DEVELOPMENT, FABRICATION AND AUTOMATION OF AN AGRICULTURAL IMPLEMENT MEANT FOR CULTIVATION

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Abstract - The labour dependency in an agriculture driven country like India is one of the major problem affecting the rate of production. This paper details the methodology and principles involved in development of an automation kit which can be mounted on any tiller for its autonomous functioning. The automation kit is developed with the efficient application of mechatronics and kinematics. A two mode system is provided namely semi automatic and automatic mode for different field conditions. The automation of a power tiller thus eliminates the arduous task of one walking behind it in the slushy areas.

Index terms - Agriculture, Production, Automation, Mechatronics, Kinematics, Power tiller.

I. INTRODUCTION

A Power tiller is one of the many several types of farm implement used for performing secondary tillage on piece of land during the process of cultivation. The blades mounted onto the tiller help to carry out the process of pulverizing the wet soil into finer particles making it easy to sow seeds.

Tillage is the manipulation of the soil into a desired condition by mechanical means; tools are employed to achieve some desired effect (such as pulverization, cutting, or movement). Soil is tilled to change its structure, to kill weeds, and to manage crop residues. Soil-structure modification is often necessary to facilitate the intake, storage, and transmission of water and to provide a good environment for seeds and roots [1]. Tillage is often classified into two types, primary and secondary. Primary tillage such as ploughing tends to produce a rough surface finish, whereas secondary tillage tends to produce a smoother surface finish, such as that required to make a good seedbed for many crops.

The power tiller is used for secondary tillage and it requires a labour to walk behind it for hours in the slushy areas. Although the operation of the power tiller is pretty simple and straight forward it is an onerous task when in the ground realities. The operator sometimes lifts the rear portion of the machine to take sharp turns at the headlands. All these efforts combined with exposure to varying degrees of solar radiation, dusty environment and above all the severe hand vibrations cause a lot of stress on the operator resulting in physiological/psychological fatigue after the daylong operation [2]. Hence, the automation was the right solution to eliminate human intervention.

In this paper, a development kit for the autonomous and semi autonomous control of the tiller is discussed and the automated tiller was tested in various field dimensions and also for its remote operations from a distance.

II. OPERATION OF POWER TILLER

The existing tiller machine used for this research is a rotovator type with a 8 Hp diesel engine. It is a two-wheel type tiller which can be driven forward and backwards with a gear system in place. The speed can be set to the requirement and locked. Steering of the power tiller is achieved by differentially driven wheel with separate clutches for left and right wheel (Fig 1). Since the power delivery to the wheels is torque vectored the clutches play a important role in its motion [3]. When both clutches are disengaged the tiller moves in a straight line as equal power is given to both wheels.

Upon engaging one of the two clutches the power is stopped to the side on which the clutch is engaged, which means if left is engaged then the left wheel stops rotating and only the right rotates at its own speed thus causing the tiller to go left. This works the same for the right side as well. The clutch lever is connected to the rod end with the help of wire which at one end are locked with a lock-pin onto a butterfly clutch system which mimics the motion of a butterfly's wing movement.

Fig1. Clutch mechanism

Another main lever is the brake cum clutch system (Fig 2). This when pulled back up to a certain length acts as a clutch engaging on both wheels and when pulled further up to a point, acts as a brake thus bringing it to a halt. The tiller engine will continue to run despite applying the brake as the power is disconnected with the help of the clutch. The current way involved the machine being guided by the farmer along the required patch of land where he himself controlled the movements of the tiller. This requires enormous strength and control to maneuver it smoothly through the rough land. But it used to be time consuming to do this as a lot of the time would go behind just monitoring the tiller for long periods. Identifying this as our main area of concern we decided to come up with a way to eliminate this intervention.

Fig.2. Brake cum clutch system.

III. FORMULATION

A mobile robot needs locomotion mechanisms that enable it to move unbounded throughout its environment. But there are a large variety of possible ways to move, and so the selection of a robot's approach to locomotion is an important aspect of mobile robot design[4].

In order for us to automate the Tiller machine we were faced with three main obstacles namely the brake lever and the two clutches which provide steering control of the machine. Since these levers required a certain large amount of force to be actuated the mechanism to be chosen to substitute the manual job had to be able to withstand such a force and be flexible enough to repeat the operations over and over again with the same intensity

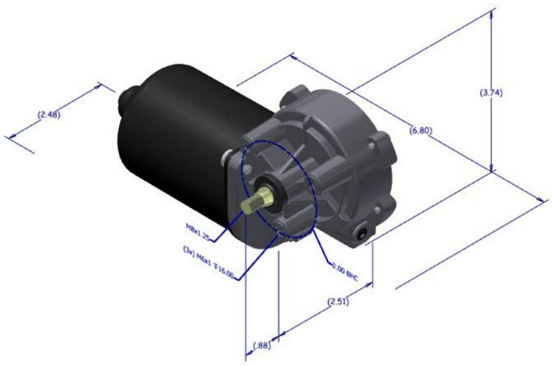

Fig. 3. Gear motor

Using the same geared motors (Fig 3) which happen to be the standard pick for wiper system of cars and trucks proved to be a good bet. These motors have a high torque capacity of the range of 800-900N of maximum load it can sustain. Having a high torque and respectable speed of 40-60rpm we found them as our best fit for the task.

Next to replicate the clutch nomenclature we fabricated a shaft that was longer than the stock one present at the butterfly system. By increasing its height and making few adjustments we were able to connect the lever with the motor through a fly by wire system (Fig 4). The wire used here is the clutch cable of a motorcycle.This wire is locked using lock pin at the shaft end and keyed onto a indigenously designed pulley.

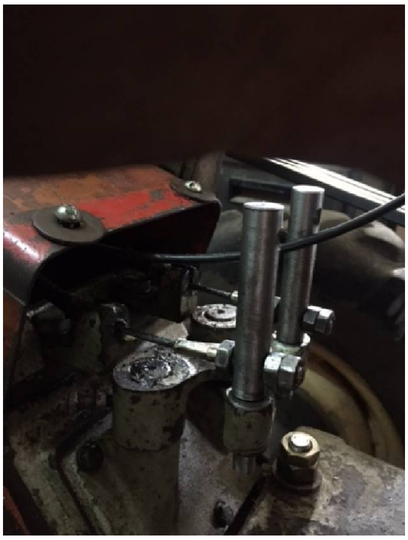

Fig. 4. Modified clutch system

The motors are mounted onto a metal sheet plate reinforced clamps which are screwed to the main housing. It is devoid of vibrations with the help of some packing material and metal paste. A similar idea is incorporated to engage the brake lever at the handle end of the tiller. These three motors are thus controlled by the micro-controller which is the brain of the unit. The program written into it sends signals to the motor drives to actuate the forward or reverse movement of the motors. With precise timing the clutches and brake are engaged and disengaged. Limit switches have been put in place to avoid any further movement of the motor. When the switch is pushed, the current goes from normally 'off ' condition to normally 'on' condition thus sending the needed feedback signal to the controller.

The whole electronics unit is devised in such a way that it imitates the manual operation with little room for error. The system can be switched over from fully automatic to semi-automation by the toggle of a switch. This state can be fully controlled using a joystick as the steering system. This proves to be helpful when the area to be ploughed is not of a definite size or shape as the fully automated type can be incorporated for square or rectangular sections of a field.

IV. AUTOMATIC TILLER MODEL

In order to accommodate the provision for autonomous control, the existing clutch head was extended to incorporate another cable which later can be connected to the motor to mimic the action of pulling. The pulling and releasing of the clutch cable (Fig 5) was performed by the gear motor.

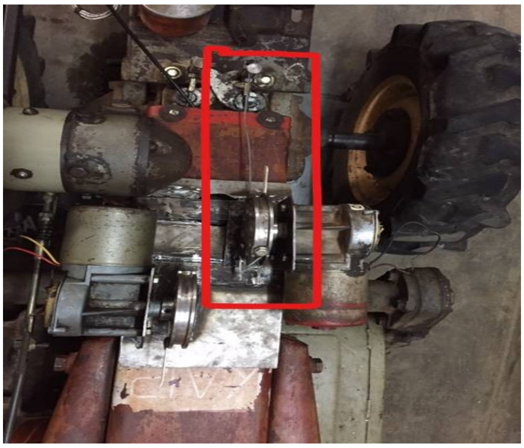

Fig.5.Motor - pulley - cable arrangement

The brake system of the tiller is combined with the clutch mechanism which is controlled by a single lever. When linearly actuated upto a certain point the lever engages the brakes on both wheels and beyond a point it engages the clutch plates thus facilitating the gear change.

This linear movement of the lever can be controlled by a cable which is driven by a pulley coupled to a gear motor (Fig 6).

Fig.6. Motor cable arrangement for gear.

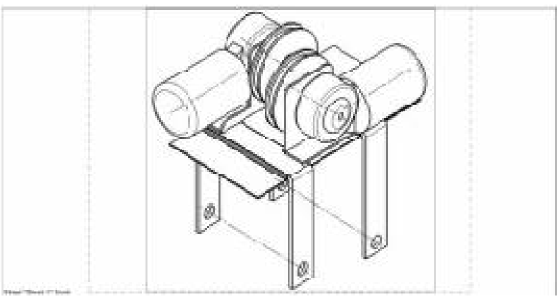

Fig. 7.Clutch motors mounting

The entire assembly to convert the tiller for autonomous operation can be mounted on to any tiller of the similar make with minimum changes and few fasteners. The attachments for the autonomous clutch control (Fig 7) can be mounted in the front end of the tiller.The assembly (Fig 8) for the operation of the brake is to be mounted on the rear end of the tiller across the handle bar. This assembly can be fixed with just a few fasteners.

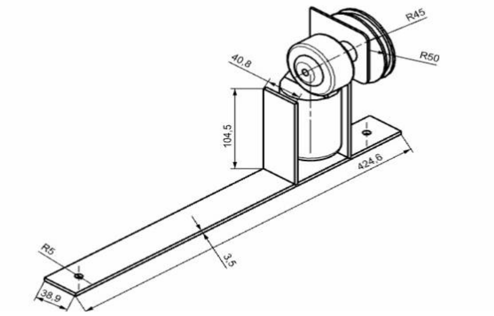

Fig. 8. Brake motor mounting

V. CONTROL SYSTEM

The three motors are controlled by the micro-controller which is the brain of the unit. The program written into it sends signals to the motor drives to actuate the forward or reverse movement of the motors. With precise timing the clutches and brake are engaged and disengaged. Limit switches have been put across the pulley to stop the motor rotation. When the switch is pushed, the current goes from ‘normally closed’ condition to ‘normally open’ condition thus sending the needed feedback signal to the controller.

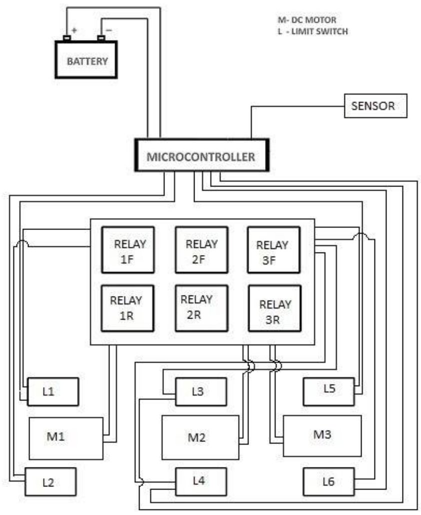

Fig.9. Circuit diagram of the control unit

The whole electronics (Fig 9) unit is devised in such a way that it imitates the manual operation with little room for error. The system can be switched over from fully automatic to semi-automation only during the start of the process. This state can be fully controlled using a joystick as the steering system. This proves to be helpful when the area to be ploughed is not of a definite size or shape as the fully automated type can be incorporated for square or rectangular sections of a field.

Automatic Tiller movement

The program is so designed that it is made to replicate the actual pattern (Fig 10) a farmer would follow during manual operation. The initial position usually is at the bottom left extreme of a square field where it traverses along the length of the given dimensions and takes a right turn to move along the breadth till half way and again takes a right turn. This is done again as it covers the length once more and turns to go back to its initial position. As it approaches this point it makes an early right turn thus leaving a gap of about two meter from start point. This marks the completion of one lap virtually. This is repeated several times thus slowly traversing along the whole dimension of the field with equal incremental shift of the breadth. So the right turn it had initially taken at the half way mark slowly moves away and reaches the maximum breadth of the dimension given. This makes it easy to program as only a few parameters varying in equal amounts throughout the whole process.

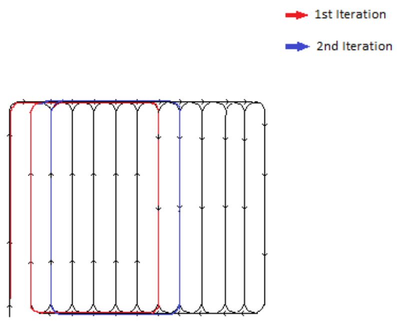

Fig.10. Tilling pattern

The program is also designed in such a way that it can make the system fully automated or semi-automated depending on the need. The fully automated condition follows the program commands to move along the pattern coded into it just by feeding in the dimensions of the field where as the semi-automated condition lets a person control the movements manually. That is with the help of a trans-receiver module which consists of a transmitter and receiver to communicate wirelessly between the system and a remote, is used to turn the machine as and when required. This condition comes handy when the area of the field is not a perfect square. During such cases the field can be divided to obtain a square where the fully-automated state is employed and the remaining part can be finished with semi-automated state. The module has a maximum controlling range of 800-1000 meters with minimal obstructions along the path of signal transmission else it reduces accordingly.

The microcontroller receives pulse from the hall effect proximity sensor which helps in calculating the distance covered. Since the circumference of the wheel is 1.8 m, a pulse is sent to the PIC microcontroller whenever the wheel completes one rotation. This in-turn guides the micro-controller to send a high signal to the right clutch motor to rotate and pull the cable for 9 seconds. The tiller completes a 90^0 turn in this 9 seconds and after that time frame the microcontroller sends another signal (low) to the reverse relay to release the clutch through reversing the motor rotation.

The simple formula which the microcontroller uses to calculate the number of pulses (N) after which it should initiate the turn is given by equation 1.

$$N = \frac{\text{Input distance} - 2}{1.8} \quad \ldots\ldots\ldots\ldots(1)$$

Say the input distance is L = 110m , B = 110m

$$N = \frac{110-2}{1.8} = 60 \text{ pulses}$$

Hence, the tiller initiates the right turn after 60 pulses and the same procedure is followed until the full area is covered.

On the other hand, In semi automatic mode when the tiller is controlled using a remote control. A basic XYZ joystick is provided to manoeuvre the tiller. The joystick controls are depicted in table 1.

Direction	Joystick Cartesian plane	Action on the tiller.
Forward	Y +ve	Releases the brake.
Left	X - ve	Steers the tiller in the left direction
Right	X +ve	Steers the tiller in the right direction.
Backward	Y - ve	Applies the brake.

Table 1 - Joystick controls

The tiller takes a turn, say left turn, as long as the joystick is manually operated in the left direction. Similarly, the right turn.

CONCLUSION

This development through automation has proved a lot about the machine's potential and ability to salvage the best out of it. By being able to demonstrate that such a mechanism works fluently would give a tough competition if brought out to the Indian market given its very minimal cost of production when compared to its competitors. As the agriculture industry has been reeling with a labour crisis, the introduction of such technology could propel the market in this sector. As observed from the field tests conducted the developed kit can be made more efficient and smarter provided the right platform and funding to make it on a larger scale. It's sheer capability of being flexible to a variety of tiller machines is a boon to the farmer who do not have to depend on one specific type of machine. Its future seems to be bright as a little research and analysis showed the numerous ways to improvise the existing kit with better technology incorporation.

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