Development Sanitizer Sprinkler For Automated Guided Vehicle (AGV)

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***Abstract*—The COVID-19 mandates an increase in the use of service robots as human replacements in polluted areas. This task encompasses logistics, patient care, and disinfection, all of which limit the danger of human exposure to the extremely infectious and fatal illness. To fulfil the criteria of the World Health Organization, the certified sanitizing system is a method for decontaminating individuals and surfaces. In this work, an automated sanitizing equipment is designed. The equipment spray a sanitizer solution is the area to be disinfected. The transportable sanitizing unit is mounted to the robot's head. SolidWorks software is used to design the equipment. Design included identifying main parts of the system, deciding about material for different parts, and 3D design of each of the parts. Finally, the assembly of the complete system is presented. The finalized product was then simulated in MATLAB. Analysis of the system included flowrate, pressure, and maximum spray distance. Results obtained are consistent with requirements.**

Keywords— Sprinkler system, Autonomous robot, Covid-19.

I. Introduction

The Covid-19 pandemic is Malaysia's biggest infectious sickness outbreak since the 1918 Spanish Flu epidemic, which killed 34,644 people, or 1% of the country's population [1]. Due to inadequate social distancing and public knowledge, healthcare personnel are opposed to working in Covid-19 institutions. Covid-19 is an airborne illness spread by droplets. Infections frequently cause mouth drops. Once symptoms arise, they become less contagious, reducing a person's virus burden.

The Covid-19 virus is more likely to contaminate ambient items in hospital settings, according to WHO (2020). We may be exposed to Covid-19. Governments worldwide recommended face masks and hand sanitizers to combat Covid-19. Social isolation was enforced, and lockdowns restricted people' movement except for essential staff. The convergence of these strategies slowed the spread of covid-19, especially with comprehensive quarantines, but it was expensive [2]. The sanitizer system is required to prevent viral propagation by contact and air, minimize sanitising costs, and quickly clean large areas.

This work aims to analyze the surface sanitizing mechanism by proposing a robot sprinkler. The proposed sprinkler not only reduces the risk to humans but also offers a more efficient way of sanitizing wide areas. Utilizing an autonomous sprinkler system helps maximize the cleanliness of an area while minimizing the amount of sanitizer that is wasted. Aside from that, the fact that this initiative is geared toward the general public in areas like walking pathways, cafes, and etc., may also save users time by simultaneously sanitizing the area surrounding sprinklers.

A similar project is XDBOT (eXtreme Disinfection roBOT) which is a wheeled robot in Singapore that can sterilise beneath furniture, tabletops, doorknobs, and switches [3]. The project saved water and energy by using just one spray session and sensors. XDBOT's arm can be controlled from 30m distant. Antennas may boost robot range to 50m (164 ft.). XDBOT's 8.5-liter (2.24-gallon) tank may include disinfectants. The robot lasts four hours and recharges in eight.

Sectors that demand small liquid droplets rely on liquid atomization. It creates particles from liquid in gas. Injecting fluids into a holey implant causes axial rotation. This research explores liquid atomization utilising pressure nozzles with cruise control inserts and offers a pressure/flowrate link [4]. This study suggests a pressure-flowrate relationship for throttling nozzles. These correlations, which have been established for tangential inflow nozzles, cannot be utilised to create good predictions for axial swirl nozzles with throttle inserts, where the geometry might be substantially more intricate.

Nozzle autonomously [5]. A front-mounted camera lets user screens view the surroundings [6]. The robot has GPS and GSM to ease data transfer for locating the robot and for control. Gas-liquid fluid blend increases sprayer speed and range. Air-based atomizing sprayer, disinfectant vessel, and stream valve atomize chemicals in the disinfection sprayer. The flow valve's repetition regulates the disinfectant splashing stream, and the sprayer's air velocity reaches the splashing distance [7]. Robot head nozzle sterilises target liquid sprayer. Pump disinfectant after adjusting. 4V-12V at 0.8A is good for water pumps. This research sanitises surfaces with low-concentration bleach and water (100:1).

II. Methodology

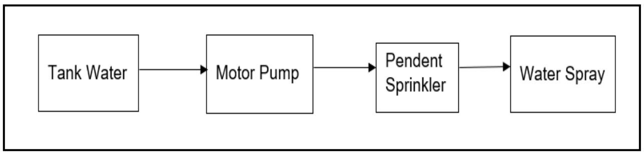

Figure 1- 1 System block diagram of the sanitizer sprinkler.

Figure 1 shows how the system works. According to [8], the water tank will be filled with 3 liters of water. The water will then be forced up to the sprinkler head by the pump. From there, flow happens, which is the objective of this work. Lastly, the pendent sprinkler intends to shoot water outward.

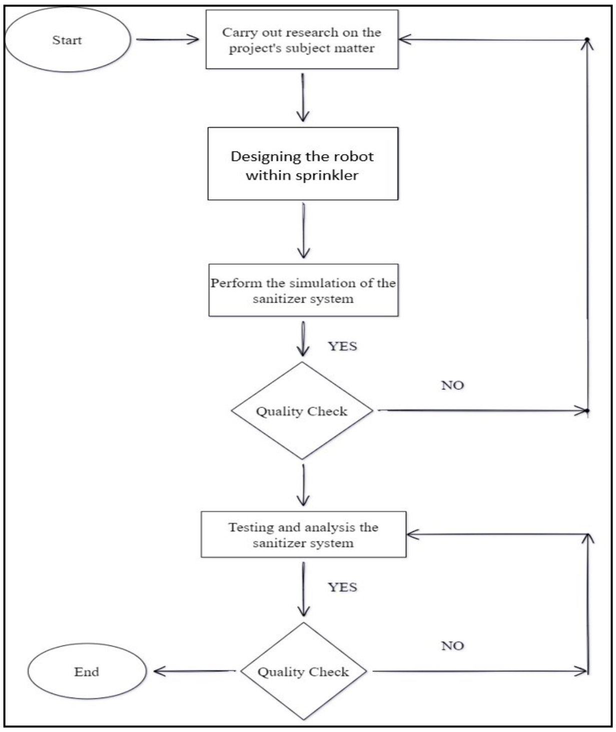

Figure 2- System operation flowchart of the sanitizer sprinkler.

The steps involved in ensuring the success of this project are outlined in the flowchart shown in Figure 2. SolidWorks software was used to create the smart sprinkler system for the Automated Vehicle Guided (AGV). AGV is a base model designed to serve as a platform for the movement of the smart sprinkler system, which includes the tank, pipe, tires, and base. After the design is completed, the model base design was sent to MATLAB for further processing.

Subsequently, the model base design from the SolidWorks software was imported into the MATLAB software and the simulation was completed. Table 1 depicts the flow of how to get from the CAD Model to the Step Simscape Model. At this level, MATLAB/Simulink software environment is used to test sprinkler motion using this model.

Table 1 Step CAD Model To Simscape Mode

CAD Model	Simscape Model
Prepare CAD model for export	Import XML file into Simulink/Simscape
Export CAD model as an XML file using Simscape Link	Verify sprinkler motion behavior

In MATLAB software, this is exported as a robot. The transfer function is used to regulate the flow rate in MATLAB software. A consequence of this is the appearance of the outcome for the result and the completion of the analysis. Furthermore, calculations were performed to assure the same or equivalent value to that of the analysis. Last but not least, provide the analysis to draw a comparison between this research and the other similar works by other researchers. That allows making improvements to the sprinkler system.

A. *Theory of Flow Rate and Pressure*

Flow rate in a pipe system is proportional to the pressure differential's square. The pressure difference between two places affects flow rate. Pipeline regulating valves (man-made pressure loss). Its effective pressure difference decreases, reducing flow rate. This reduces the pipeline's pressure dips.

$$Q = v.A \qquad (\mathrm{m}^3/\mathrm{s}) \tag{1}$$

Where:

v = fluid flow rate

A = plumbing cross-sectional area

B. *Theory of Projectile Motion*

A projectile motion is a bilaterally symmetrical, parabolic motion with a parabolic velocity. Trajectory is the journey from A to B. After a single force at the beginning of the journey, only gravitational attraction will interfere. This study explored projectile motion's numerous components. Launch angle, θ, affects a projectile's speed and trajectory. That in turn affects the projectile's range, height, and duration. Flight time, T, is related to launch angle and object height and is given by,

$$T = \frac{2v\sin\theta}{g} \tag{2}$$

Maximum Height, h, can be calculated using.

$$h = \frac{v^2\sin\theta}{2g} \tag{3}$$

Lastly, range of Projectile, R, is calculated using,

$$R = \frac{v^2\sin 2\theta}{g} \tag{4}$$

In above equations v is the projectile initial velocity and g gravity accelaration.

III. Results and Discussion

A. *Design model based in Solidwork*

1) *The base*

The 15 mm-thick, 450 mm×220 mm foundation shown in Figure 3 3, can accommodate the water tank. Tank may go on base. Frame is galvanized iron. Galvanized steel is coated with zinc to prevent corrosion and erosion. Galvanized steel lasts longer than non-galvanized steel.

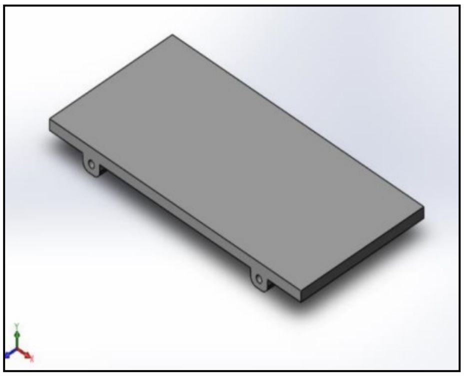

Figure 3- The base.

2) *The extension pipe*

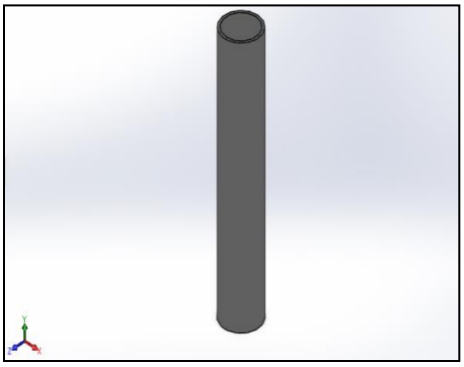

Figure 4- The extension pipe.

Pipe that drains tank water to the sprinkler. The pipe has a 16-inch-diameter, 100-mm-long hole that shown in Figure 4. Extension connects the tank and sprinkler. The robot may patrol a predetermined area for sterilisation and disinfection. The sprinkler's double-acting pneumatic cylinder forces air into the tank. This pipe can move up and down automatically.

3) The Pendent Sprinkler

This sprinkler feature sprays water dependent on the hole size. A pipe connects the two components. This sprinkler rotates when water is discharged. The high-pressure water pipes will sanitise the region. Reference [9] report that a Lpc2148 microprocessor can be used to control the sprinkler unit. It manages the mobile robot's structure and behaviour to complete tasks. The control system perceives, thinks, and acts. Perception provides external environment information. Output data instructs actuators to engage the mechanical structure.

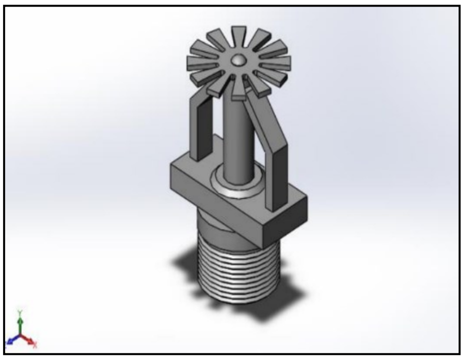

Figure 5- The Pendent Sprinkler

4) The Tank

The completed tank measures $525 \times 300 \times 325$ cm. When filled, this tank holds 3 litres. Connecting this tank to a pipe releases the water. The water tank is large enough to include a 'Electric Submersible Pump' to propel water into the sprinkler head. This submersible pump is particularly quiet since there is no "peak" of pressure when water passes through it. This submersible pump may save energy compared to others [10].

The polyethylene sanitising tank, basically, UHMWPE (UHMW). This polyethylene has far greater molecular weights than HDPE, making it very dense. It's employed in protective coatings and high-performance equipment since it can be spun into threads with greater tensile strengths than steel [11].

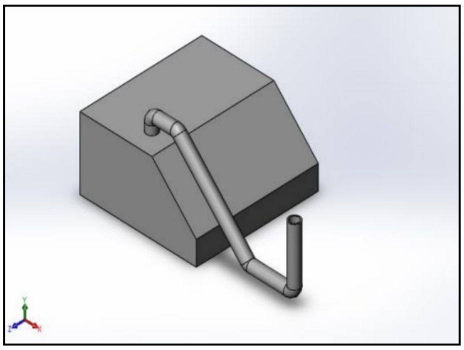

Figure 6- The Tank

5) The tire

The robot's tire propels it. Front wheels can change direction when there's an impediment in front of the vehicle, while rear wheels can only travel forward and backward. This tire's teeth make climbing hills simpler. This tyre will feature four tyres and a flanged base 84-inch tyre.

The number and kind of tyres on an autonomous vehicle depend on its wheel arrangement. Four-wheeled sprinkler robots are more stable than two- or three-wheeled robots. This wheel arrangement's centre of gravity is usually within the rectangle. The wheel is made of polyethylene, which is harder than nylon and polyester. The wheel form is designed for rapid speed on flat ground.

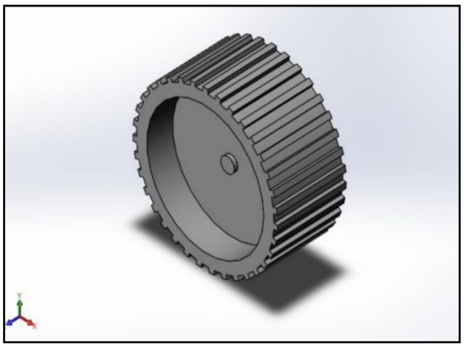

Figure 7- The Tire

B. Result for Assembly Component

The isometric view, side view, and top view make up the three primary perspectives of the model (Figure 8, Figure 9 and Figure 10). This demonstrates that the evidence may be seen quite well in 2D conceptions.

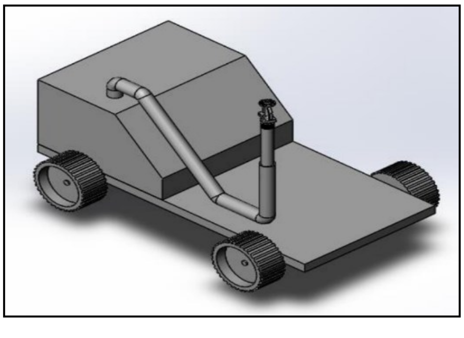

Figure 8- Isometric view of the complete assembled design.

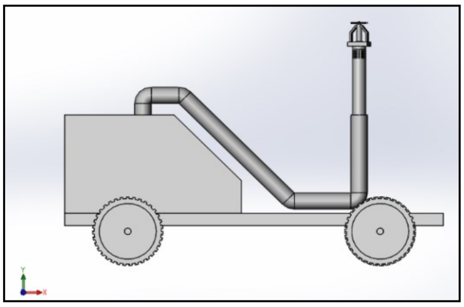

Figure 9- Side view of the assembled design.

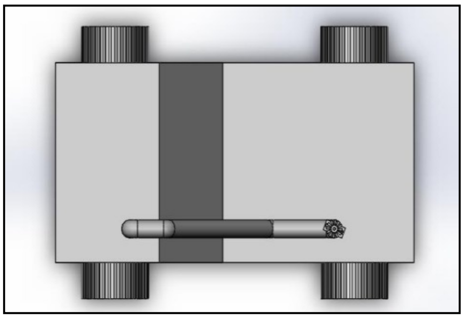

Figure 10- Top view of the assembled design.

C. Simulation movement functionality

The Simscape file containing the smart sanitising robot's model-based design is exported to MATLAB. Simscape is a fast environment for developing Simulink component models. Due to the nature of this project, the model-based design was converted into a Simscape file to work as an intelligent cleaning system. Therefore, MATLAB block functions are employed in Simulink models to describe specific properties.

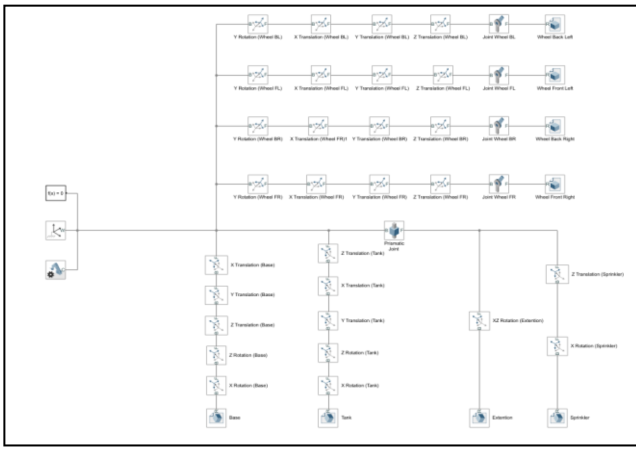

Figure 11- Model block diagram in Simscape

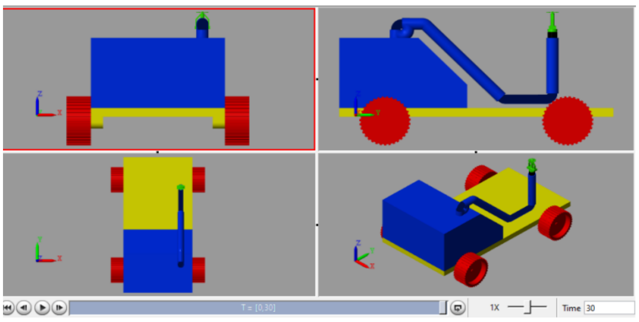

Figure 12- The movement of pipe extension in Simscape

Figure 11 depicts the capability of pipe extension to move higher and downward in accordance with the design block diagram shown in Figure 12.

D. Simulation of data

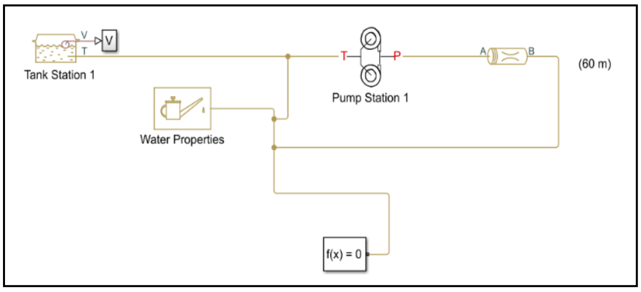

Figure 13- Design schematic data analysis

Figure 13 depicts a design for data analysis that includes a tank station, a pump station (also known as a motor pump), and a pipe. The model-based design is used to determine each parameter. In Figure 14, the design for the pump station is more specific.

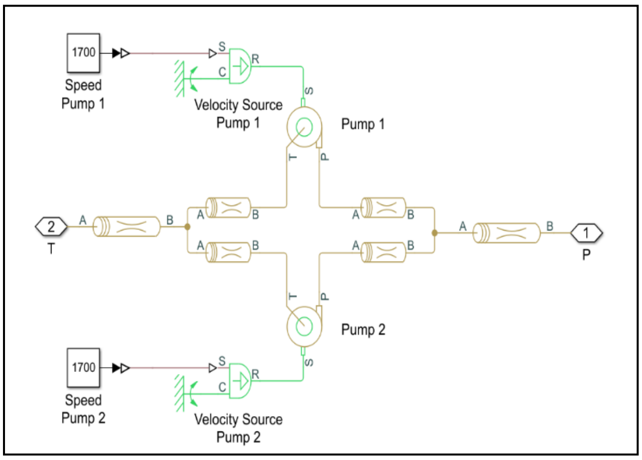

Figure 14- Design schematic inside the pump station.

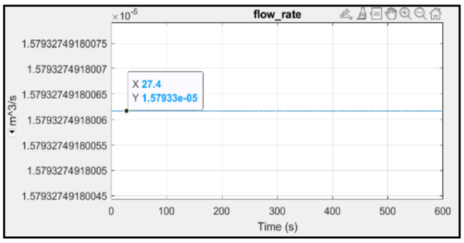

Figure 15- Value Of Flow Rate

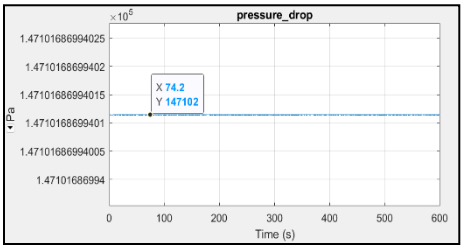

Figure 16- Value Of Pressure

As shown in Figure 15 and Figure 16, the result is $Q = 1.57933 \times 10^{-5}\ \mathrm{m^3/s}$. Pressure is $P = 1.47102 \times 10^{5}\ \mathrm{m^3/s}$. Until the sprinkler sprays it, water may flow from the tank. A computation must be conducted to make sure that the simulation flowrate value matches the simulation outcome.

E. Calculated Results

1) Calculation of flow rate

Using the equation of continuity flow rate

$$Q = v.A \quad (\mathrm{m^3/s}) \tag{5}$$

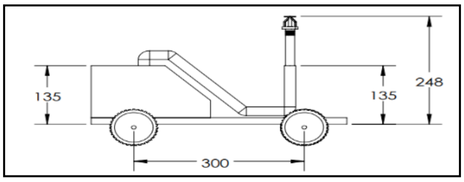

Figure 17- Measurement of model-based design robot

Using the equation of continuity velocity, v

$$\begin{aligned} v &= \sqrt{2 \times g \times H} \\ &= \sqrt{2 \times 9.81 \times 0.248} \\ &= 2.21\ \mathrm{m/s} \end{aligned} \tag{6}$$

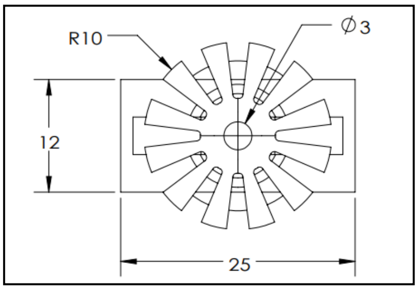

Figure 18- Measurement of Sprinkler

Using the equation of continuity Area of sprinkler, A.

$$\begin{aligned} A &= \frac{\pi}{4} \times d^2 \\ &= \frac{\pi}{4} \times (3 \times 10^{-3})^2 \\ &= 7.0695 \times 10^{-6}\ \mathrm{m^2} \end{aligned} \tag{7}$$

Where:

d = diameter of cross-sectional area sprinkler (mm).

Finally, just insert the values of v and A from (6) and (70, respectively, inside (5) to get the value of flow rate, Q

$$Q = 1.562 \times 10^{-5}\ \ \mathrm{m^3/s}$$

This calculation is performed to ensure that the result shown in Simulink is the same as the result shown manually. Note that the height of the pipe is 248 mm and the cross-sectional area sprinkler size is $7.0695 \times 10^{-6}\ \mathrm{m^2}$. So the value of velocity is $2.21\ \mathrm{m^2}$. The flowrate is consistent with the value of $1.562 \times 10^{-5}\ \ \mathrm{m^3/s}$. As a consequence, If the height of the pipe or the cross-sectional area sprinkler is changed, the value of the velocity will vary as well. Besides, there is no difference between this flowrate calculation and the value that was presented in Simulink.

2) Calculating Time Taken to Empty the tank

We have,

$$Q = \frac{v}{t} \tag{8}$$

where t is the time taken in seconds.

Equation (8) can be used to calculate t.

$$t = \frac{v}{Q} \tag{9}$$

Substitute, v = 3 litres and Q = 0.00001562 $\mathrm{m^3}/s$

$$t = \frac{3\ litre}{0.00001562}$$

$$t = 19206.15\ \ \text{second}$$

or

$$t = \frac{19206.15}{60} = 320.10\ \text{minute}$$

The tank water runs out in about 5.34 hours, which is a short amount of time. As a result, this model-based design is very adaptable for use in practice

3) Calculation of Projectile Motion

The distance a projectile travels when struck by gravity equals $\sin\theta \times \frac{v^2}{g}$, where is the angle, v is the starting velocity, and g is gravity's acceleration. Assuming $\frac{v^2}{g}$ is constant, the greatest distance occurs when $\sin\theta$ is maximal, when $\theta =$ 90degrees or $\frac{\theta}{2} = 45$ degrees [11]. Current pendent sprinklers spray between 45 to 90 degrees, with 45 being the lowest and 90 being the most as shown in Table 2

4) Graph based on angle

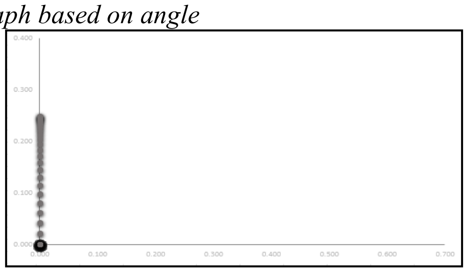

Figure 19- Angle in 90 degree

Figure 19 demonstrates that the water will not go very far due to the 90-degree angle employed. As can be seen, the highest point at which water will be sprayed is 0.257 m. However, in the reality, this angle cannot be employed since the range is 0 m.

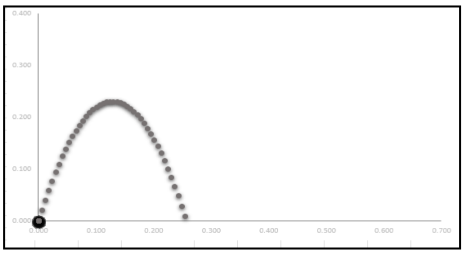

Figure 20- Angle in 75 degree

Figure 20 shows indicate that the sprayed water reaches a height of 0.237 m and a range of 0.256 m. Although this angle may not be as high as 90 degrees, it is the most reasonable angle to be the highest.

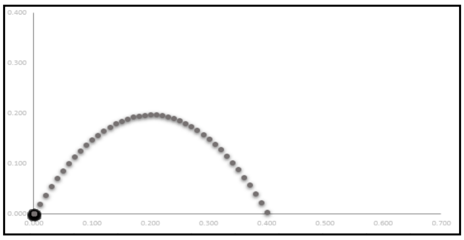

Figure 21- Angle in 60 degree

The sprayed water is shown to be as high as 0.209 m above ground and as far away as 0.405 m from the ground on the graph.

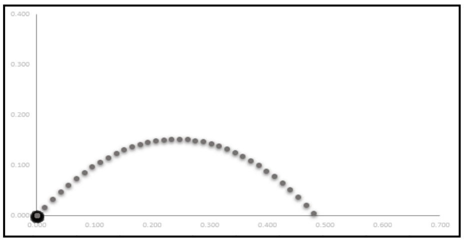

Figure 22- Angle in 60 degree

Figure 22 demonstrates that the sprayed water reaches a height of 0.157 m while reaching a range of 0.497 m. When compared to the other angles, this angle is the most distant.

As a consequence, the flow rate and pressure data were analyzed, and the results showed that everything was in fine shape. The calculations included confirming. In addition, the calculation demonstrates that this project may be put into effect in terms of the 5.34 hours required for the application of the utilization sanitizer.

However, changes in height and distance will occur as a result of the changes in angles. Using this technique, the pendent sprinkler will be able to spray water within a specified distance from both the model and the surrounding wall. The robot is also modelled on the lowest height necessary to spray the water as well as the maximum range that the pendent sprinkler may work within a safe distance between the robot and the wall, as well as any other relevant information.

IV. Conclusions

The Covid-19 healthcare setting is proving to be the ideal application for the autonomous sanitizing robot. The need for human involvement in the sanitation process is minimized as a result. Because the system that was created is extremely small, it is quite simple to move this robot to any location. The Covid-19 pandemic provides a further justification for the use of mobile robots for risk-free cleaning in areas designated as quarantined. In order for this initiative to reach its full potential, it will need financial backing from an adequate budget as well as the acquisition of the necessary tools. In addition, without the need for labour, this initiative has the potential to shape the future of technology.

V. References

[1] J. H. Hashim, M. A. Adman, Z. Hashim, M. F. Mohd Radi, and S. C. Kwan, “COVID-19 epidemic in Malaysia: epidemic progression, challenges, and response,” Frontiers in public health, vol. 9, p. 560592, 2021, doi: 10.3389/fpubh.2021.560592.

[2] S. B. Aw, B. T. Teh, G. H. T. Ling, P. C. Leng, W. H. Chan, and M. H. Ahmad, “The covid-19 pandemic situation in malaysia: Lessons learned from the perspective of population density,” International journal of environmental research and public health, vol. 18, no. 12, p. 6566, 2021, doi: 10.3390/ijerph18126566.

[3] “NTU Singapore researchers build disinfection robot to aid cleaners in COVID-19 outbreak,” Corporate NTU. https://www.ntu.edu.sg/news/detail/ntu-singapore-researchers-build-disinfection-robot-to-aid-cleaners-in-covid-19-outbreak (accessed Jun. 30, 2022).

[4] K. Lachin, C. Turchiuli, V. Pistre, G. Cuvelier, S. Mezdour, and F. Ducept, “Dimensional analysis modeling of spraying operation–Impact of fluid properties and pressure nozzle geometric parameters on the pressure-flow rate relationship,” Chemical Engineering Research and Design, vol. 163, pp. 36–46, 2020, doi: 10.1016/j.cherd.2020.08.004.

[5] T. M. Fernández-Caramés, “An intelligent power outlet system for the smart home of the Internet of Things,” International Journal of Distributed Sensor Networks, vol. 11, no. 11, p. 214805, 2015, doi: 10.1155/2015/214805.

[6] B. W. Dionova, M. Mohammed, S. Al-Zubaidi, and E. Yusuf, “Environment indoor air quality assessment using fuzzy inference system,” Ict Express, vol. 6, no. 3, pp. 185–194, 2020, doi: 10.1016/j.icte.2020.05.007.

[7] Q. C. Feng and X. Wang, “Design of disinfection robot for livestock breeding,” Procedia Computer Science, vol. 166, pp. 310–314, 2020, doi: 10.1016/j.procs.2020.02.093.

[8] K. Sivakumar, A. Ramakrishnan, D. Selvamuthukumaran, and E. S. Murugan, “Design and fabrication of sanitizer sprinkler robot for covid-19 hospitals,” 2021, vol. 1059, no. 1, p. 012070.

[9] S. Harishankar, R. S. Kumar, K. Sudharsan, U. Vignesh, and T. Viveknath, “Solar powered smart irrigation system,” Advance in electronic and electric engineering, vol. 4, no. 4, pp. 341–346, 2014.

[10] M. Hurlbatt, “How Submersible Pumps Work: Advantages and Disadvantages of Submersible Pumps,” Pump Solutions Australasia, Apr. 13, 2016. https://pumpsolutions.com.au/how-submersible-pumps-work-advantages-and-disadvantages-of-submersible-pumps/ (accessed Jun. 30, 2022).

[11] T. Rogers, “Everything You Need To Know About Polyethylene (PE).” https://www.creativemechanisms.com/blog/polyethylene-pe-for-prototypes-3d-printing-and-cnc (accessed Jun. 30, 2022).