DEVELOPMENT OF A PROTOTYPE OF A SOLAR POWERED PLOUGHING ROBOT

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Abstract

This paper discusses the development of a prototype of Solar Powered Ploughing Robot. The device is an autonomous mobile robot powered by solar power. Solar energy is abundantly available for most parts of the year in the konkan belt with average time between sunrise and sunset at 6.5-8 hours per day. This device effectively utilizes the available solar energy for generation of power for ploughing small fields. The device reduces the dependency of farmers on diesel powered vehicles and animals. The human effort for the ploughing process is reduced. This method not only saves electricity but also avoids air pollution and the emissions of toxic gases into the atmosphere. It eliminates use of bulls and human labor. It also reduces the time taken to plough the fields. Motion control through Arduino ultrasonic sensors, moisture sensors and solar panel with 20 W capacity and DC motor for vehicle movement are the critical components of the device.

Keywords: *Ploughing Robot, Ultrasonic Sensor, Sensors, Arduino Controller Board, Microcontroller.*

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1. INTRODUCTION

The plough or plow is an equipment used in agriculture sector for cultivation of soil in preparation for sowing seed , to loosen or turn the soil. A plough is usually fabricated out of wood, steel or cast iron with a stick or blade attached used to pierce the earth. It has been a basic equipment for most of recorded history of mankind and it represents one of the major advancements in the field of agriculture. The basic aim of ploughing is to turn over the upper layer of soil and bring the fresh nutrients to the surface, while burying weeds and the remains of the older crops and allowing them to break down. Drawing the plough through the soil leads to the formation of trenches of fertile soil called furrows. In modern use, a ploughed field is typically left to dry out, and then harrowed before ploughing .Ploughs were powered by people initially, but the process became highly efficient once animals like bulls were pressed into service. The first animal powered ploughs were drawn by oxen, and later in by horses and mules in some areas, although various other animals have also been used for this purpose. In industrialised nations, the first means of pulling a plough was powered by steam engines (ploughing engines or steam tractors), but these were replaced by tractors powered by IC engines.

2. OVERVIEW

The prototype of the Solar Powered Ploughing Robot utilizes a 20 W capacity solar panel to convert the light energy into electricity. Solar Powered Ploughing Robot (SPPR) is controlled by the charge controller. A mild steel plough is mounted on a aluminium frame. The motion of the robot is controlled by Arduino microcontroller which is aided by using three Ultrasonic proximity sensors for obstacle detection. Batteries supply power to the microcontroller and the DC motors. Four DC motors are utilized for the driving mechanism and one DC motor is used for the ploughing mechanism. Microcontroller controls the DC motor by relays and a motors driving circuit. Ultrasonic sensors are placed to detect the presence of obstacles during its movement. The sensors send the signals to the microcontroller unit which takes the necessary action for the movement of SPPR.

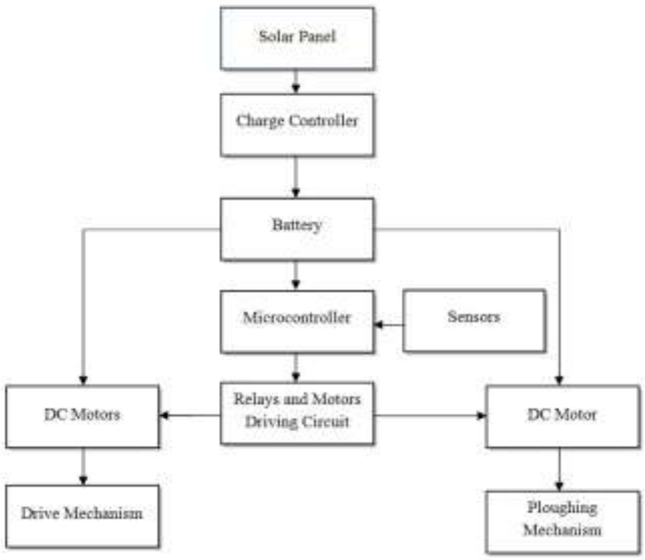

Fig.1 Block Diagram of SPPR

3. MECHANICAL STRUCTURE

3.1 Design

The total force acting on the plough was calculated considering the Mc-key Formula..

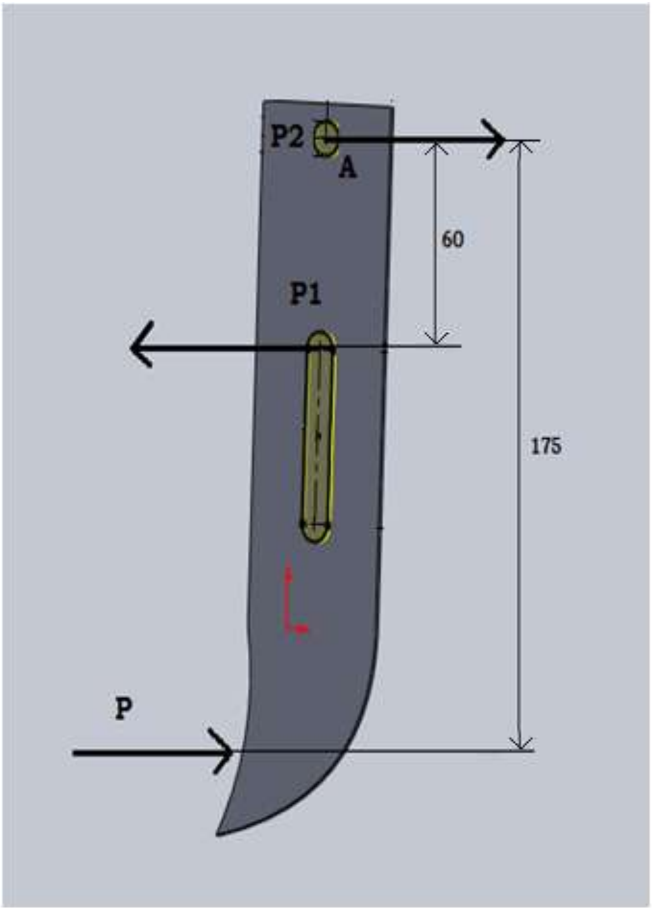

Fig 2. Forces acting on Plough

The total soil strength force P, is composed of the force P1 on the center zone, plus the forces from each side P2, in the x-z plane.

$$P = (\gamma g d^2 N_\gamma + c d N_c + g d N_q + c_a d N_{ca}) w$$

In the above equations g is the total soil density, c_a is soil to tool adhesion strength, f is the angle of internal friction of soil, a is the tool angle, d is the friction angle between tool and soil, g is acceleration due to gravity, d is tool working depth below the soil surface, c is soil cohesion, w is tool width, and Ng, Nc, Nq, and Nca are factors which depend not only on the soil frictional strength, but also on the tool geometry and tool to soil strength properties. In order to find the amount of forces acting on the plough, physical property of clay loam soil was used.

Table 1: Properties of Clay loam Soil

ϕ, degree	δ, degree	γ, kN/m^3	c, kN/m^2	c_a,kN/m^2
37.3	27.3	11.8	33.5	9.4

Through design calculations it was found that the value of P1= 7.05 KN and P2= 4.63KN

A 3D model of SPPR was developed using solid works is shown in Fig.3

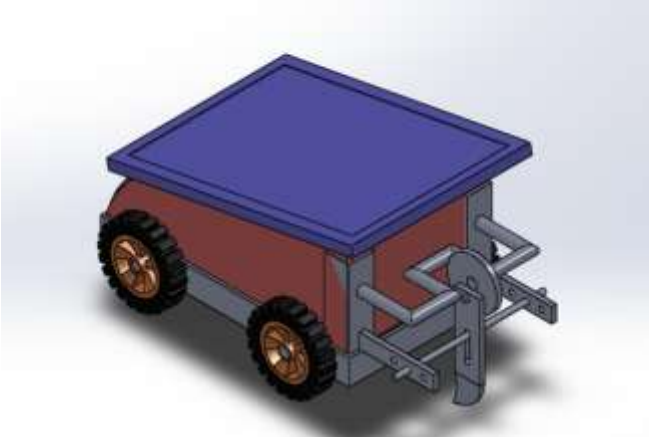

Fig 3. Solid works Model

A. ANALYSIS

The analysis of this SPPR model was carried out in ANSYS to check whether the design of the frame is safe. The results obtained are shown in Fig. 4 which indicates that the Von Mises stresses were within the allowable limits. Also the deformation of the structure was negligible

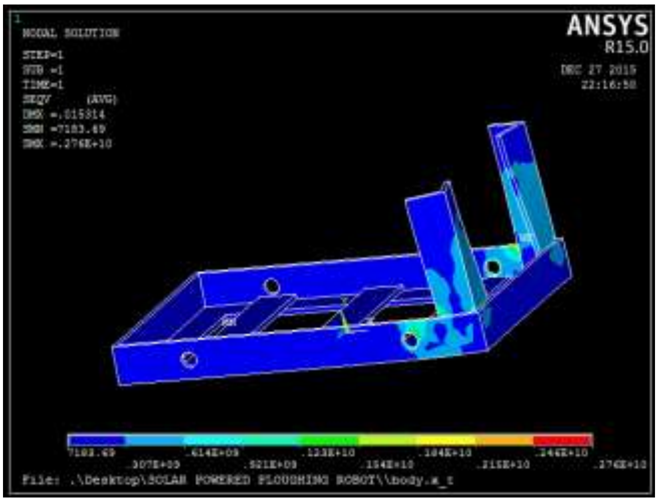

Fig. 4 (a) Plot of stress developed in the structure

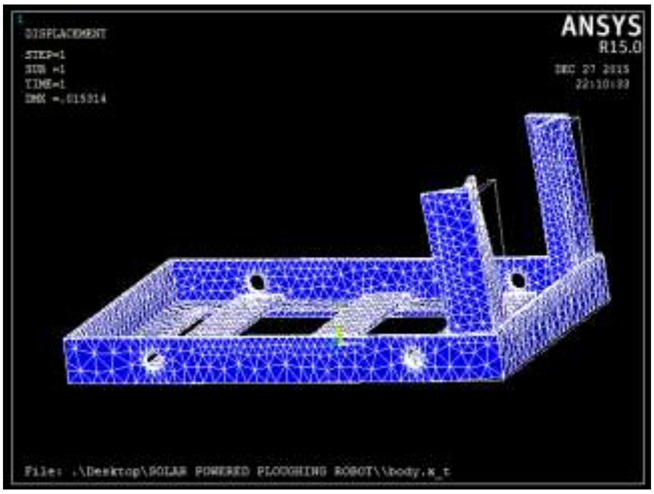

Fig. 4 (b) Plot of nodal displacement in the structure

B .Fabrication

After modelling, designing and carrying out the analysis of the frame on ANSYS, fabrication of the frame is the next step. The material as mentioned before is aluminum alloy 2011 channels. The aluminium channels are cut to the required dimensions and riveted together. The frame is the main body of the SPPR and supports all the components on it. Holes are drilled in the frame wherever required to accomodate other parts of the assembly. The wheels are attached to the frame with the help of a screw tightened on the motor shaft.

The back part of the frame supports MS channels for holding the ploughing mechanism and the channels are mounted on the frame using nuts and bolts. The frame is light but has high load bearing capacity.

4. OVERVIEW OF THE AUTOMATION SYSTEM

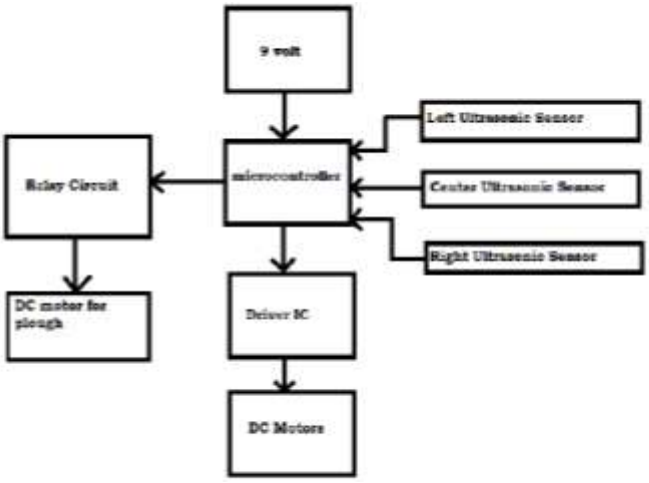

Fig 5. Block Diagram of Automated SPRR

The block diagram of the automation system is shown in Fig.4.The electric supply to the microcontroller Arduino Uno is given through the 9V battery. Three ultrasonic sensors have been used for detecting the obstacles in the path of the robot. When the switch is put ON the robot will start and the robot will sense for the obstacles. The three sensors are placed in front, left and right of the SPPR. If there is no obstacle in the Solar Powered Ploughing Robot (SPPR) path, then the microcontroller will send a signal to the motors to keep moving forward. When the front sensor detects an obstacle then the SPPR takes a left or a right turn. When the front and the left sensors detect obstacles then the SPPR takes a right turn and when the front and the right sensors detect obstacles then the SPPR takes a left turn.

A. SPPR Controller Board (ARDUINO BOARD)

The Arduino Uno is powered by either an external power supply or an USB connection can be used The power source is automatically selected. External power can be in the form of an AC-to-DC adapter or battery. The adapter is connected via a 2.1 mm center-postive plug into the power jack of the board. The board can be operated on an external supply of 6 to 20 volts. If supplied with less than 7V, however the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, overheating of the voltage regulator takes place and may be lead damage of the ARDUINO kit. The recommended range is between 7 to 12 volts.

Fig 6. Arduino Uno Board

B. Ultra Sonic Sensor

Ultrasonic sensors pick up the acoustic signals with a range accuracy can reach to 3mm. The entire set up includes ultrasonic transmitters, ultrasonic receiver and the control circuit. The ultrasonic sensors are shown in figure below

Fig 7. Ultrasonic Sensors

5. SOFTWARE PROGRAMMING

A. Features of Logic and Program

Driving: Turn the motor according to the sensor states Sensors: Proximity sensors used as edge following sensors, since here the edge is the deference in distance.

B. Explanation of Flowchart

There are three sensors on the robot, one on the front and two on the sides the robot. The ploughing robot has to be operated in a rectangular field marked by boundary walls. The sensors consider the boundary wall as an obstacle. When the vehicle reaches the boundary wall it takes a turn. The vehicle stops only at the corner of the field.

When there are no Obstacles , Switch on the system (start).Once the system is switched ON the FRONT SENSOR is also switched ON. The FRONT SENSOR is continuously looking for any obstacle in the way and accordingly sends signals to the microprocessor. When the

FRONTSENSOR detects an obstacle it sends signal 1 (FRONTSENSOR=1) to the microprocessor (ARDUINO Board). When obstacle is not detected it sends signal 0 (FRONTSENSOR=0 i.e. FRONTSENSOR not equal to 1) to the microprocessor.

The microprocessor processes the signal sent by the FRONT SENSOR. This way microprocessor picks up the signal, processes the signal and gives the output signal as shown in the IF loop.

IF LOOP: If the condition FRONTSENSOR=1 is FALSE (no obstacle detected) then the microprocessor will turn ON the 4 motors which drive the machine. The motor controlling the Plough mechanism and the "solenoid push/pull plunger" is also powered. The plough enters the soil as the machine
moves forward• The following cycle continues till any obstacle is detected. (. . . . FRONTSENSOR detecting an obstacle! No obstacle detected (FRONTSENSOR=0)!

Signal(FRONTSENSOR=0)sent to the microprocessor! Microprocessor switches ON the motors FRONTSENSOR detecting an obstacle!. . . ..)When there is an Obstacle Initially in the program we consider a parameter ''COUNT". The value of COUNT is set to 0 initially. COUNT is basically the number of turns taken by the machine.

In addition to FRONT SENSOR there are two additional sensors LEFT SENSOR and RIGHT SENSOR. LEFTSENSOR or RIGHTSENSOR is triggered only when the machine reaches the corner of the field. LEFTSENSOR and RIGHT SENSOR send the signal 0 to the microprocessor till the machine reaches the corner of the field.

When the machine detects an obstacle in the front i.e. when FRONT SENSOR=1 the two IF loops with conditions 'IF LEFT SENSOR=1' and ÍF RIGHTSENSOR=1' check if the LEFT SENSOR and RIGHTSENSOR have detected an obstacle. If any of these two sensors have detected an obstacle (i.e. RIGHTSENSOR=1 or LEFTSENSOR=1) it means that the machine has reached the corner of the field. When this condition occurs the system turns off (Stop). When there are no obstacles detected at the sides i.e. LEFT SENSOR=0 and RIGHT SENSOR=0 the IF loop with condition "IF COUNT%2=0"checks if COUNT is odd or even. If COUNT is odd the vehicle turns LEFT and if COUNT is even vehicle turns RIGHT. (% is remainder function).For initial condition i.e. COUNT=0 .COUNT%2=0. Since 0 is even the vehicle will turn right. 2) For COUNT=3, COUNT%2=1.

Since 3 is odd the vehicle will turn left. Once the vehicle takes a turn COUNT will be incremented by 1 i.e. COUNT=COUNT+1.

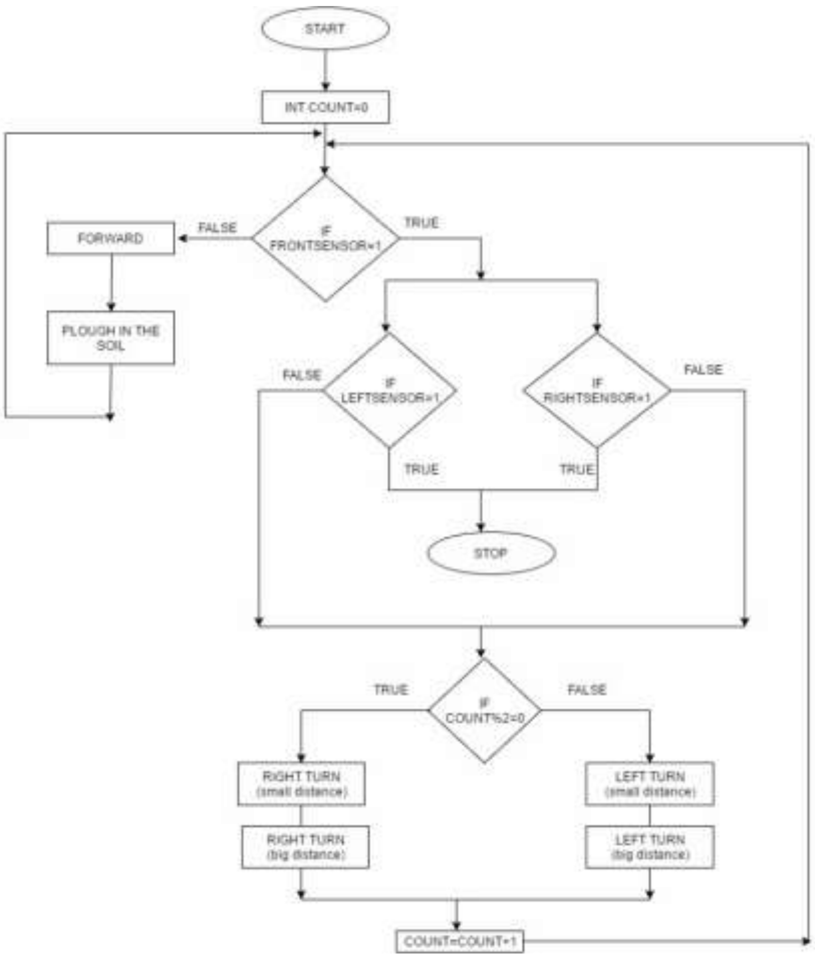

Fig 8. Flowchart of Programming of SPRR

Fig 9. Prototype of SPRR

CONCLUSION

The project was tested for a 5 meter run using a simple program and it gave satisfactory result. The SPPR when developed on a larger scale will find implementation in paddy fields for cultivation. SPPR can also be used for cultivation of wheat, maize and other crops.

It can be used throughout the year irrespective of climatic conditions

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