Important Issues Uncovered in Condunducting Summer 2020 Prototype Wash Effectiveness Experiment

Through conducting the Summer 2020 Prototype Wash Effectiveness Experiment, it was found that the linear actuator could compress the shirt far less than the prototype was supposed to. It seemed apparent that the piston head was stuck and being prevented from moving in some way, indicated by the piston not being able to be retracted, and not being able to be moved without additional load added such as a shirt in the chamber.

Despite this issue, there was some movement of the piston head (roughly 0.20”), so the test was continued under the assumption that it could be conducted again at a later date if needed.

After conducting the experiment, the piston head was made to move again using the linear actuator. However, when a shirt was placed back into the wash chamber along with the volume block used for testing, the linear actuator was still unable to compress the clothing to the desired volume. This is an issue that has to be explored further, as it jeopardizes the viability of this process being used to wash clothing.

There are a number of possible causes to this issue. Some possible causes could be a malfunction that remains unidentified and unresolved, they could be prototype specific, or it could be a fundamental issue with the design. Only with further testing can this be determined. Some of the possible causes of this problem include:

1. The frame constructed isn't precisely made, and it is not braced to prevent horizontal movement or rotation on multiple axes. This means that the frame could be causing the linear actuator to be pushing against components of the washing machine instead of just the piston head.
2. The resistance of the O-Ring seals is too high for the linear actuator to counteract, and still compress the shirt to the desired volume. This is a possibility, as the piston can only be physically moved using a mallet or by hitting the shaft for the piston head against a hard surface while holding the wash chamber. Beyond that, the actual force required to move the piston head is not known.
3. The linear actuator could actually not be as strong as anticipated. Though the linear actuator is rated for being able to apply a force of 6000 newtons, or roughly 1348 lbf, it is possible that it is producing less. Testing this is not possible with the means available.
4. The force required to compress a shirt to the desired volume is much greater than anticipated, which would invalidate the feasibility of this design for washing clothing altogether. This possibility is unlikely since testing was conducted to determine if this function was possible in the past, but it is a possibility that should be explored nonetheless.

**Response to This Issue:**

The most important cause for this issue to rule out is finding the force required to compress a shirt enough for the washing machine to perform each of its functions. If this force is too great for a machine to feasibly apply, then regardless of the presence of any other causes, the washing machine design is not viable as it is currently designed. Once this test is conducted, several others will follow.

1. **Finding Clothing Specifics**

With tests being conducted, the most important thing to look for is the specifications of the clothing being tested. The volume of the tested clothing will be found by placing it along with a set amount of fluid in a liquid measuring container. The difference between the liquid volume and the volume of the water-shirt mixture is the volume of the shirt. In addition to this, a baseline value for how much water can be mechanically removed from the shirt will be found by wringing it out to determine a volume of fluid that should be present in the shirt following compression of the washing machine.

1. **Equipment Test**

Measuring devices will be checked to see if they yield correct values before any tests are conducted using them.

1. **Clothing Press Test**

This test will be conducted to find the volume an article of clothing can be compressed to with various forces being applied. With this data, the volume in the container can be calculated by finding the distance between the bottom of the chamber, and the piston head. With this distance, and a known radius, the volume between these bounds can be calculated. With this value, the volume of the shirt can be subtracted from the result to find the total fluid in that area.

1. **Seal Reaction Force Press Test**

Until this test, all tests utilizing a piston head will not include seals in order to isolate the forces required for a given function from the forces required to move the seals. With these values, it can be found how much force exactly the linear actuator is able to apply, and if the seals are or are not the cause of the deficiency in the prototype. Just like the press test, a downward force will be applied to the piston head, only the force being found is a constant number. Force will be added to the system until the seals move to find this number.

With exception of prototype specific experiments, all of these tests have been conducted during the 2019-2020 school year as well as during the summer of 2020. Since the results of those tests show that the washing machine should be able to compress clothing further, these tests must be redone to ensure that the data behind the design is correct, and support the possibility of it functioning.

Some key differences in the available materials means that testing can be conducted more easily and accurately. With the 4” Schedule 40 Clear PVC Pipe used in the actual prototype, results can be measured directly and not calculated from other measurements, and the wall of the pipe is more precise than any other materials used in the past. Additionally, the 4” Schedule 40 Clear PVC Pipe also provides for better insight on what happens inside the wash chamber. Better fitting 3” Schedule 40 PVC End Cap that made the piston head is sized more precisely to better represent the material used for the washing machine, and should also provide for better data.

Even with these improvements, conducting these tests still cannot be as thorough as desired due to the main measuring device, a scale for measuring applied force, does not have the capability of measuring weight over 400 lbs. While the expected plateau for the relationship between change in volume and force applied begins to show great diminishing returns at around 300 lbs as per previous testing, with the maximum of 400 lbs for weight measurement, approaching that number could yield unreliable results.