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Ergonomic Development of Manual Hand Washing Machine to Ameliorate the Deadly Effect of COVID 19 Pandemic

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Abstract: The corona virus disease (COVID 19) is an infectious disease caused by the newly discovered corona virus. Its high rate of transmission makes it more deadly, as it can be easily spread from person to person. One of the ways in which the spread of this deadly virus can be curbed is regular washing of hands with soap and running water. Hand washing is a critical activity in preventing the spread of infection in health-care environments and food preparation areas. In order to eradicate hand contact between the tap and the hands a manual hand washing machine was designed and fabricated. The machine employs the use of pedal operated clutch cable and a return spring to operate the water tap, while making use of pedal operated contact spring for the spraying of soap. The average human height was considered to make the machine ergonomically satisfactory, so as to make its usage more comfortable. The materials for the fabrication of the machine were sourced locally, so as to minimize the cost of production and make it readily available for low income earners in developing nation.

Keywords: Corona virus, Clutch cable, Ergonomic, Hand washing, Pedal operated

I. INTRODUCTION

The origin of human corona viruses can be traced back to 1960 when Tyrrell and Bynoe isolated a virus named B814 from a boy while working at the British Common Cold Unit of the British Medical Research Council [1]. More than 8,000 people were infected by July 2003, and 774 died. A small outbreak in 2004 involved only four more cases [2]. The novel coronavirus refer to as SARS-CoV-2 is responsible for coronavirus disease (COVID-19) pandemic which originated in Wuhan, China, December 2019 has now spread to 113 countries and territories outside of China [3; 4]. SARS-CoV-2 is a beta coronavirus that causes fever, headache, and respiratory problems such as cough and shortness of breath [5]. Healthcare Workers (HCWs) and other public personals are at risk of been infected by COVID-19 due to constant exposure to infected people and contaminated surfaces [6; 7]. SARS-CoV-2 appears to be transmitted person-to-person through respiratory droplets and close contact, as previously seen in SARS-CoV and MERS-CoV, the two other zoonotic coronaviruses. The necessity of practicing respiratory hygiene and hand hygiene, and using appropriate personal protective equipment have been highlighted by [8] and [9]. On 29 December 2019, the first four cases of an acute respiratory syndrome of unknown etiology among people linked to a seafood market ("wet market") were reported in Wuhan city, Hubei province, China [10]. This deadly virus has now spread widely to almost every part of the world. Many countries, cities and rural areas are on lock down to reduce the spread of the disease, hence technologies and technocrats needs to developed medicines to cure victims and machines to ameliorate the transmission among the citizen.

Foreign developed countries have produced advance hand washing machines which are expensive for developing countries. This paper therefore highlights the review of COVID 19 and the development of a simple low cost ergonomic hand washing machine affordable in our rural area.

Origin of Hand Washing

The origin of hand hygiene may be very difficult to trace accurately, but religious hand washing has been around for the past thousands of years in Jewish and other religions, but in medical practices, the belief of germ spreading by hand has been around for only about 130 years [11]. In the history of mankind, there is an urgent need for an appropriate hand washing and sanitizing machine more than never before, especially the one with no hand contact, so as to curb the increasing spread of corona virus. Water is one of the most important and commonly used natural resources. It needs to be mined from its sources that are from rivers, ditches, sky and beneath the ground for man's regular use [12; 13; 14]. Water is the most essential elements require in washing of the hands and arms. Importance of hand washing cannot be over-emphasized, especially in developing nations where eating with hands is a common practice. In some developing cultures, there is always the reluctance of hand washing before meals; and in some, hand washing has become a culturally accepted norm. Effective hand washing is widely acknowledged to be the single most important activity for reducing the spread of infection in clinical environments and food preparation areas [15]. To prevent the spread of the disease, it is recommended to maintain an overall good personal hygiene, to wash hands frequently, avoid touching the eyes, nose, or mouth with unwashed hands, to cough or sneeze into a tissue [16]. Germs and viruses causing these diseases are passed on by such routine things as handling food, touching door knobs, shaking hands and putting mouths on a telephone receiver. The promotion of hand washing with soap is also a key strategy for controlling the spread of Avian Influenza (bird flu). Although the viral load of coronaviruses on inert surfaces is not known during an outbreak situation, it is crucial to reduce it on these surfaces by disinfection, especially on frequently touched surfaces where the highest viral load can be found. Using the correct disinfectant is an important part of preventing and reducing the spread of COVID-19 along with other critical aspects such as hand washing [17]. This prompted us to contribute with this project as a way to increasing the practice of hand washing in our society so as to remain healthy [18].

Recent Advancement in Hand washing Technique

Hand washing machines as recorded some advancement in recent years, [19] addressed the problem of single-hand gesture recognition in hand washing and recently gesture recognition has been applied to hand washing as stated by [20]. Wide range of vision-based hand gesture recognition techniques application was considered by [21]. [22; 23] work on spatio-temporal hand gesture recognition using neural networks for effective hand washing, whereas [24; 25] studied recognition of gestures using Hidden Markov Models (HMM) for proper hand washing technique. [26] proposed a robust hand posture detection method based on the [27] detector. [28] modeled hands and the towel as a flock of features describing its approximate shape. Three independent particle filters consisting of the right, left hands, and the towel were used.

In the developing nations several hand washing and sanitizing machines have been developed based on different techniques over the years. Low-cost hand washing technologies for households may differ from facilities for multiple users. For households, options include tippy taps, bucket/container with tap, conventional tap with/without basin, valve/tap fitted to bottles, bucket and cup, camp sink. Options for multiple users include: adapting household technologies for multiple users, water container fitted to a pipe with multiple taps, water container fitted to a pipe with holes [1; 29].

Most of these machines are operated manually with the hands which makes it susceptible to the transmission of disease by hand to hand contact via operating the tap. The design machine is expected to eliminate the hand contact by utilizing a foot pedal.

Ergonomic

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Ergonomics is a science that deals with the limitations and merits associated to humans, the information gathered are used to design products, machinery, facilities, environment, and work system. The main objective of an ergonomic application is the utilization of healthy condition, safety, and working comfort to achieve a good quality of work. At a higher level of ergonomics aims to create optimal working conditions. In ergonomics occupational Safety and health are dual major factors that cannot be separated because they have the same goal which implies improving the work quality [30]. The definition of ergonomics can be described based on the focus, objectives and approach as mentioned by [31]. The ergonomics focuses on human interactions with the product, equipment, facilities, procedures, and environments where human daily live and work. The goal of ergonomics is to increase the effectiveness and efficiency, improved safety and reduced fatigue, while the approach is the application of information about human limitations, capabilities, behaviour characteristics and motivation to design procedures and the environment in which human activity daily.

This work is aimed at using materials sourced locally to develop a manual hand washing and sanitizing machine at a comparatively lower cost, which will be operated with the use of pedal, hence, eradicating the risk of corona virus transmission which may be encountered due to hand contact. It is also meant to ensure the users are comfortable through the application of ergonomic principles.

II. MATERIALS AND METHODS

The machine was designed based on a simple working principle to accommodate a person at a time. The principle of ergonomics was put in place for convenience; an average standard height was designed to position the tap at a height of 1030 mm. Hence it can be conveniently used by almost everyone regardless their height. The working diagram for fabricating the machine frame and other components is shown in Fig. 1.

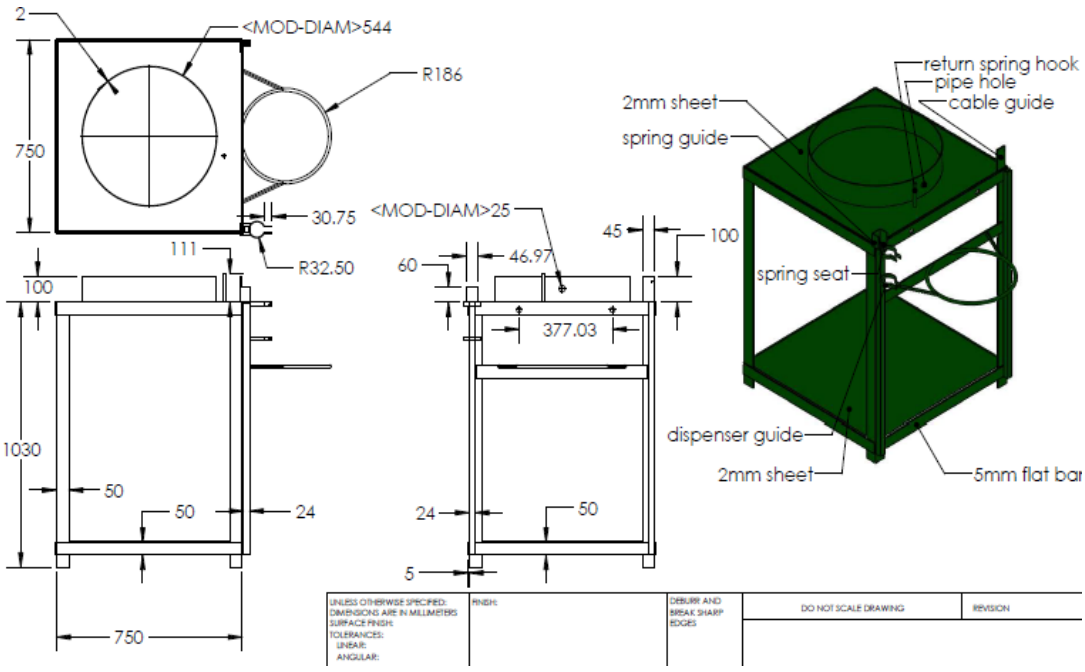

Fig. 1: Working Diagram of the Designed Machine

All the materials used were sourced locally such as the mild steel plate, angle iron, flat bar, clutch cable, spring and tap. These materials were selected based on their availability, cost and usability owing to their strength, durability, weight and ease of been join together.

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III. DESIGN ANALYSIS FOR MACHINE COMPONENT SPECIFICATIONS

Determination of the spring stiffness

According to "Hooke's law" which states that the force F needed to extend or compress a spring by some distance X is proportional to that distance.

Force downward = Upward pull by the spring (due to extension)

$$Mg = kx \tag{1}$$

$$\frac{Mg}{x} = k$$

Mg= numerical value of the weight

x= extension or displacement

K = spring constant.

That is: $F = kX$, where k is a constant factor characteristic of the spring: its stiffness, and X is small compared to the total possible deformation of the spring.

The spring constant K is measured in newtons per metre (N/m), or kilograms per second squared (kg/s^2)[32; 33].

The force exerted by the weights.

where,

mass, m = 5kg and acceleration due to gravity, g = 9.81m/s^2

$F = (mass)\ x\ g$

F= 5×9.81= 49 N.

F= kx (2)

where x is the displacement produced in the spring when the weight is suspended.

The displacement in this case is 10cm.

$$k = \frac{f}{x} = k = \frac{49}{0.1}$$

k = 490 N/m. is the stiffness of the spring.

The Pipe System Geometry

Loss Due To Sudden Enlargement in the Tap Pipe

Water tank orifice diameter (D_1) = 10mm, Tap pipe diameter due to enlargement (D_2) say 20 mm

Assuming hydraulic gradient rises by 10mm

Applying Bernoulli's equation to small and large pipe sections,

$$\frac{p_1}{W} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{W} + \frac{V_2^2}{2g} + Z_2 + h_e \tag{3}$$

$$h_e = \frac{(V_1 - V_2)^2}{2g} \tag{4}$$

$$A_1 V_2 = A_2 V_2 \tag{5}$$

$$V_1 = \frac{A_2 V_2}{A_1} = \frac{D_2^2 V_2}{D_1^2} = 4V_2 \tag{6}$$

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Substituting V_1 into equation 4

$$h_e = \frac{(4V_2 - V_2)^2}{2g} = \frac{9V_2^2}{2g} \quad (7)$$

$$\frac{p_1}{W} + \frac{(4V_2)^2}{2g} + Z_1 = \frac{P_2}{W} + \frac{V_2^2}{2g} + Z_2 + \frac{9V_2^2}{2g}$$

$$\frac{16V_2^2}{2g} - \frac{V_2^2}{2g} - \frac{9V_2^2}{2g} = \left(\frac{p_2 + Z_2}{w}\right) - \left(\frac{P_1 + Z_1}{w}\right) = 0.01m$$

$$\frac{P + Z}{w}$$

$$\frac{6V_2^2}{2g} = 0.01$$

$$V_2 = \left(\frac{0.01 \times 2 \times 9.81}{6}\right)^{\frac{1}{2}} = 0.181m/s$$

$$h_e = \frac{9V_2^2}{2g} = \frac{9 \times (0.181)^2}{2 \times 9.81} = 0.051m$$

$$\phi = A_2V_2 = \frac{\pi}{4} \times 0.02^2 \times 0.181 = 0.00005m^3/s$$ [34].

Part Descriptions

The various components welded and coupled together to make the machine were listed and explained in the section below. The design process of the hand washing machine was based on the functionality of individual parts.

Main Frame

The main frame is the basic frame for the machine. In this frame, all another part is attached using bolt, nuts and welding. The dimensions of this part are measured based on anthropometrics from average size people. The height of the main frame only is two third the average height of adult people which around 162 cm [35]. So, the dimensions of the main frame are 103 cm height, 75 cm width, and 75 cm length. The frame was designed and constructed to carry the water container without deformation and to withstand the force exerted on both pedals. The principle of ergonomics was also put into consideration by using the standard height of the domestic washing hand basing which is 90 cm [36]. The frame being the main support for the machine was designed and fabricated to withstand stresses and load with mild steel angle bar.

Water Container (Bucket)

A durable bucket was used which serve as an overhead tank or water reservoir. It has the capacity to carry nothing less than 50 liters of water. Rubber container as shown in Fig. 2 was used owing to its lightness, corrosion resistance and cheaper price.

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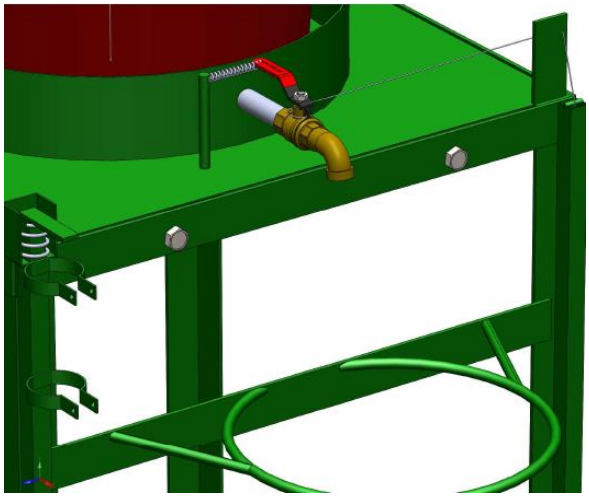

Fig. 2: Rubber Container Placed on Metal Frame

Clutch cable

The clutch cable as shown in Fig. 2 is a long thin wire that runs from the pipe to the pedal. To withstand tension and shock loading as a result of sudden load applied by the foot a 2.0 mm clutch cable was used. This clutch cable enables the operator to open the tap base on foot press on the pedal.

Return Spring (extension spring)

The return spring was used that has the ability to withstand sudden load as generated by pressing the pedal and return the soap knur to the close position. This will enable the machine to release the liquid as required.

Water Dispenser Pedal

The water dispenser pedal in Fig. 3 was fabricated with a 20 mm square pipe of height 675 mm welded to a 150 x 50 x 5 mm flat plate made of mild steel.

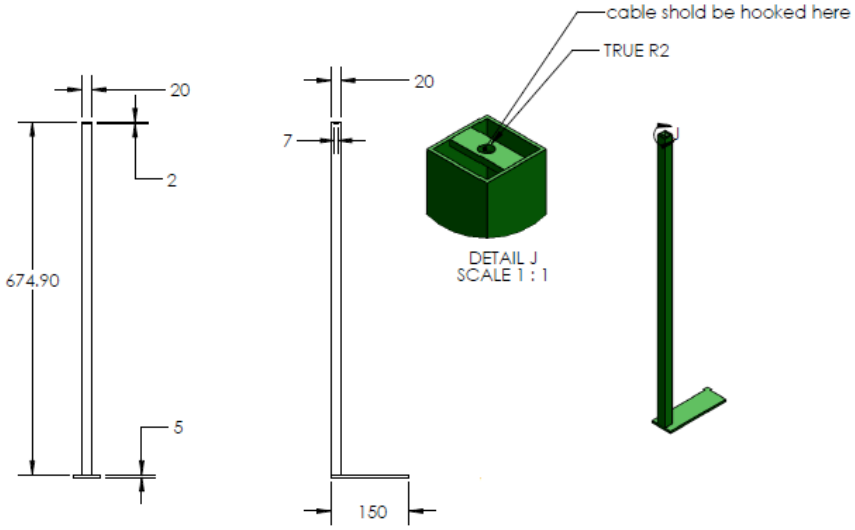

Fig. 3: Water Dispenser Pedal

Soap Dispenser Pedal

This soap dispenser pedal in Fig. 4 is fitted with an helical spring for quick return of the close knur of the liquid soap after

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usage. It was fabricated with a 20 mm square pipe of height 1041 mm welded to a 150 x 50 x 5 mm flat plate made of mild steel.

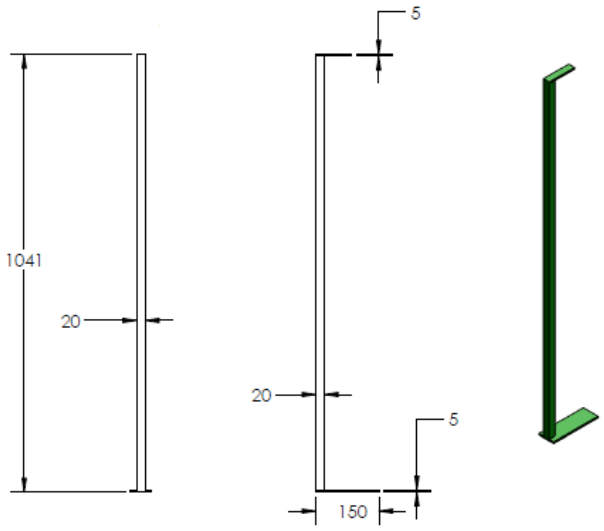

Fig. 4: Soap Dispenser Pedal

Water Tap

An aluminum water tap was used. Aluminum was much preferable due to its lightness and resistance to corrosion. The actual position is shown in Fig. 5, it is attached to the water bucket connected with pipe at a height above the machine frame.

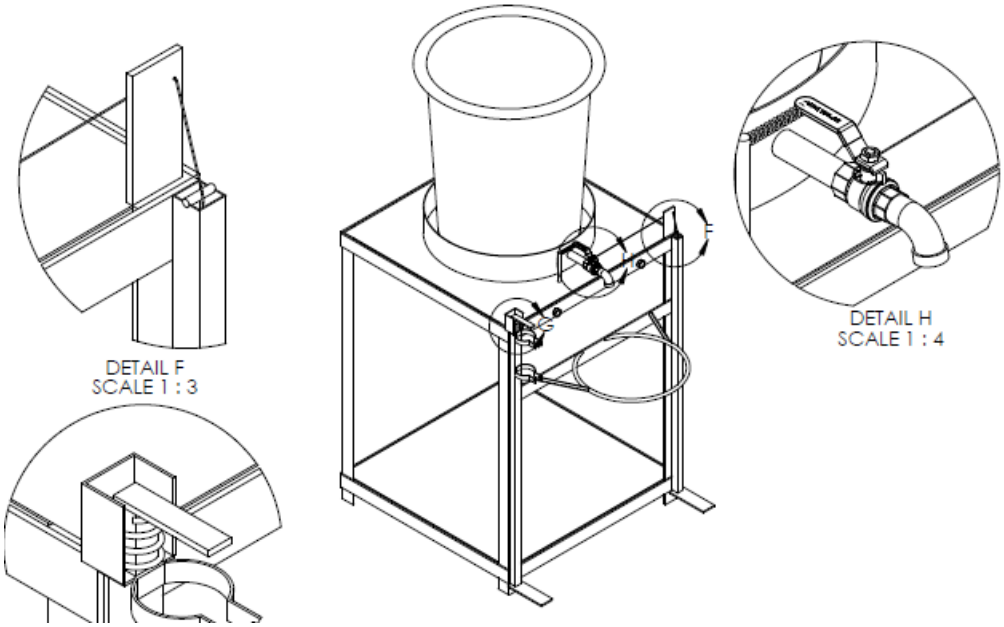

Fig. 5: Water Tap, Spring and Cable Positioned

Compression Spring

This compression spring was used so that the soap dispenser pedal could return to its normal position after use.

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Hand Washing Basin

The hand washing basin is made of a plastic bowl in which the hand is being washed to prevent splashing of water on the users body. Rubber type bowl was used based on its lightness and resistance to corrosion. It is positioned under the tap as shown in Fig. 6. The tap is connected with a pipe to the water bucket.

Fig. 6: Washing Hand Basin Place under the Tap

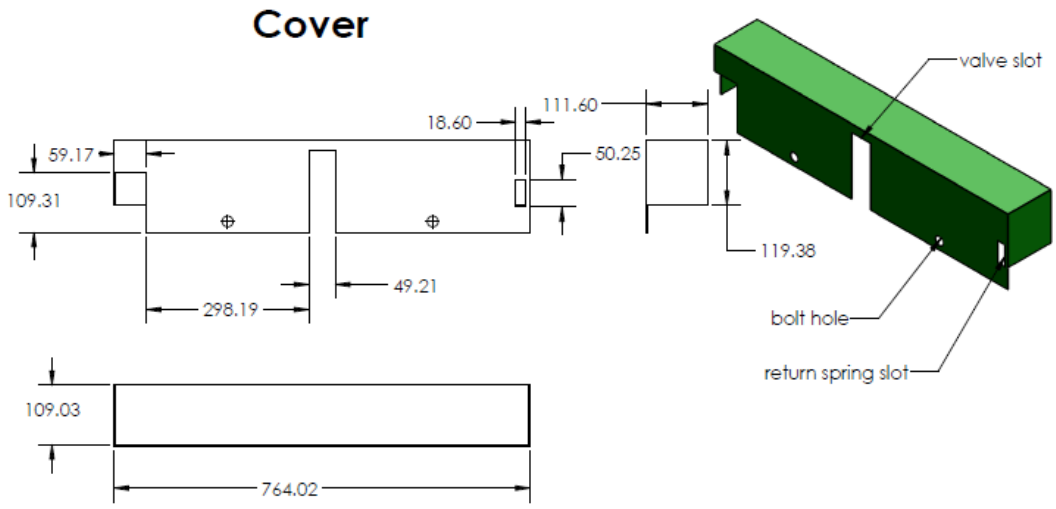

Fig. 7: Casing to Cover the Machine Mechanism

Mode of Operation

The machine was designed and fabricated to operate based on a simple mechanism. An extension spring was fixed to the lever of a tap in a closed position and a clutch cable was connected to the tap. This clutch cable was in turn connected to the pedal such that when the clutch cable is tensioned as a result of pressing the pedal, the tap will open and once the pedal is released, the extension spring will return to its unloaded position hence, close the tap.

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IV. CONCLUSION AND RECOMMENDATIONS

CONCLUSION

An ergonomic manual hand washing machine was designed, fabricated and tested to eliminate hand contact with the machine throughout the washing process, in order to minimize the spread of corona virus transmission. The materials use for the construction were locally sourced. The machine cost is $100 per unit.

RECOMMENDATIONS

The mass production of the machine when supported and funded by NGOs or Government will go a long way to reduce the cost drastically and make it available to the poorest of communities. In future the technologist can venture into the application of sensors and microcontrollers for skin colour detection, motion segmentation, particle filtering and gesture description methods to attain a properly clean hands with the aid of a video tracking device. Sound artificial intelligence when applied will also dramatically improve the efficiency of the machine.

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