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DESIGN, IMPLEMENTATION AND EVALUATION OF POTATO YIELD MONITORING SYSTEM

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Abstract— **In this paper the design, implementation, monitoring and evaluation system at a workshop a potato yield monitoring has been studied. This study developed a method is accurate for potato yield mapping. First a yield monitoring system consists of a tray weighing, 2 load cells, Encoder, PLC controller and a mobile computer on a potato harvesting machine was mounting. In this study, PLC as a controller in communication with a mobile computing and control applications developed with Visual Basic Win-Pro-ladder and is capable of Encoder and Load cells data received and can be received on the data planning was necessary. Workshop was designed to evaluate the system and get the best performance of this system, laboratory tests were conducted on potato harvesting machine. The independent variables tested were: traveling speed, angle, plate thickness and shock absorber. In order to analyze and compare the results of laboratory analysis of variance with Duncan's test with a confidence level of 5 percent was used. In order to investigate the interactions of various factors of the factorial experiment in completely randomized design was used. In examining the interaction angle, speed and performance-related shock absorber on the best product to the tray angel 37 degrees, traveling speed of 2 km.h^{-1} and without shock absorber with 2.81 percent error was the best. In this situation the best performance in reading and data entry system designed for mass (yield) is found.**

Keywords— **crop yield monitor, load-cell, PLC controller, shaft encoder, tray weighing.**

I. INTRODUCTION

Precision farming (PA) involves the use of sophisticated tools to assess field conditions and apply fertilizer, chemicals and other farm inputs based on the conditions. Through the use of technologies such as positioning systems, satellites, electronic sensors, controllers and advanced software can create images of their operations to detailed. Traditionally, farmers measure the crop yield in large parts of farm or field. New technologies allow farmers to measure yield at much smaller levels of each field. Variability of soil properties and environmental conditions certainly affect production. Recent advances in technology and data processing techniques, has provided the opportunity for farmers to address this issue. Some of today's agricultural producers, site-specific crop management apply. Electronic yield monitoring mainly is the first step in the development of site-specific crop management or precision agriculture applications. Detailed data on the performance of the product can be integrated into many types of soil and environmental conditions data to develop a precise crop management system. Between applicable precision agriculture applications, most logical starting point for the farm is the yield crop evaluation that is process of measuring and mapping the specific location of the farm and the effects of soil properties, climate and management on crop yield (Moore, 1997). Since 1999 has started extensive research in the yield crop monitoring in the world. Goginen (2002) designed and implemented sweet potato yield monitoring system. Image data obtained from this system were analyzed by image processing software. In this method, the image segmentation procedure was used for processing potatoes images. Image segmentation technique was identified 80 percent of potatoes in the images. Durrence, et.al, (1999) was designed a peanut yield monitoring based on load-cell in the university of Georgia. Error of this system was simulated on field conditions. Qualitative evaluation of the system showed that the system has the low capacity to determine the yield of certain parts of the field in order to yield monitoring. Caryn (2002) installed a sugarcane yield monitoring system on Cameco CH combine. Yield monitoring system was including mass data obtained from the system and a Differential Global Locating System (DGPS) to determine the location which was used a weighing tray held by the four load-cells. The evaluation results showed that the average error is equal to11.5 percent and the sugarcane crop species were effect to results but the growth stages of sugar cane, the length of the row and crop flow rate have no important effects on the results. Lee, et.al, (2002) designed a yield monitoring system to silage forage. In this study, global positioning systems, load-cell, Bluetooth for data transfer and humidity sensor was used. This system has an error of 1.96 percent. Bassam.et.al, (2006) have developed the performance of a sensor for measuring the onion specific gravity. They showed that the measuring of specific gravity of mushrooms, onions and fruit may be done on the harvester machine that can increase its market value, and give approach to precision agriculture. They were used tow shock load-cells and a tray made from acrylic and a shock absorber made of polypropylene that designed to measure the onions specific gravity. The results showed that the order of the onions on the conveyor has no effect on the accuracy and sensitivity of the sensor and the distance between the outlet of conveyor and the center of the tray reduces the accuracy of the sensor. Accuracy is reduced if shock absorber thickness be lower than of 10 mm which is mounted on the tray. Using 30 mm thickness shock absorber, sensor accuracy improved (even at higher height) and error was reduced less than 2 percent. Angle between tray and shock absorber was selected 37 degrees that was best angle to prevent again collision of the onions on tray after the initial collision and also accumulation of soil on the weighing tray. The ultimate objective of this research is to designing, construction and evaluation a system for on-the-go measuring yield crop and to obtain the best system performance at different tray angles relative to the horizontal, shock absorber and traveling speed.

II. Materials and Methods

Potato harvesting machine used in this research had two chain conveyors. These types of machines are used in different areas of Iran, especially in areas with light soils. This machine is suitable for use in above condition, but when the soil is moist and sticky, not used. The major advantage of potato harvesting machine with chain conveyor is delivering potatoes on a row in the field that will facilitate the gathering potatoes by hand, although it will not be caused a significant reduction in the number of workers needed to collect the potatoes. Compared with other types of harvesting machines, components of this type of machine have higher erosion. Dimensions properties of machine used in this study are summarized in Table 1.

TABLE1.
DIMENSION DATA OF POTATO HARVESTER

specifications	unit	double rows	one row
dimension	cm	117×183×253	120×140×234
width	m	1.4	0.7
weight	kg	690	410
power	hp	60	45
type of connection	-	three point hitch (ride)	three point hitch (ride)
PTO speed	rpm	540	540
field capacity	acres per hour	0.5	0.2

In order to monitor the yield of potato crop, the changes were implemented in the harvester machine such as installing a gateway at the end of the studs on the chain conveyor to avoid the collapse of many potatoes on weighing tray and to possible individual collapsing of potatoes on the weighing tray. This gateway was made of steel and thickness 3 mm. The weighing of potatoes was done by three trays made from wood (MDF), a thickness of 10 mm and dimension 220 × 295 mm that each was installed with a different angle on the test plant. This tray was installed at the end of the chain conveyor to the height of 240 mm from the edge of the conveyor chains which two load-cells were installed below tray.

The trays were installed with angles of 30, 37, and 45 degrees to the horizon at the end machine. Weighing tray scheme is shown in Figure 1.

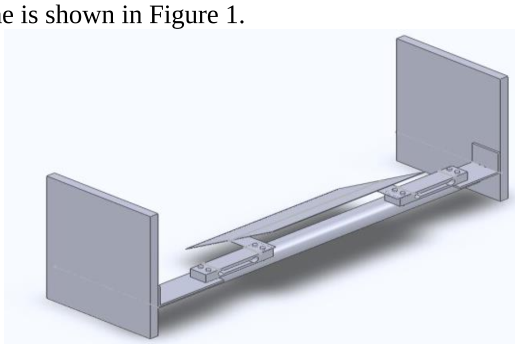

Figure1. Schematic of weighting tray

To avoid hitting again weighted potatoes onto tray after the initial deal, which would lead to errors in the measurement system and vibration reducing, two shock absorbers made of types of polymer and thicknesses of 10 and 20 mm and a shock absorber made of double wall polycarbonate sheet was used. Double wall polycarbonate sheet is light weight and impact resistance. The resistance of that is 200 times of glass. In order to weighing potatoes two AB120 load-cells was used with error less than 0.03 percent made in Korea at the end of the tray and horizontally that one over the sensor was connected to the frame and the other end is connected to the weighing tray. Considering the load-cell analog signal output (in mily volts), is requirement to analog converter in order to standardize the output load-cells signal suitable for connection to the PLC module. Load-cells output signals are converted to standard analog signals, for a load-cell was used a convertor (total of two), with standard output signal 4-20 mA and 0-10 V made in South Korea, manufactured by SEWHA company. In this study the PLC we used as a controller that in connection with a computer and control software developed with Visual Basic and Win-Pro-ladder can get shaft encoder and load-cells data. PLC used in this study is FATEK PLC FBs-24MC product which is capable of receiving 14 DC digital inputs. The current frequency of the two inputs was 200 kHz and the other inputs were 20 kHz. Potato harvesting machine in along with the equipment used is shown in figure 2.

Figure 2.Chain type potato harvester and used instruments

A. *Laboratory tests performed*

For evaluation of the designed system and get the best performance of the system, 108 laboratory tests were conducted on potato harvesting machine. Independent variables to test include traveling speed, angle tray and different shock absorbers. In order to analyze and compare the results of laboratory tests, Analyze of Variance (ANOVA) with Duncan's test with a confidence level of 5% was used. To study the interaction of various factors, factorial experiment in a completely randomized design was used.

B. *Calibration of load-cells*

To calibrate Load-cells used in system, five potatoes at different sizes were used in four modes. These potatoes were numbered, and the exact weight of the tomatoes was recorded by a digital scale. The experiments was done in four different modes: in the first case without shock absorber, second case with shock absorber with a thickness of 10 mm, the third mode with a thickness of 20 mm and a fourth state of shock absorber with double shock absorbers made of polycarbonate sheet. In each of the states each potato dropped in dynamic state and in five iterations on a tray and weight was recorded by load-cells, average of data obtained was calculated. With the actual size and the size of the data read by sensor, calibration coefficients, and the corresponding diagram was calculated and plotted by Excel software. In each case, four calibration coefficients obtained and tests were applied to these coefficients.

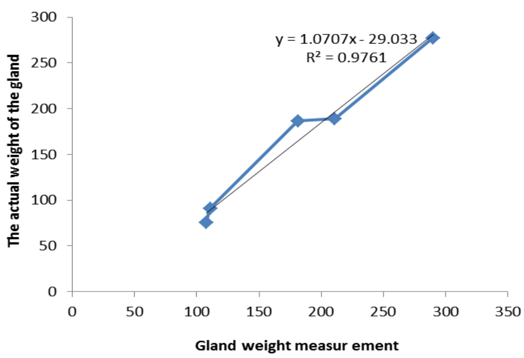

Figure3. Calibration Diagram of Load-cell with shock absorber made of polymer with thickness plate 20 mm

III. Results and Discussion

A. Weighing system calibration test results

Figure 3 indicates the calibration graphs of weighing systems for the shock absorbers made of 20 mm thick polymer. As seen in figure 3, using load-cells data fitted with a line, equation 1 will result that the correlation coefficient is R^2= 0.9761.

$$Y=1.0707X-29.033 \quad (1)$$

In the diagram above, because R^2 is close to one so the system is capable of weighing values of potatoes weight compared to other shock absorbers more accurately.

B. Analysis of the data obtained from the Analysis of Variance

Table 2 shows the results of the Analysis of Variance with a confidence level of 5%. The angle, traveling speed and shock absorbers are independent variables and the dependent variable is the mass of the tomatoes. As seen in the table at the point of angle treatment, significant difference was observed. This means that by changing the angle of the tray (30, 37 and 45 degree) found significant difference between the results obtained data. Treatment for traveling speed as well as treatment for angular is statistically significant difference. Confidence level for shock absorbers treatment is equal to 0.57, and no significant differences were observed. The significant level of 0.38 was calculated for repeat and there was no significant difference.

Source of variation	Sum of squares	Degrees of freedom	Mean-square	F	Significant
Angle	1.932 $\times 10^8$	2	9.659 $\times 10^7$	21.791	0.000
Speed	7.332 $\times 10^7$	2	3.666 $\times 10^7$	8.270	0.001
Fender	8836712.289	3	2945570.763	0.665	0.577
Repeat	8503756.995	2	4251878.498	0.959	0.388
Angular speed	1.595 $\times 10^7$	4	3987877.250	0.900	0.469
Angle, shock absorbers	1.022$\times$ 10^7	6	1703819.410	0.384	0.877
Speed, shock absorbers	4.407 $\times 10^7$	6	7344991.370	1.657	0.145
Angle * Speed * Shock absorber	1.256 $\times 10^8$	12	1.047 $\times 10^7$	2.361	0.013
Error	3.103 $\times 10^8$	70	4432686.317	-	-
Total	5.908 $\times 10^9$	108		-	-

Table2.
Analyze of Variance (ANOVA) for test data

C. Interaction angle, velocity and mass data recorded on the bumpers

Table 3 shows average of mass data read by load-cells, lower and upper limit of mass data with interaction angle, speed and shock absorbers. In this analysis, the best arrangement was angle of 30 degrees, moving with a speed 4km.h^{-1} and use the shock absorber made of 20 mm thick polymer. Error for this mode was 4.85 percent. The best arrangement in angle of 37 degrees was moving with a speed 2km.h^{-1} without using shock absorbers with an error of 2.18 percent. The best angle in 45 degrees was moving with a speed 2km.h^{-1} speed and use the shock absorber made of 20 mm thick polymer with an error 16.34 percent. As seen best in all the three analyzes conducted is moving with a speed 2 km.h^{-1}, the tray angle of 37 degrees without using a shock absorber that has the least error compared to other states.

Table3.
Interaction between plate angle, speed and shock absorber

Angle (degree)	Traveling speed (Km/hr)	Shock absorber	average	Standard error	95% Confidence level: Lower limit	95% Confidence level: Upper limit	Error (%)
30	4	Without shock absorber	5064.947	1215.550	2640.609	7489.285	4.85
		Thickness 10 mm	6660.385	1215.550	4236.047	9084.723	
		Thickness 20 mm	9514.713	1215.550	7090.375	11939.051	
		Double wall polycarbonate	5559.403	1215.550	3135.065	7983.742	
37	2	Without shock absorber	9718.522	1215.550	7294.184	12142.860	2.81
		Thickness 10 mm	7375.126	1215.550	4950.787	9799.464	
		Thickness 10 mm	11394.071	1215.550	8969.732	13818.409	
		Double wall polycarbonate	8370.050	1215.550	5945.712	10794.389	
45	2	Without shock absorber	5898.741	1215.550	3474.402	8323.079	16.34
		Thickness 10 mm	6945.942	1215.550	4521.604	9370.280	
		Thickness 20 mm	8365.639	1215.550	5941.300	10789.977	
		Double wall polycarbonate	5200.700	1215.550	2776.362	762.038 5	

IV. CONCLUSION

In the use of shock absorbers made of 20 mm thick polymer because the value of R^2= 0.97, and was close to 1, weighting system measured weight values close to the actual values. In Analysis of Variance (ANOVA) and Duncan's comparison method, by changing the angle of tray and traveling speed, results significantly changed, but with various shock absorbers and repeat no significant difference seen.

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