"Design and Fabrication of Solar Powered Semi Automatic Pesticide Sprayer"

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Abstract - *Agriculture has a predominant role in our day to day life. Spraying of pesticides is an important task in agriculture for protecting the crops from pests. The conventional methods were person carrying a sprayer and manually actuating a lever to generate and pump the pesticide through a tube or a mobile vehicle carrying an inbuilt compressor and sprayer unit. Another major drawback in human operated systems is that the operator is exposed to the harmful chemicals while spraying which is extremely detrimental to operator's health.*

A solar powered semi automatic pesticide sprayer model consists of a solar panel, a battery, two DC motors, pump, container, microcontroller and zigbee device which is operated by a wireless remote(range of 30 to 50meters) which runs on power source as a DC battery(12V, 9.5Ah). The capacity of the container in the sprayer was designed with 4 liters capacity for an uninterrupted operation of 10 minutes with the discharge rate of 0.556 lpm. Analysis of solar radiation data from Bangalore showed that the sprayer can be best operated during 9 AM to 5 PM. The vehicle is powered using an onboard solar powered battery which runs down the running cost. Besides reducing the cost of spraying, there is a saving on fuel as well. The farmers can do the spraying operation without human interference thus protecting them from noxious chemicals.

KEYWORDS: solar power, semiautomatic, solar energy, pesticide sprayer, zigbee

1. INTRODUCTION

Agriculture has been the back bone of Indian and Nepalese economy and culture and it will be continued to remain as such for a long time in future. Spraying of pesticides is an important task in agriculture for protecting the crops from pests. In Nepal and India, near 70% peoples are dependent upon agriculture. Agriculture is a profession of many tedious processes and practices, one of which is spraying of pesticides in the crops. Solar pesticide sprayer is a useful machine which is ergonomics, motion stable which is more efficient to workers, and the energy source used in non conventional. Hence it poses a great scope in future.

Present scenario in agricultural field in Nepal and India related to sprayer is that farmers are using hand operated sprayer or motorized sprayer. Fuel operated spray pump exhaust carbon dioxide as pollutant which has a detrimental effect on our environment and human health. Hence, these conventional sprayers are not very efficient. This motivated us to design and fabricate a model that utilizes solar energy for spraying pesticides. Semi automatic solar pesticide sprayer which consists of solar panel, a battery, motor, pump, container and microcontroller is a 3 wheeled vehicle which is operated by a wireless remote which runs on power source as a DC battery. So with this background, design and construction of solar powered sprayer system was made. The control of the vehicle is achieved using an inbuilt microcontroller unit which is programmed to respond to the zigbee wireless device.

- **Literature review**

F.Pezzi,V.Rondelli [1]

The performance of a sprayer fitted with two vertical adjustable air outlets has been studied in vineyards investigating the effects of changing speeds(1400 ,2000&2500 rpm) and the direction of the air- jet (90 &120 backward angle of the outlet side deflectors in relation to the treated row).

Isabelle Baldi, Pierre Lebailly [2]:

Isabelle Baldi and Pierre Lebailly an epidemiologist, demonstrated in a study published in 2001 that exposure to a number of pesticides used on grapevines brought about a reduction in cognitive function (selective attention, memory, speech, ability to process abstract information) in winemakers in the Bardelais region.

Burrell J, Brooke T and Beckwith.R [3]:

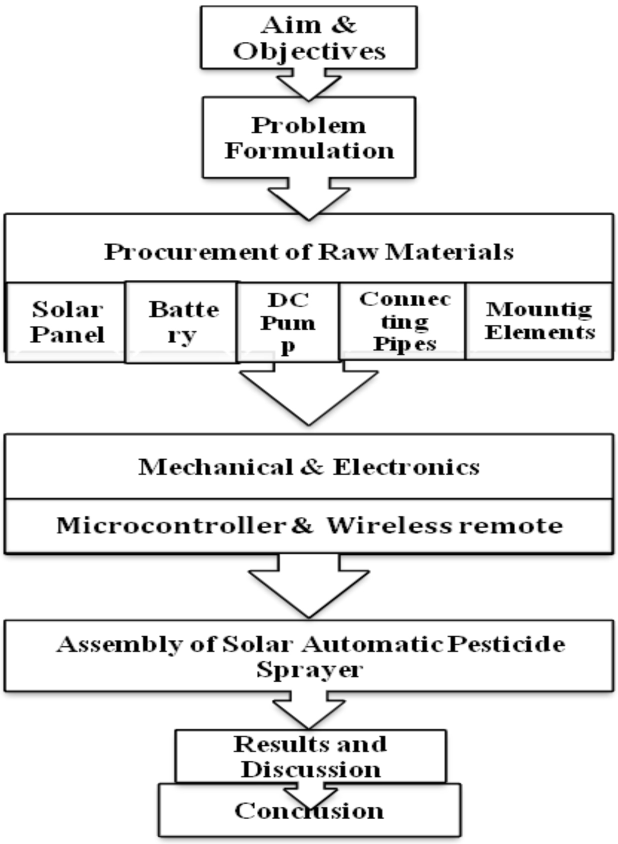
Using ethnographic research methods, the authors studied the structure of the needs and priorities of people working in a vineyard to gain a better understanding of the potential for sensor networks in agriculture. The study's larger purpose is to find new directions and new topics that pervasive computing and sensor networks might address in designing technologies to support a broader range of users and activities.

A. Ruckelshausen and E. Wunder [4]:

The scientists are working in the fields of unmanned or remote controlled autonomous field robots, navigation, image-based sensors fusion as well as agricultural applications. The authors have developed a 3D simulation environment which allows the virtual test of the robot platform prior to its application.

2. METHODOLOGY

Design and fabrication of solar powered semi automatic pesticide sprayer has the following steps.



- A 12V battery powers the entire unit including the D.C. motors, pump, sensors and micro-controller. As soon as the sprayer is turned on the vehicle starts moving and spraying.
- The vehicle is controlled by wirelessly via zigbee module and pump sprayer ON/OFF is controlled by remote controller.
- User can control vehicle motion like FORWARD, LEFT, and RIGHT & STOP wirelessly to navigate the model as per the requirements.

2.1 Selection of Components

The selection of component has been done according to the requirements. Following are the list of components with specification.

- Solar panel
- DC battery
- DC motor
- DC pump
- Wheels
- Nozzle
- Microcontroller and relay

Solar panel –
Material: silicon semiconductor
Type: dark blue
Panel size: 40cm * 26cm
Maximum power: 10W

DC Battery –
Weight of the battery: 2 kg
Operating voltage: 12V
Rated current: 7.5 Ah
Type: lead acid battery

DC motor –
Operating voltage: 12V
Current: 2.1 amps
Speed: 80 rpm
Torque: 100 N- m

DC pump –
Operating voltage: 12V
Operating current: 0.5A
Liquid discharge: 1 lpm

Wheels –
Material: nylon
Dimension: 8cm diameter
Properties:
Low wear and extremely abrasion resistance
Low roll resistance.
Possible to carry heavy loads

2.2 Finite Element Analysis

Chassis frame is analyzed for the displacement for the hydrostatic load acting on it. Initially in the ANSYS workbench the static structural analysis module is selected for the analysis. For the different load conditions analysis has been carried out.

Table 1: base frame dimensions and properties

Object Name	Geometry
State	Fully Defined
Definition	
Length Unit	Centimeter
Element Control	Program Controlled
Display Style	Part Color
Bounding box(Base frame dimensions)	
Length X	56cm
Length Y	48cm
Length Z	51cm
Properties	
Volume	1.2738e-3 m^3
Density	7850 kg/ m^3
Mass	10 kg

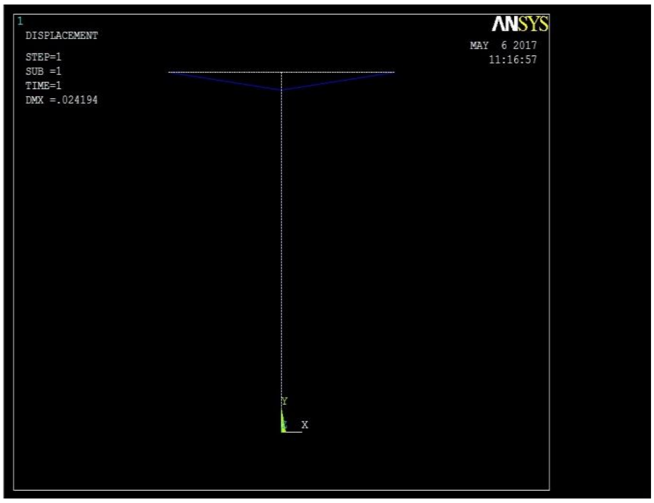


Figure 1: analysis only due to solar panel weight

Figure 2: analysis due to column and solar panel

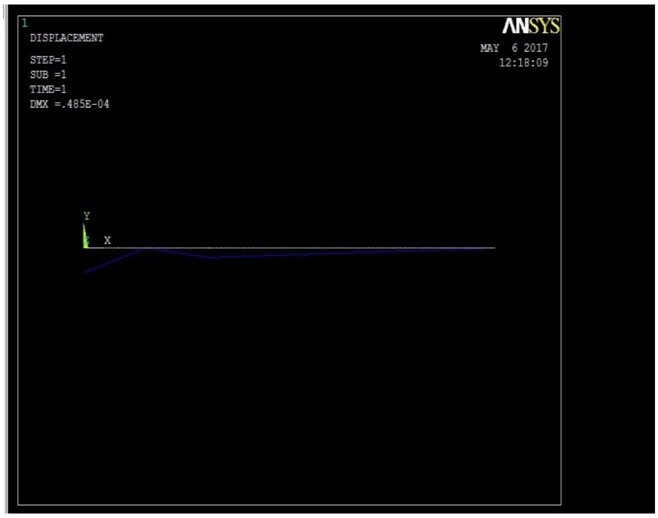


Figure 3: analysis due to battery, column and container

Table 2: load condition with maximum displacement in mm

Load condition	Displacement(mm)
Due to solar panel (fig 1)	0.24194
Due to column and solar panel(fig 2)	1.20968
Due to battery, column and container(fig 3)	0.485E-3

From the analysis we concluded that, the displacement was negligibly low so we can proceed further for design and fabrication.

2.3 Computer Aided Design of the Model

For the CAD of the model we have used solid edge software. Figure 4 shows the assembly design of the prototype and figure 5 shows the frame or chassis of the model.

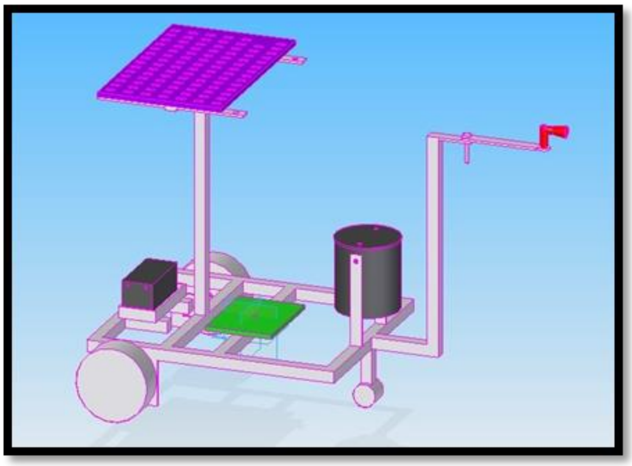


Figure 4: solid edge assembly design

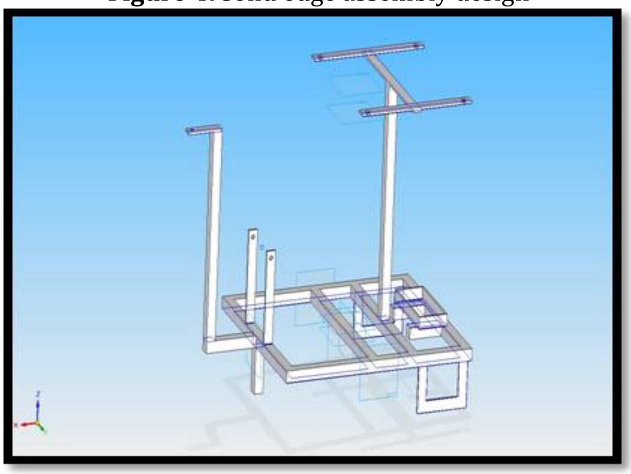


Figure 5: frame design

2.4 Mathematical Calculations

2.4.1 Power Conversion Efficiency:

The Solar cell Power Conversion Efficiency can be calculated by using the relation,

$$\text{Power Conversion efficiency} = \frac{P_{out}}{P_{in}}$$

Where, Input Power P_{in} = Incident Solar radiation x Area of the Solar panel

= I_T x A watt

The output power P_{out} = V x I

∴ P_{in}= 500 x 10^{-3} W/cm² x 40cm x 26cm

= **520 watt**

∴ P_{out} = V x I = 12 x 7.5 = **90 watt**

$$\text{Power Conversion Efficiency} \ \frac{P_{out}}{P_{in}} = \frac{90}{520}$$

$$= 0.173076 = \mathbf{17.308\%}$$

2.4.2 Time Required For Charging

- *Testing of Charging Time:*

Instrument used to measure Sun Radiation=Sun Meter or pyrometer

The Sun Radiation are measured in mW/cm²

Required voltage for charging the Battery=12volt.

- *Time Measurement:*

When the Solar radiation is between 200 to 300 mW/cm² = 3 to 4 hrs.

When the Solar radiation is between 300 to 400 mW/cm² = 2 to 3 hrs.

When the Solar radiation is between 400 to 600 mW/cm² = 1 hour.

We know the Power generated by solar panel= 10 watts.

$$\therefore \text{Time required for Charging (hrs)} = \frac{\text{Power Generated}}{\text{Power of Solar Panel}} \times \text{Time Measurement}$$

Also Consider,

Battery **12V, 7.5A-h** (Amp-Hr) current

∴ Power = V*I = 12*7.5 = **90 watts**

Now for different solar radiation say,

When the Solar radiation is between 200 to 300 mW/cm² = Time is 3-4 Hrs

When the Solar radiation is between 300 to 400 mW/cm² = Time is 2-3 Hrs.

When the Solar radiation is between 400 to 600 mW/cm² = 1 hour.

Consider average Time Measurement as **2.5 Hrs.**

$$\therefore \text{Time required for Charging (hrs)} = \frac{90}{10} \times 2.5$$

$$= \mathbf{22.5Hrs.}$$

2.4.3 Backup Time of Sprayer

Motor- 12V, Current-2.1amp

Pump- 12V, Current-0.5 amp

Zigbee and microcontroller- 12V, Current-1.5 amp

$$\text{Backup Sprayer Time} = \frac{\text{Power Stored in Battery}(w-hr)}{\text{Power Consumed}(w)}$$

$$= \frac{90}{12 \times 2.1 + 12 * 1.5 + 12 * 0.5}$$

$$= \mathbf{1.83hrs}$$

*Note-Time varies because of intensity of sun radiations at different days.

3. RESULTS AND DISCUSSIONS

Speed of model

Distance covered (m)	Time taken (sec)	Speed (m/s)
5	16	0.313
8	25	0.320
11	35	0.313

V= average speed = **0.315m/s**

Rate of spray

Quantity(cc)	Time taken(s)	Flow rate(lpm)
500	45.28	0.6625
250	27.23	0.5508
125	14.33	0.4417

Q = Average flow rate = **0.556lpm**

We conducted the experiment with the model and observed the following data as

Average speed of vehicle obtained= **0.315m/s**

Average rate of spray = **0.556lpm**

Operating time of battery = **100-120min**

Power efficiency = **17.308%.**

Time required for charging = **22.5hrs** = **1350min.**

Backup time of sprayer= **1.83hrs** = **110min.**

The cost of the fuel increases day by day. It should be reduced by the modified model which works on the principle of solar energy. The operating cost of power sprayer for one hour operation is calculated and its value is compared with the operating cost of solar sprayer. Its seems that there is no need of operating cost but, the initial investment towards the charging unit is a onetime investment with a period of three years which is almost equal to the unit cost of the power sprayer with twist of petrol engine. Hence this modern model is more effective than any other spray pump. Figure shows the developed prototype of our proposed pesticide sprayer. Based on the experiments, it is found that charged solar pump sprayer can be used during day time between 9 AM to 5 PM. All the tests are successfully carried out at same time.

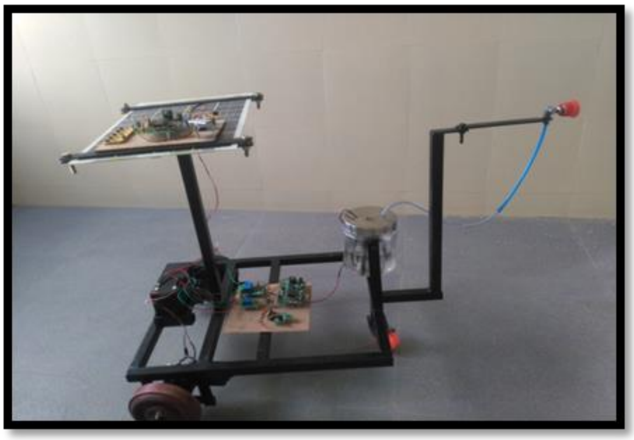


Figure 6: developed model

4. APPLICATIONS AND ADVANTAGES

The solar sprayer is mainly used for spraying liquefied pesticides. The developed system can be used for spraying the fertilizer, fungicides. It can also be used as automatic Spray Painting robot. The same technique and technology can also be extended for all types of power sprayers. This model can be also used as mosquito repellent.

Reduces fuel consumptions and brings down running cost due to Solar Powered Working. The sprayer not only minimizes the drudgery of the work but is also more effective than the conventional ones. It prevents the Operator exposing from noxious chemicals and pesticides. It is good alternative for engine sprayer. The use will be most welcomed when the fuel resources are over. It is noiseless, eco friendly and doesn't produce vibration. The construction is simple and not as difficult as other sprayers. It is simple to use and easy to manufacture.

5. CONCLUSIONS

This project demonstrates the implementation of robotics and mechatronics in the field of agriculture. This being a test model the robustness of the vehicle is not very high. The performance is satisfactory under laboratory condition. The model gave a fairly good rate of area coverage and the cost of operation as calculated was also reasonably low.

In addition the safety and long term health of the farmers is ensured by eliminating human labor completely from this process. It does not compromise the performance of a petrol based pesticide sprayer.

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