**Wash Process Calculations**

With the wash process outlined in 5: Detailed Overview of Wash Process, how can the effects of the wash process machine be quantified? Though most of these calculations are not particularly useful for the design and prototyping of the washing machine, they can be useful for improving the effectiveness of the wash process through experimentation, make the system safer, or be useful in executing the wash process.

*It is worth noting that this is a subject I do not have experience or much knowledge in.*

**Determining Pressure Generated In Wash Process:**

This is a very important piece of knowledge for the actual prototype design. With this, the washing machine can be designed to handle these pressures with a factor of safety. For cases where this value increases beyond where the machine is designed to handle, relief valves can be set to safely vent fluid. The values that ensure safety and smooth operation are done in these calculations.

To find pressure, a pressure gauge can be used at a point in the washing machine, or the distance that the chamber top moves from its initial condition can be used to calculate it. The spring force for the chamber top works against the resultant force of the pressure generated by the fluid. The equivalent force of the pressure on the chamber can be described by , where was previously found to be the area of the surface of the chamber top. The force applied by the spring on the chamber top can be described by where k is the spring constant of the spring used.

Fluid pressure could also be determined using the load cell attached to the piston head, but it cannot be under any other load such as compressing a clothing item. By comparing the pressure read by the load cell to the pressure in the system determined through other means, the accuracy of equipment can be measured and calibrated. The equivalent force can be represented by

The method of using the chamber top travel to measure internal pressure has an error in that whichever force is acting to move the chamber top needs to act against the friction of the seal between the chamber top and chamber walls. By taking both into account as well as other variables such as acting piston position. The pressure can be predicted, and if there is a discrepancy, the system can be stopped as a safety feature.

**Determining of Desired Fluid Present in Wash Chamber:**

This is a very important part of figuring out the design effectiveness as well as operation. The fluid volume in the washing machine will always be at the volume predetermined at the beginning of the wash process unless the chamber top is moved while mid-wash. What is important is knowing the uncertainty in the wash chamber being filled with water or air. For every cycle of fluid being purged from the system, the volume of the new fluid compressing the clothing will be the volume of the chamber minus the uncertainty.

What does Uncertainty mean? If the wash chamber is purged of a fluid, it is compressing the clothing item as much as possible to reduce the volume of the chamber. When this happens, fluid displaced is discharged from the system rather than sent to the chamber top. The resulting volume minus the known volume of the clothing is how much fluid is known not to be the fluid entering the wash chamber upon decompression. While the fluid in the chamber can be some amount of both air and water which cannot be accounted for, the maximum discrepancy between the ideal and actual cannot exceed the volume of fluid left non displaced following compression. Uncertainty can be represented with this equation:

The fluid volume from this process is then found to be the volume of the wash chamber minus the volume of the clothing item minus the uncertainty due to incomplete clothing compression. The goal is to get as low of an uncertainty as possible, though getting no uncertainty is impossible since a clothing item cannot be fully compressed into a homogeneous mixture, meaning there will always be packets for fluid to take up space under compression. Volume of a given fluid present in the wash chamber can be represented with this equation:

**Determining Flow Rate at Various Point in Washing Machine:**

This measure is useful for furthering the design to improve wash effectiveness, but largely serves no purpose to the design of this prototype. It may be useful along with other calculations for finding pressure generated for water flowing through the resistance of the clothing item in order to escape the wash chamber under compression.

This value can be defined by relating the rate of change in chamber volume with the volume of the inlet or outlet to the chamber (Which in this design is the same pipe). By looking at the equation of a cylinder: and taking the derivative with respect to time (treating r as a constant), the rate of change in volume can be described as . Knowing that the rate of volume entering or leaving the wash chamber and entering or leaving the plumbing of the system, the equation can be used to find the rate of fluid through the system. Substituting the dimensions of the pipes and wash chamber in as well as the speed that the piston compresses at, the rate at which fluid of the cross sectional area flows through the pipes. Multiply this quantity to get a quantity of volume per unit of time of fluid flowing through the pipes.

It is worth noting that the speed at which the acting piston moves will be varied based on the load it is acting against. Many variables could dictate changes in flow rate and pressure across the system, but it should not exceed the applied load of the piston divided by the area of force application.