until soiled and get new clothing in resupply missions from earth. Dirty clothing is deorbited with trash (burned up I the atmosphere). This procedure is not tenable for prolonged missions further from Earth.

The proposed solution is a to use machine capable of working in the environment of a spaceship to wash dirty clothing so that clothing does not become a limiting factor to prolonged and more distant manned space flights.

Washing clothing entails completing several phases of the “Wash Process” including:
Clothing hydration > Soaking and Agitation > Drying of Clothing > Disinfection

The press design is being explored for a variety of reasons including but not limited to:
The design…

- Has the potential to accommodate every phase of the wash cycle
- Has high potential to be fully automated
- Has high potential to be compatible with an spaceship environment, generating minimal vibrations or harmonic motions, having the potential to be compact and fit in an ISS EXPRESS LOCKER, can function using supplied electrical power and clean water
- Relative simplicity
- Capability to be iterated on and given additional functionality

The purpose of this experiment is to determine the potential viability of a press to agitate clothing by performing variations of the “Compression Phase” of the wash cycle with a rudimentary prototype. The question being answered by this experiment is “Is using this method to actually clean clothing worth looking further into and refining?”

Experimental Design

Goal: Determine potential viability of compression wash method for agitating clothing

Scope experiment: The purpose of this experiment is to generally find out if repeated compression is a viable method for removing contaminants from a clothing item

Method: add contaminant (washable paint) to shirt and run wash process to determine wash effectiveness, then measure paint left in clothing item after wash completion (visual)

Independent variables: Compression force and number of compressions during wash cycle

Dependent Variable: Contaminant left in clothing item (before and after picture)

Control Variables: Wash time, amount of water used,

Control: “Best Wash” in washing machine (no detergent), “Worst Wash” wet and dry with minimized agitation.

Procedure:

1) Mark all clothing items with equal amount of selected contaminant
2) Pick one clothing item, label clothing item so it can be differentiated from the others and take a picture of it.
3) Wash clothing item according to planned procedure (Number of compressions, compression weight for each compression)
4) Remove and dry clothing, if necessary, without agitating it further
5) Take after picture with label
6) Repeat steps 2-5 until all trials are completed

Expected Sources of Error in Experiment:

- Human error in operating wash cycle (not currently automated)
- Error from imprecise instruments and measurement tools

Hypothesis: The agitation method will yield better agitation than the control “worst agitation”, but will be worse than that of the control “best” performed by a commercial washing machine.

Experiment Execution

The experiment started with finding the control “best” and “worst”. The “best” was done by washing one clothing item in a commercial washing machine with no detergent. The “worst” was found by soaking the clothing item in water for the same period of time as the control “best”.

For the actual test with the prototype, the first trial yielded concerning results. The procedure was hard to follow, since there were a lot of variables that came up and weren’t initially accounted for in addition to several disqualifying errors. Listed are a few:

- Reactions to compression that were also time dependent, and resulted in problems with correctly following procedures
- Location of the contaminant on the clothing relative to the location of the wash chamber outlet yielded varied results
- It was very hard to get consistent force application for a variety of reasons including some listed above
- Inconsistent application of contaminant between trials
- Inconsistent distance travelled by piston head between compressions

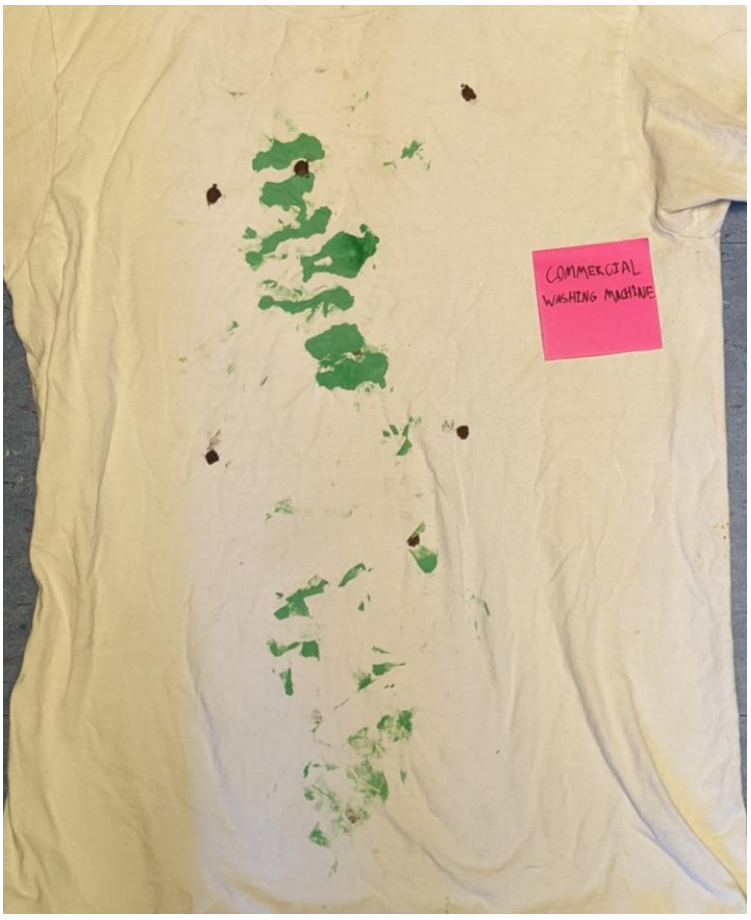
With this , it is important to know that of the listed labels, only one of them (the 600 lbf 20 compressions) is correct for the trials conducted with the prototype. All other trials are conducted with varying wash procedures, all between 10 and 15 compressions, over 600 lbf compression force over roughly 20 minutes per wash cycle, and altered compression procedure.

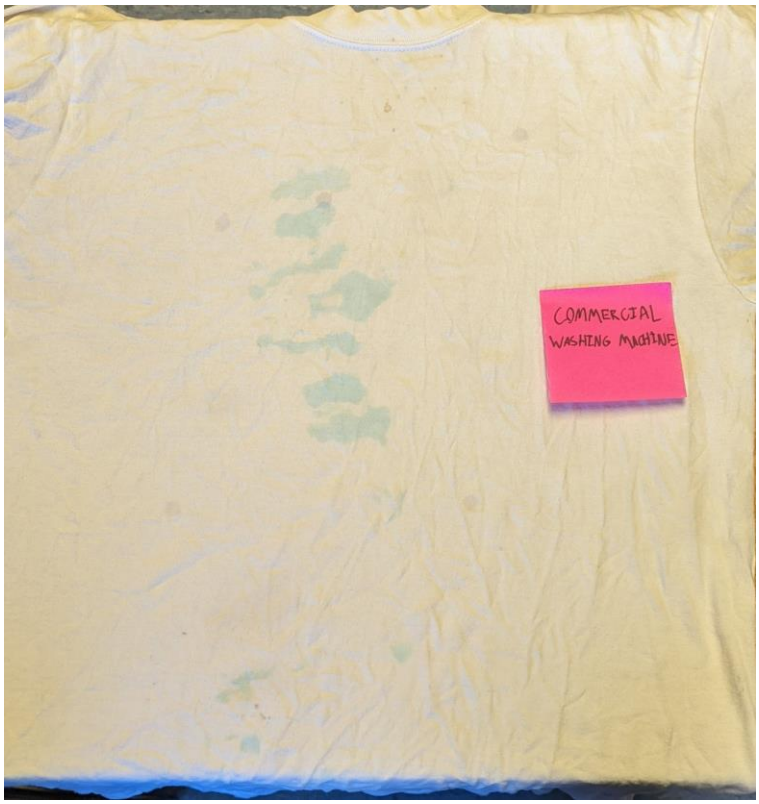
This experiment, although not carried out to completion, may yield some very informative and insightful results.

Experiment Results

Control Minimum Agitation Before and After

Control Best Agitation With Commercial Washing Machine





Experiment Results

Above is the only data set that went along with the test, and was performed before the test procedure was altered. It is worth noting that for whatever reason, more washable paint is present in the clothing item than the other clothing items my a significant margin.

It is also worth noting that this clothing item did not come out completely clean after being washed in a commercial washing machine with detergent (shown right)

Experiment Results

Shown below are the before and after trials of the altered procedure for the washing machine prototype. The labels do not match the procedure set initially for agitation.

Observed Phenomena

High Compression Force Varies with Time Beyond ~400 lbf

Observation:

Without the load of clothing or when the clothing item is not compressed beyond ~400 lbf, resistance to water exiting the wash chamber is negligible. Starting at around ~400 lbf at the absolute lowest and increasing to ~660 lbf compression on, the resistance becomes dependent not only on compression distance, but time under static compression (Not necessarily static, but without the linear actuator driving the piston head. The shaft being rather crude almost acts like a spring and extends the piston head almost ~1/8" over several seconds with the linear actuator remaining stationary. The reaction force of the clothing item also reduces over time. The clothing item can be compressed further following the resistance becoming constant with time.

Clothing items that experienced this phenomenon and were compressed further for multiple cycles seemed to have experienced better agitation.

Potential Explanation of Phenomenon:

It appears that beyond this threshold, the clothing item is forced together to a point where the channels that the water can travel through are so restricted that the clothing resists the flow to the point where it cannot easily leave the chamber and creates a lot of resistance to the linear actuator. This means that the water is being forced through the clothing item and sees a lot of obstruction and friction between the fluid and the clothing item. Water seems to be the cause of this since the piston is able to continue compression as the water makes its way though the high-pressure area of the clothing item and into the reservoir where the displacement and pressure of the piston head is not experienced.

Conclusions Drawn:

Compression appears to have a greater role in agitating the clothing than initially thought. This observation is evidence that fluid flow through a clothing item is a key motive force in agitating the clothing, but it looks like high compression is a key factor in achieving fluid flow through the clothing item.

One hypothesis of this experiment was that lower compression would lead to greater compression, since contaminants would see less obstruction to exit the clothing item, but at least in the case of the water-soluble washable paint, the opposite was true for the reasons listed above.

Observed Phenomena

Greater Agitation at Points Close to Wash Chamber Outlet

Observation:

When clothing items were oriented so that the paint was closer to the outlet to the wash chamber, they seemed to experience better agitation than those where the paint was on an opposing side of the wash chamber to the outlet.

Potential Explanation of Phenomenon:

As predicted, flow of clothing into the clothing item leads to better agitation. Not only does the clothing item physically experience a spraying effect of the outlet as water is drawn back into the wash chamber close to the outlet, but in general, the areas close to the outlet experience greater flow rates than that of locations far from the outlet.

Conclusions Drawn:

Flow of water into, through, and around the clothing item is a key factor in agitation of clothing items in the wash process. This can be done by all sorts of potential components of the flow including pressure of impact on clothing, friction caused by the flow, turbulence near the outlet, and much more.

Conclusions Drawn in Experiment

- Wash cycle has potential to agitate clothing adequately enough to continue developing the design

- More work needs to be done to create a more accurate experiment before trying to improve the design or conduct more accurate or telling experiments (creating an experiment quantifying the effectiveness of the wash process and testing varying types of contaminants)

- Flow of water through and into the clothing item does the most work to agitate and remove contaminants

- Compression serves a key role in facilitating flow of fluid through the clothing item and successfully agitating clothing items

Potential Design Changes Informed by Experiment

With the increased agitation under high compression and in area local to the outlet, there are a few things that may be worth looking into for future designs:

- Finding ways for flow through outlet to dislodge and reorient clothing item so all areas of clothing see increased agitation as apposed to one

- Multiple outlets to reduce localized agitation issues

- Using spray nozzles to facilitate more agitation and reorientation of clothing upon decompression

- Change in compression procedure, compressing clothing to a threshold, waiting for compression to force to decrease independent of piston head being driven, and continuing to compress clothing in the same manner until there is no decrease in reaction force done by the clothing-wash water mix to ensure max compression and therefore agitation

- Splitting Agitation phase into multiple sub-phases, with high compression high agitation, minimum compression clothing reorientation, and potentially sub phase for evacuating solid/other contaminants trapped in clothing item

- Incorporating a high resistance spring in the shaft driving the piston head into the design to facilitate better agitation according to observations made during experiment

Additional Notes

The washable paint did not wash very well even with detergent. Shown below are the clothing items after being washed with a commercial washing machine using detergent.







Additional Notes Continued

The best compression with the commercial washing machine clearly had access to more water than that of the other tests. While that may be easy to see, error such as presence of soap or detergent during the wash (most likely residual from past washes in normal use) was also present. The settings were chosen to be similar to the conditions of the other tests, being cold and under normal load.