

## The Study of Dynamically Active Washing Process of a Washing Machine

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**Abstract**—In area of washing machines and clothes washing technology industry, there are many features of clothes washing machines. All these available machines have two main washing technology configurations which can be presented by top loading and front loading. These washing technology involve a washing drum which filled with washing liquid contain detergent and the submerged dirty clothes are cleaned with rotary motion of an actuator or rotating drum. In the washing process, clothes mixed up with detergent solution and the rotary washing action given by actuator or rotating drum help to dissolve grease and carry away dirt into washing liquid. The rotary actuator with ribs rotate clothes with washing liquid added into vertical dram during washing process. These known washing machines are deficient relatively. It is because the passive washing process takes place efficiently only after some period of time. Proposed a new washing technology where it introduces active process in washing action. This washing technology will produce better outcome result in term of improved quality of washing process.

**Keywords:** washing machine, technology, active and passive washing process.

### I. INTRODUCTION

All known technology of clothe washing processes generally can be characterized as passive and semi passive processes. Washing process involves clothes contained in rotary drum and rotation of the washing liquid. Clothes fall down and lifted up on some level due to rotation of the drum and actuator action. These multi repeatedly falls of the clothes presents element squeezing action of washing process. The washing process with rotary actuator in non-rotated drum will rotate and clean the clothes. Such process involves multi repeatable catches of the clothes with rounded ribs of actuator and followed relieve of the clothes that involve some simple process of squeezing of the clothes. Both type washing processes are not productive and take long time. Washing process occurs with used liquid and

it is impossible to recognize that clothes are clean or still dirty. Only visual inspection of the washed clothes gives answer on this question. All this disadvantages of known washing processes should be considered as the lack ones.

New washing technology presents process that involves motion of the liquid with high speed of motion at different directions in a non-rotating drum. This is a very dynamical process that involves kinematical forces of motion of the liquid. High speed motion of the layers of liquid in counter and changeable direction create the very active squeezing process. Additionally the motion of the liquid is turbulent at different directions that cannot be described mathematically due to extremely complex nature of motions. In such conditions of the new washing process, the experimental research can give true solutions of the process that include such parameters like the directions of the liquid streams, frequency of their change, kinematical pressure of the liquid and other.

This new washing technology will work with a non-rotating drum. Detergent and supplied water will clean the dirty clothes fill in the washing drum with rotary motion created by the nozzle of inclined direction. This is an active washing process as water is directed to clothes by nozzle and this will exert force on the clothes surface. This surface force on cloth and help of detergent as lubricant will remove any contaminations on it. It is a proposed double-action cleaning technology since it introduces direct squeezing force and interface between washing liquid and cloth compared to the recent passive washing process in the market which depends on the rotor efficiency and actuator to rotate the drum and squeeze the clothes.

Washing machine is rated based primarily on washing ability, efficiency, capacity, and noise and gentleness. For washing, machines were loaded with 8 pounds of cotton items, run on their most aggressive cycle, and judged on soil removed from test items. Energy efficiency is based on electricity needed to run the washer. Water efficiency denotes how much water per pound of clothing it took to wash an 8-pound load. Capacity denotes how large a load each machine could wash effectively. Noise reflects judgments by panelists.

This new technology will eliminate the used of rotary units. On the same time, it tackles the washing machine major failure such as excessive vibration and balancing problem which produced by rotating mechanism. Noise which generally produced by tumbling and rotary mechanisms can be avoided. Gentleness is taken account for evaluation of washing machine too as to maintain the cloth initial shape. The washing liquid is recycled by passing through a filtration unit hence save up water used. Since this is an active washing machine, shorter time needed to clean

amount of cloth and this also means less power used. It has good capacity too as there is flexible nozzles help in rotary cleaning for directions. In addition, the washing process is becoming more efficient with ultrasonic technology installed in the washing machine.

## II. BRIEF DESCRIPTION OF NEW WASHING TECHNOLOGY

Electric motor will convert electric power to mechanical energy to initiate the pump. Pump gives pressure and speed to water. Control unit will actuate the function of valve according to time and sequences. Washing liquid exit from the drum will pass through filtration unit to be recycled. Washing liquid will first filtered in mechanical filter and next move into chemical filtration unit. Clean water will be recycled and it is pumped into the washing drum. The washing cycle will repeat until all clothes are cleaned.

High pressure and speed of water from pump is directed into the washing machine drum. The nozzle will give inclined direction of water flow and point it towards clothes. The washing liquid will rotate and squeeze the clothes. The controller unit will change the direction of rotating liquid to clockwise and anticlockwise or rotating against or perpendicular to the drum axis follow the timing set. The ultrasonic machine will enhance the agitation and rotary motion of washing liquid during washing process which could save up time, energy and cost.

High pressure and speed of water from pump is directed into the washing machine drum. The nozzle is installed at the necessary inclined direction to permit flow of liquid into drum and point in necessary angle towards clothes. The washing liquid will rotate and squeeze the clothes according to the technological set up. The controller unit changes the direction of rotating liquid to clockwise and counter clockwise or rotating against or perpendicular to the drum axis follow the timing set. Such complex motions of the washing liquids can guarantee the squeezing process of all part of clothes and quality of the washing process. It creates better level cleanse of clothes and high speed of process. New washing process is quite complex to describe mathematically as it is some very complex problem that impossible to solve it practically using known mathematical models for this complex motions of the fluids today. Nevertheless it is possible to present first mathematical approach for the parts of the washing process that enable to describe the behavior of the clothes, washing liquids and other technical parameters. This approach can be based on the known theory of fluids, Bernoulli equations and others that can be modified and improves by experimental coefficients and other factors that can give acceptable results and dependencies. Such approach will be useful for designers and manufacturers of the washing machines and to get optimal decisions in construction.

Figure below presents sketch of main components of washing machine construction. This new washing machine is quite simple and contents many standard elements like electromotor, centrifugal pump, hydraulic controller, filters, pipes and so forth. It means that it will be cheaper than known ones and can be conquerable in marketing area by criterions quality of cleaning process, productivity rate, price of washing machine, etc.

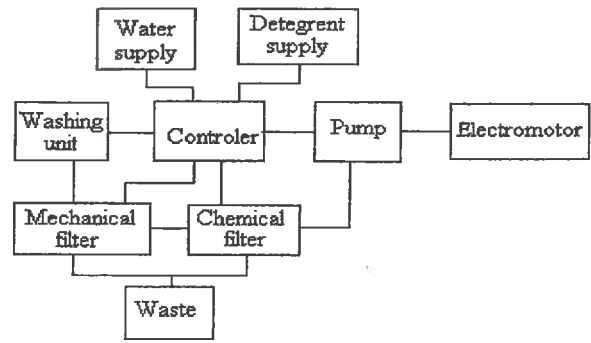


Figure1: Overall system of washing machine assembly unit.

## III. ANALYTICAL APPROACH

New washing process involves the action of the kinematical pressure of the liquid, which energy is used for cleaning and squeezing of the clothes. Analytical approach will find the expressions of these energy and forces acting to the surfaces of clothes that can give solution not to damage the clothes and fulfill washing process desired performance with high quality and short time.

Fluid in motion without referring to forces causing the motion is known as kinematics study. The dynamic equation of fluid motion is obtained by Newton's second law to a fluid element. The fluid is assumed to be incompressible and non-viscous.

Stress on the cloth surface represent squeezing force exerts on a cloth element. This new technology of washing will generate more stress on the cloth surface compared with passive washing process as direct force is exerted on it. The strength of cotton material from 3.3 to 3.6 grams/denier is taken as bench mark.

Motion of cloth rotating in the washing liquid can be defined as vortex motion. The whole fluid mass rotates about an axis and the flow pattern within curved. When fluid flow between curved streamline, centrifugal force produced and it's counter-balanced by radial pressure force. Forced vortex flow take place in washing machine because there are external energy supplied such as pump. Pump transfer mechanical power and imparts constant torque to give rotary motion to the fluid.

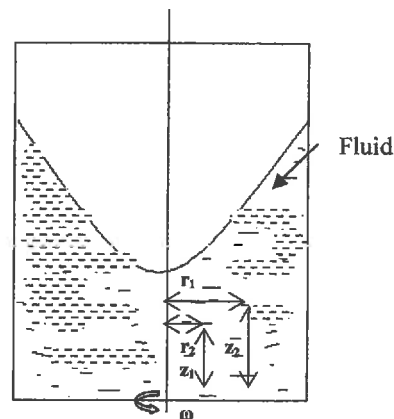


Figure 1: Motion of liquid in rotating drum.

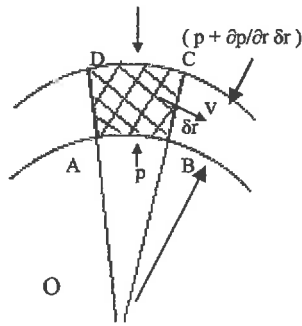


Figure 2: Flow in a circular part.

Forces acting on the fluid element are:

- i. centrifugal force
- ii. pressure force on face AB
- iii. pressure force on face CD

$$V = \omega r,$$

$$F_c = m v^2 / r,$$

$$F_p = P \delta A,$$

$$m = \rho \delta A \delta r,$$

Equating the forces in radial direction based on figure 2,

$$(p + \partial p / \partial r \delta r) \delta A - p \delta A = m v^2 / r$$

$$\text{With } m = (\rho \delta A \delta r),$$

$$p + \partial p / \partial r \delta r) \delta A - p \delta A = (\rho \delta A \delta r) v^2 / r$$

$$\partial p / \partial r = \rho v^2 / r$$

Variation of pressure given by hydrostatic law,

$$\partial p / \partial z = -\rho g$$

As the pressure is the function of  $r$  and  $z$ , total derivative pressure  $p$ ,

$$\partial p = \partial p / \partial r dr + \partial p / \partial z dz$$

$$= \rho v^2 / r dr - \rho g dz$$

For forced vortex flow,

$$p = \rho \omega^2 r^2 / 2 - \rho g z$$

Integrating between point 1 and 2,

$$\partial p = \rho \omega^2 r dr - \rho g dz$$

$$\int_1^2 \partial p = \int_1^2 \rho \omega^2 r dr - \int_1^2 \rho g dz$$

$$p_2 - p_1 = \omega^2 \rho / 2 (r_2^2 - r_1^2) - \rho g (z_2 - z_1)$$

$p_2 = p_1$  when point 1 and 2 are at the free surface. Then,

$$p_2 - p_1 = \omega^2 \rho / 2 (r_2^2 - r_1^2) - \rho g (z_2 - z_1)$$

$$z_2 - z_1 = \omega^2 (r_2^2 - r_1^2) / 2 g$$

If point 1 lies on the axis of rotation, then

$$v_1 = \omega_1 r_1 = 0$$

Let  $z_2 - z_1 = z$

$$z = \omega^2 r_2^2 / 2 g$$

If point 1 and 2 lie at the free surface, hydrostatic force:

$$dF = w dA z$$

Rotational force:

$$F_R = \int dF$$

$$= \int w dA z$$

where notation of:

$\partial p / \partial r$  = pressure gradient,

$V$  = tangent velocity of fluid particle,

$\omega$  = constant angular velocity of fluid mass,

$r$  = radius of fluid particle from axis of rotation,

$m$  = fluid particle mass,

$F_c$  = centrifugal force,

$F_p$  = pressure force,

$\rho$  = mass density,

$g$  = gravity acceleration,

$r_{1,2}$  = radius at point 1 and 2 from axis of rotation,

$z_{1,2}$  = height water level from the container bottom,

$w$  = weight density

#### IV. CASE STUDY

A 0.225 m open circular cylinder and its height is 1.5 m long and contain water up to height 1.05 m as shown in figure 3. If the water in the container rotate in high speed about its vertical axis so that the axis depth become zero and the water rise to the maximum cylinder height, find the speed at which the cylinder may rotated by not spill the water out. Find the pressure force due to rotation at the bottom of cylinder.

Let  $h = \omega^2 r^2 / 2g$  be the height of water from the tank up to free surface of water at radius  $r$ .

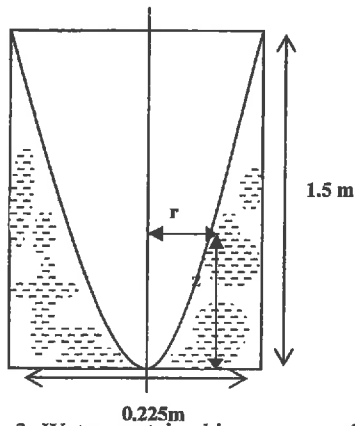


Figure 3: Water contained in an open cylinder.

Solutions:

$$z = \omega^2 r^2 / 2g$$

$$1.5 = \omega^2 r^2 / 2g$$

$$1.5 = \omega^2 (0.1125)^2 / 2 * 9.81$$

$$\omega = 48.22 \text{ rad/s}$$

$$\text{Let } w = 9810 \text{ N/m}^3$$

$$dF = w \, dA \, z$$

$$= 9810 * 2\pi r \, dr * \omega^2 r^2 / 2g$$

$$= 3141.6 * \omega^2 r^3 \, dr$$

$$F_R = \int dF$$

$$= \int w \, dA \, z$$

$$= \int 3141.6 * \omega^2 r^3 \, dr$$

$$= \int_0^{0.1125} 3141.6 * \omega^2 r^3 \, dr$$

$$= 3141.6 * (48.22 \text{ rad/s})^2 r^4 / 4 \Big|_0^{0.1125}$$

$$= 3141.6 * (48.22 \text{ rad/s})^2 * 0.1125^4 / 4$$

$$= 292.52 \text{ N}$$

hence there is two moment  $2 * M$  moment at the center of the cylindrical drum axis.

$$M_T = 2 * F_R * r$$

$$= 2 * 292.52 * 0.1125$$

$$= 265.82 \text{ Nm}$$

If the rotational direction is about the cylinder horizontal axis, the moment will act correspond to half of water height water contained so,

$$M_T = 2 * F_R * z/2$$

$$= 2 * 292.52 * 1.5/2$$

$$= 438.78 \text{ Nm}$$

## V. CONCLUSION

This paper has discussed on washing technology in the laundry world. It introduces new active washing approach which is more efficient in term of washing ability, efficiency, capacity, and noise and gentleness compare to the common practice of passive washing process. Water is recycled by a mechanical and chemical filtration unit to save its consumption. Ultrasonic technology is an additive element to improve the quality of washing process.

Empirical and mathematical approach will determine the best design of this new type washing machine.

## ACKNOWLEDGMENT

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