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Multi-Nozzle Pesticide Sprayer for Agriculture

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Abstract

In the agricultural sector, farms are producing more productively thanks to automated spraying systems. This has resolved the labor issue. However, things are different in a location like India, where automation in the agricultural sector is challenging and the majority of Indian farmers are not in good financial standing. Consequently, there are several uses for the manually operated pesticide sprayer under these circumstances. Small-scale farmers highly value manually lever-driven backpack sprayers due to their affordability, design, and versatility. Two kinds of sprays are utilized in agriculture in nations like India: 1. Pump operated by hand; 2. Pump operated by fuel. The primary drawback of the hand-operated spray pump is that the farmer who uses it cannot use it continuously for longer than five to six hours because of the pump's weight. On the other hand, the fuel-operated spray pump needs fuel, which is costly and difficult to come by in remote areas. In this study, a manually operated multi-nozzle pesticide sprayer pump model is proposed that will reduce

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farmer fatigue while spraying at maximum rate in the shortest amount of time without requiring fuel.

Keywords: Agriculture Field, Multi-nozzle, Pesticides, Pump, Mechanism.

1. INTRODUCTION

Over 75% of India's population, either directly or indirectly, comes from farming, making it a predominantly agricultural nation. Farmers have been using the same outdated tools and techniques for decades, such as plowing, seeding, spraying, weeding, and other similar tasks. To boost agricultural output, efficient systems for weeding and spraying are required. India is an agricultural nation made up of rich, medium-sized, marginal, and small farmers. Small-scale farmers highly value manually lever-driven backpack sprayers due to their affordability, design, and versatility (Ahalya et al., 2017).

The conventional spraying method involves the farmer using a spray backpack, which makes the crop spraying process time-consuming, expensive, and mostly focused on the farmer's (user's) weariness. The sprayer is a crucial tool in today's farming and agriculture processes. Sprayers can be either hand-operated or powered, and they differ in these aspects. Pesticide spraying is a crucial farming procedure. There are many different kinds of pesticide sprayers on the market. While they differ in terms of size, form, design, and material type, they all serve the same purpose (Bhagat, 2017). The project's goal is to cut down on the amount of time, money, and labor needed for spraying. The reciprocating pump and nozzle mechanism at the front end of the spraying apparatus is the basis of the sprayer. A set of adjustable nuts is supplied so that the pressure can be adjusted (high or low) as needed. Productivity in the agriculture industry is increased by efficient pesticide spraying equipment, which is advantageous for the nation's production and GDP growth (Gaodi et al., 2016).

1.1. *Problem Statement*

The backpack spraying mechanism features two adjustable straps and a tank capacity of 15-20 liters. The operation of the fluid flow required for pesticide spraying requires continuous pumping, which causes muscular pain or disorders. The backpack sprayer dribbles and drifts because it cannot maintain a steady pressure due to the uneven terrain of the farm field. It takes effort and time to maintain consistent pressure. It is difficult for a farmer to work under continuous pressure for an extended length of time.

1.2. *Scope & Objective*

Designing a cutting-edge spraying machine that operates efficiently under various working conditions is paramount. Our focus lies in revolutionizing the spraying method to significantly reduce labor costs while catering to the needs of small-scale farming lands, as small as 5 acres. The goal is to develop a machine that not only decreases spray time but also maximizes the sprayed area within minimal time frames. To achieve this, we prioritize incorporating proper adjustment facilities tailored to different crop sizes and heights, ensuring precise and effective spraying. Additionally, our design includes the capability to attach multiple nozzles and a trolley for enhanced functionality and versatility. Furthermore, environmental sustainability is at the core of our system, achieved through the implementation of eco-friendly features such as a spray guard to minimize spray drift and environmental impact.

2. METHODOLOGY

The reciprocating pump is the basis for the multiple sprinkler system's operation. This reciprocating pump has a single slider crank mechanism, which uses a small crank that is positioned on a different shaft. One sprocket is fixed directly to the wheel axle, while the other two are mounted on separate axles. Through a disc, the connecting rod is fastened to a different sprocket axle. The reciprocating pump's piston receives power from the rotation of the wheels.

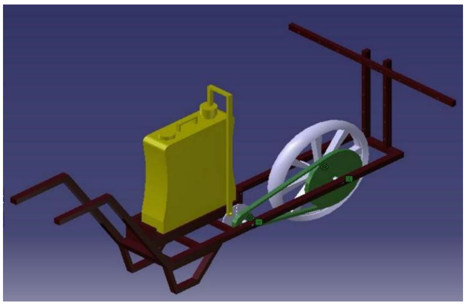

Fig. 1. Multi-Nozzle Wheel Spray Pump.

2.1. *Construction*

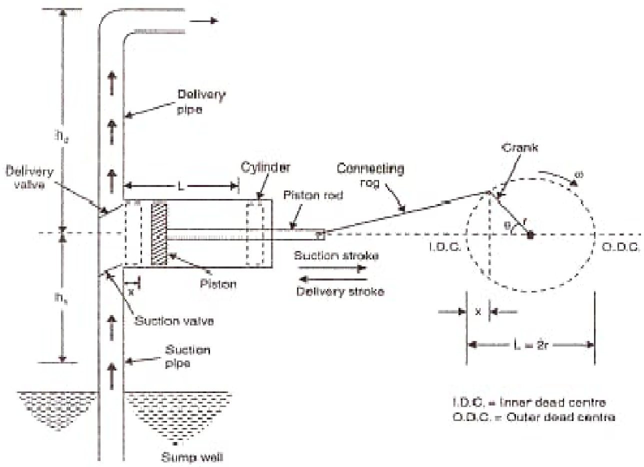

Fig. 2. Slider crank mechanism (pumping).

2.1.1. Sprockets

In general, any wheel that has radial projections that contact a chain that passes over it is referred to as a "sprocket." Sprockets differ from gears because sprockets are never directly meshed; they also differ from pulleys because sprockets have teeth while pulleys are smooth. To arrange the chain and sprocket, we utilize a freewheel and a chain wheel.

Fig. 3. Slider crank mechanism.

2.1.2. Chain

The steel chain, which has no slip, is utilized to transfer power from the gear sprocket to the pinion sprocket.

Fig. 4. Slider crank chain mechanism.

2.1.3. Crank

Transferring motion from the prime mover to the connecting rod for additional activity is the purpose of the crank. This circular disk has an eccentricity that causes the connecting rod to reciprocate, or move linearly, when the crank rotates.

2.1.4. Connecting rod

Converting rotary motion into reciprocating or linear motion is the connecting rod's primary purpose. Here, the connecting rod transforms the crank's rotary motion into the pump's and extension rod's reciprocating motion.

2.1.5. Pump

It has a cylinder and piston arrangement and a lever to control the piston's reciprocating motion. The pump produces a 2-bar pressure and a 2 lpm discharge.

2.1.6. Nozzle

It's a mechanism that transforms fluid pressure energy into kinetic energy. A spray nozzle is a precise tool used to help disperse liquid into a spray. A nozzle is used to disperse a liquid over a surface.

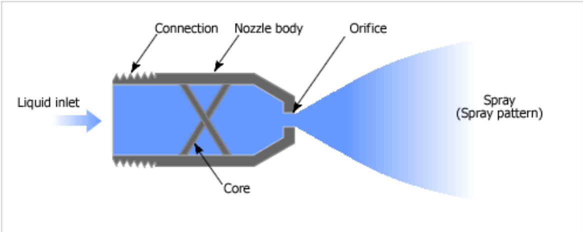

Fig. 5. Nozzle mechanism.

2.1.7. Wheel

The entire assembly is carried by a bicycle wheel, which rotates to transport the machine from one location to another. A bicycle wheel is a wheel made specifically for a bicycle, usually a wire wheel. The purpose of a bicycle wheel is to accommodate a bicycle tire and fit into the frame and fork via dropouts. A metal hub, wire tension spokes, and a metal or carbon fiber rim that houses a pneumatic rubber tire are the common components of a modern wheel. Our tire wheel is tubeless.

2.1.8. Frame

The primary purpose of the frame is to support the entire assembly; hence, it needs to be sturdy enough to do so. Mild steel is shaped into square pipes that make up the frame.

2.1.9. Tank

The tank should be able to support its weight and as much fluid as possible. We have a tank that holds around 15 liters. Plastic fiber makes up the tank's composition. When compared to other materials, the weight of the plastic fiber is quite low. It's also incredibly affordable.

2.2. *Working*

The reciprocating pump is the basis for the multi-sprinkler system's operation. The little sprocket installed on a different shaft serves as the crank in the single slider crank mechanism used by the reciprocating pump. One sprocket is fixed directly to the wheel axle, while the other two are mounted on separate axles. Through a disc, the connecting rod is fastened to another sprocket axle. Here, the reciprocating pump's piston receives power from the wheel's spin.

3. DESIGN CALCULATIONS

3.1. *Selection of Wheel*

- Gap between two plants = 1.25 ft = 38 cm
- Line covered by a single wheel spin = 4

$$38 \times 4 = 152 \text{ cm}$$

$$152 = 2\pi r$$

$$r = \frac{152}{2\pi} \approx 25 \text{ cm}$$

$$\text{Diameter of wheel} = 2r = 50 \text{ cm}$$

3.2. *Design of Chain and Sprockets*

$$\text{Transmission ratio (i)} = 3$$

Using the PSG Design Data Book, number of teeth on small sprocket is

$z_1 = 25\text{ch}$

$$z_2 = i \times z_1 = 3 \times 25 = 75 \ (\textit{since } z_{2,max} \approx 100\text{–}120, \textit{safe})$$

Center distance (ideal range):

$CD = (30 \text{ to } 50)P$

Assume $CD = 500$ mm.

$$500 = (30 \text{ to } 50)P \ \Rightarrow \ P = \frac{500}{30} \text{ to } \frac{500}{50} \approx 16.66 \text{ to } 10$$

Select standard pitch $P = 12.7$ mm from PSG Design Data Book.

Chain selected: ***08A-1 R40*** *(Simplex type)*

- Pitch = 12.7 mm.
- Roller diameter = 7.95 mm.
- Bearing area=0.44 cm^2
- Breaking weight = 1410 kg.

3.2.1. Number of links and chain length

$$a_p = \frac{a_0}{P} = \frac{500}{12.7} \approx 39.37$$

$$L_p = 2a_p + \frac{z_1 + z_2}{2} + \frac{(z_2 - z_1)^2}{4\pi^2 a_p}$$

$$L_p = 2(39.37) + \frac{25 + 75}{2} + \frac{(75 - 25)^2}{4\pi^2(39.37)}$$

$$L_p \approx 78.74 + 50 + 1.608 \approx 130.34 (\text{Take } L_p = 132)$$

Actual chain length:

$$L = L_p \times P = 132 \times 12.7 = 1676 \text{ mm} \approx 1.6 \text{ m}$$

Actual center distance:

- $e = L_p - \frac{z_1+z_2}{2} = 132 - 50 = 82$

  $$m = \left(\frac{z_2 - z_1}{2\pi}\right)^2 = \left(\frac{50}{2\pi}\right)^2 \approx 63.32$$

  $$a = \frac{e + \sqrt{e^2 - 8m}}{4} \times P$$

  $$a = \frac{82 + \sqrt{82^2 - 8 \times 63.32}}{4} \times 12.7 \approx 510.70 \text{ mm}$$

  Use $a = 510$ mm in design.

- Pitch circle diameter (PCD):

  $$D_1 = \frac{P}{\sin\left(\frac{180}{z_1}\right)} = \frac{12.7}{\sin(7.2°)} \approx 82.4 \text{ mm}$$

  $$D_2 = \frac{P}{\sin\left(\frac{180}{z_2}\right)} = \frac{12.7}{\sin(2.4°)} \approx 247.2 \text{ mm}$$

- PCD with roller diameter ($d_r = 7.95$ mm):

  $$d_1 = D_1 + 0.8 \times d_r = 82.4 + 6.36 \approx 88.76 \text{ mm}$$

  $$d_2 = D_2 + 0.8 \times d_r = 247.2 + 6.36 \approx 253.56 \text{ mm}$$

3.3. *Design of Frame*

- Mass of frame = 7.4 kg
- Center distance used in design = 510 mm

3.4. *Design of Nozzles*

- Pump capacity: 20 liters
- Operating pressure: 2–4 bar
- Nozzle type: ATR-60 (Italian)

- Spray angle: 60°

Discharge rate at 5 bar: 0.73 lit/min

Discharge rate at 1 bar: $\frac{0.73}{5} = 0.146$ lit/min

At 4 bar pressure:

$Q = 0.146 \times 4 = 0.584$ lit/min

Table 1. Specifications of ATR 60.

Type of nozzle	**Discharge at a given pressure**
Albuz ATR-60	0.584 liters/min/nozzle

- To achieve spray, we employ six nozzles: Discharge = 0.584 × 6 = 3.504 lit/min
- The pump has a 20-liter capacity.
- The time it takes six nozzles to spray 20 liters is equal to 20 / 3.5, or 5.71, or 6 minutes.
- The distance between the two nozzles is 1.25 feet, which is equivalent to 38 cm or 0.38 meters.
- The strip supporting nozzle length is equal to 0.38 × 5 = 1.9 m.

4. RESULT AND DISCUSSION

4.1. *Simulation & Analysis*

4.1.1. Component 1 – The Frame

The pump's 196 N load acting downwardly concentrates the component's stress, causing it to bend in the places where the stress concentration is highest. Following the simulation, the outcomes were

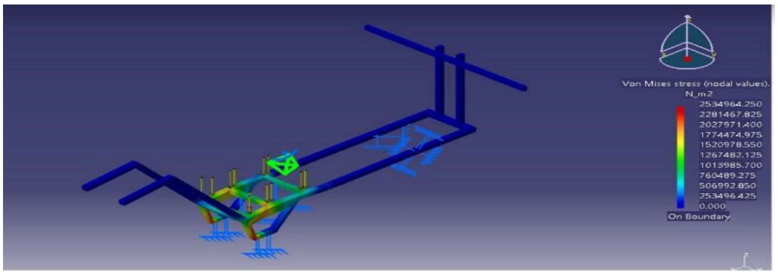

Fig. 6. Von Mises analysis.

- Result: 2.54 N/mm^2 is the highest nodal value when applying Von Misses stress.
- The frame material's permissible yield stress is 247 N/mm^2.

- Between 2.54 and 247 N/mm^2,

4.1.2. Component 2 – Support for Pump

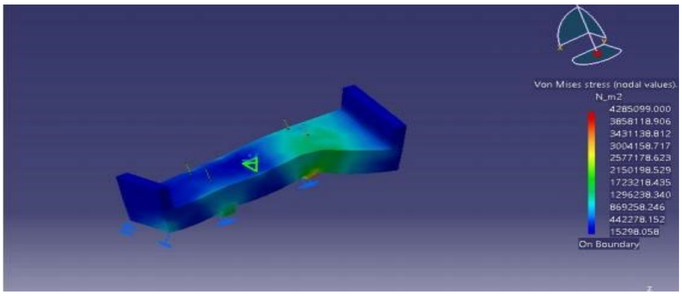

Fig. 7. Von Mises stress analysis.

- 4.5 N/mm^2 is the highest nodal value while applying Von Misses stress.
- The frame material's permissible yield stress is 247 N/mm^2. 4.5 N/mm^2 << 247 N/mm^2.

5. FUTURE SCOPE

Our innovative spraying machine stands as a beacon of reliability, thriving effortlessly under diverse weather and working conditions. Employing lightweight yet robust materials for its frame ensures durability without compromising on portability. We've introduced a groundbreaking design that eliminates the need for a pushing mechanism, streamlining operations and enhancing user experience. By adopting a portable spraying method, we've successfully slashed labor costs, making it an economically viable solution for small farmlands ranging from 6 to 7 acres.

With the ability to accommodate multiple nozzles, our machine maximizes coverage, enabling more area to be efficiently sprayed. Our design prioritizes time efficiency by covering the maximum spraying area in the shortest amount of time. Additionally, our system boasts proper adjustment facilities, allowing for precise adaptation to various crop sizes and heights, ensuring optimal spraying results every time.

6. CONCLUSION

Introducing an upgraded design of the backpack sprayer, now mechanically operated to cater to the needs of small-scale farmers. This innovative model not only eliminates the need for fuel power, significantly reducing operational costs, but also minimizes maintenance expenses compared to traditional spraying machines. One of its standout features is the alleviation of back pain and muscle soreness, achieved by relocating the tank onto a moving structure rather than burdening the shoulders. Multiple nozzles ensure maximum coverage in minimal time, reducing the labor-intensive nature of manual spraying. Moreover, the design structure and strategic nozzle placement mitigate excessive pesticide use, promoting sustainable farming practices. The issue of constant manual lever operation is effectively resolved, enhancing user convenience and efficiency. Versatility is key, as this machine is adaptable for spraying multiple crops, catering to diverse agricultural needs. While slightly heavier than backpack-operated sprayers, its efficiency shines in rough farmland conditions, providing reliable performance even on uneven terrain. Smoother surfaces or less undulating land further enhance the machine's effectiveness, thereby maximizing productivity. Overall, this mechanically operated sprayer offers a holistic solution to common farming challenges, empowering farmers with a reliable, efficient, and ergonomic tool for crop spraying operations.

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