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ELECTRO-HYDRAULIC CONTROL SYSTEM FOR PLOUGH MACHINE OPERATION

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ABSTRACT

An electro-hydraulic control system is designed to control the demining depth of a mine plough machine equipped with plough blade of "V" type. A Linear Variable Differential Transformer (LVDT) is used to account for blade position and an ultrasonic distance sensor is used to provide precise, non-contact, level distance measurements through dusty environment. The proposed control system is implemented to the operating hydraulic system of a scaled model of a plough mechanism. The operating hydraulic actuators used to control the plough mechanism are controlled through a microcontroller and system relays to maintain plough blade depth constant. Results show that significant match between operating surface topology and clearing depth is validated by the proposed control system.

KEY WORDS

Plough mechanism, Depth control, mechanical demining, and earth moving equipment control system.

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INTRODUCTION

Earth moving equipment is one of the most important and powerful tools for achieving land reclamation and demining in a productive manner. Plough machines are common equipment used in mechanical demining for wide track clearing of mines for certain depth; normally operator controlled as shown in Figure (1).

Fig. 1. Plough mechanism fitted by an arms with sensor shoes.

Operator controlled ploughing depth is highly depending on operator skills and effected with time delay for plough depth mechanism response. Automatic control of blade depth was considered in several applications using several techniques to maintain blade depth within order. Some of these techniques depend on operator control through joystick and operation control through microprocessor and electro-hydraulic controlled actuators [1-4], while other developed techniques depend on sensing blade position and terrain topology according to data created from what so named Inertia Navigation System (INS) [5]. Global Positioning System (GPS) which draws three dimensional terrain paths through series of points collected using the GPS and controlling blade depth using electro-hydraulic controlled actuators via microprocessor controller [6], this technique depends on the accuracy of GPS which receives data. A geography altering machine, including onboard computer, stores a reference line and a three dimensional computer model of the desired topography was developed [7], in this technique, digging/ploughing process is fully automated and hence it may be useful in track train ploughing or an underwater digging.

In this study the conventional position and level of a plough machine are modified and implemented to be automatically controlled through different terrain topologies. A control system includes an ultrasonic sensor to sense the shape of ground in front of the plough machine. The position of plough blade according to a defined reference is controlled by LVDT. An electronic controller module is designed to receive the required depth of cut from the operator and sensors signals. The Difference between the required depth of cut and blade position is calculated. The ultrasonic sensor sends a signal to plough mechanism hydraulic actuator to automatically maintain the depth of cut according to different terrain topology (ground profile), as shown in figure (2).

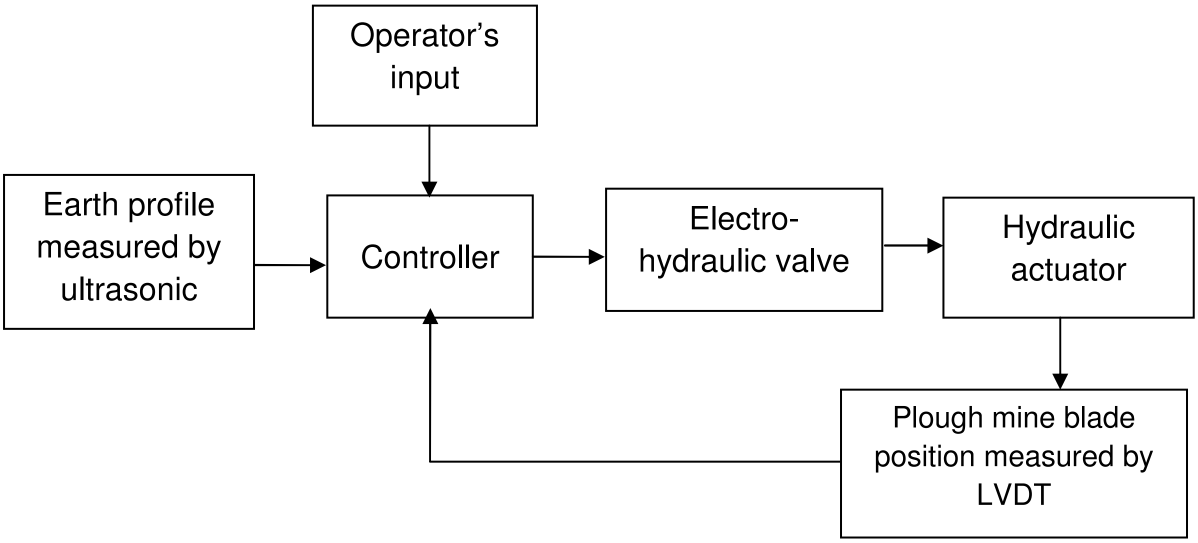

Fig. 2. Proposed control system block diagram.

MATERIALS AND METHODS

A vehicle model with power supply moves on a soil bin of 5m length, 1.7m width has been used. The vehicle is equipped with a plough mechanism model, which contains V-type blade and mechanical linkage system. As shown in Fig. 3, the plough mechanism is operated by a simple hydraulic system. Proposed hydraulic system for plough mechanism is shown in Fig. 4. The hydraulic system is controlled by an electronic control system which consists of a designed microcontroller with interface circuit, shown in Fig. 5.

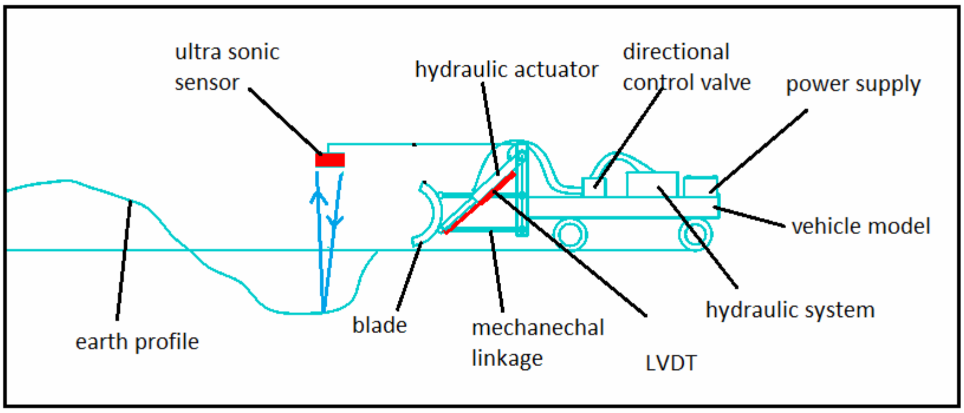

Fig. 3. Proposed control system applied to plough mechanism.

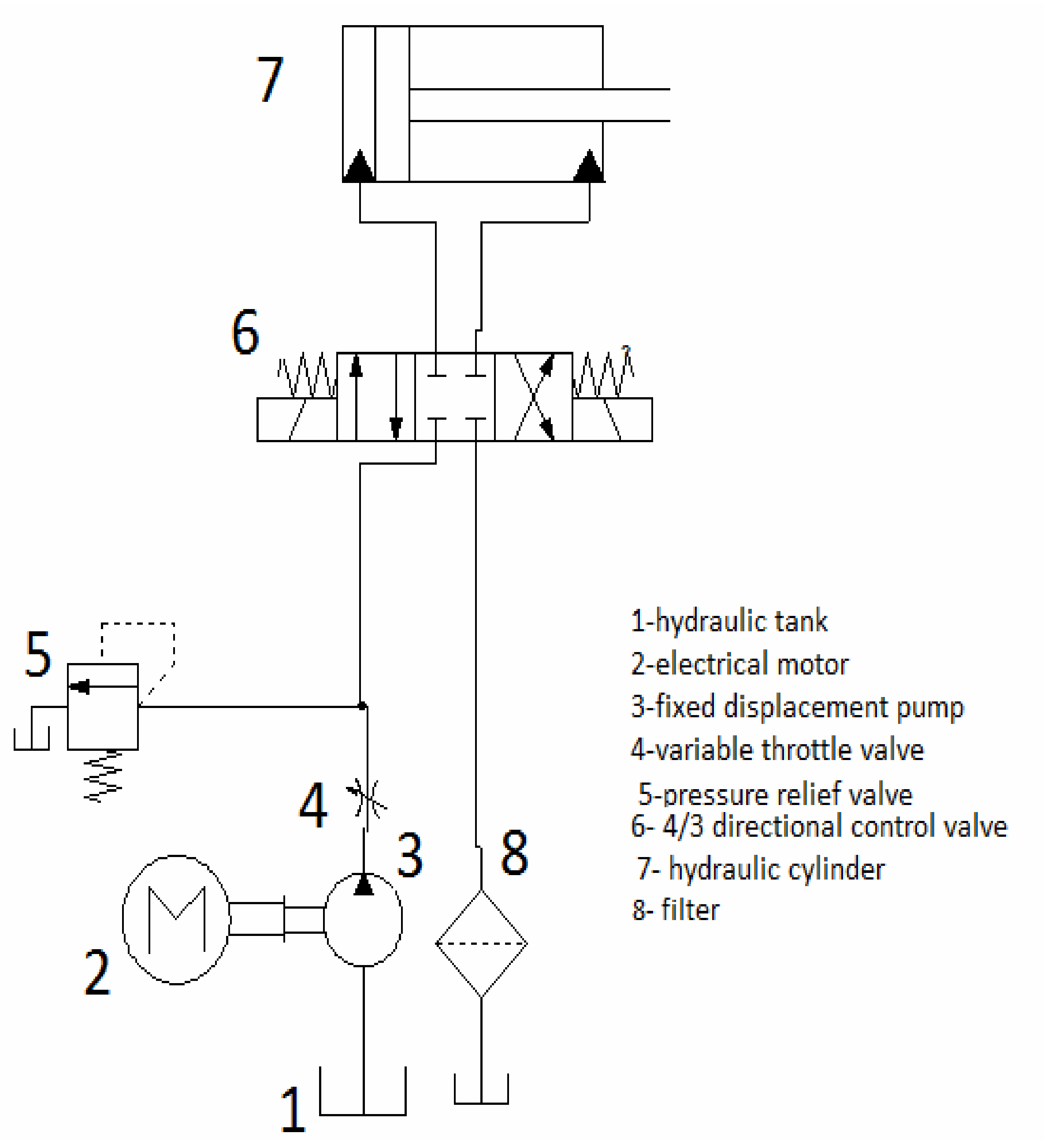

Fig. 4. Proposed hydraulic system for plough machine.

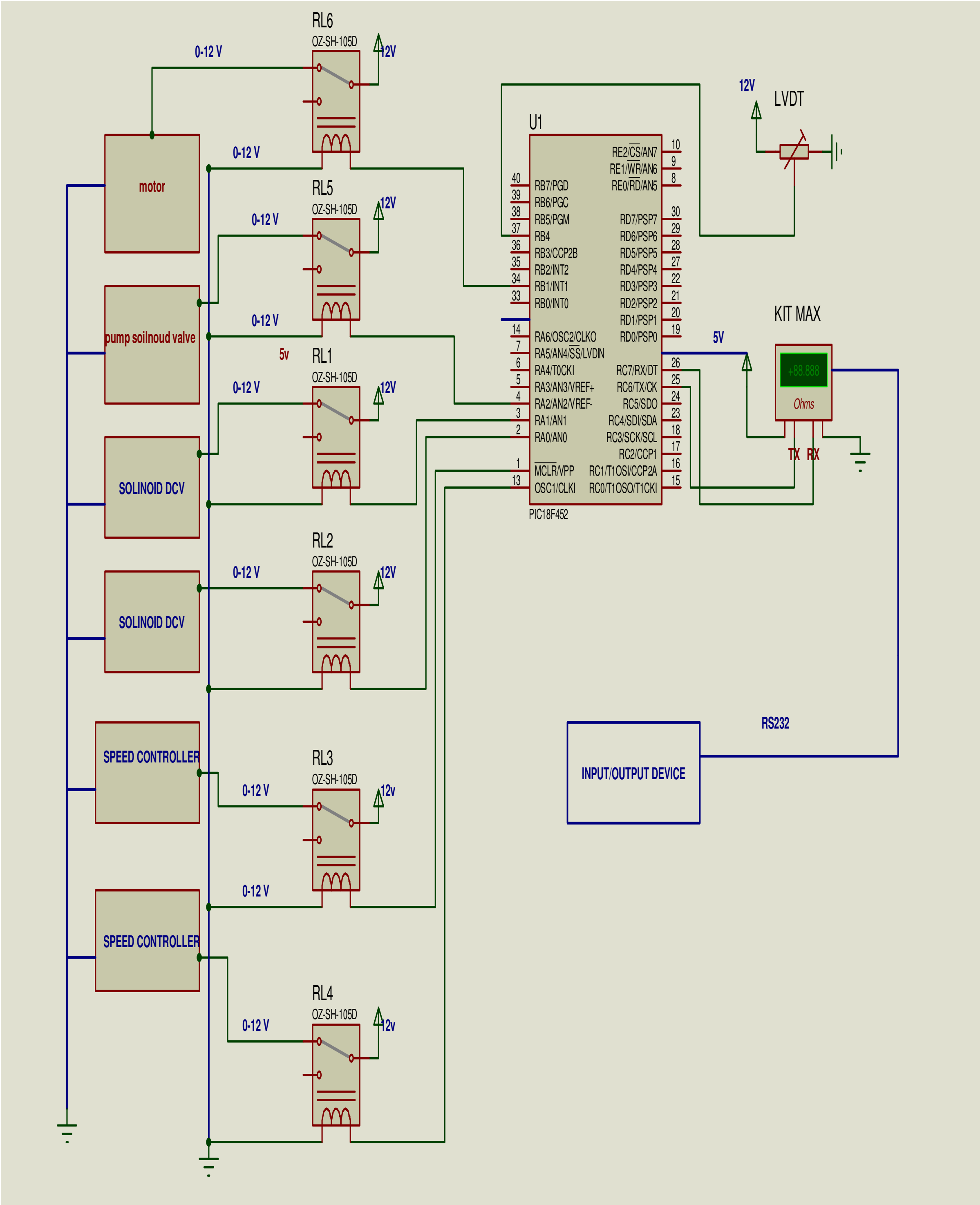

Fig. 5. Designed interface circuit of plough mine control.

The hydraulic system actuates the plough mine mechanism according to the operator's input signal; necessary sensors are added to detect earth profile, detecting the plough mine blade position. The sensors output signals are sent to the controller to obtain necessary correction to keep constant depth of cut through different earth profile automatically, the required depth of cut has been entered digitally to an electronic control system by the operator via a designed graphical user interface.

A graphical user interface (GUI) is designed to assist the operator in operating the machine and managing the mining process, the algorithm of the graphical user interface is shown in Fig. 6.

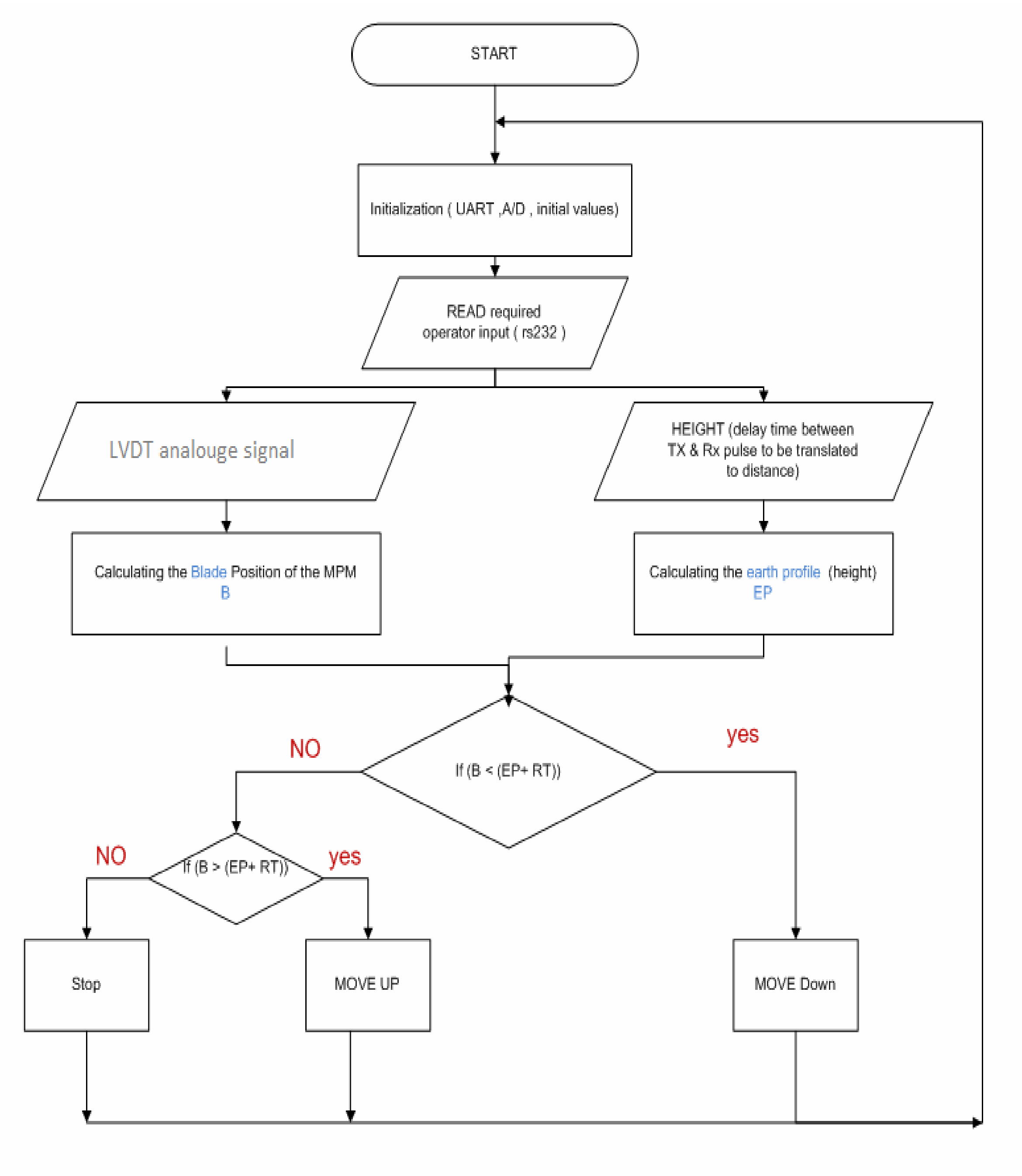

Fig. 6. Interface program flowchart.

RESULTS AND DISCUSSION

Many experiments for different earth profiles as well as different cut of depth have been carried out. The different earth profiles have been scanned by the ultrasonic sensor. The depth of cut has been controlled to maintain constant by an economical electric control system via a designed microcontroller.

A designed electronic control system has been primarily tested by scanning a quasi graded earth profile using the ultrasonic sensor, the result is shown in figure (7). Visually good agreement between the real earth profile and the image one is obtained.

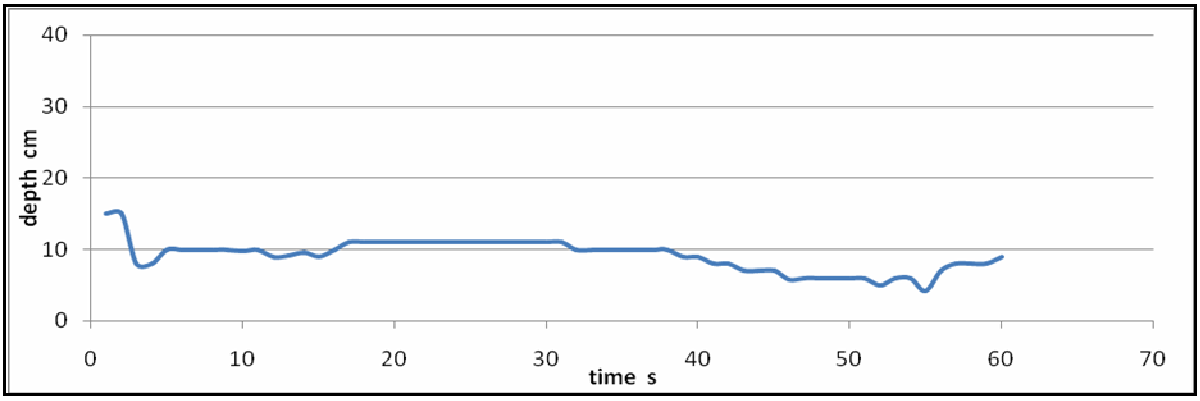

Fig. 7. Quasi graded earth profile.

Figure 8 shows a blade position on a scanned earth profile, at zero depth of cut and 3.6cm/s vehicle speed conditions.

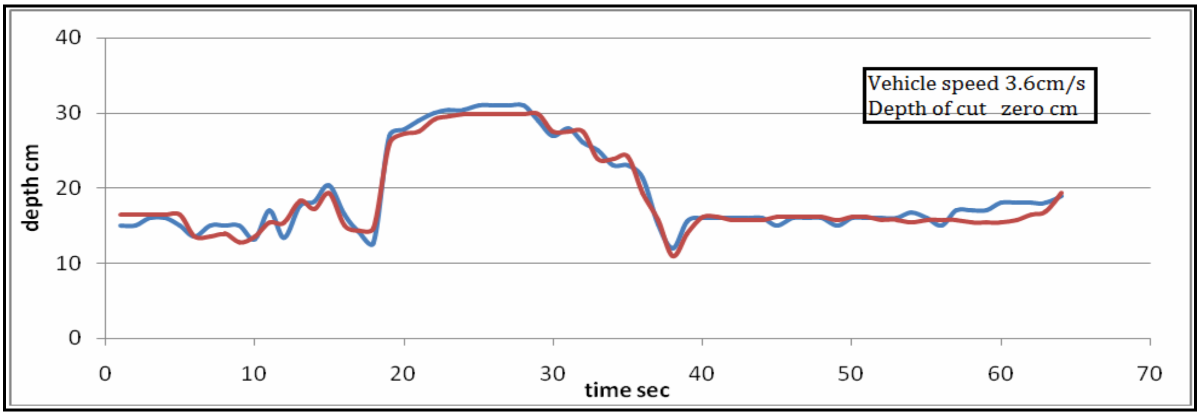

Fig. 8. Comparison between scanned earth profile and Real blade position on an earth profile.

Figure 8 shows very good agreement between the scanned earth profile and zero depth of cut, where there is no soil resistance to the plough blade. Zero depth of cut means the blade moves according to the scanned earth profile. It is considered as primarily test for the application of the designed electronic control system.

Another earth profile is scanned and then the required 2cm depth of cut is ordered to the electronic control system by the operator, the vehicle speed is 3.6 cm/s, and the result is shown in Fig. 9.

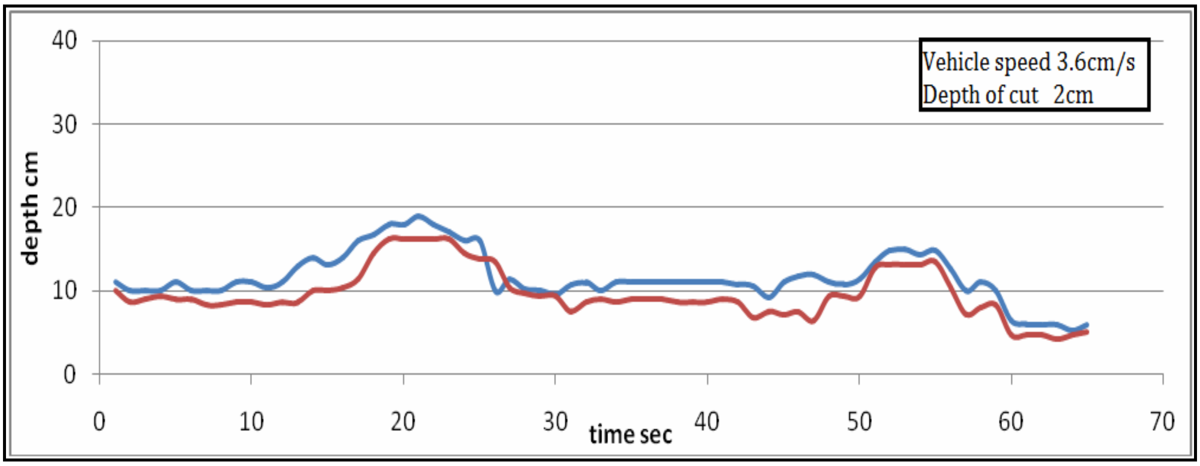

Fig. 9. Comparison between scanned earth profile and Real blade position on an earth profile.

A very good agreement between the depth of cut profile and the earth profile is obtained. The depth of cut is maintained constant by about 90%, but there is a delay of time between the scanned earth profile and real blade position that delay occurred due to construction of the test rig where the ultrasonic sensor is located at the front of the plough blade by distance of 15 cm as shown in Fig. 9. Then the microcontroller input signal from the ultrasonic sensor is delayed. Also due to the resistance of soil increased specially in period of time 25-30 seconds. From Fig. 9, it is observed that the delay time is estimated to be of order 4 sec at 3.6 cm/s vehicle speed. The value of delay time is verified mathematically and it is found to be of 4 seconds. For the same earth profile that used with zero depth of cut the constant depth of cut of 2.5cm, 3.6 cm /s vehicle speed and 4 second delay time conditions are carried out as shown in Fig. 10.

Figure 10 shows very good agreement of results and insures the validation of the designed control system with used delay time which calculated before.

The validation of the designed control system is observed by another experiment with 3 cm depth of cut. 3.6 cm/s vehicle speed and 4 second time delay. This is shown in Fig. 11 with different scanned earth profile.

Figure 11 shows also very good result except the time period from 30 to 50 seconds interval operation. This is due to the inclination between the higher and lower levels of the earth at the time interval from 30-50 seconds, also increasing the depth of cut leads to increasing of soil resistance especially for rough terrains.

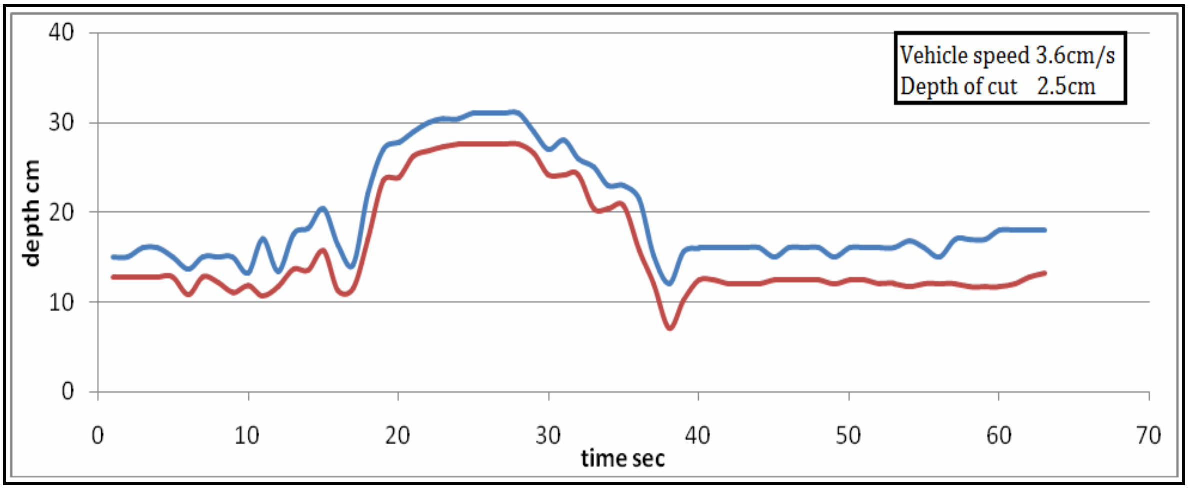

Fig. 10. Comparison between scanned earth profile and Real blade position on an earth profile.

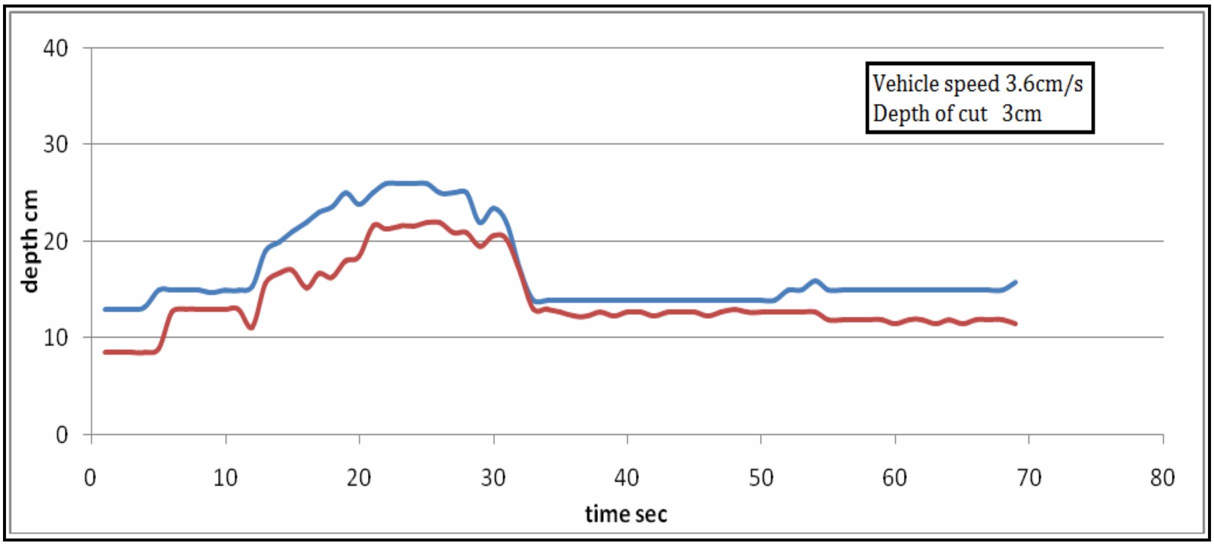

Fig. 11. Comparison between scanned earth profile and Real blade position on an earth profile

Figure 12 shows graded earth profile, as well as a greater cut of depth of order 5 cm has been applied with 3.6 cm/s vehicle speed and 4 sec time delay.

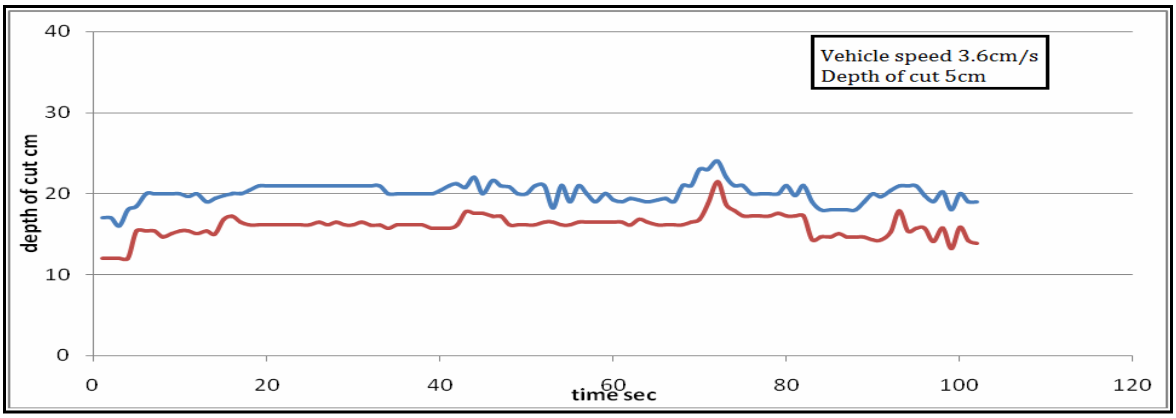

Fig. 12. Comparison between scanned earth profile and Real blade position on an earth profile.

Figure 12 shows a very good agreement between the earth profile, constant depth of cut, for a quasi graded earth.

CONCLUSIONS

- Plough machine model with enhanced control system has been setup.
- An economic electronic control system has been designed for plough machine model.
- The deeper the cut of depth, the more energy is needed to overcome the resistance force resulting from the accumulated soil as well as side and adhesion forces.
- A delay time signal feedback is needed for enhancement of the automatic ploughing operation.
- The depth of cut has been maintained constant with about 90% accuracy.

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