Designing, developing and testing of Arduino-based slip meter

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ABSTRACT

A simple technique based on a hall sensor was developed to measure wheel slip of agricultural tractors and an embedded storage system based on a micro-controller was incorporated for recording the slip data. The slip meter comprised five components viz power supply, hall sensor, magnets, micro-controller and storing unit. The system developed was simple in design and could be built on any make and model of the agricultural tractors. Slip meter was evaluated under laboratory as well as under field conditions. Field trials were conducted and were compared with the traditional method. The analysis of the measurements obtained from designed slip meter with the actual measurements obtained indicated that there was no significant difference between the readings.

Keywords: Hall effect sensor; slip meter; wheel slip; micro-controller; Arduino; fixture

INTRODUCTION

Slip is the single most significant parameter in terms of tractor performance prediction and measurement. Slip indicates the right combination of tyre pressure, operating speed and tractor weight (ballast) resulting in the correct traction for fuel saving and efficient performance of the tractor. It can also determine a tractor drive train and tyres wear and expected life time. A wheel slip that is too small may be a sign that the drive train is strained and that excessive weight is transferred. A very high wheel slip on the other hand indicates that tyres wear excessively and that excessive rotations are likely to waste fuel. Thus it is important in assessing tractor efficiency. The conversion of engine power to tractor drawbar power has to be improved with increased use of tractors in carrying out various farming operations. Significant efforts must be made to improve the drawbar efficiency of a farm tractor. A common parameter, wheel slip along with soil-wheel parameters, is included in the relationships developed by few researchers (Zoz 1970, Wismer and Luth 1974, Ismail et al 1981, Garber 1985, Brixius 1987) for predicting the tractor performance. When the slip is too high or too low, drawbar power drops rapidly from its maximum value. It shows that drawbar power is maximum at a particular wheel slip for a particular condition.

Several attempts to measure slip parameter have been made by various researchers understanding the significance of the slip. They used different techniques for accurate slip measurement such as electronic circuits using photo-transducer (Lyne and Meiring 1977, Prasad 1990), doppler radar effect (Thansandote et al 1977, Thompkins et al 1988) etc. Such designs were complex and expensive. The reliability and the precision of measuring the slip values in difficult terrain using the above methods mentioned have not been reported widely. These methods were mostly based on the theoretical velocity calculation on the test bed rather than working on a hard surface. The defined 'zero' condition was not precise thus indicating inaccurate slip values. In addition the measurement of tractor tyre slip with different implements and field conditions makes it even more difficult to indicate instantaneous slip. The methods or instruments which are currently in use for measuring slip are either less accurate or highly sophisticated expensive technologies. Generally the wheel slip is measured by counting the number of revolutions of rear wheel under load and no-load condition. But it has certain shortcomings since it is a time consuming and cumbersome method which is often susceptible to human error. Moreover more than one observer and recorder is required for measuring wheel slip and this method cannot be practiced for measuring wheel slip at higher velocities. Studies indicate that the acceptable range of wheel slip is in between 10 to 15 per cent.

Present study was conducted at KCAET, Tavanur, Kerala Agricultural University, Thrissur, Kerala to develop and evaluate a micro-controller-based wheel slip meter suitable for wide range of makes and models of tractors for automatic slip recording.

MATERIAL and METHODS

For the VST Mitsubishi Shakti Vt 224-1D, a micro-controller Arduino-based slip meter was developed. It essentially consisted of five parts viz power supply, hall effect sensor, magnets, micro-controller and storing unit. The power was supplied through a power bank. A micro SD card was used to record and store the slip data and data were analyzed through the system.

Conceptual design

Slip is defined as the proportional measure by which the actual travel speed of a wheel falls short or exceeds the ideal or zero slip speed. Therefore the slip magnitude depends on how the zero slip is measured and identified. The slip can be recorded by counting the number of revolutions of wheel. This can be achieved with the help of magnets and hall effect sensor. It is required to attach the hall effect sensor to the tractor by means of suitable fixtures attached to the tractor. The sensor must be held in position by using this fixture. A metal sheet of diameter 500 mm having equal divisions of 10^{o} marking was used to attach the magnets. The hall effect sensor senses and counts the number of magnets passing and thus can get the count of wheel revolutions. Thus the slip measurement can be accurately done by using sensors, micro-controller development board and a suitable storing unit. The micro-controller is used to communicate and control the sensor (Fig 1).

Fixture for sensor and magnets

The fixture for attaching the sensor should have enough strength and the component should be made of non-magnetic material. The component was fixed to the tractor with certain removable nuts and bolts arrangement which was already on the tractor as shown in Fig 2(a). It is necessary to attach the sensor in the tractor in such a way that the sensor must be stationary with respect to tractor tyre. The fixture which is attached to the tractor by means of fasteners, positions the sensor in the correct position without much vibration and with no hindrance to the movement of the tractor.

A metal sheet of diameter 500 mm was used to attach magnets at fixed position as shown in Fig 2(b). The metal sheet was made with magnetic material so that it held the magnets rigidly. This metal sheet was fixed to the tyre hub using magnets with opposite pole (North pole) since South pole causes the hall effect sensor to produce the voltage output. It is important to fix the magnet at specific distance or specific angle (say 10^{o}). To provide accuracy in marking angles on the sheet, angles were marked on a sticker and the printed sticker was pasted to the metal sheet.

Sensor for measurement of wheel revolution

The rear wheel of the tractor was fitted with metal sheets having 36 number of magnets at 10^{o} apart. With the aid of a device that included a micro-controller, hall effect sensor and magnets, the rear wheel revolution was measured at load and no-load. The metal sheet was attached to the rear wheel hub. The hall effect sensor for rear wheel was attached to fixture support from the tractor. The sensor counts the number of magnets fixed on the rear wheel. Clearance between the magnet and the sensor was not greater than 1.5 cm and was so close to the magnet (Fig 3).

A voltage pulse was generated each time a magnet passed through the hall effect sensor and this was detected by the micro-controller. Therefore for a single wheel revolution, there were 36 pulses. The assembled unit consisted of a micro-controller development board to detect the pulses and a micro SD card to store the data of number of revolutions on load and no-load conditions. Arduino development board was selected for programming which is simple and open

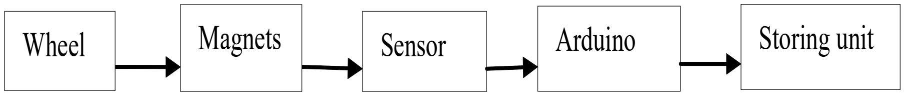
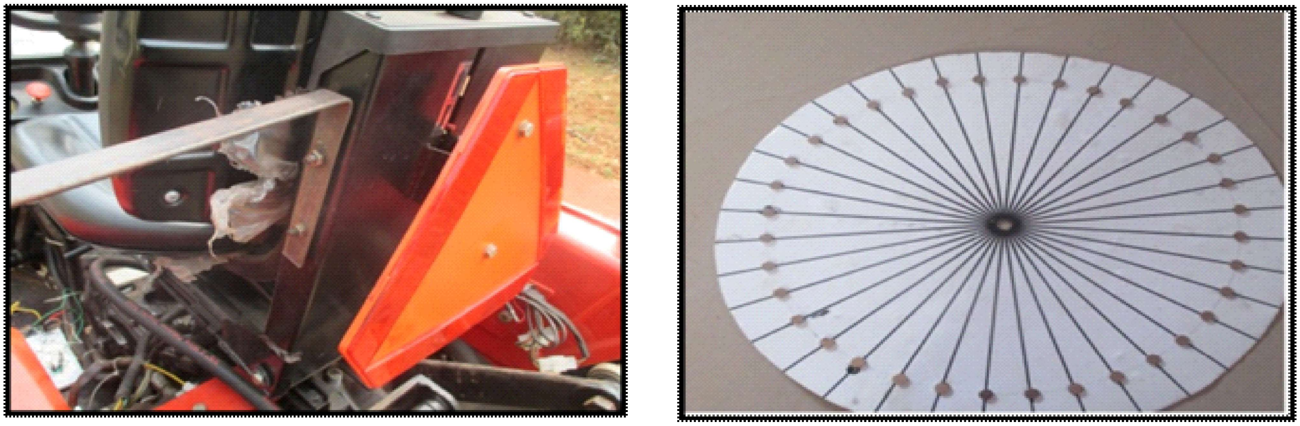


Fig 1. Block diagram of conceptual design



(a) **(b)**

Fig 2. (a) Fixture for sensor in VST Mitsubishi Shakti Vt 224-1, (b) Fixture for magnets

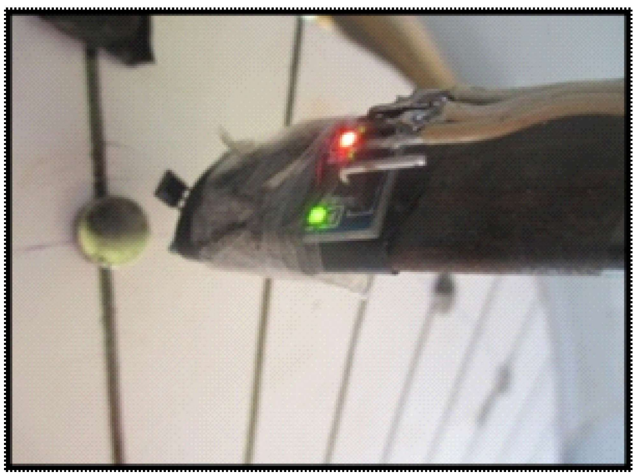


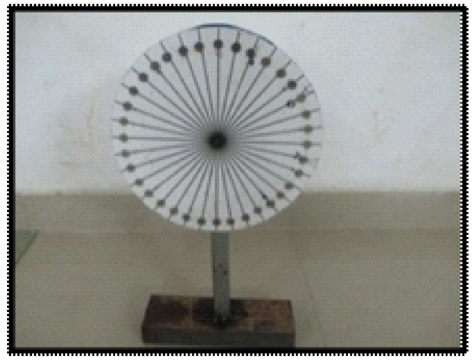
Fig 3. Closer view of sensor

source prototype platform. Arduino controls the movement of the instrument to take the readings and to store the readings. These data were then analyzed in the system and the slip was calculated.

For the working of Arduino board, 5 V supply is needed. A power bank was used to supply power to the Arduino. Recommended voltage value for Arduino is 7 to 12 V and the operating voltage value is 5 V. Power bank is sufficient to provide the recommended voltage.

Procedure for slip measurement

Laboratory test: The testing of the slip meter was carried out in laboratory setup to check the accuracy of slip meter; for the testing a rotating shaft supported by bearing block with two metal discs on both sides were used. Each disc was fixed with a circular metal sheet one having graduations from 0 to 360^{o} (sheet 1) as shown in Fig 4(a) and the other was divided equally into 36 parts (sheet 2) as shown in Fig 4(b) on which the magnets were attached. The circular sheets were fixed into the disc by means of magnets (using North pole). A handle was fixed on the shaft. Sheet 2 was fixed with magnets at the marked positions. The whole structure was supported on a stand. By rotating the shaft the number of revolutions was calculated by graduated scale and with slip meter. Indicated and actual values were compared using chi-square test.



(a) **(b)**

Fig 4. Metal sheet with (a) graduations, (b) magnets

Field test: The tractor was operated with two gears, low first and second for different rpm values viz 1,500 and 2,000. With the assistance of a micro-controller system the rear wheel revolution was recorded in terms of passing magnets. The revolutions were detected under load and no-load conditions for each gear as shown in Figs 5(a) and 5(b) transferred to the micro-controller. These data represented wheel revolutions at no-load condition (*nnl*) and load conditions (*nl*). The code for controlling the Arduino was prepared in Arduino IDE and loaded to the controller. The programme was able to estimate the rear wheel revolutions (*nnl* and *nl*) and stored in the micro-controller which in turn got stored into the memory card. Inserting memory card into the system gave the data in an excel file and thus indicated slip (*Si*) obtained using the equation as under:

$$Si\,(\%) = 1 - \frac{nnl}{nl} \qquad \text{.....(1)}$$

By using the similar equation, the actual slip (*Sa*) was calculated manually by counting the number of wheel revolutions (*nnl* and *nl*) as shown in equation (2). The comparison between the actual (*Sa*) and indicated values (*Si*) of slip was done using the chi-square test. The flowchart of the programme is shown in Fig 6.

$$Sa\,(\%) = 1 - \frac{nnl}{nl} \qquad \text{.....(2)}$$

RESULTS and DISCUSSION

The rear wheel revolutions in terms of magnets passing were recorded with the help of a micro-controller system for different rpm values (say 1,500 and 2,000) with two gears, low first and second. Arduino programme controlled the entire operations of the slip meter. Counting the number of revolutions and recording the values in the memory card were the various operations in the slip meter which were accomplished with the help of Arduino. The values of the number of rear wheel revolutions under load (*nl*) and no-load (*nnl*) conditions using the slip meter and the indicated slip values (*Si*) are given in Table 1. These numbers of revolutions were fed to the micro-controller so that slip could be calculated instantaneously for different gears and rpm values. Similarly the actual slip (*Sa*) measured using manual method for the same gears and rpm are also shown (Table 1).

Evaluation of the developed slip meter

On comparison the indicated slip values (*Si*) were found to be closer to the actual slip value (*Sa*). Some variations in the values were due to the errors occurring while rounding off the number of revolutions on calculating the slip manually. Thus the use of slip meter reduced these errors and gave much more accurate result with an accuracy of 10^{o}. The indicated and actual values were compared by using chi-square test statistically. As per the results obtained from this statistical measure it was concluded that the variations in the slip meter were insignificant and the slip meter developed was sufficiently precise in indicating the slip of the wheel. The variation was found to be in the range of 0 to 5.2 per cent (field trials) and 0 to 0.5 per cent (laboratory trial).

CONCLUSION

With the developed system consisting of magnets and hall effect sensor, rear wheel revolutions under load and no-load conditions were measured with

(a) **(b)**

Fig 5. Working of slip meter under (a) load condition, (b) no load condition

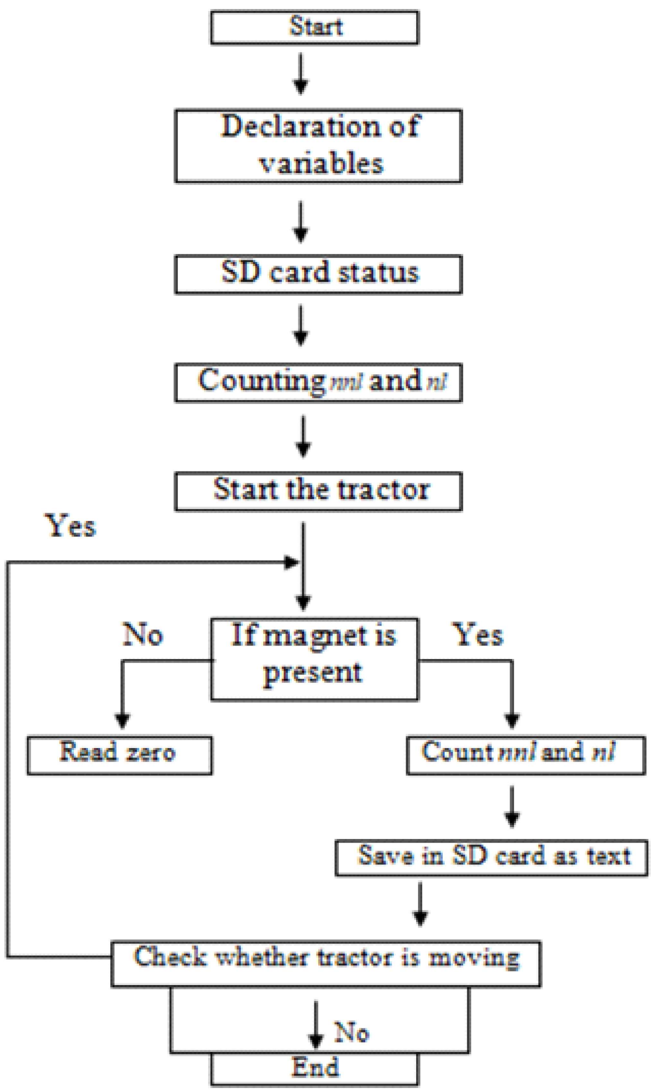


Fig 6. Flow chart for the software developed for slip measurement

Table 1. Indicated slip (*Si*) values using slip meter and actual slip (*Sa*) values using manual method

rpm	Indicated slip (*Si*) values				Actual slip (*Sa*) values			
	Gear (low)	*nl*	*nnl*	*Si* (%)	Gear (low)	*nl*	*nnl*	*Sa* (%)
1,500	1	4.36	3.86	11.50	1	4.50	3.75	16.70
1,500	2	5.05	3.83	24.20	2	5.00	3.75	25.00
2,000	1	4.39	3.83	12.80	1	4.25	3.75	11.76
2,000	2	5.06	3.83	24.30	2	5.00	3.75	25.00

a maximum variation of 5.2 per cent from the actual slip at different gears and rpm values. The indicated and actual slip values were closer which thus concluded that there was no significant difference.

The variations between actual and indicated values were on an average of 0.16 per cent under the laboratory test. The variations between actual and indicated values were within an average of 1.9 per cent while testing the slip meter in the field. Since the fixture component for the tractor was designed for VST Mitsubishi Shakti Vt 224-1D, for using the slip meter in any other make and model of tractor requires changes in the dimensions of the fixture component attached to the tractor. In general the developed slip meter can be used for any make and model of the tractor with minute modifications.

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