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Design and Fabrication of Wheel-Driven Sanitizer Sprayer Pump

Varsha M. Magar[1], Shreyas A. Baviskar[2], Manas R. Jatkar[3], Digant V. Pawar[4], Mayur S. Shende[5]

[1]Varsha M. Magar H.O.D. in Department of Mechanical Engineering, S.S.J.C.O.E. Dombivli (E), Maharashtra, India.
[2,3,4,5] BE Students (8th Semester) in Department of Mechanical Engineering, S.S.J.C.O.E. Dombivli (E), Maharashtra, India.

Abstract- *The design and fabrication of wheel-driven Sanitizer sprayer. Wheel-Driven sanitizer sprayer pump consists of back pack sprayer which is mounted on the tank base of the trolley. The piston rod of the tank is connected to the crank. The pump is connected to the pressure tank, which pressurizes the fluid during operation and stores in the pressure tank. Using a flexible hose, the pressurized sanitizer is transferred to the multiple nozzles. According to the need the valve is operated so as to obtain a fine spray throughout. By using manually operated sanitizer sprayer, the strain, which is caused to the workers in conventional backpack sprayer, is reduced and larger area can be covered in a short time.*

Key Words: Multi-Nozzle, Back pack Sprayer, Sanitizer, Manually operated, pump.

1. INTRODUCTION

We are one of the largest populated countries in the world. That being said, disinfectants have become a part of our life due to the recent pandemic. During this trying time, we need to keep ourselves and our loved safe by using various things like masks, often sanitizing our hands with alcohol-based disinfectants. The need for disinfectant has been made to find a safe and suitable disinfectant available in the vicinity. To ensure the safety of our community, we have to help in any minute possible way to ease the suffering from the pandemic.

The centers for Disease Control recommends we all take steps to clean and sanitize high-touch surfaces in our homes. Below, we get into the weeds of how long the virus might last on surfaces, which disinfectants may kill it, and the steps you should take to keep clean.

Researchers have found that the novel coronavirus is capable of living on surfaces such as cardboard for 24 hours, but up to two or three days on plastic and stainless steel. So cleaning and disinfecting high-touch surfaces is a step we should all take, even if we aren't leaving the house. Anytime items or people come in and out of your home, there is some possibility of exposure.

Cleaning or disinfecting areas we live in or work in is extremely essential in the time of coronavirus. Disinfecting, which is an advanced form of sanitizing is important to reduce the potential risk of COVID-19 contamination to your loved ones. Sanitizing your home or workplace is important to keep yourself healthy and fit. Person-to-person transmission of coronavirus is more likely than from the surface so you must use your face mask hand sanitizers as an ultimate precaution in addition to cleaning your homes. To kill viruses or bacteria we must be disinfecting our homes thoroughly to reduce the chances of surface-to-surface transmission.

1.1 CONSTRUCTION

The main components of wheel-driven sanitizer sprayer pump are as follows:

1) Pump: A pump is a piece of equipment used to move fluids, such as liquids or slurries, or gases from one place to another.

2) Tank: It is the storage place of chemical solution. It is made up of PVC, Brass, etc.

3) Agitator: It is the devices which stirs the solution and maintain the contents in homogenous state.

4) Pressure gauge: It is a dial gauge which shows the pressure at which the liquid is delivering from the pump.

5) Pressure regulator: The pressure regulator use for some important functions. It is the means of adjust the pressure is necessary for any spray job within the pressure choice of the pump.

6) Strainer: It is a little circular plastic ring with nylon wire mesh to filter any dust element coming with the chemical solution it is included in the suction line connecting the chemical tank and the check valves.

7) Frame: - The main function of the frame is to carry the whole assembly on it so it has to be strong enough to hold it. The frame is made of square pipe and it is formed out of mild steel.

8) Crank: The function of the crank is to transfer motion from the prime mover to the connecting rod for further operation. Here the circular disc having eccentricity at which rotary motion of crank is converted into reciprocating/linear motion of the connecting rod.

9) Nozzles: It is a device that converts the pressure energy of fluid into kinetic energy, a spray nozzle is a precision device that facilitates the dispersion of liquid into a spray. The nozzle is used for the purpose to distribute a liquid over an area.

10) Sprocket: The name 'sprocket' applies generally to any wheel upon which radial projections engage a chain passing over it.

11) Chain: The chain is made of steel which is used to transmit power from gear sprocket to pinion sprocket, and it has no sleep.

12) Connecting rod: The main function of the connecting rod is to convert rotary motion into reciprocating/linear motion. Here connecting rod converts rotary motion of crank to reciprocating motion of pump and extension rod.

13) Bearing: A bearing is a machine element that constrains relative motion and reduces friction between moving parts to only the desired motion. The design of the bearing may, for example, provide for free linear movement of the moving part or for free rotation around a fixed axis; or, it may prevent a motion by controlling the vectors of normal forces that bear on the moving parts.

14) Wheel: -The wheel is used to carry the whole assembly and move the machine from one place to another by the rotary motion of it. A bicycle wheel is a wheel, most commonly a wire wheel, designed for a bicycle. The bicycle wheel is designed to fit into the frame and fork via drop outs, and hold bicycle tire.

1.2 WORKING

Wheel driven sanitizer sprayer work on the principle of reciprocating pump. This reciprocating pump uses a single-slider crank mechanism, in which the wheel sprocket works as a crank. There are two sprockets that are mounted on two different axles in which one sprocket is directly attached to the wheel axle. The Connecting rod is attached to another sprocket axle through the disc. This power is given to the piston of the reciprocating pump through rotation of the wheel.

When the piston reaches the top dead centre, it creates negative or low pressure inside the cylinder due to the pressure difference between reservoir and cylinder space, water moves to fill the cylinder chamber space. In this process, the suction valve opens, and the delivery valve closes.

When the piston reaches the bottom dead centre, it creates high pressure inside the cylinder chamber & due to the pressure difference between the cylinder & delivery pipe. Water moves through the discharge pipe to sprinkle. In this process, the suction valve closed and the delivery valve open. This process repeats again and again to get the desired output.

Motion transmission by chain and sprockets arrangement by using Slider cranks mechanism this mechanism converts Rotary motion of wheel into reciprocating motion of pump.

2. LITERATURE REVIEW

V. B. Bhandari's book Design of Machine Elements [1] this book consists of many different aspects for designing a mechanically operated system. It consists of various types of designs like chain, sprocket, bearing, connecting rod design. Through this book we got our basic idea how to do design components for our wheel-driven sanitizer sprayer. Also studying through research paper from "International Journal of Mechanical Engineering & Technology" titling "Self Powered Pesto-Sprayer" [2]. Through this research paper we got our basic idea how to do design components for our wheel-driven sanitizer sprayer. The other references listed in references sections discusses similar concepts in their respective field such as multi-nozzles are used for sanitization purposes, operated manually or automatic. For designing the wheel-driven sanitizer sprayer we got help from various websites in various aspects in various aspects like material selection, etc.

Following is a table of some reviewed papers which we used for references, respective work done by them is specified there.

Table -1: Literature Review

Sr. No	Paper Title	First Author	Date of Publication	Work Done
1	Agricultural sprayer vehicle with router weeder and seed sower [3].	Prof.N.R. Jadhao	April 2015	A multifunction device that will come in handy that can be put to use in different stages of farming as per requirements.
2	Development Of Multi-nozzle Sanitizer Sprayer Pump [4].	H.Poratkar	April 2013	A model of a manually operated multi-nozzle pesticide sprayer pump which will perform spraying at a maximum rate in minimum time.
3	Design & fabrication of pesticide series spraying machine for multiple agricultural crops [5].	V. Pranoy	May 2017	A sprayer with a feature of 360-degree pipe rotation & adjustable pipe length.
4	Experimental Investigation of Agricultural Sprayer & Weeder [6].	S.Siva	March 2019	A study of different types of spraying methods.

3. PROBLEM DEFINITION

1) People can catch COVID-19 from others who have the virus. The disease can spread from person to person through small droplets from the nose or mouth which are spread when a person with COVID-19 coughs or exhales. These droplets land on objects and "Surfaces" around the person. The Surface can hold the COVID-19 virus for up to 5 hrs. So surface sanitization is necessary nowadays.

2) After the pandemic, it's very useful to sanitize hospitals, schools, office spaces, restaurants & food preparation areas, etc. where big vehicles can't enter for sanitization which costs around 80,000.

3) For the backpack type sanitizer sprayer, the user needs to carry the heavy tank at the back and oscillate the lever that required more effort. As we know, this is the most type of sanitizer pump sprayer that users use for sanitization purposes & farming. Users need to hold the nozzle when spraying out the sanitizer.

4) The second type of spray pump used is fuel operated spray pump, which is heavier than the hand-operated backpack pump. This type of pump is running on a petrol engine. We know that petrol is one of the costly fuels. Also, the pump produces more vibrations which are hazardous to users back muscles, this pump makes unwanted noise.

4. OBJECTIVES

The main objectives of this project are

1) The aim of this project is that the operator needs not to carry the entire sanitizer sprayer pump on his shoulders but just pull/push the mechanism mounted on the trolley to operate the pump and spray the sanitizer. This makes the farmer feel comfortable, relaxed, and less tiresome.

2) To reduce human efforts due to the constant pumping action for creating pressure inside the sanitizer sprayer and thereby provide a suitable environment for the user reducing the fatigue load acting on the body.

3) Multi-nozzle is used and hence larger areas of the field can be sprayed at a faster rate in minimum time& proper adjustment facility with respect to height and width of the space to be sanitized.

4) Decrease the operational cost by using a new mechanism, cost of machine & labor cost by advancing method.

5) Work reliability under different working conditions.

5. DESIGN SPECIFICATIONS

1. Total Weight:

Maximum stroke of pump= 8.5 cm = required crank radius = 28.5= 4.25 cm

Weight of Pump = 21.385 kg

Approximate weight of empty pump = 4 kg

∴ Total Weight = 21.385 + 4

= 25.385 kg

Note: For safety & design point of view, we will consider the total weight as 30 kg.

Total Weight of trolley (trolley + pump) = 15 + 30 = 45 kg

2. Selection of Pinion:

Minimum no. of teeth available on pinion = 14

Outer dia. Of pinion = 8 cm = 80 mm

Inner dia. of pinion = 6.5 cm =65mm

Pitch circle diameter (D_p) = $\frac{80-65}{2} + \frac{Do-Di}{Di} + (Di)$

D_p = 72.5 mm

Gear Ratio = 1:3

On rotation of gear sprocket gives three rotation of pinion sprocket, we required three strokes to generate adequate amount of pressure.

3. Selection of Gear Sprocket:

$$\frac{1}{3} = \frac{14}{tg}$$

$$tg = 14 \times 3$$

$$tg = 42$$

$$\frac{tp}{tg} = \frac{Dg}{Dp}$$

$$\frac{14}{42} = \frac{Dg}{80}$$

$$Dg = 26.67 \approx 27 \text{ mm}$$

$$\text{Pitch} = \frac{\text{Number of teeth on pinion}}{\text{pitch circle diameter of pinion}}$$

$$= \frac{14}{72.5}$$

$$\text{Pitch} = 0.19 \text{ mm}$$

4. Selection of Chain:

Chain type: roller chain

ISO Chain no. 05B

Pitch = 0.19 mm

Length of chain, L = K.P No. of chain,

No. of chain,

$$K = \frac{T1+T2}{2} + \frac{2X}{P} + \frac{T2-T1}{2\pi} \times \frac{P}{X}$$

$$K = \left(\frac{14+42}{2}\right) + \left(\frac{2 \times 479}{0.25}\right) + \left(\frac{42-14}{2\pi}\right) \times \left(\frac{0.25}{479}\right)$$

K = 28+ 3832+0.0023

K= 3860 mm.

L = K × P

L = 3860 ×0.25 L = 965 mm L = 96.50 cm

5. Design of Frame:

Length of frame = (Centre dist. between two sprockets) + (Width of tank) + (Excess)

= 400 + 200 + 350

L = 1000 mm

Height of Frame = 480 mm

Width of Frame = 400 mm

Total length of pipe = 5020 mm

Cross section area of hollow square pipe = $20 \times 4 - 16 \times 4$ = 16mm^2

Volume of frame = 16×5020 = 80320 mm^3

Density of G.I. material = 7.85×10^{-6} kg/mm^3

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Mass = density ×volume

= (7.85 x 10^{-6}) × 80320

Mass = 0.63 kg

Yield stress of G.I. material = 425 MPa = 425 N/mm^2

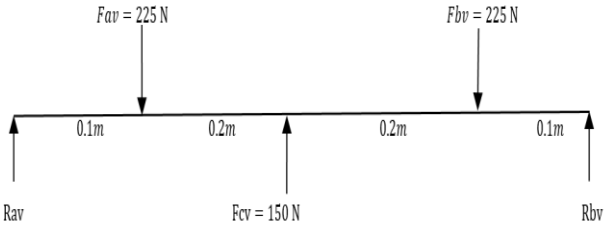
$$\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{425}{16} = 26.5625 \text{ N/mm}^2$$

Therefore, 26.5625 < 425 N/mm^2, hence the design is safe

6. Design of driving shaft:

Total weight of assembly = 45 kg × 9.81 = 441.45 ≈ 450 N

As shown in fig the shaft consist of 5points, where at point B and D, the force is applied on the shaft.



F_{cv} is vertical force applied by the chain sprocket on the shaft. The reactions will be offered on the wheels, i.e. R_{AV} and R_{EV}. The vertical force calculated by reverse engineering on sprocket is 150N. Thus, F_{CV} =150 as the geometry is symmetric,

$R_{AV} = R_{ev} = (250 + 250 - 150)/2 = 175$ N

Now power developed on the shaft, P = F_m x V

Where, F_m = force applied on the shaft.

V = velocity of the man.

Generally, man can apply force up to 400N by single hand. We are designing sprayer to be pushed by double hands.

Thus, F_m= 400+400 =800N

General walking speed of a man with pushing a load= 0.6m/s

Thus, P = 800 x 0.6 = 480 watt

Equivalent torque is given by,

Where T= Torsional moment.

M= Bending moment.

Angular velocity of wheel is given by,

ω = V/R

Where, V = velocity in m/s and R = Radius in m.

The diameter of selected wheel =0.3m

Thus radius R= 0.15m

Angular velocity ω = 0.6/ 0.3 = 2 rad/sec

Power is also given by,

P= Torque x ω

T = P/ ω =480/2

T= 240 N-m ……..(1)

Vertical bending moment,

M_B = 175 x 0.1 = 17.5 N-m

M_C= (175 x 0.3) – (250 x 0.2) = 2.5N-m

M_D =175 x 0.1 = 17.5N-m

Thus maximum bending moment,

M= 17.5N-m ……..(2)

From equation (1) and (2),

Equivalent Torque,

$$Te = \sqrt{Kt \times T + Kb \times M}$$

K_b = Combined shock and fatigue factor applied to bending moment = 1

K_t = Combined shock and fatigue factor applied to torsional moment = 1

$$Te = \sqrt{1 \times 240 + 1 \times 17.5}$$

Te = 240.63 N-m ≈ 241 N-m

7. Diameter of shaft:

τ_{max} for mild steel is, 55N/mm^2 x 0.75 =41.25 N/mm^2

Te = 241 N-m = 241 x 10^3 N-mm, FOS =1.2

T_{max} = T_ex FOS = 289.2×10^3 N-mm

$$\tau_{max} = \frac{16Tmax}{\pi d^2} = \frac{16\times289.2\times10^3}{\pi\times d^3}$$

d= 32.92 mm ≈ 33 mm

For more strength we selected "d" = 35 mm

8. Bearing selection:

As we have shaft diameter (d) = 35 mm

From design data book following options are available,

Table- 2: Bearing Selection

DEEP GROOVE BALL BEARING	Static Capacity, kgf C_o	Dynamic Capacity, kgf C	Maximum Permissible Speed, rpm
SKF 6007	880	1250	130000
SKF 6207	1370	2000	10000
SKF 6307	1760	2600	8000
SKF 6407	3250	4300	5600

Selecting SKF 6007 Deep Groove Ball Bearing.

9. Selection of Pump:

We are going to join four nozzles then pump required to produce the discharge is,

(4)× (0.3333) = 1.3332

Total discharge of pump is 1.3332 lpm.

For above discharge, pump which give pressure above 1.33 bars is to be selected.

So, we can select a pump that gives pressure up to 2 bar.

10. Nozzle Selection:

Diameter of wheel =30 cm

Let's consider farm of 1 Acre,

Therefore, 1 acre = 4046.86 m^2

L= $\sqrt{4046.86}$ = 64 meters

Number of tiles in 64 meters,

NT = $\frac{64}{0.38}$ = 168

From survey earlier when hand backpack spray pump used then 60 litre of sanitizer are used for 1 acre farm. Consider 60 ltr. of sanitizer is required for 1 acre farm so how much amount of sanitizer is required for one tile. Total number of tiles in 1 acre,

$$168 \times 168 = 28224$$

$\frac{60}{28224}$ = 2.1258×10^{-3} litre/tile

Consider time required for 1 acre area to spray a sanitizer is 3 hrs. = 180 minute

$= \frac{180}{28224}$

$= 6.3775 \times 10^{-3}$ min/tiles

$= 1/6.3775 \times 10^{-3}$

= 156.8 tiles/min.

Discharge = $(2.1258 \times 10^{-3}) \times (156.8) = 0.3333$

Find the pressure drop,

$$\left(\left(\frac{Q2}{Q1}\right)^2\right) = \left(\frac{P2}{P1}\right)$$

$$(P2) = (P1) \times \left(\left(\frac{Q2}{Q1}\right)^2\right)$$

$$(P2) = (2) \times \left(\left(\frac{0.3333}{0.4166}\right)^2\right)$$

$$(P2) = 1.28 \text{ bar}$$

Pressure drop = $P1 - P2 = 2 - 1.28 = 0.72$ bar

11. Design of Manifold and Pipe Selection

When we carry out small survey we come to know that various pump are used by different farmers but the most probably use pump is having capacity 16 Litre. With pressure of 2-4 bars.

Pump Pressure = 2-4 bars

Spray Pipe Material = Plastic

Pump discharge = 2 ltr./min = $3.333 \times 10 = 3.333 \times 10^{-5}$ m^3/sec

$$Q = A \times V$$

$$V = \frac{3.33 \times 10^{-5}}{\frac{\pi}{4} \times d^2} = \frac{4.244 \times 10^{-5}}{d^2} \text{ m/sec}$$

Major Losses,

Take a Friction Factor, f = 0.09

$$h_{fm} = \frac{(4FLV^2)}{(2gd)} = \frac{(4)\times(0.09)\times(3.4)\times\left(\left(\frac{4.244\times10^{-5}}{d^2}\right)^2\right)}{(2)\times(9.81)\times d}$$

$$= \frac{1.123\times10^{-10}}{d^5}$$

Loss at Entry,

$$h_{fE} = \frac{(0.5\times V^2)}{(2\times g)} = \frac{(0.5)\times\left(\left(\frac{4.244\times10^{-5}}{d^2}\right)^2\right)}{(2)\times(9.81)} = \frac{4.590\times10^{-11}}{d^4}$$

Loss at Out,

$$h_{fO} = \frac{V^2}{2g} = \frac{\left(\left(\frac{4.244\times10^{-5}}{d^2}\right)^2\right)}{(2)\times(9.81)} = \frac{9.180\times10^{-11}}{d^4}$$

Loss at T Section

Take, Bending Coefficient, k = 0.54 for 90°

$$h_{ft} = \frac{(KV^2)}{(2g)} = \frac{(0.54)\times\left(\left(\frac{4.244\times10^{-5}}{d^2}\right)^2\right)}{(2)\times(9.81)} = \frac{4.9573\times10^{-11}}{d^4}$$

Total Losses, $h_{fT} = h_{fm} + h_{fE} + h_{fO} + h_{ft}$

$$h_{fT} = \frac{1.123\times10^{-10}}{d^5} \pm \frac{4.590\times10^{-11}}{d^4} \pm \frac{9.180\times10^{-11}}{d^4} \pm \frac{4.9573\times10^{-11}}{d^4}$$

Required Pressure at nozzle is 2 bar,

Therefore, pressure, P = 2 bar = 2×10^5 N/m^2

P = ρgh

$$(2 \times 10^5) = (1000) \times (9.81) \times (h)$$

h = 20.38 m of water

Therefore, $h_{fT} = \frac{1.123\times10^{-10}}{d^5} \pm \frac{4.590\times10^{-11}}{d^4} \pm \frac{9.180\times10^{-11}}{d^4} \pm \frac{4.9573\times10^{-11}}{d^4}$

$$20.38 = \frac{1.123\times10^{-10}}{d^5} \pm \frac{4.590\times10^{-11}}{d^4} \pm \frac{9.180\times10^{-11}}{d^4} \pm \frac{4.9573\times10^{-11}}{d^4}$$

$$d = 5.611 \times 10^{-3} \text{ m}$$

$$d = 5.61 \text{ mm} = 0.6 \text{ cm}$$

6. MODELLING AND DESIGN

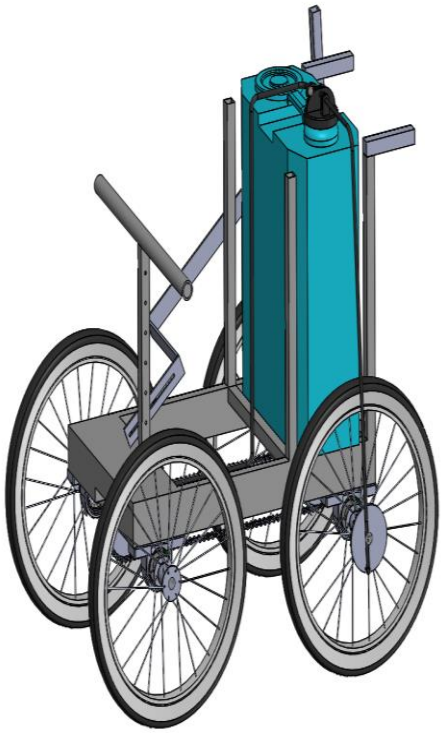


Figure-1: Isometric View of the Model

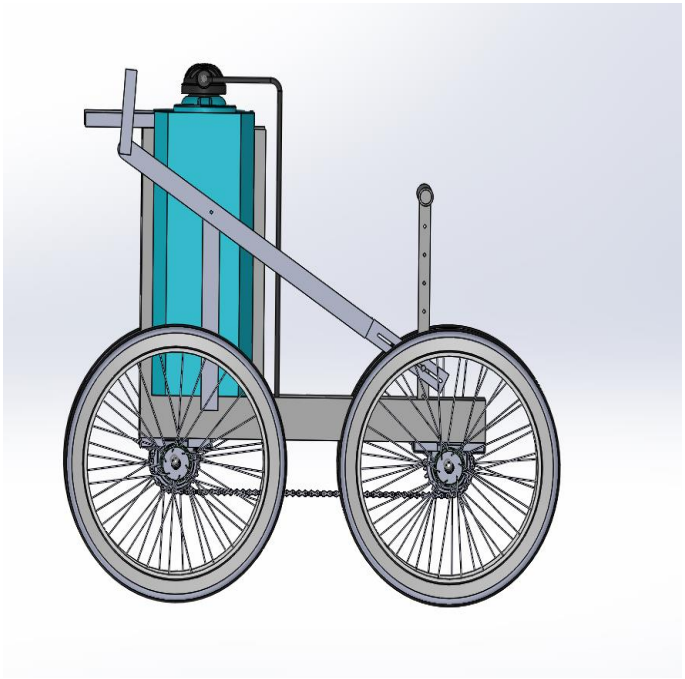


Figure-2: Right Hand Side View of the Model

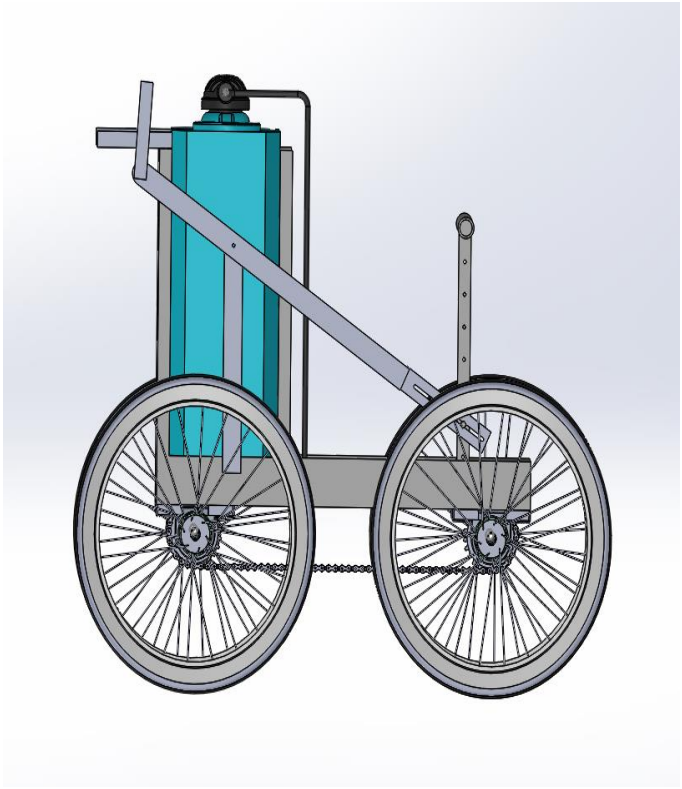


Figure-3: Left Hand Side View of the Model

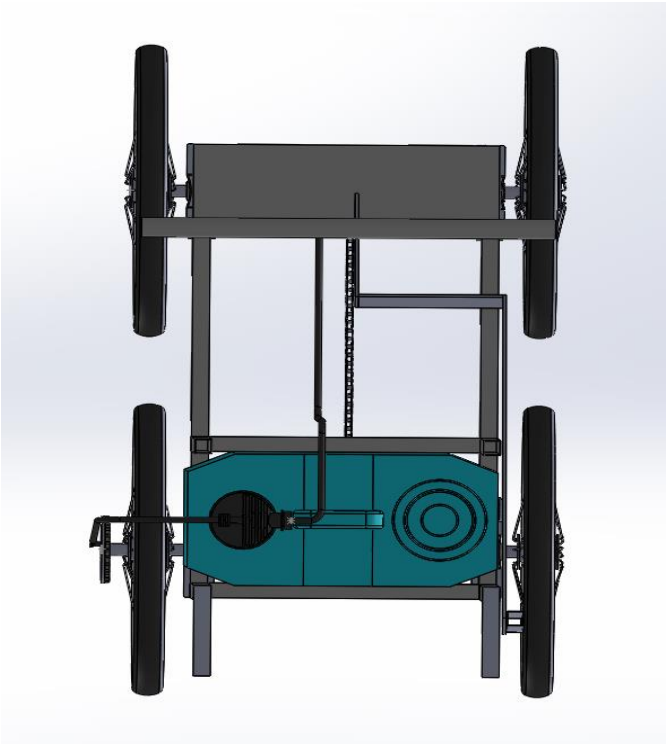


Figure-4: Top View of the Model

7. CONCLUSIONS

1) This suggested model has removed the problem of back pain since there is no need to carry the sanitizer tank on the back. This model has a greater number of nozzles which will cover the maximum area of spraying in minimum time & at a maximum rate.

2) The mechanism used and machine is simple & consumes less energy to pull the machine.

3) The performance of the equipment will increase when it is operating on the smooth surface or less uneven surface.

4) For easy handling and comfort of usage, some additional mechanisms like cut-off valve and sprockets have been used. It is a low budget sprayer for small and middle-scale companies which is compact and easier to use also maintenance is very low.

8. FUTURE SCOPE

1) Using control valve we can maintain the fluctuation pressure.
2) More number of nozzles can be used.
3) The product can be sealed using the casing.
4) Imported different kind of nozzle we can achieve the better performance like as hollow cone nozzle we reduce the drifting problems.
5) By using a flexible hose & lance we can spray the sanitizer around the area concerning their size from one position.
6) High capacity backpack can be used.
7) A new design can be implemented to eliminate the need for pulling the machine manually.
8) Stronger but light in weight materials can be used for the frame.

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