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The Application of Ultrasonic Sensor and Atemega 328 Arduino to Measure the Ploughing Depth Elevation of Drainage Channel

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Abstract: ***The measurement of ploughing depth is still carried out manually using ruler which pinned down into the soil through leg fissure and its narrow leg. This practice is considered as non-valid measurement. Therefore, an improved measurement should be developed such as using ultrasonic sensor. The objective of this research was to (a) develop automatic mole ploughing depth elevation measurement, and (b) gain the deviation magnitude resulted from set point and ploughing depth elevation position. Ultrasonic sensor was permanently attached heading to the target. A plat was attached onto hydraulic support. The sensor will detect the ploughing depth-distance when the hydraulic lifting or lowering the mole plough. As shown in the result of ploughing depth elevation, it could be seen that ultrasonic distance sensor was appropriate to detect the ploughing depth. The deviation occurred at M, N, O and P tracks with magnitude of 0,99%; 1,04%; 0,63% and 0,87% respectively.***

Keywords: mole plough, depth elevation, set point, deviation, ultrasonic sensor

1. Introduction

A research on constructing electronic control system on hydraulic-driven mole plough had been conducted (M. Hariansyah et al., 2013). The mole plough was designed to create sub soiler drainage channel at a depth of 40 cm that aimed to discharge water excess at an agricultural land. The measurement of ploughing depth is still conducted manually using ruler pinned into the leg fissure and its narrow leg. This practice is considered as non-valid measurement. Therefore, an automatic measurement such as using ultrasonic sensor should be developed. The objective of this research was to (a) develop automatic mole ploughing depth elevation measurement, and (b) gain the deviation magnitude resulted from set point and ploughing depth elevation.

2. Research Design and Method

2.1Research Design

The design of ultrasonic sensor attached to the tractor which constructed by M. Hariansyah *et al.* (2014) is shown in Fig. 2.1.

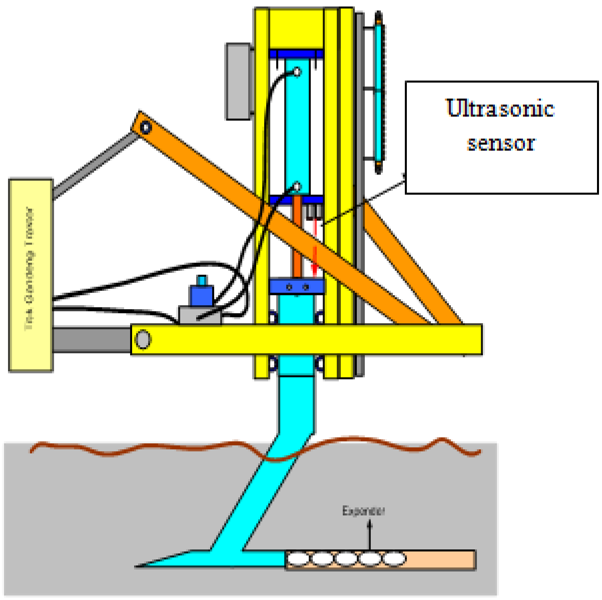


Figure 2.1: Design of ultrasonic sensor

Referring to the Atmel (2010) guidance, the relationship between ultrasonic sensors with Arduino Atemega 238 micro-controller is shown in Fig. 2.2.

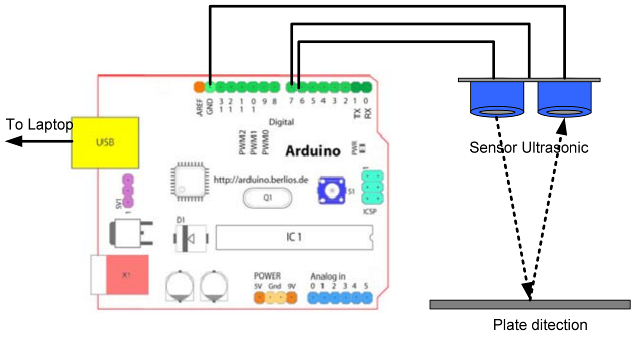


Figure 2.2: Design of ultrasonic sensor with Arduino Atemega 328 micro-controller

According to Prawiroredjo K & Asteria N (2008), ultrasonic is a sensor that works by sending particular wave and then calculating the time when is received back by the sensor. Ultrasonic wave works at frequency ranging from 20 kHz up to 20 MHz. The working frequency of ultrasonic wave is limited by the medium including low density of gaseous, liquid and solid phase.

The physical characteristic of ultrasonic wave is wave arising from mechanical motion with frequency is greater than the upper limit of the human hearing range i.e. 20 kHz. Ultrasonic wave propagates in two types. Periodic wave is formed when oscillating wave occurs periodically and continuously. In this condition, particles at similar wave-points has similar phase. The distance between consecutive maximum value of oscillation (transverse waves) or the distance between consecutive compression values of oscillation (longitudinal wave) is called wavelength. The period (T) is the time needed to go through one complete cycle. The relationship between wavelength and period is expressed in this equation:

$$\lambda = C.T \qquad (2.1)$$

Eq. 2.1. can also be written as speed of the wavelength divided by frequency as shown below:

$$\lambda = \frac{C}{f} \qquad (2.2)$$

Whereas, wave frequency (f) is rate of oscillation. The wavelength magnitude is very important to determine the resolution threshold of imaginary system. The ultrasonic image of two structural shapes with narrow wavelength can't be separately identified. The speed of sound propagating through medium depends on the density (ρ) and medium compressibility (B). When pressure changing in the medium occurs, material with heavy molecule relatively moves slower than the lighter molecule. Highly compressible material such as gaseous will transmit the sound wave slower. Therefore, the increasing of intensity or compressibility will decrease the sound speed. Mathematically, the ultrasonic wave is written as follow:

$$s = \frac{v.t}{2} \qquad (2.3)$$

Where *s* is distance in meter unit, *v* is sound speed of 344 m/s and *t* is time needed in second unit. When ultrasonic wave encounters an object, a part of it will be reflected, absorbed and transmitted. The absorbed wave will be calculated by comparator and transmitted into binary number.

In general, ultrasonic sensor is used to measure the distance from the sensor to the object. Therefore, ultrasonic sensor can be used for distance measuring device. Fig. 2.3 shows the construction of ultrasonic sensor given by Sukhrisna N, Falaqi F. (2013)

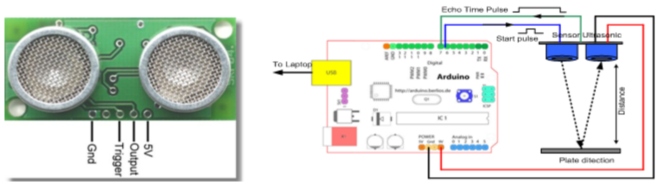


Figure 2.3: The construction of ultrasonic sensor and its working method

According to Boylestadt, Robert and Louis Nashelsky (2007), the design of ultrasonic sensor is constructed from two circuit units i.e. transmitter and receiver as shown in Fig. 2.4.

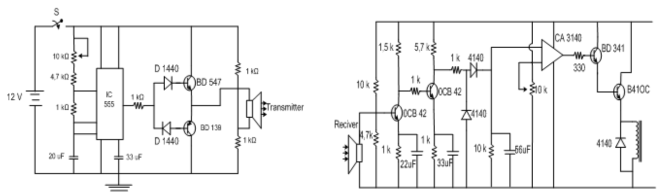


Figure 2.4: Ultrasonic sensor circuit

a. Transmitter Circuit b. Receiver Circuit

This sensor requires two I / O pins to communicate with the microcontroller, the TRIGGER and ECHO. To activate the SRF04 microcontroller sends a positive pulse through the TRIGGER pin at least 10 us, and then the SRF04 will send a positive pulse through the ECHO pin for 100 us to 18 ms, which is comparable to the distance of objects. Pulse width represents the distance between the objects. Form of SRF 04 timing diagram shown in Figure 2.5 below.

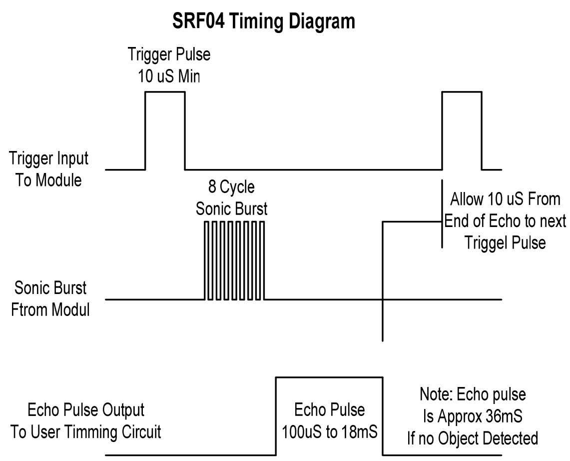


Figure 2.5: Signal Ultrasonic Sensor SRF04

After this, microcontroller measures the pulse width and then converts it into distance unit. The equation will be:

$$s = \frac{2.l}{29{,}034.10^{-6}} \qquad (2.4)$$

Whereas, s is distance in cm, l is pulse width.

2.2 Research Method

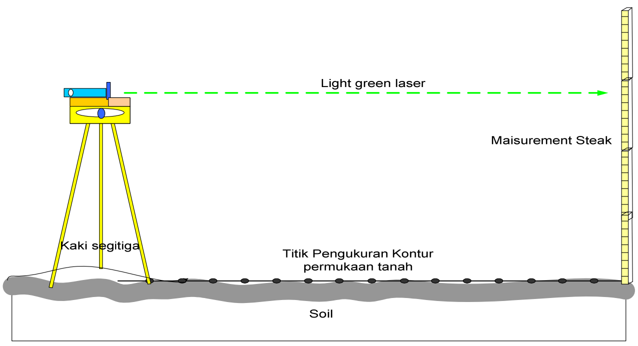
2.2.1 Time and Location

The construction and testing process of ultrasonic control system were carried out from March to April 2014. The research was taken place in Laboratory of Electrical and Machinery Engineering, Faculty of Engineering, University of Ibn Khaldun, Bogor. Field testing was taken place in Laboratory of Agricultural Engineering, Department of Mechanical and Biosystem, Faculty of Agricultural Engineering and Technology, Bogor Agricultural University and Field Laboratory of Siswadhi Soepardjo, Bogor.

The first stage of the research was to measure the farming area which was designed to create drainage channel using mole plough. The farming area was 30 m length and 6 m width. The width side was divided into 4 tractor's tracks i.e. M, N, O and P. Each track was 1,5 m. The elevation of mole plough was set at 0,02% using control system. Measuring profile of soil surface was carried out prior creating the drainage channel.

2.2.2 Soil Profile Measurement

Saeys W, *et al.* (2004) stated that soil land measurement was started with measuring the profile of soil surface. The profile is measured using a set of laser beam and stake meter. Elevation was measured by placing one stake at each field corner for reference and then leveled as shown in Fig. 2.6. The stake meter was placed at 2, 4 up to 30 m length. The measurement was conducted at each tracks and the result was written on the table.



Gambar 2.6 Land measurement and stake position for tractor track

2.2.3 Tractor Track

The track was created for tractor movement with distance among tracks was 1,5 m to avoid crossing-over. The width of rear wheel was 1,5 m. After completing the works at A track, tractor then moved to B track. This position rotated the right-wheel side into the left-hand side of the tractor. The track of the tractor is shown in Fig. 2.7.

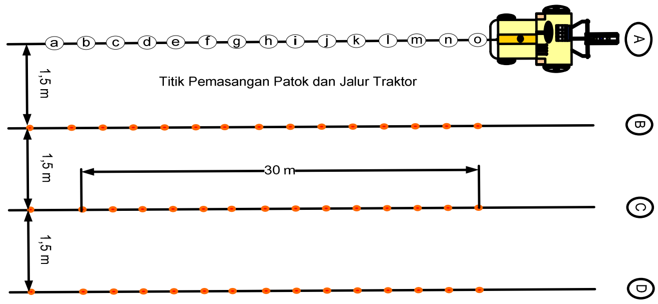


Figure 2.7: The tractor track

Titik pemasangan patok dan jalur traktor: the position of stake meter and tractor track

2.2.4 Creating Drainage Channel

Mole drainage channel was created by activating the tractor's hydraulic lever alongside the track. As the tractor moved forward, the mole plough was pulled up to 20cm depth of soil and then stop at the initial measurement point. Drainage mole was created at four testing tracks i.e. M, N, O and P with 0,02% slope. The hydraulic lever controls the slope of mole plough. The method on creating drainage channel is shown in Fig. 2.8

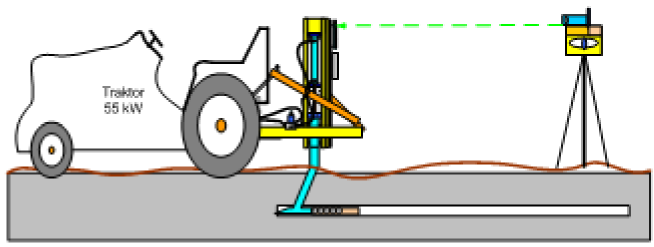


Figure 2.8: Method on creating the drainage channel

2.2.5 Program to control the depth

Controlling the depth was conducted by directing the green laser beam onto light receiver photodiode sensor which placed at level 4. Push and pull timing were programmable designed. As the position of green laser beam moved from level 4 to level 3, program activated relay and relay instructed solenoid to open the valve to drag the mole plough based on the defined set point. The illustration of the receiver sensor movement toward the movement of green laser beam is shown in Table 2.2

Table 2.2: The movement of receiver sensor toward the shifting of green laser beam

Input position	Depth (cm)	Function
Level 4 to 1	15	Lifting
Level 4 to 2	10	Lifting
Level 4 to 3	5	Lifting
Level 4	0	Initial position
Level 4 to 5	-5	Lowering
Level 4 to 6	-10	Lowering
Level 4 to 7	-15	Lowering
Level 4 to 8	-20	Lowering

According to Table 2.2, it is predicted that the receiver sensor will shift continually as photodiode sensor was attached at the mole plough construction which pulled by the tractor. The ploughing depth was suited to the level of light receiver sensor. The distance among level was 5 cm. The initial position was adjusted to the specified set point. The ploughing elevation was controlled at three levels ranging from 0%, 0,1% and 0,2% of the total 30 m length. Prior testing, the position of three-point hitch was locked to avoid up and down movement. The movement of up and down only performed by mole plough hydraulic which aimed to perform elevation depth control system.

2.2. Method to Measure the Ploughing Depth

The measurement of ploughing depth was conducted by ultrasonic sensor. The sensor was permanently attached to avoid movement. The moving object was iron plat that was permanently attached to the hydraulic piston. As cylinder piston pushed or pulled the mole plough, the iron plat eventually moved. This movement was detected by sensor and the information was sent into Arduino micro-controller which the result could be directly read at the computer.

3. Materials and Tools

Materials and tools used to measure the depth of drainage channel using mole plough are shown in Table 3.1.

Tabel 3.1 Materials and tools of the research

Tools:		
One set of tractor	:	55 kW, Holand
One set of external hydraulic mounting to tractor	:	Capacity 50 liter/minute, 250 bar
One set of solenoid	:	30 A, 4 channels (2 in 2 out)
One set of accu battery	:	12 V, 7,6 Ah for transmitter
One set of pressure meter	:	250 bar
Fujitsu laptop for monitoring device	:	screen 11", Hard disc 250GB, ram/rom 8 GB
Hydraulic hose and its features	:	Flexible 3/8"
One set of ECU	:	ATMEGA Arduino 238
One set of distance sensor	:	Ultrasonic, 3 m
Hydraulic cylinder	:	Length 50 cm, diameter 10 cm, piston diameter 5cm, 10 tones
One set of electronic device	:	Solder, pliers, screwdriver, wire, VCB, tin
Iron materials of the mole plough	:	Plat ST 37, length:1200mm, height: 25mm, width: 250mm,
Mole plough size	:	Height 125 cm, width 250 cm, thick 25 mm
One set of theodolite	:	DT. Nikon NE-205 (2^{nd})
Material:		
Hydraulic oil	:	Pertamina, SAE 20, 50 liter
One set of	:	Stake meter, rope and so on
Ruler meter	:	Stainless steel ruler, 60 cm
Field testing	:	30 m length x 16 m width
Total of tracks	:	16 tracks

4. Result and Discussion

4.1 Result

The result of the research consisted of the profile of soil surface and the ploughing depth elevation.

4.1.1 The profile of soil surface

The profile of soil surface passed by tractor is shown in Table 4.1

Table 4.1: The profile of soil surface passed by tractor

No	Track and distance markers	Measurement of tractor trajectory profile (cm)															
		0	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000
1	Track M	0	1	2	2	2	4	5	5	5	9	10	11	11	11	12	12
2	Track N	0	2	2	3	4	3	5	5	7	9	9	10	10	11	11	11
3	Track O	0	2	2	4	6	7	8	8	8	9	9	9	9	10	10	11
4	Track P	0	0	1	1	1	4	6	8	7	9	10	10	10	11	11	11

According to Table 3.1., it can be seen that slight difference of soil profile occurred among the tracks.

The elevation result at 0.2% slope

The result of ploughing elevation at 0,2% slope of the total field length or $0,18^{o}$ slope angle using controller and depth measurement using ultrasonic sensor is shown in Table 4.2

Table 4.2: The result of ploughing depth elevation using controller at 0,2% slope

No	Track and distance markers	Measurement of tractor trajectory profile (cm)																Remarks
		0	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	
1	Track M	-20	-22	-23	-24	-25	-27	-28	-28	-30	-34	-35	-36	-37	-38	-39	-40	To test the control slope of 0.2% mole plow
	Position Mole Plough	-20	-21	-21	-22	-23	-23	-23	-24	-25	-25	-25	-25	-26	-27	-27	-28	
	Level sensor on	4	4	4	4	4	4	4	4	4	5	5	6	6	6	6	6	
2	Track N	-20	-22	-23	-24	-25	-26	-28	-29	-31	-33	-34	-35	-36	-37	-37	-38	
	Position Mole Plough	-20	-20	-21	-21	-21	-23	-23	-24	-24	-24	-25	-25	-26	-26	-26	-27	
	Level sensor on	4	4	4	4	4	5	5	5	6	6	6	6	7	7	7	7	
3	Track O	-20	-22	-23	-25	-27	-29	-30	-31	-32	-34	-35	-36	-36	-37	-38	-38	
	Position Mole Plough	-20	-20	-21	-21	-21	-22	-22	-23	-24	-25	-26	-27	-27	-27	-28	-28	
	Level sensor on	4	4	4	4	5	5	5	6	6	6	6	7	7	7	7	7	
4	Track P	-20	-21	-22	-23	-24	-28	-30	-32	-32	-34	-35	-36	-37	-38	-39	-39	
	Position Mole Plough	-20	-21	-21	-22	-23	-24	-24	-24	-25	-25	-25	-26	-27	-27	-28	-28	
	Level sensor on	4	4	4	4	4	5	5	6	6	6	6	7	7	7	7	7	
	Set point mole plough	-20	-21	-21	-22	-23	-23	-24	-25	-25	-26	-27	-28	-28	-29	-30	-30	

Set point bajak mole: mole plough set point. The result of ploughing depth elevation as shown in Table 4.2 can be converted into graphical form shown in Fig. 4.1.

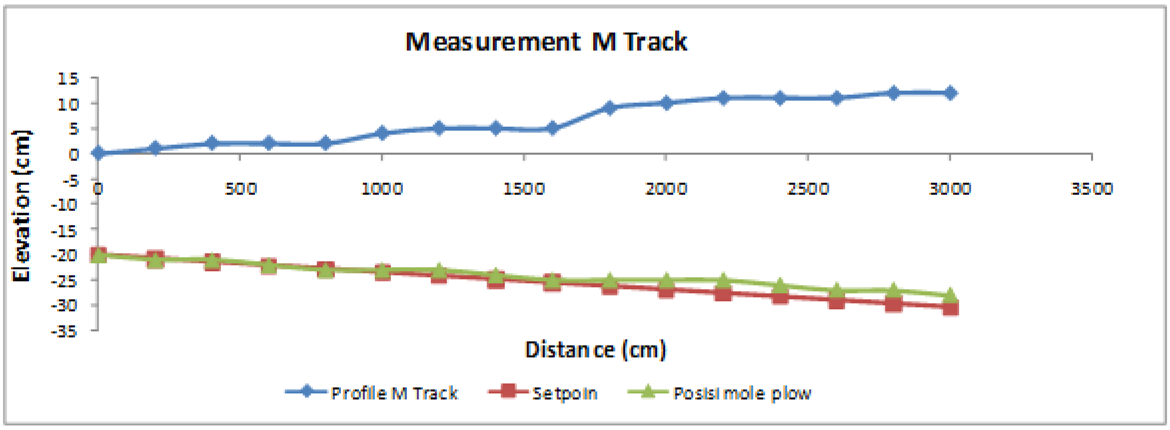


Figure 4.1: Graph of ploughing elevation toward setpoint at M track

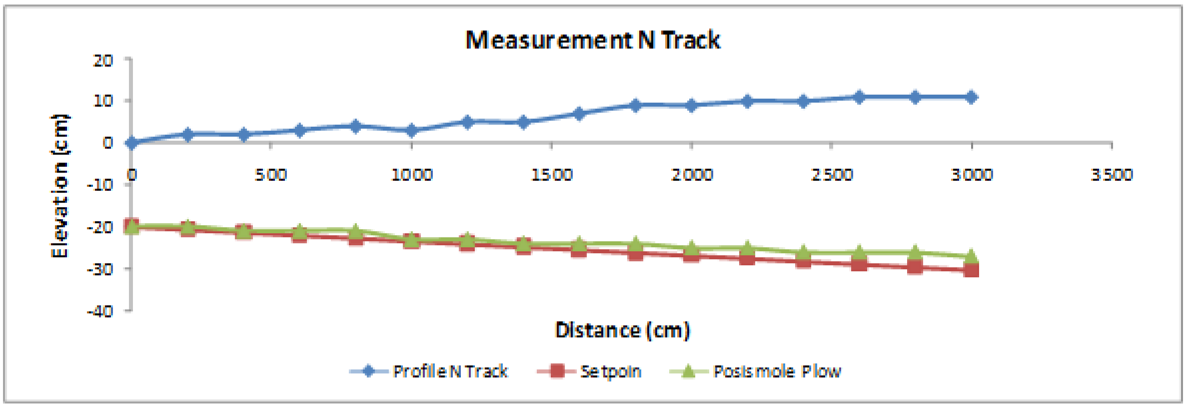


Figure 4.2: Graph of ploughing elevation toward setpoint at N track

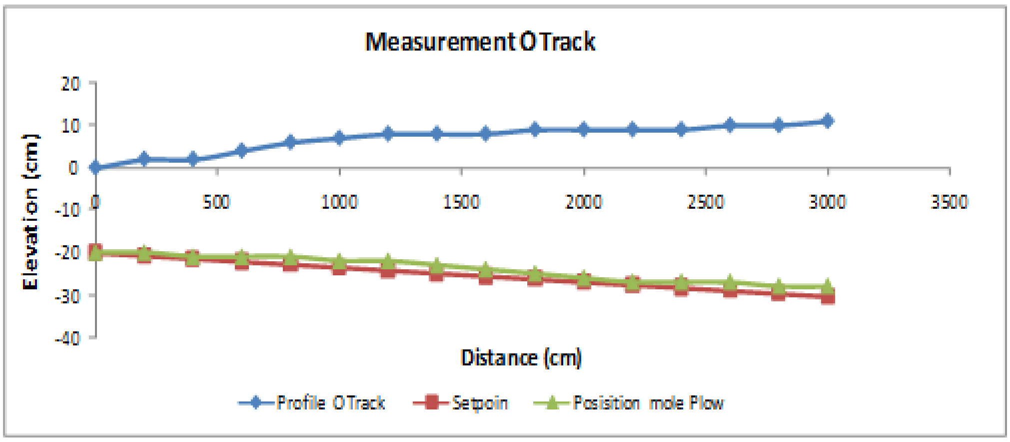


Figure 4.3: Graph of ploughing elevation toward setpoint at O track

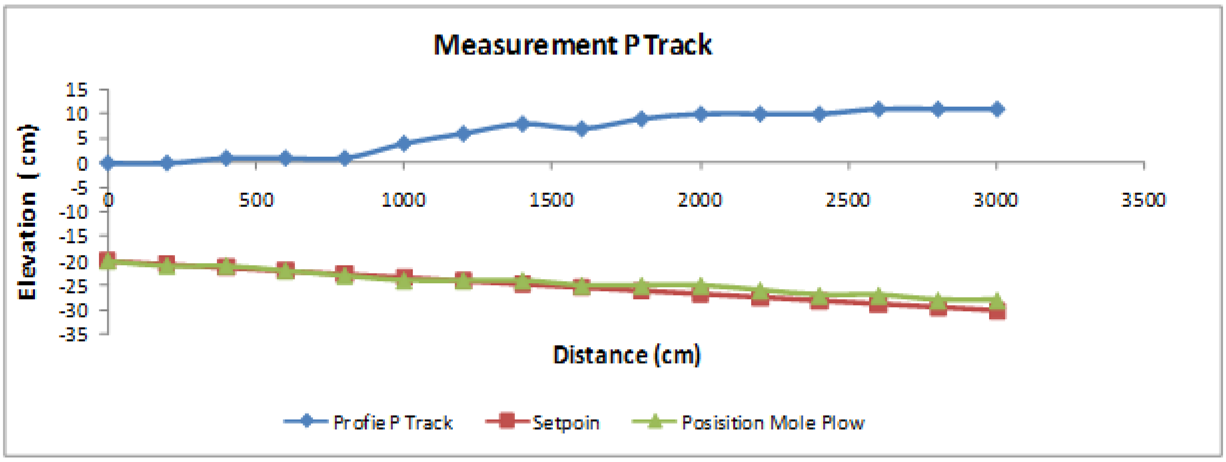


Figure 4.4: Graph of ploughing elevation toward setpoint at P track

Referring to Fig. 4.1 up to 4.4, it can be seen that the soil surface profile still influenced the ploughing depth. Therefore, a deviation between set point and the actual position still occurred. When the elevation of soil surface increased, the position of mole plough was maintained close to the specified set point.

4.2 Discussion

Referring to Fig. 4.1 up to 4.4, the result of soil surface profile significantly influenced the result of ploughing depth elevation. Therefore, a deviation between set point and ploughing depth still occurred. The deviation was analyzed using Eq. 4.1.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - x_n)^2}{n}} \quad (4.1)$$

Whereas:
n : number of data
x_i : data average
x_n : n-data

Based on the measurement and analysis, the deviation magnitude is shown in Table 4.3

Table 4.3: Deviation between set point and ploughing elevation

Track	Deviation (%)	Slope
M	1,05	Controlled at 0.2 % slope
N	1,08	
O	0,78	
P	0,96	

5. Conclusion

Referring to the research result using control system at 0,02% slope showed that the profile of soil surface still influenced the ploughing depth position. When the elevation of soil surface increased, the position of mole plough was maintained close to the specified set point. Ultrasonic distance sensor was appropriate to detect the ploughing depth. The deviation occurred at M, N, O and P tracks with magnitude of 0,99; 1,04; 0,63 and 0,87, respectively.

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