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INSTRUMENTATION SYSTEMS REVOLUTIONIZING AGRICULTURE: A COMPREHENSIVE REVIEW

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Abstract

Accurate measurement of parameters plays a crucial role in advancing the research and development of farm machinery. The reliability of data is imperative for the mass production of efficient agricultural machines. Instrumentation, involving computerized instruments and electronic systems, has been pivotal in achieving this accuracy. This paper delves into the realm of instrumentation in the context of agricultural machinery, addressing its significance, components, and diverse applications.

The utilization of instrumentation spans various sectors, but its prominence in agriculture is indisputable. From farm surveying to processing, storage, and laboratory experiments, instrumentation finds multifaceted applications. Notable advancements have been witnessed in electronic instrumentation systems, with components such as load cells, strain gauges, sensors, and transducers gaining prominence.

To exemplify the practical application of instrumentation, the study highlights several instances. Owende and Ward's (1997) low-cost data acquisition system, the towed ring, is an embodiment of this technology. John et al. (2007) used pressure transducers to evaluate soil post-load responses, and cone penetrometers with load cells have been employed to assess soil strength and density. Mardani et al. (2010) and Ale et al. (2013) developed instrumentation systems for draught and compaction measurement.

In the context of precision seed planting, monitoring tools have emerged for quantifying planting quality and quantity. Utilizing technologies like photoelectric and piezoelectric effects, infra-red sensors, and single-chip microcomputers, these systems enhance the accuracy of planting operations. Techniques like electromagnetic induction, magnetic resistance effects, and the hall effect have also proven valuable in quality and quantity measurement, even in harsh environments.

The study's focal point is the automatic measurement of draught and counting of planted stakes in cassava planters. Achieving these goals

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necessitates sophisticated instrumentation systems. This paper presents a comprehensive exploration of the theoretical and practical aspects of agricultural instrumentation, shedding light on its pervasive influence across diverse stages of farming processes. Through the integration of electronic components and advanced sensing technologies, instrumentation continues to play a pivotal role in reshaping agricultural practices for enhanced productivity and efficiency.

1. INTRODUCTION

Accuracy in measuring parameters is key in research and development of farm machinery. It is required in order to provide reliable data for farm machinery industries to mass produce efficient machines for agricultural production. This can be achieved through instrumentation which involves the use of computerized instruments and electronic system. Instrumentation was defined by Haslam et al. (1993) as the application of instruments for monitoring, sensing and measurement. Its purpose may be product testing and quality control; monitoring in the interest of health safety or costing; part of a control system or research and development. Various types of instrumentation systems especially the mechanical ones have been in use but there is an increasing usage of computer and electronic equipment (Haslam et al., 1993). The major components of the electronic instrumentation system are load cells, strain gauges, sensors and transducers (Haslam et al., 1993; Suwanee et al., 1999; Usher and Keating, 1996). The use of instrumentation systems varies from one area of life to the other, but in agriculture, instrumentation system is applicable almost in all aspects of agriculture starting from farm surveying to processing and storage in terms of monitoring and control, even in laboratory experiment.

Owende and Ward (1997) developed a towed ring which was a low-cost data acquisition system for tillage tool to measure draught, vertical force reaction, moment about the vertical axis, depth and speed. The main components of the towed ring include a data logger with a portable computer, tensile load cell, chain-driven tachogenerator and speedometer units for recording and monitoring speed respectively, a linear potentiometer for sensing depth and a two-component octagonal ring transducer for measuring moment and vertical force reaction in the shank of the mounted tool.

John et al. (2007) used a pressure transducer to assess the soil post load response to 1,338 kg bogie striking the post at 33 km/hr. Cone penetrometer that consists of a load cell had been widely used in tillage and off-road mobility researches as an indicator of soil strength and density characteristics (Manuwa and Ale, 2011; Nader – Boldaji et al., 2008). In a soil – tool interaction study reported by Mardani et al. (2010), the instrumentation system used for data acquisition system was made up of some sensor outputs interfaced to a computer system. It was reported by Mamman et al. (2002) that the draught of model chisel plough in a laboratory soil bin by the use of bonded electric resistance wire strain gauges to measure the horizontal component of working resistance in the direction of motion. An extended octagonal Rig Transducer (EORT) was used to measure the horizontal and vertical reaction forces generated from soil tool interaction on the field (Pitla et al., 2009). The EORT consisted of a machine block made of AISI 1045 alloy steel. An instrumentation system was also developed by Ale et al. (2013) to measure the values of draught of a mouldboard plough at varying speed forward speeds and compaction characteristics. The system consists of a 10-ton load cell that was interfaced with a computer system and sensor outputs, strain gauge amplifier and a data logger.

In the area of precision for seed planting, there are devices that can monitor the quantity and quality of planting in terms of the number of seeds planted per hectare per time. The monitoring of metering quality could be technically done by photoelectric effect, piezoelectric effect and highspeed photography (Hu and Li, 2005;

Soyoye, 2018). In the single chip micro computer technology, infra-red photoelectric sensors are installed near the furrow openers to monitor the performance of the planter (Gong, 2008). Kocher et al. (1998) and Soyoye (2018) respectively used optoelectronics technology to detect the uniformity of row spacing and automatic counting of seeds planted. An automatic monitoring system for direct seeding was designed by Zhang and Zhao (2008). With the development of electronics and sensors, the following methods are applicable for quality and quantity measurement. The electromagnetic induction method that is based on Faraday's law of electromagnetic induction; magnetic resistance effect method which utilizes the changing characteristics of materials resistance under magnetic field; hall effect method that is achieved by measuring the electromotive force; the magnetic resistance imaging which is by absorption or radiation of a certain frequency of electromagnetic wave in the magnetic field and the magnetic optical method which utilizes magneto optical and magneto-structure effects. This method is unique because of its adaptability to harsh environment Soyoye, (2018).

Accurate measurement of draught is important for determining power requirement of a cassava planter and selecting appropriate tractor as well as choosing the forward speed to operate the planter. It is also necessary to know the number of stakes cassava planter plants per time.

The objective of this study was to install and evaluate the performance of an instrumentation system for automatic measurement of draught and counting of planted stakes.

2. MATERIALS AND METHODS

2.1 Instrumentation System

The Instrumentation system for the automatic measurement of draught and the electronic counting consists of a load cell and the data acquisition components which include load cell amplifier, opto coupler module, Micro-Controller, LCD display, SD-card shield and Cable.

2.1.1 Load Cell

A 5 tons load cell (Figure 1) of no. 091209770 and output 2.005mV/V- (TM AUTO INSTRUCO, LTD) was used for the soil draught measurement.

Figure 1: Load Cell

2.1.2 Data Acquisition System

The data acquisition system (Figure 2) consists of the load cell amplifier that performs the function of amplification of electronic signal from as sensed by the load cells; opto-coupler module for light emitting; micro-controller for precise motion control; LCD display for electronic digital display of values as measured by the system; SD-card shield for data storage and cable for wire connection between the system and the tractor. The system was designed to be powered by the battery of the tractor.

Figure 2: Data Acquisition System

2.1.3 Installation of the load cell and Circuitry Works of Instrumentation System

The load cell was installed on the frame of the cassava planter by the use of brackets as presented in Figure 3. The components of the system were circuited at the Instrumentation Laboratory of the Department of Physics, Federal University of Technology, Akure. The circuit diagram of the system is presented in Figure 4.

Figure 3: Load Cell and Bracket as installed on the Cassava Planter

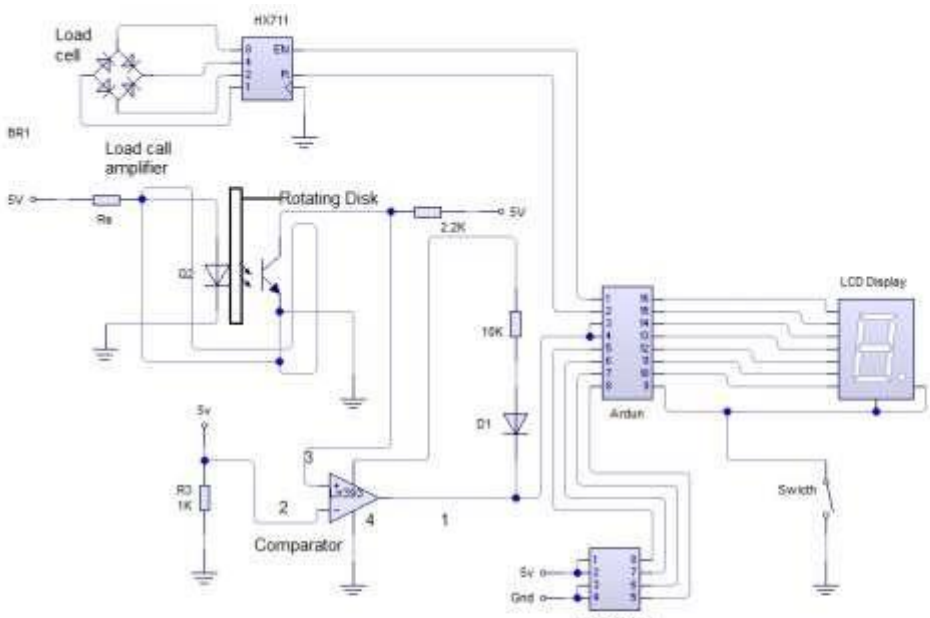

Figure 4. Circuit Diagram for the Instrumentation System

2.1.4 Calibration of the Instrumentation System

To ensure the accuracy of the measurements, the instrumentation system was calibrated in advance of being used for force measurement using the dead weight method (Figure 5).

Figure 5: Calibration Process of the Instrumentation System

2.2 Field Performance Evaluation of the Cassava Planter

The performance evaluation of the cassava planter was carried on the Teaching and Research Farm of Federal University of Technology, Akure, Nigeria. The performance evaluation to determine the effect of the draught and the power requirement of the planter. In the experiment, low tractor forward speeds of 1.5, 1.8, 2.1, 2.3 and 2.6 km/h were used at the constant furrow depth of 100 mm. The low speed selected for the study were within the acceptable values for operation of farm machinery in its category. At each of the forward speed, the soil draught was electronically measured using the on-the-go soil draught measuring instrumentation system developed for this research purpose. Details of the soil preparation, soil measurements and analysis, method of data analysis and the evaluation procedure are presented below.

2.3 Soil Bulk Density and Moisture Content

Soil samples were collected from the depth of 0-5, 5-10 and 10-15 cm by the use of a core sampler of 5.8 cm diameter and 5 cm height. The core sampler was driven into each depth of the soil and the collected soil was kept in an air tight polythene bag to avoid moisture loss. The sample was oven dried and weighted. The oven dried soil was allowed to cool for one hour. The bulk density was determined using the standard Equation (1). The moisture content of the soil was taken using a soil moisturemeter at the soil depth of 5, 10 and 15 cm.

$$\text{Bulk Density} = \frac{Mass(g)}{Volume(cm^3)} \tag{1}$$

3. RESULTS AND DISCUSSION

3.1 Result of the Calibration Test of the Instrumentation System

The calibration test on the load cell showed excellent linearity with the coefficient of determination r^2 of 0.9997. The calibration curve is presented in Figure 6. This is in conformity with the results obtained by Mardani et al. (2010) and Ale et al. (2017) for similar studies of soil-tool interaction on outdoor soil bin. The results have shown that the system has the potential to be used for the on the go and automatic measurement of soil forces in soil machine interaction studies.

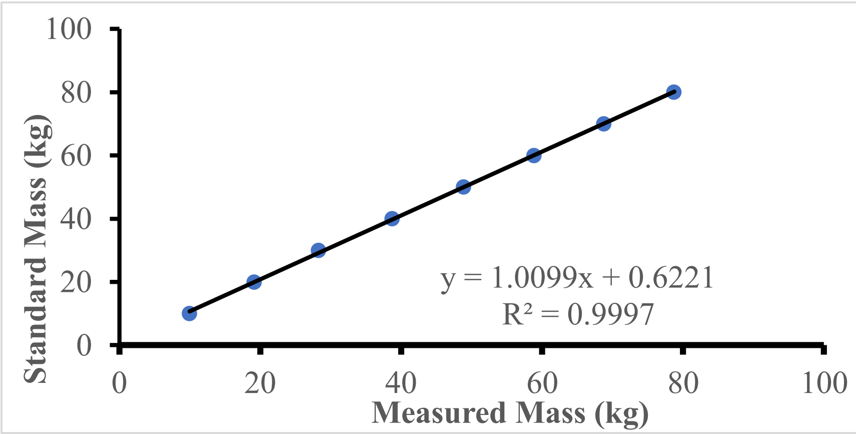

Figure 6: Calibration Curve of the Load Cell

The electronic stake counting system was also tested suitable for automatic counting of the number of cassava stakes planted per time (planting rate). The real-time curve of the test is presented in Figure 7. Average planting rate of 30, 36 and 42 stakes per minute were recorded as measured by the instrumentation system in the test at the forward speed ranging between 1.5 and 2.6 km/h.

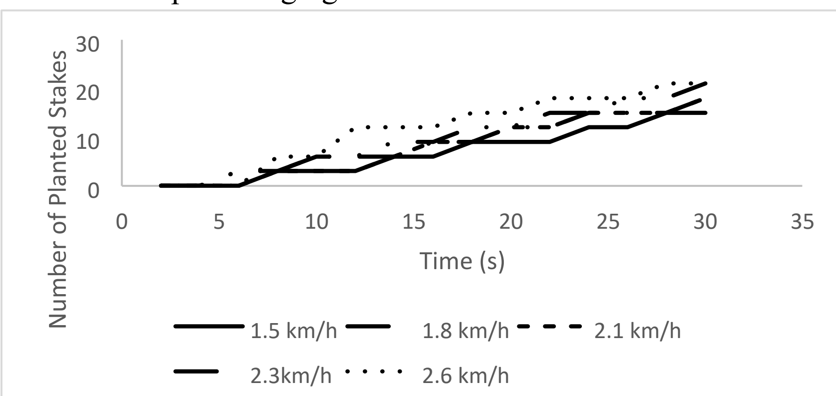

Figure 7. Real-Time Curve of the Automatic Counting System of stakes

3.2 Effect of Tractor Forward Speed on the Draught Requirement of the Planter

The performance evaluation of the cassava planter showed that there was an increase in the average value of draught from 24.91 N to 744.44 N as forward speed increased from 1.5 to 2.6 km/h at a soil depth of 100 mm and average soil moisture content of 14 %. This is in conformity with the study by Veerangouda and Shridhar (2009) in which the effect of planter forward speed and depth of operation on ground wheel speed was carried out. The result was also similar to Abdalla and Mohamed (2017). But it was contrary to Ale et al. (2017) that reported that the values of draught increased with an increase in operating speed and later decreased with further increase in speed in the study on the performance evaluation of an instrumentation system for soil draught measurement in which high tractor forward speeds and a mouldboard plough as the tillage tool were used. The power regression model that described the relationship as presented in Figure 8 is with coefficient of determination r^2 of 0.9377.

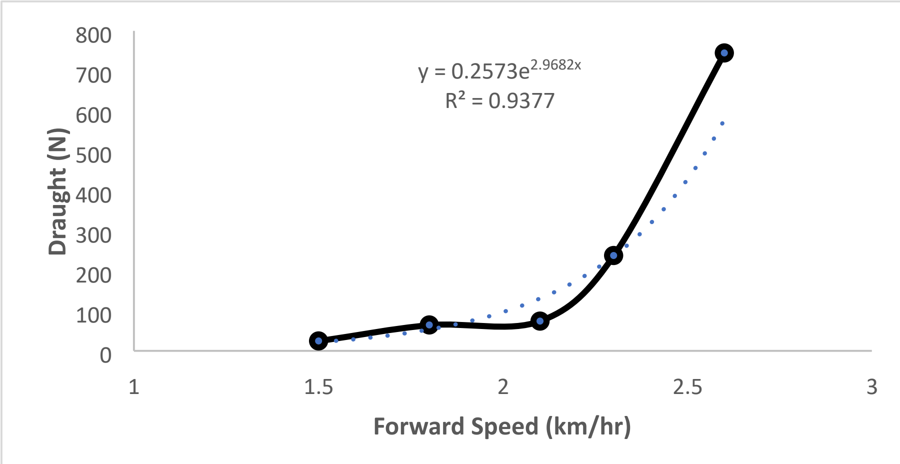

Figure 8: Effect of Tractor Forward Speed on draught Requirement of the Planter

4. CONCLUSIONS

The following conclusions can be drawn from this study:

1. Electronic instruments were developed and installed on the cassava planter for automatic measurement of draught and counting of planted stakes per time.
2. The instrumentation was found suitable for automatic measurement of the draught of the planter as well as counting of stakes planted per area per time.
3. The forward speed had a strong correlation with the draught requirement of the planter.

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