Pedal operated multipurpose bicycle with sprayer and water lifting pump

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Abstract: There are millions of people live in the villages of Indiawithout having reliable energy sources and means of power supply needed for the domestic or agricultural fields. Considering this, an attempt is made to develop a water lifting system using the pedal operated power with additional featuresas a sprayer for pesticides and insecticides. This setup is portable (mobility) as it is mounted on the same bicycle. The pedal operation of this cycle reduces alternate source of energy. At the same time it can be used for spraying the liquids (chemicals) with the same pedal power. The time of operation depends upon the efficiency of this reciprocating pump used to lift the water. This mechanism is more reliable and useful in the remote village to get the sufficient source of power. The multi ability makes it more special. The pump setup includes a housing in which a foot pedal and drive shaft rotate an eccentric disc rotating with the drive shaft moves a connecting rod which in turn causes push rod to move linearly.

Keywords: Agricultural, Bicycle,Eccentric disc, Portable, Pump, reliable, Sprayer.

1. Introduction

The purpose of this paper is to design and build a bicycle powered water lifting and a pedal powered sprayer. Its mobility is main strength of this project. The main purpose for the development of this project is to utilize the human powered bicycle for communicating where electricity is unavailable or impractical. Energy has generally been applied through the use of the arms, hands, and back. This portable spraying system is an assembly of a modified sprocket-pump assembly, tank and adjustable sprayer boom can be mounted on any bicycle available in the market.

Indigenousagricultural implements of Indianowadays gives the idea that the current water pump did not complete with a best future which is meeting the ergonomic and economic requirement. It is to fulfil the requirement based on farmers and human activity at third world countries that difficult to get water supply. Besides that, the development of bicycle powered water pump is due to the place that unavailable and unpractical electricity power supply. The farmers who use conventional backpack sprayer faces many problems like fatigue, tiredness, pain in spinal cord and muscles etc.

The design was specifically developed for use in rural areas for agriculture, but the technology could easily use in any development countries or area without electricity. Its main advantage over existing technology is its mobility which means that it is suitable for a variety of applications such as irrigation, agricultural, light industrial and domestic water transportation. This design of pedal powered water lifting and sprayer converts an unwanted bicycle into a device for water lifting from any source, and sprinkling of insecticides, weedicides, pesticides and other chemicals for agricultural purpose. To develop a novel product that is manufactured from waste material and creating a simple and efficient way of pumping and spraying utilizing a human powered bicycle for communicating where electricity is unavailable or impractical.This spray can be mounted on any bicycle available in the market. Here the reciprocating pistons are connected to the sprocket with linkage mechanism. A number of spraying nozzles are connected to a manifold and their direction and height are adjustable according to requirements. The driving sprocket and the driven sprocket are interchanged from their usual position in a conventional bicycle. Generally, water lift by using motor by using bicycle operated centrifugal pump mechanism for water lifting we can reduce the human and electric power.The main objective of this project is to develop the bicycle powered water pump and agro sprayer. Basically the development of the bicycle powered water pump and agro sprayer consist of the designing process, fabrication and lastly will come out with analysis based on the gearing system and power of the pump itself to produce maximum output.Its main advantage over existing technology is its mobility which means that it is suitable for a variety of applications such as irrigation, agricultural, light industrial and domestic water transportation. Fig. 1 shows the 2D model of propsed system.
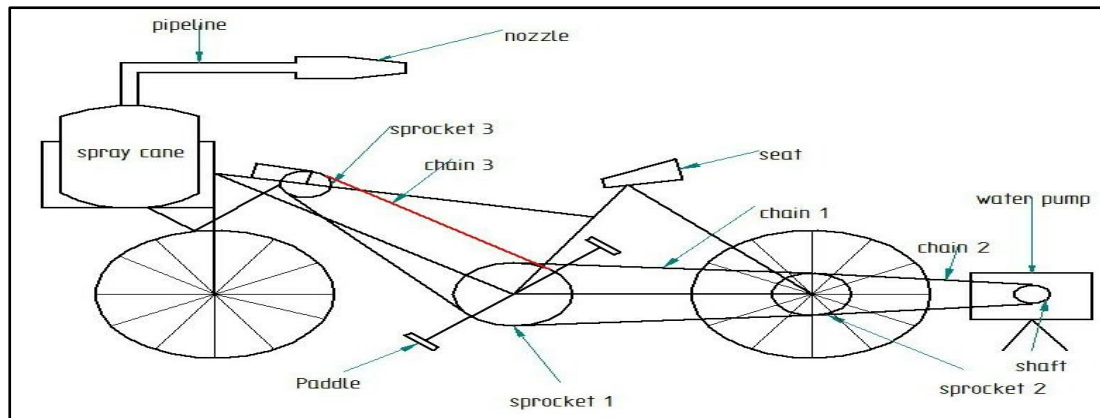
Fig. 1 2D model of the project

2. Literature Review

Pumps are a common means of lifting water from a clean ground water source to a useful point of access given inJournal of arboriculture weed control in landscape plantings, but all pumps have moving parts and are therefore destined to break proper selection of a pump will reduce undesirable downtime and will empower the local community to manage their water source. Here we use the foot pedal pump, powered by our legs instead of arms to lift the water from a depth range of seven meters. Throughout history human, energy has generally been applied through the use of the arms, hands, and back. With minor exceptions, it was only with the invention of the sliding-seat rowing shell, and particularly of the bicycle, that legs also began to be considered as a normal means of developing power from human muscles.

Most of the pesticides are applied as sprays. The liquid formulations of pesticide are explained by Pedro and Lagos [1] either diluted (with water, oil) or directly are applied in small drops to the crop by different types of sprayers. Usually the EC formulations, wet able powder formulations are diluted suitably with water which is a common carrier of pesticides. In some cases however, oil is used as diluent or carrier of pesticides. The important factors for spray volume consideration are: The volume of spray liquid required for certain area depends upon the spray type and coverage, total target area, size of spray droplet and number of spray droplets.

Das and Nag [2] explained that use of electric operated centrifugal pumpfor pumping the water are a sub-class of dynamic axis symmetric work-absorbing machinery. Electrical operated Centrifugal pumps are used to convert rotational kinetic energy to the hydrodynamic energy of the liquid flow. The rotational energy comes from electric device like motor. The fluid enters the pump impeller along o to the rotating axis and is accelerated by the impeller, flowing radials in chamber outward into volute chamber, from where it exits.

Its Common uses include petroleum, water bodies, and petrochemical pumping. The function of the centrifugal pump is converting potential energy of water pressure into mechanical rotational energy.

AtulGanorkaret al [3] haveproved that Pedal Powered Water Pump (PPWP) along with water purification (PPWP) is an eco-friendly system. The PPWP works only on mechanical energy without electricity. PPWP provides drinking water and irrigation in remote areas where electricity is still a major problem.Along with providing eco-friendly environment it also helps to regulate a good health while pedaling PPWP is not only free from pollution but also provide healthy exercise. PPWP Produces the rising energy costs. PPWP was designed as a portable one which can be used for irrigation in various places. PPWP consists of a centrifugal pump operated by pedal power. The centrifugal pump is positioned on its stand in such a way that driven shaft of the centrifugal pump has butted to the bicycle wheel. By pedaling the bicycle, the bicycle wheel rotates, thereby rotating the centrifugal pump which in turns discharges water from the sump and transmitted to pre filters which purify the water simultaneously.

This portable spraying system is an assembly of a modified sprocket-pump assembly, tank and an adjustable sprayer boom. VishalGarg et al [4] explained that spray mounted on any bicycle available in the market. A drum containing the solution is firmly attached to the frame of the bicycle. The reciprocating pistons are connected to the sprocket with linkage mechanism. A number of spraying nozzles are connected to a manifold and their direction and height are adjustable according to requirements. The arm containing the nozzle holding manifold can be folded back while not in use. The driving sprocket and the driven sprocket are interchanged from their usual position in a conventional bicycle. The bigger sprocket is fitted to the wheel hub and the smaller sprocket is the driven one. While pulling along the bicycle, the forward and backward

movement of the bicycle through the chain and modified sprocket arrangement is transferred to a pump assembly which pumps air into the tank to generate pressure for spraying through the sprayer boom nozzles.

3. Working principle and components
The working principles and selection of different components are given below

3.1 Sprayers
The hand sprayer is a small capacity pneumatic sprayer. It consists of chromium plated brass tank having a capacity of 0.5 to 3 liters (one liter is more common) which is pressurized by a plunger pump. The air pump remains inside the tank. The sprayer has a short delivery tube to I which a cone nozzle is attached. In some models, the nozzle is attached at the top of the tank with flow, spring actuated lever, which regulates the flow of the spray liquid. For sprayingexplained in Serazul Islam et al [5] explained the tank is usually filled to three-fourths capacity and pressurized by air pump. The compressed air causes the agitation of the spray liquid and forces it out, on operation of the trigger or shut off type valve. Usually the chemicals with suspension characteristics cannot be effectively sprayed with this type of sprayer.
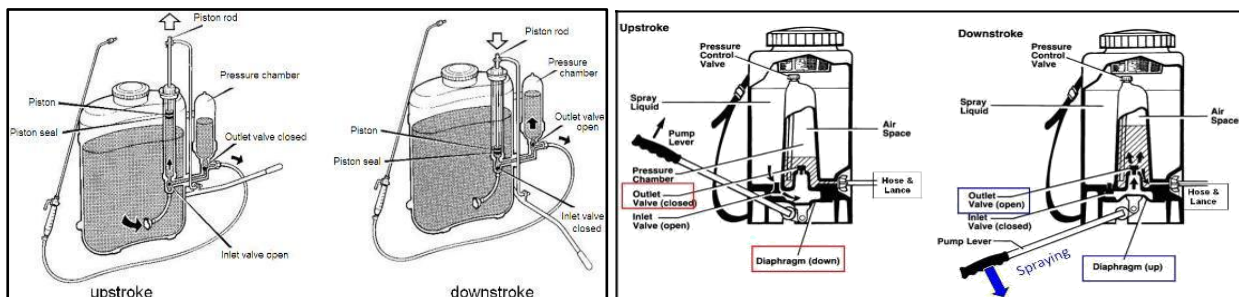

Fig.2 working principle of sprayer

3.2 water pump
Pumps are a common means of lifting water from a clean ground water source to a useful point of access, but all pumps have moving parts and are therefore destined to break proper selection of a pump will reduce undesirable downtime and will empower the local community to manage their water source..

Suction and lift are important considerations when pumping fluids. Suction is the vertical distance between the fluid to be pumped and the center of the pump, while lift is the vertical distance between the pump and the delivery point. The depth from which a hand pump will suck is limited by atmospheric pressure to an operating depth of less than 7 meters. The height to which a hand pump will lift is governed by the ability of the pump and the operator to lift the weight in the delivery pipe. Thus the same pump and operator will be able to achieve a greater lift with a smaller diameter pipe than they could with a larger diameter pipe. Range of lift is given in TABLE 1.

Reciprocating pumps designed for delivering high pressures must include methods for releasing excessive fluid pressures. The pumps should include for built in relief valves or relief valves should be included in the fluid circuit which cannot be isolated from the pump. This feature is not required for safety for the air operated diaphragm valve. These types of pump operate by using a reciprocating piston. The liquid enters a pumping chamber via an inlet valve and is pushed out via an outlet valve by the action of the piston or diaphragm.

Reciprocating pumps are generally very efficient and are suitable for very high heads at low flows. This type of pump is self-priming as it can draw liquid from a level below the suction flange even if the suction pipe is not evacuated. The pump delivers reliable discharge flows and is often used for metering duties delivering accurate quantities of fluid.

The reciprocating pump is not tolerant to solid particles and delivers a highly pulsed flow. If a smooth flow is required then the discharge flow system has to include additional features such as accumulators to provide even flows.

Table 1 Range of lift

Type	Range
1. Suction pumps	0 – 7 meters
2. Low lift pumps	0 – 15 meters
3. Direct action pumps	0 – 15 meters

4.	Intermediate lift pump	0– 25 meters
5.	High lift pumps	0 – 45 meters, or more

4. Sprayer module

Fig. 3 and Fig. 4 show the assembly and position of pedal operated agro sprayer, whereas the construction and the working principle is explained below.

Fig. 3 assembled sprayer on bicycle

Fig. 4 position of pedal operated agro sprayer on bicycle

4.1 Crank-slotted mechanism

In crank-slotted mechanism explained in crank is connected with slotted connecting rod. One end of connecting rod is connected with crank and the other end of rod is connected with the piston rod of pump. Center of this rod is fixed with the frame of trolley and the rod is oscillating on this point. The crank slotted mechanism. This mechanism converts rotary motion into reciprocating motion. So this mechanism converts sprockets rotary motion into reciprocating motion of piston of pump.

When we pedal the cycle, larger pulley rotates. This pulley is connected with another pulley by the chain; this pulley is connected with crank-slotted mechanism. This mechanism converts rotary motion into reciprocating motion. So due to reciprocation of piston the pressure develops in the hydraulic pump. In manual operation of pump this pressure can be developed by oscillating the handle of pump. So by this mechanism we can easily develop the pressure in the pump. This pressure chamber and other end is connected with the nozzle. Thus, instructed by the pressurized pesticide-water mixture comes in the discharge line and from there this mixture is come outside by the help of nozzle. So, in simple words when we pedal the stationary cycle the

pulley rotates which is connected with another pulley by the chain. This pulley rotates crank and thus the connecting rod oscillates on its fixed point and the piston of pump is reciprocate and pressure develops inside the hydraulic pump. So the pressurized pesticide comes in the discharge line of pump. At the end of discharge line there are cut off valve by which we can control the pressurized pesticide and increase or decrease the flow of pressure. The length of discharge line is adjustable so by adjusting the position of delivery pipe we can adjust the length of discharge pipe. When the distance between two rows of plant is more(Max. 0) then we can increase the length of discharge pipe, so we can easily spray the pesticide to these rows and when this distance is so closed(Min. 0) then we can decrease the length of discharge pipe and spray the pesticide easily. So in both situation we can easily spray pesticide very effectively and this advantage of this mechanism.

5. Pump module

The description about pump system used to construct the proposed mechanism is explained below

5.1 Pumps

The main component of the proposed mechanism is a reciprocating pump and here the reciprocating pistons are connected to the sprocket with linkage mechanism. A number of spraying nozzles are connected to a manifold and their direction and height are adjustable according to requirements. The driving sprocket and the driven sprocket are interchanged from their usual position in a conventional bicycle. Pumps come in a variety of sizes for a wide range of applications are observed from Ademola Samuel et al [6]. They can be classified according to their basic operating principle as dynamic or displacement pumps. Dynamic pumps can be sub -classified as centrifugal and special effect pumps. Displacement pumps can be sub -classified as rotary or reciprocating pumps. In principle, any liquid can be handled by any of the pump designs. Where different pump designs could be used, the centrifugal pump is generally the most economical followed by rotary and reciprocating pumps.

Reciprocating pump

Reciprocating pumps are those which cause the fluid to move using one or more oscillating pistons, plungers or membranes (diaphragms).To Reciprocate means 'To Move Backwards and Forward'. A reciprocating pump therefore, is one with a forward and backward operating action. The simplest reciprocating pump is the 'Bicycle Pump', which everyone at some time or other will have used to re -inflate their bike tires. Reciprocating -type pumps require a system of suction and discharge valves to ensure that the fluid moves in a positive direction. Pumps in this category range from having "simplex" one cylinder; to in some cases "quad" four cylinders or more. Most reciprocating -type pumps are "duplex" (two) or "triplex" (three) cylinder. Furthermore, they can be either "single acting" independent suction and discharge strokes or "double acting" suction and discharge in both directions. The pumps can be powered by air, steam or through a belt drive from an engine or motor. This type of pump was used extensively in the early days of steam propulsion (19th century) as boiler feed water pumps. Reciprocating pumps are now typically used for pumping highly viscous fluids including concrete and heavy oils, and special applications demanding low flow rates against high resistance.

Hand pumps are manually operated pumps they use human power and mechanical advantage to move fluids or air from one place to another. They are widely used in every country in the world fora variety of industrial, marine, irrigation and leisure activities.

There are many different types of hand pump available, mainly operating on a piston, diaphragm or rotary vane principle with a check valve on the entry and exit ports to the chamber operating in opposing directions. Most hand pumps have plungers or reciprocating pistons, and are positive displacement.

The most common and well-known form of displacement pump is the piston or "bucket" pump shown in Fig. 5, a common example of which is illustrated in. This works by applying both the principles i.e., in the example of, water is sucked into the cylinder through a check valve on the up-stroke, and the piston valve is held closed by the weight of water above it; simultaneously, the water above the piston is propelled out of the pump as. On the down-stroke, the lower check valve is held closed by both its weight and water pressure, while the similar valve in the piston is forced open as the trapped water is displaced through the piston ready for the next up-stroke. A typical traditional design of brass-lined cylinder borehole pumps with a metal foot valve and a metal piston valve; the piston has two leather cup-washer seals (indicated on the diagram). The outer casing and end fittings are normally cast iron in a pump of this kind.

There are various basic relationships between the output or discharge rate (Q), piston diameter (d), stroke or length of piston travel (s), number of strokes p minute (n), and the volumetric efficiency, which is the percentage of the swept volume that is actually pumped per stroke (n *Vol)

if the swept area of the piston is A = 14
Swept volume per stroke will be V = A*s
Discharge per stroke will be q
Pumping rate (per minute) is Q = n*q

Fig. 5 assembly of reciprocating pump on bicycle

6. Eccentric disc

In eccentric mechanism following specifications are considered to fulfill our requirements. In mechanical engineering, an **eccentric** is a circular disk (eccentric sheave) solidly fixed to a rotating axle with its centre offset from that of the axle hence the word "eccentric", out of the centre.According to the stroke length of the piston the eccentric hole is drilled, from the centre point of the disc.represented in fig. 6

- Diameter of the disc- 16.5cm
- Thickness- 0.2cm.
- The eccentric hole is drilled 4cm from centre of the disc.
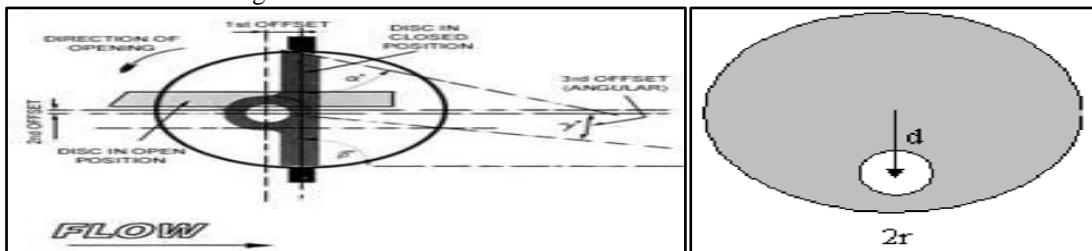- The total stroke length is 8cm.

Fig. 6eccentric mechanism

6.1 Considerations of knapsack sprayer
- Rinse and clean the sprayer.
- Determine nozzle discharge (by selecting a nozzle) in L/min at known pressure (V).
- Calculate the walking speed of the operator (starting point, end point) in m min^{-1}.
- Determine the width of the spray swath in meters (W).
- Calculate the area sprayed in one minute (W x L) m^2/min
- Area sprayed per min = Swath width of spray x Forward speed min^{-1}.
- The application rate for any given area:
- Volume of spray in L/unit area

A knapsack sprayer for applying insecticides and fertilizers comprises a large tank in which is mounted a pressure vessel. A pumping assembly is connected with the bottom portion of the container tank. It consists of a double acting piston assembly, a valve and passages to connect a portion of the cylinder chamber above the piston assembly to the pressure vessel and to the container tank.

6.2consi9derations water lifting pump
- It is used for to achieve manual operated water pumping non automated by simple mechanism.
- Its operation and maintenance is very simple.
- It is compact and portable.
- It is simple and rigid in construction.
- Manufacturing cost is lesser than modern water pumping machine.

- It provides better speed changes method on the driving unit.
- Power saved and good exercise for all people.
- To calculate the volume of the cylinder
  i.e Volume=Area*length
  Where, $= \frac{\pi * D2}{4} XL$ (1)
  D=Diameter of the piston and L=length of stroke

7. Specifications and calculations
As there are so many mechanisms working and every mechanism have its own specifications and working calculations as follows:-

7.1 Gear train calculation
Fig 6.1 shows on Design of Machine Elements-II by J.B.K. Das and P.L.Srinivasa Murthy [7] the gear train schematic representation. Sprocket 1 is the driver member, sprocket 2 and 4 are the driven member, and sprocket 3 is connected to shaft of the sprocket 2 it as a driver member for sprocket 4. T_1 be the slack side of the chain drive and T_2 be the tight side of the drive system. The gear ratio can be calculated by assuming speed of the pedaling sprocket as 60 rpm or one revolution per second

Speed ratio: $\frac{n1}{n2} = \frac{z2}{z1}$ (2)

Speed of second sprocket: $n2 = \frac{n1*z1}{z2}$

$= \frac{60*44}{16}$

$= 165$ rpm

$n_1 = n_3$

$\frac{n3}{n4} = \frac{z4}{z3}$ (3)

$n_4 = \frac{n3*z3}{z4}$

$= \frac{165*43}{14}$

$= 507$ rpm
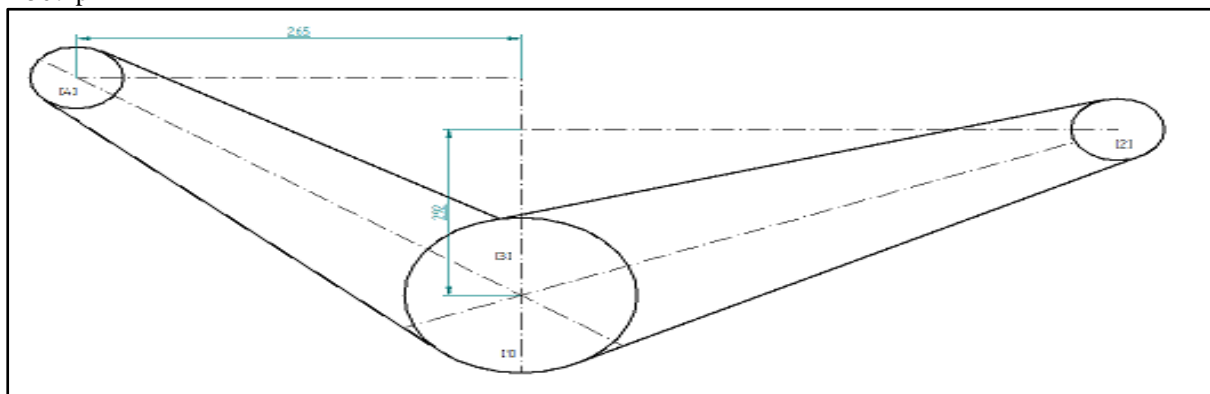

Fig. 1.7 schematic representation of gear trains

7.2 Chain length calculation for sprocket 1 and 2
Chain Length, $L_1 = 2C_1 + 1.57(d_1+d_2) + (\frac{d1-d2}{4C1})^2$ (4)

$= 2 * 546 + 1.57(203.2+70) + (203.2-70)^2/ (4*546)^2$

$= 1520.98$ mm or approximately 1521 mm

Pitch: $P_1 = d_1*sin(\frac{180}{z1})$ (5)

$= 203.2*sin(\frac{180}{44})$

$= 14.50$ mm

Velocity of pump attachments: $V_1 = \frac{p1 z1 n1}{60000}$ m/sec(6)

$$= \frac{14.5 * 44 * 165}{60000}$$

$$= 1.76 \text{ m/sec}$$

7.3 Chain length calculation for sprocket 3 and 4

Chain length: $L_2 = 2C_2 + 1.57(d_3 + d_4) + (\frac{d3 - d4}{4C2})^2$(7)

$$= 2 * 265 + 1.57(177.8 + 60) + (\frac{177.8 - 60}{4 * 265})^2$$

$$= 903.45 \text{mm or approximately } 904 \text{ mm}$$

Pitch, $P_2 = d_3 * \sin(\frac{180}{z3})$

$$= 177.8 * \sin(\frac{180}{43})$$

$$= 12.98 \text{ mm}$$

Velocity of spray attachement : $V_2 = \frac{p2 z4 n4}{60000}$ m/sec   (8)

$$= \frac{12.98 * 14 * 507}{60000} \text{m/sec}$$

$$= 1.54 \text{ m/sec}$$

7.4 sprayer specifications

Observing the farmer difficulty to carry the loaded sprayer on his back and to walk around the cultivated land to spray insecticides to the plant. This proposed model of pedal operated sprayer to overcome the above problem. But here two persons required for the operation, one for pedaling the bicycle and another person is to spray the insecticide on the surrounding of the bicycle placed. It is more efficient and gives better output by reducing the time of operation.

Nozzle discharge   = 1 L/min.
Spray width (W)   = 0.75 meter.
Walking speed (m/min) = 70 m/min.
Area sprayed per minute: $A = W * L$(9)

$$= 0.75 * 70$$

$$= 52.5 \text{ m}^2/\text{min}$$

$$= 52.5 * 60$$

Area sprayed = 3150 m²/hour
1 Acre of land = 4046.86 m² of land
Therefore, Area sprayed = 0.79 acre/hour.

7.5 water lifting pump specifications

Let, D = diameter of cylinder   d = diameter of piston rod
A = cross section area of cylinder
N = rpm of crank
r = radius of crank
L = length of stroke = 2r
h_s = suction head
h_d = delivery head
ρ = density of water
g = acceleration due to gravity
P = power
N = no. of revolution per second
Q = discharge of water in one revolution

$$= A * L   (10)$$

$$= \frac{\pi * d2}{4} * L \text{ m}^3/\text{cycle}$$

$$= \frac{\pi * d2 * L}{4 * 60} * N \text{ m}^3/\text{second}$$

$$= \frac{ALN}{60}$$

$$= 2.68 * 10^{-5} \text{ m}^3/\text{sec}$$

$$= 96.62 \text{ litres/hr}$$

work done/second: w= weight of water delivered per second * head lifted

$$= W * (h_s + h_d) \tag{11}$$
$$= m * g * (h_s + h_d)$$
$$= \rho * Q * g * (h_s + h_d)$$
$$= \rho g Q * (h_s + h_d)$$
$$= \rho g A L N * (h_s + h_d) / 60$$

$$P = \frac{work\ done}{second} = \frac{\rho g A L N * (h_s + h_d)}{60000} kw \tag{12}$$

Dimension: 43 cm x 17 cm x 43 cm

8. Advantages, disadvantages and applications of proposed model

Even if all the other pumps and sprayer are similar in use the pedal operatedreciprocating water pump agro sprayer is more advantageous than the other pumps.

- This is of compact in size.
- Less maintenance is enough.
- The water pumped is of higher pressure.
- Effective working principle.
- It doesn't have any prime mover, like electric motor related to the unit.
- Initial and maintenance cost is less.
- Easy to use.
- Does not require buying any specially designed pump.
- Uniform spraying.
- Portable and ergonomic.
- Can work efficiently during all seasons.

Disadvantages of the proposed model are

- Problems in using tyre tubes.
- Corrosion at a longer run.

Applications considered are

- Agricultural fields
- Domestic purpose
- Industrial & painting applications.
- For the insecticides application to control insect pests on crops and in stores, houses, kitchen, poultry farms.
- For applying the powdery formulation of poisonous chemicals on the crops.
- For the herbicides, fungicides, weedicides, pesticide application, to kill various threats of crops.

9. Conclusion

This paper focused on modeling, design and control of pedal operated water pumping and filtering system, with emphasis on lightweight, portable appliances. An innovative method of minimizing manual stress and thus reliably stabilizing the pumping was also presented. The paper can make an impression in the small scale industrial and domesticareas.

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