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Development of Digital Tractive Transducer

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Abstract: Construction equipment, agricultural tractors and cross-country vehicles can only perform their given tasks when tyre matches the vehicle design, the vehicle weight and the ground on which they operate. This Research involves the design and fabrication of a digital tractive transducer to measure the effects of press wheel vertical force on the germination rate of grain crops. Design criteria, calculations and analysis of various components of the transducer were critically carried out, and then used to design, fabricate and assemble the digital tractive transducer. The effect of press wheel vertical force on seed germination showed that the crops germinated well at low press wheel loads, while high press wheel loads adversely affected the percentage germination of the crops. Maize and soybean had increasing percentage germination trends between no load and 60 N load, where any press wheel load of more than 60 N greatly affected their germination rates. For cowpea, it is better planted with no additional loads on the press wheel because the highest percentage germination was recorded at no load.

Keywords: Tractive, press wheel, vertical force, planter, germination rate, grain crops

1. Introduction

Net traction ratio is one of the pertinent measures of tyre tractive performance [1]. An adequate knowledge and understanding of the basic principles of tire traction is essential to help managers and engineers for proper designing of new machinery and appropriate matching and selection of tractor-implement system [2; 3]. Research studies indicate that about 20–55% of the energy developed to the drive tractor wheels is wasted in the tyre–soil interaction [4; 3]. This energy is not only wasted but the resulting soil compaction created by a portion of this energy may be detrimental to crop production. Consequently, this loss of energy by pneumatic tyre has promoted researchers to search for operational parameters that could improve net traction ratio and tractive efficiency [5; 6].

The most common application of high energy requirement of the agricultural tractor is soil preparation with implements hitched to the drawbar, and sometimes in the three-point hitch [7]. In both situations, the draft force required to perform the specific agricultural labour is available due to the balance of forces at the interface agricultural soil-tractor or better soil- traction device (in most cases, the traction device is a tyre), through the phenomenon called Traction [8; 6].

1.1 Statement of Problem

Tractive performance parameters of driven wheels account for the most prominent operational task of agricultural tractors. Qualitative and quantitative analysis of traction force in a precise manner needs to be feasibly performed in soil and crop environment under the provision of a controlled condition. Also, the proper optimization of tractive parameters could, therefore, help to minimize energy dissipation.

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1.2 Aim of the Research

The purpose of this research work is to design and calibrate a digital tractive soil transducer. The basic components required in building and calibration of a digital tractive soil transducer includes; a load cell, HX711 weight sensor module (consisting of an amplifier, Arduino UNO), standard masses, and battery. The digital tractive soil transducer is then calibrated and tested on the press wheel of a grain crop planter.

2. Materials and Methods

2.1 Design Consideration

The following design considerations were made in the design of a digital tractive soil transducer:

i. **Affordability**: In the construction of the digital tractive soil transducer, cost-efficient materials were used.
ii. **Availability of Materials of Construction**: Materials used in the design were locally sourced.
iii. **Design Complexity**: For the ease of fabrication and assembling, the complexity of the design was straightforward.
iv. **Design Accuracy**: The accuracy of each component in the design were factored into this project. Like the load cell, which is a resistive element.
v. **Strength and Durability**: For the optimum performance of the device, materials of considerable strength and durability were used in this project.

2.2 Description of the Machine

The conception of the machine is based on measuring the tractive force exerted on the soil by the tractor tyre. This involves the Input and Output processes. In this research work, Arduino was used to control whole the process. Load cell senses the weight and supplies an electrical analog voltage to the HX711 Load Amplifier Module. The HX711 is a 24 bit analogue to digital converter, which amplifies and digitally converts the Load cell output. A load cell usually consists of four strain gauges in a Wheatstone bridge configuration. The load cell is a transducer that transforms force or pressure into electrical output. Then this amplified value was fed into the Arduino. The magnitude of this electrical output is directly proportional to the force being applied. Load cells have a strain gauge, which deforms when pressure is applied to it. Then strain gauge generates an electrical signal on deformation as its effective resistance changes on deformation. The electrical signals generated by the Load cell are in few millivolts, so they needed to be further amplified by some amplifiers and hence HX711 Weighing Sensor comes into the design. HX711 Weighing Sensor Module has HX711 chip, which is a 24 high precision A/D converter (Analogue to digital converter). HX711 has two analogue input channels and it can get gain up to 128 by programming these channels. So HX711 module amplifies the low electric output of Load cells and then this amplified and digitally converted signal is fed into the Arduino to derive the weight (Fig. 1).

The load cell is connected with the HX711 Load cell Amplifier using four wires. These four wires are Red, Black, White, and Green/Blue. There may be a slight variation in the colours of wires from module to module. Below the connection details and diagram:

i. RED Wire is connected to E+
ii. BLACK Wire is connected to E-
iii. WHITE Wire is connected to A-
iv. GREEN Wire is connected to A+

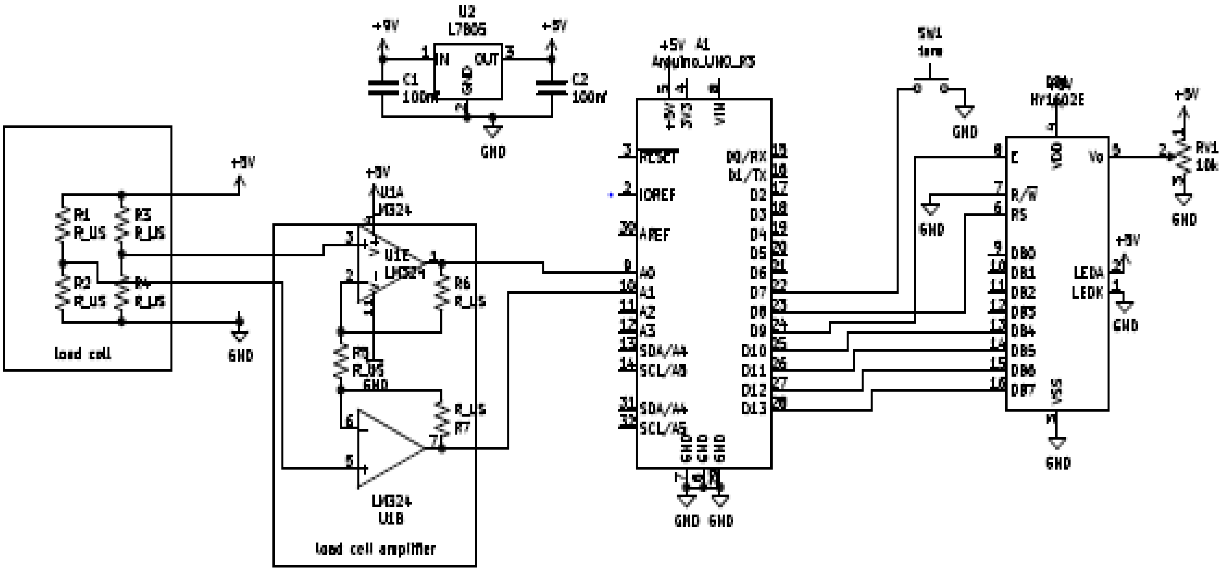

Fig. 1 - The Circuit Diagram of the Transducer

2.2 Arduino UNO Board

There are various types of micro-controllers ranging from PIC, Motorola, 850, AVR among others. Arduino make use of the AVR (Atmega-328) to design the board (Arduino-UNO) because it is user friendly. Also, it is suitable for this project because it is flexible, its power management and less expensive. This board is programmable, and this can be done through the Programmable port connected to the board (Fig. 2 and 3). The programmable language is C++ (Fig. 4). After, Calibration is done. The board undergo a calibration procedure using an Arduino Sketch (Arduino 1.8.10) using 57600 baud rate. This is crucial for calibration, to register the standard masses for measurement. The Arduino-UNO board converts the amplified electrical signal from the HX711 Weighing Sensor Module to be displayed on the Liquid-crystal display screen.

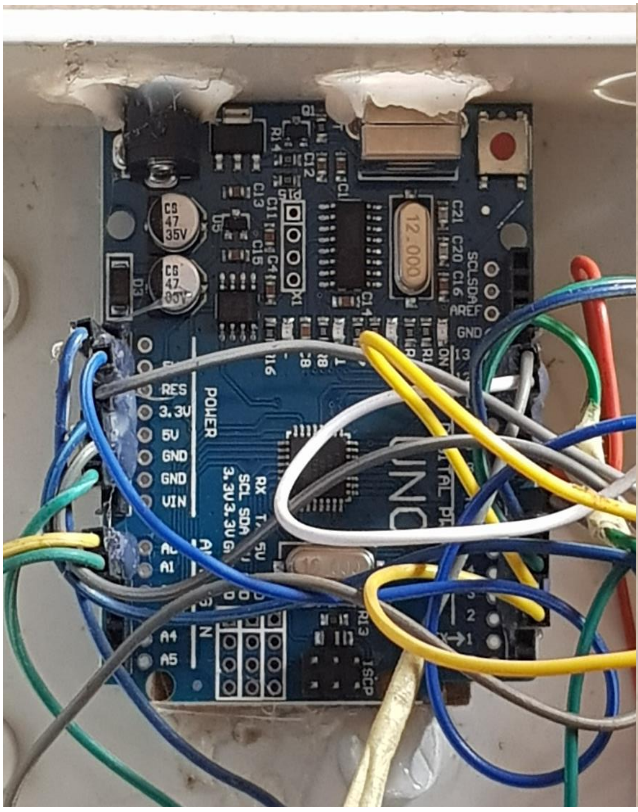

Fig. 2 - Arduino UNO board

Fig. 3 - Programmable port and chargeable port

```
/*
Arduino  pin  2 -> HX711 CLK 3 -> DOUT 5V -> VCC GND -> GND
*/

#include "HX711.h"
#define DOUT  3
#define CLK  2

HX711 scale(DOUT, CLK);
#include <Wire.h>
#include <LiquidCrystal_PCF8574.h>

LiquidCrystal_PCF8574 lcd(0x3F);
float calibration_factor = -96650;
const int SW = 7;
void setup()
{
  Wire.begin();
  Wire.beginTransmission(0x3F);
  pinMode(SW, INPUT_PULLUP);
  lcd.setBacklight(255);
  lcd.begin(16, 2);
  lcd.setCursor(0,0);
  lcd.print("Nissi 3kgLoadCell");
  lcd.setCursor(0,1);
  lcd.print("Press Sw to tare");
  scale.set_scale(-849650);
  scale.tare();
}
 void loop()
 {
   lcd.setCursor(0,1);
   lcd.print("W =  ");
   lcd.setCursor(6,1);
   lcd.print(scale.get_units(),3);
   lcd.println(" kg   ");
   int x = digitalRead(SW);
   if(x == LOW)
   {
 |   scale.tare();
   }
 }
```

Fig. 4 - Programming of the Transducer

2.3 Load Cell and Supporting Structure

The load cell is secured and protected in a designed frame such that the weight could be put directly on the frame before the impact could be felt by the load cell. A base is also required to fix the load cell over it by using nuts and bolts. Here, hard wood was used for the frame for placing things over it and a wooden board as the base (Fig. 5).

Fig. 5 - The Load Cell with Support Structure

3. Results and Discussion

3.1 The Developed Machine

The complete designed, fabricated and assembled digital tractive transducer was calibrated using standard loads (Fig. 6).

Fig. 6 - Calibration of the Developed Transducer

3.2 Field Experiment

The calibrated digital transducer was attached to the press wheel of a multigrain crop planter for vertical loading measurement (Fig. 7). A tubeless with low pressure tyre was selected for the press wheel. This was chosen to reduce soil compaction and to give the best soil-seed conducive and interactive environment. The diameter and width of the wheel were 0.15 m and 0.07 m respectively. The press wheel is incorporated with the tractive transducer to vary the vertical forces applied on the planted crop. The effect of these varying loads on the crop germination was well monitored. The press wheel has a support which was constructed using a hollowed mild steel rod of 1 mm thickness and 25 mm squared length with a cross sectional area of 9.6×10^{-5} m^2. The wheel support has five (5) segments of total length of 1.09 m, whose volume, mass and force were calculated to be 1.046×10^{-4} m^3, 0.821 kg and 8.06 N respectively. The press wheel is a component of the planter that helps in soil-seed consolidation. A load cell incorporated on the press wheel helped in the application of varying loads (forces) on the soil-seed. The germination test for maize, soybean and cowpea before planting was conducted randomly for each seed samples. This test was conducted on the seeds to establish effect of the press wheel loads on the germination rate of the seeds. The germinated seeds were counted after 4 to 7 days and were expressed as percentage of the total seed expected. During the operation of the planter, varying loads were applied on the planted seed and the number of days before emergence of the seeds with respect to the varying loads were noted, recorded and tabulated accordingly. The percentage germination of the planted seeds on each of the plots was determined by counting the germinated seeds on each of the plots at the end of the seventh day of planting (Fig. 8). The total number of germinated seeds was expressed against the total number of expected plant stand in each of the plot to obtain the percentage germination.

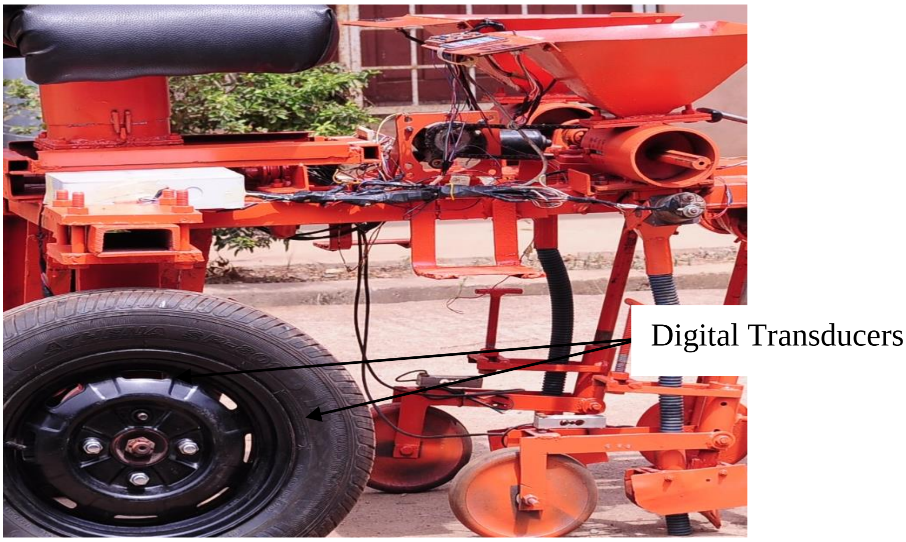

Fig. 7 - Transducer Attachment to the Press Wheels

Fig. 8 - The Plant seeds on the Plot a day and seven days after Planting

3.3 Effect of Press Wheel Vertical Force on Seed Emergence

The press wheel is a component of the planter that helps in soil-seed consolidation. A load cell incorporated on the press wheel helped in the application of varying loads (forces) on the soil-seed. The germination test for maize, soybean and cowpea was conducted randomly for each seed samples before planting. During the operation of the planter, varying loads were applied on the planted seed. The germinated seeds were counted 7 days after planting and were expressed as percentage of the total seed selected. The percentage germination of the planted seeds on each of the plots was also determined by counting the germinated seeds on each of the plots at the end of the seventh day of planting. The total number of germinated seeds was expressed against the total number of expected plant stand in each of the plot to obtain the percentage germination. Fig. 9 showed that the three crops germinated well at low press wheel loads and high press wheel loads adversely affected the percentage germination of the crops. The maize crop has an increasing percentage germination trend between no load and 60 N load (no pressure to 17.14 kPa). The same trend was recorded for soybean, where any press wheel load of more than 60 N greatly affects its germination rate. For cowpea, it is better planted with no additional loads on the press wheel because the highest percentage germination was recorded at no load (Fig. 9). The findings could be compared with what was recorded by Chen *et al*. [9] when they investigated the effect of press wheel and gauge wheel and fertilizer banding attachment on the performance of drill planter under field and laboratory conditions. They showed that when the press wheel and/or gauge wheel were not used, plant population was reduced and crop emergence was delayed both in normal and dry soil. But in a very wet seeding condition it resulted in better emergence and plant population. Also it was observed that seeding depth is less uniform when press and gauge wheels are not used. In the same trend, Hanna *et al.* [10] studied the soil loading effects of planter depth-gauge wheels on early corn growth. They concluded that, the emergence rate of corn plants was affected by load level and soil moisture conditions. With moist soil or in wet conditions, corn emerged more rapidly with a low load.

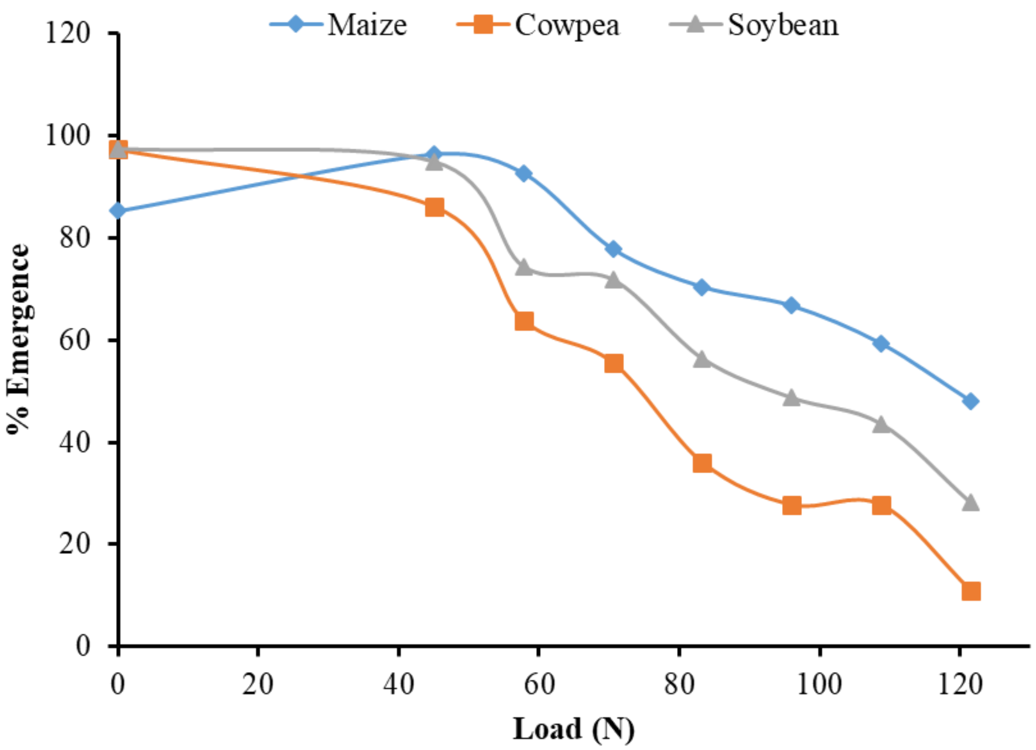

Fig. 9 - Effect of Press Wheel Vertical Force on Seed Emergence

4 Conclusions

An indigenous digital transducer was designed, fabricated and assembled using locally available materials. Instruments were installed on the transducer for prompt data collection and to enhance its performance. The effect of press wheel vertical force on seed germination showed that the crops germinated well at low press wheel loads, while high press wheel loads adversely affected the percentage germination of the crops.

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