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Detection of blockage of seed tube in seed drill by using lasor diode sensor

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Abstract
This research developed and tested an embedded laser diode detection system to sense seed flow and detect blockages in seed delivery tubes on seed drills. A model was designed to evaluate the system for a single furrow opener. The detection system used a laser module and receiver module positioned across the seed tube to sense interruptions in seed flow. An Arduino controller activated an alarm and LED indicator when a blockage was detected. The system was tested at tractor speeds of 3, 5, and 7 km/h and seed rates of 90, 100, and 110 kg/ha. Performance metrics evaluated were detection accuracy, false alarm rate, and alarm response time. Results showed the blockage detection system had 100% accuracy in detecting blockages, unaffected by speed or seed rate. The false alarm rate was low, ranging from 0.3 to 1.5 alarms per 100 data points. Higher speeds and seed rates increased the false alarm rate slightly. Alarm response time varied from 10-26 seconds depending on operating parameters. The developed laser diode system accurately and reliably detected seed tube blockages under different operating conditions with minimal false alarms. The system provides real-time feedback to the operator to take corrective action and prevent yield losses from unseeded areas during blockages.

Keywords: Sensor-based, seed drill, blockage and laser diode

Introduction

Sowing crops requires carefully placing seeds in the soil for optimal growth Gursoy (2014) [1]. This is achieved by using seed drill powered by tractor, power tiller, animal or human being. As farm mechanization has increased in India while animal power has declined, tractor-drawn seed drills are becoming more popular for sowing different crops. Mechanization rates for wheat sowing are around 45% in India, much higher than for paddy, cotton and corn Goyle (2013) [2]. Efforts to further increase mechanization rates for sowing should be made to facilitate subsequent mechanized operations. Tractor-drawn seed drills typically connect to the tractor's three-point hitch behind the operator. An important issue in cropping is using the proper plant density per area. The seed drill meters seeds based on ground wheel rotation, making the seeding rate independent of tractor speed. Seed drill performance depends on whether seeds actually drop into the furrows from the metering mechanism Raheman and Singh (2003) [11]. Since the operator cannot see the furrows as they are immediately closed after seeds are dropped, it is unknown if all seeds are properly placed. Another common problem is seed delivery tubes getting clogged from damp soil and residue accumulation, causing seeds to back up Kumar and Kumar (2023) [5]. Overcoming these issues would increase sowing mechanization and enable more effective subsequent operations.

Two main causes of missing seeds in the furrow during seed drill operation are no seed flow from the metering mechanism or a clogged boot Cuhac *et al.* (2012) [3]. These issues can arise due to several factors related to the machine, seed, field conditions, and operator. Machine factors include improper design of the seed meter, boots, and ground wheel; shifter stopper wheel vibration. Seed factors are high moisture content, shape/size (seed variety), and surface friction. Field factors are large clods, high soil moisture, residue, and uneven terrain. Operator factors include forgetting to lower the drill after turning and refilling the hopper when empty.

The key points are that seed flow and boot choking cause missing seeds, this arises from many factors, and some type of electronic feedback system is needed to alert the operator to take corrective action. Many researchers have tried detecting seed flow in seed drill delivery tubes using various technologies like visual sensors, capacitive sensors, microwave, piezoelectric, ultrasonic, infrared, and image processing Steffen (1976) [12]; Grimm and Paulson (1978) [10]; Lan *et al.* (1999) [6]; Karayel *et al.* (2006) [8]; Navid *et al.* (2011) [7] and Okopnik and Falate (2014) [9]. Though accurate for planting, it is untested for continuously dropped seeds like wheat and rice. A fiber optic sensor is used with transmitters, receivers, and amplifier to detect seed flow Al-Mallahi and Kataoka (2013) [4]. However, handling many emitters/receivers for each opener on a seed drill is difficult. Phototransistors also sense ambient light, causing errors. A specialized receiver is needed to receive only certain wavelengths. Various seed flow detection technologies have been tried, with laser diode showing promise. A laser diode detection system is needed to detect flow and warn operators on seed drills. This study aims to design such an embedded laser diode detection system to sense seed flow and boot-choking on seed drills for successful sowing.

Materials and Methods

The materials and methods section describes the design concept for the laser diode sensor, the development of the detection system, the experimental procedure and the performance evaluation of the developed system.

Laser diode System

It is comprised of laser module and a laser receiver module. The laser module produces beam light and the laser receiver module sense incoming signal from the laser module.

Laser Module

A laser module is a device that produces a highly focused beam of light, usually in the visible range. A laser diode is a semiconductor device that emits a light beam when current is supplied through it.

Laser Receiver module

The laser receiver module is utilized to accurately read the incoming signal. It provides a digital output, which is high when the laser is detected and low when the laser is not detected. This module plays a crucial role in capturing and interpreting the laser signal, ensuring precise detection and reliable performance.

Fig 1: Laser module and Laser receiver module

Design and development of an experimental setup for the detection of blockage in seed tubes

The chosen sensor for detecting blockages in seed tubes proved highly efficient.

It was designed to withstand vibrations, dust, and seed impact forces. While blockages typically occur at the boot due to soil, straw, etc., the sensor is strategically positioned on the lower boot to avoid being affected.

The experimental setup includes hardware, software, and control units.

The laser diode and receiver are opposite the boots. When seeds are obstructed, LED light transmits data and a buzzer activates.

Development of a model for measurement of the detection of blockage

The model was designed to measure blockage detection, essential for sowing machines. The entire model focuses on a single furrow. All aspects of its construction, components, configuration, and design were based on this. It has a seed hopper, shaft, flute, seed tube, furrow opener, and frame. A motor connects to ensure smooth operation and control. The motor has a regulator to adjust system speed. Seed rate can be adjusted by the flute exposure length. The blockage detection sensor is strategically positioned and the model allows focused development and testing of the detection system for a single furrow. The motorized system enables control over seed rate and speed.

Fig 2: Developed model for detection of blockage

Development of a program for the detection of blockage

A program was developed in Arduino IDE to detect blockages in seed tube boots. In the circuit diagram, the laser diode output pin connects to pin 2 and the receiver module output pin to pin 10 on the Arduino board. Pin 6 connects to an LED bulb positive pin and pin 7 to a buzzer positive pin. The positive and negative pins of the LED, buzzer, and IR sensor connect to the 5V and GND pins on the Arduino board respectively. The Arduino program interfaces with the laser diode, receiver, LED indicator, and buzzer to detect and signal seed tube boot blockages. The components are wired to specific Arduino pins to transmit and receive signals and power the indicator outputs shown in Fig. 3.

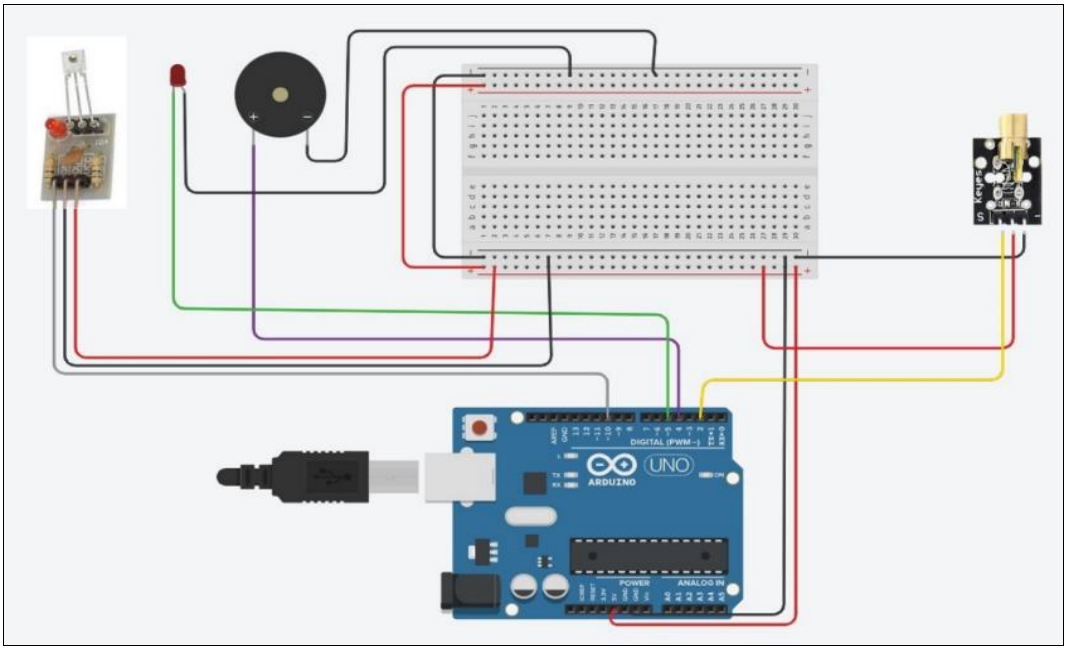

Fig 3: Circuit diagram for connecting the Laser module for blockage detection.

Evaluation of a developed system for the detection of blockage in the seed tube

The developed setup organizes the hardware, software, and controls. Sensors at the seed drill boots detect blockages. Blockage information is transmitted to the Arduino board, indicated by activating a buzzer and light. The system is evaluated for accurately detecting blockages. It is tested at various speeds and seed rates. Accuracy is checked by artificially blocking the tube and verifying the blockage is correctly indicated and signalled quickly. The sensing system was evaluated for blockage detection accuracy, false alarm rate, and alarm response time at three speeds (3, 5, 7 km/h) and three seed rates (90, 100, 110 kg/ha).

Experimental procedure

For testing, the model connects to the sensor at the boot and alarm/LED on the breadboard. The Arduino board connects to a laptop for programming and power. Blockage data displays on the Arduino serial monitor, showing blockage status and time in milliseconds. Accuracy was assessed by manually blocking and unblocking the boot, observing the system response. The false alarm rate was calculated from 100 seconds of data by tracking how often alarms were triggered without blockages. Alarm response time was measured by artificially blocking and timing activation.

In testing, the model was connected to the motor and sensing system. Data was collected under varying speeds adjusted via the motor regulator and seed rates adjusted by the flute length. The system was thoroughly tested for blockage detection performance under different operating conditions by connecting the instrumentation, artificially inducing blockages, and measuring the detection response.

Results and Discussions

This section of the research paper discusses the performance of the developed system in terms of the accuracy of blockage detection, false alarm rate, and alarm response time. The circuit developed for sensing seed flow and detection of choking in seed delivery tubes was verified using the laboratory setup. The flow chart of the developed detection system is shown in Fig. 4.

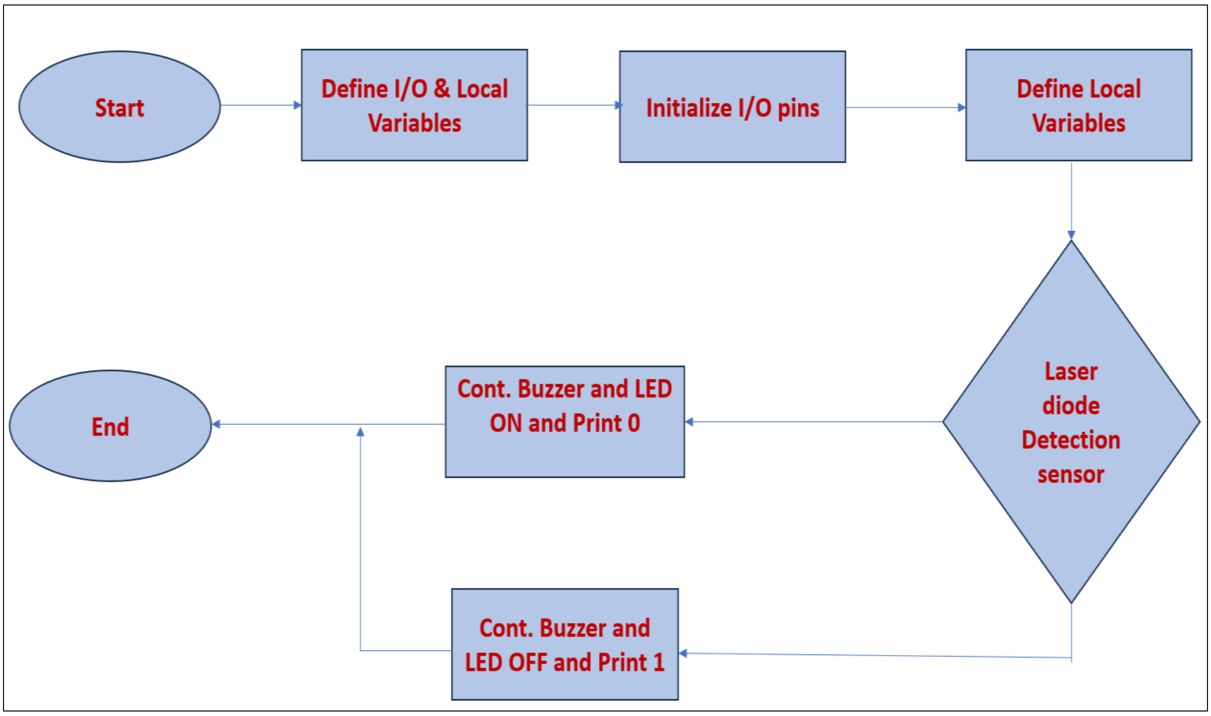

Fig 4: Flow chart for the developed embedded system.

Table 1: Fluted roller rpm and exposure length required for obtaining different seed rates of wheat.

Forward Speed of tractor, km/h	Speed of fluted roller, rpm	Exposure length of fluted roller, mm	Seed rate, kg/ha
3	20	8	90
3		8.5	100
3		8.75	110
5	33	8	90
5		8.5	100
5		8.75	110
7	46	8	90
7		8.5	100
7		8.75	110

Performance evaluation of the developed system for detection of blockage using laboratory setup

The developed system was evaluated at three different forward speeds and three different seed rates, as shown in Table 1. The developed system was evaluated in terms of the accuracy of detecting blockage of the seed tubes, the false alarm rate, and the alarm response time after a blockage occurred.

The developed blockage detection sensing system had 100 percent accuracy. This was checked by manually blocking the seed tubes and verifying that the sensing system detected it. There was no effect of RPM or seed rate on the accuracy.

Table 2: False alarm rate of Laser Diode sensor at different speeds and different seed rates

RPM/Seed rate, kg/ha	90	100	110
20	0.3	0.8	1.1
33	0.5	1	1.3
46	0.9	1.1	1.5

Table 3: Time delay (second) in Laser diode system at different speeds and different seed rate

RPM/Seed rate, kg/ha	90	100	110
20	26	23	21
33	17	15	13
46	12	11	10

Table 4: Unshown Area (m^2) during time delay at different speeds and different seed rate

RPM/Seed rate, kg/ha	90	100	110
20	4.3	3.9	3.6
33	4.3	3.9	3.6
46	4.3	3.9	3.6

Evaluation of developed detection system in terms of False alarm rate

The false alarm rate was the rate of false indications of an alarm without actual blockage of the seed tube. The developed system took data at 0.1-second intervals over 100 seconds. During these 1000 data points, the number of times an alarm incorrectly indicated a blockage was calculated as the false alarm rate. The false alarm rate at three different RPMs of the fluted shaft and three different seed rates is shown in Table 2. The false alarm rate was minimal at 20 RPM of the fluted shaft and 90 kg/ha seed rate, and reached a maximum at 46 RPM of the fluted shaft and 110 kg/ha. As the speed increased, the false alarm rate also increased, and similarly as the seed rate increased.

The time delay in the alarm response time was mainly due to the time needed for seeds to fill the boot and reach the level of the sensors in order to trigger the blockage signal and alarm. The response time was maximum at lower speeds and lower seed rates because it took more time to fill the boot to the sensor level. It was minimal at higher speeds and higher seed rates. The minimum alarm response time occurred at 46 RPM and 110 kg/ha seed rate, while the maximum response time occurred at 20 RPM and 90 kg/ha seed rate. The data on alarm response time is shown in Table 3. During this alarm response time, some area went unshown and this area had no yield because of lack of seed. The corresponding unshown area is tabulated in Table 4. The unshown area was constant at every seed rate at different speeds because the area covered at a fixed seed rate was calculated based on speed and time. If speed increased, the response time decreased so the area remained constant. With an increase in seed rate, the unshown area decreased because the volume of the boot was fixed, so as the seed rate increased, the time required to fill the boot decreased.

Conclusions

The developed system could successfully sense the seed flow and blockage detection at seed rate from 90-110 kg/ha at different forward speeds of the tractor (3-7 km/h). The developed system provides information of the blockage of seed tube in term Alarm ON. The following specific conclusions were drawn from the study concluded:

1. The blockage detection system had 100% accuracy in detecting blockages.
2. The false alarm rate was low overall, ranging from 0.3 to 1.5 false alarms per 100 data points. Higher RPM and seed rate increased the false alarm rate slightly.
3. The alarm response time ranged from 10-26 seconds depending on RPM and seed rate. Higher RPM and seed rate decreased the response time.
4. The response time delay resulted in some unshown areas during blockages. The maximum unseeded area was 4.3 m^2 at low RPM and seed rate.

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Conflict of interest

There are no conflicts of interest, either directly or indirectly, related to the work submitted for publication.

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