CHAPTER I

INTRODUCTION

Tractors are specifically designed to deliver a high tractive effort at slow speeds, for the purposes of hauling a trailer or machinery used mostly in agriculture. Agricultural implements may be towed behind or mounted on the tractor and the tractor also provide a source of power and act as a prime mover so many implements like cultivator, rotavator, mould board plough, disc plough etc. It can be classified as two-wheel drive tractor and four-wheel drive tractors based on the number of axles or wheel to which power is delivered. Power produced by the engine must be transmitted to the implement to do the actual work intended for the implement. There are so many parameters which affect the effective working of a tractor, among that slip is one of the most relevant parameter.

In terms of measurement, prediction, and presentation of tractor performance, slip is the single most important parameter. It is an indicator of right combination of tyre pressure, tractor weight(ballast) and operating speed resulting in correct traction for efficient performance and fuel saving. It can also determine wear and expected life time of a tractor drive train and tyres. A wheelslip that is too low may be a sign that the drive train is being strained and excessive weight is being hauled. Conversely, a very high wheelslip suggests that tyres are wearing excessively and wasted rotations are likely wasting fuel. Thus it is important in assessing tractor efficiency. Tractive efficiency is a measure of the ability of the tractor to transfer power from the axle to the drawbar through the tyre and soil interface. This implies that tractive efficiency depends on wheel slip, soil and tyre conditions as well as drive configuration. There is a range of wheelslip where tractive efficiency is highest. Tractive efficiency falls rapidly from the maximum value if the slip is too high or too low. It is therefore an absolute necessity to measure an indicated slip for getting maximum drawbar output from the tractor. Draw bar power is greatly affected by wheel slip. Drawbar power falls rapidly from the maximum value if the slip is too high or too low.It shows that drawpower will be maximum at a particular wheelslip for a particular condition. Slip is defined as the proportional measure by which the actual travel speed (or distance) of a wheel falls short or exceeds the ideal or it can be defined as the relative motion between the wheel of the tractor and the surface. It can be generated either by the tyres rotational speed being greater or less than the free rolling speed (percent slip) or by the tyres plane of rotation being at an angle to its direction of motion (slip angle).

Factors affecting which affects wheel slip include type and operation of implement, type of soil, tyre pressure, design of tread, slope, velocity, rolling radius, speed of tractor, moisture content of soil.

Knowing the importance of slip, various researchers used different techniques like Doppler radar effect, electronic circuit using photo-transducer etc for accurate measurement of slip. These designs were complicated and costly. The methods or instruments which are currently in use for measuring slip are either less accurate or highly sophisticated technologies with high accuracy. Generally the wheel slip was measured by counting the number of revolution of rear wheel under load and no load condition. But it has some disadvantages such as time consuming and cumbersome, chance of human error will be high, more than one operator is required for measuring wheel slip, for high velocity, wheel slip cannot be measured manually. Studies says that the acceptable range of wheel slip is in between 10%-15%

This research work aims in developing a slip-meter for determining slip to overcome some existing problems related to error measurement in fields.

The main objectives of this research works are following:

- To devolop a low cost slip-meter for automatic recording of slip.
- To fabricate and evaluate the slip-meter.

CHAPTER II

REVIEW OF LITERATURE

A brief review of work done relevant to various aspect of the present investigation is reported here.

2.1 SLIP MEASURING DEVICES

Raheman *et al.*(2006) carried out a study on wheel slip measurement on 2WD tractor with a microcontroller based slip sensor. The sensor consist of 4 components: Power supply(power is taken from the tractor battery itself), sensing of throttle position(rotary potentiometer is installed on the tractor), gear position and wheel rpm(proximity switch is installed); processing of collecting data and display unit. Performance of developed slip sensor was evaluated both on tar macadam surface and field. The variations between indicated and actual slip is found to be 0 to 5%.For both the surface thus indicating the accuracy of slip measurement by the developed slip sensor.

Tewari *et al.* (2016) conducted an experiment to develop a wheel slip measuring device with mechatronics based digital draft force. It has a load cell based dynamometer to measure the draft force, hall sensor to measure wheel slip by counting the magnetic pin mounted on the disc, an amplifier to amplify the readings taken by the dynamometer and a microcontroller to process the received load cell, hall sensor data to calculate the draft force, wheel slip and display on the LCD screen as well as record the data on the SD card module. To compare the access the degree of accuracy of the developed draft measurement system, the degree of accuracy of the developed draft measurement system, wheel slip measurement system a system involving instrumented 3 point linked was developed to measure the draft force for simultaneously and a non-contact type radar sensor was used to validate the wheel slip measurement system. A maximum variation of +2 .1%to -2.1% wheel slip was observed between developed and manual measured values.

Ashok Kumar *et al.* (2016) developed a simple technique to measure wheel slip with the help of hall sensor and microcontroller based embedded digital system wheel slip is displayed on display board and warn the operator with audible and visible warning if the optimum range is exceeded. Hall sensor slip measurement system was evaluated in controlled soil bin condition, tar macadam surface and actual field condition and compared with commercial radar system. The developed system is simple in construction and can be mounted to any model of tractor by entering appropriate rolling radius via the computer interface.

Pranav *et al.* (2010) calculated the actual and theoretical speed of tractor by measuring the rpm of front and rear wheel respectively using optical slot sensor and used the actual speed and theoretical speed to calculate the slip of the tractor.

Pandey *et al.*(2012) developed a microcontroller based automatic wheel slip control system for two wheel drive tractor. Wheel slip was calculated using the actual and theoretical speed of the tractor obtained by measuring the rpm of front wheel and rear wheel respectively.

Macmillan (2002) in his book 'The Mechanics Of Tractor-Implemnt Performance' quoted the use of free rolling wheel (such as an attached 5th or a tractor front wheel) as a nonslip reference overcomes this problem in principle. The method involves the use of revolutions of free wheel (n0 and n) to infer the rear wheel revolution under zero pull (N0) test. Corresponding to the unknown distance used for pull test (for which N revolutions where recorded)

Wheel slip= (N-(n/n0) N0)/N

From equation it can be seen that the rear wheel revolution no for zero pull test are scaled by ratio of the free revolution for zero pull and with pull test n0 and n, to give zero pull, rear wheel revolution corresponding to the pull test distance.

In order to use this method, it is necessary to have a wheel counter (to measure fraction of a revolution) on both driving and front wheel. It should also be noted that free wheel revolutions are affected by speed and surface condition. So the free wheel may need to calibrate if accurate result are to be obtained, particularly at small slip.

Lu Zhixiong *et al.* (2013) developed a slip measurement system for agricultural 3WD tractor based on lab view software. It consist of a primary sensor, hardware and a software to measure the wheel slip. It uses a fifth wheel fitted to the front wheel. The slip of this fifth wheel is considered as zero slip condition. Wheel slip of back wheel and front is then compared with the zero slip condition to determine the slip of front and back wheel separately.

Davies *et al.* (1973) conducted a study to understand the relation between the wheel slip and soil compaction. Wheel slip proved to be more important factor in addition to working load to create compaction of soil.So that slip must be controlled to reduce the soil compaction.

Taiwo *et al.*(2015) conducted a study to determine the wheel slip of 2WD tractor during primary tillage operation with 2 bottom and 3 bottom disc plough and then with tandem disc harrow. The main aim of this study is to compare the wheel slip of tractor when implemented with different implements. In this study there is no significant difference in the wheel slip of tractor equipped with different implements. The wheel slippage of the tractor for first and second ploughing operations when mounted with a 2-bottom disc plough were 10.31 and 12.13 % respectively while it was 9.92 and 11.93 % respectively when mounted with a 3-bottom disc plough. Although the use of 2-bottom disc ploughmounted on 2-WD tractorresulted in higher wheel slippage for primary tillage and subsequent secondary tillageoperations in the Atabadze soil series of Ghanathan that obtained with the use of 3-bottom disc plough, the difference was not significant.

Damanauskas *et al.*(2015) carried out a study to determine difference in tractor performance parameters between single wheel 4WD driving system. Vertical load and tire pressure are the main parameter that plays a significant role in tillage operations for limiting slip which involves energy losses. It also affects the fuel consumption and field performance of tractor. This experiment determined the effect of wheel slip on fuel consumption and field performance due to variation in air pressure on the tire.

Zoerb *et al.* (1967) studied about the relation of wheel slip with fuel consumed. Generally tractive efficiency will be maximum at driving wheel slip between 10% - 15%. Tractive efficiency will drop down when wheel slip is greater than 15%.Exessive slip also cause rapid tire wear which has economic significance. Rate of wear at a wheel slip of 10-15% is acceptable. The operator should add weight to the rear wheel if the slip is more than 15% for reducing the slip. This experiment use a slip indicator attached to the pto of tractor for measuring the wheel slip. It measures the draft of pto without implement and take that condition as zero slip condition. Then draft on the pto is measured when the implement is connected. This two reading is used for determining the slip of the tractor at different conditions.

D.N Sharma *et al.* (2013) recorded a difference in wheel slip at different soil in his book ‘Farm Machinery Design Principles And Problems(third edition)’. It says that wheel slip of concrete road will be 4-8%,tilled soil is 11-13% and soft and firm soil posses a large percentage of slip i.e. 14-16%

Micheal *et al.* (1898) in his book ‘Principles Of Agricultural Engineering’ described usual method for slip measurement. The procedure says to make a mark on the tractor drive wheel with coloured tapes. After that measure the distance tractor move under no load condition (say A) for a fixed revolution. Then measure the distance tractor move under load condition (say B) for the same surface and same revolution. Then wheel slip can be calculated by the equation (A-B/A)*100

2.2 ARDUINO IN AGRICULTURE

Hariansyah *et al*. (2012) measured the ploughing depth elevation of drainage channel by The Application of Ultrasonic Sensor and Atemega 328 Arduino. The objective of this research was to develop automatic mole ploughing depth elevation measurement, and gain the deviation magnitude resulted from set point and ploughing depth elevation position. Ultrasonic sensor was permanently attached heading to the target. A plat was attached onto hydraulic support. The sensor will detect the ploughing depth and distance when the hydraulic lifting or lowering the mole ploughs. Controlling the depth was conducted by directing the green laser beam onto light receiver photodiode sensor which placed at specified level. As the position of green laser beam moved from that level, program activated relay and relay instructed solenoid to open the valve to drag the mole plough based on the defined set point. The receiver sensor will shift continually as photodiode sensor was attached at the mole plough construction which pulled by the tractor. The ploughing depth was suited to the level of light receiver sensor. The measurement of ploughing depth was conducted by ultrasonic sensor. The sensor was permanently attached to avoid movement. The moving object was iron plat that was permanently attached to the hydraulic piston. As cylinder piston pushed or pulled the mole plough, the iron plat eventually moved. This movement was detected by sensor and the information was sent into Arduino micro-controller which the result could be directly read at the computer.

Ananthi *et al*. (2014) designed an automated Soil Testing Device which can be used to measure N (Nitrogen), P (Phosphorous), K (Potassium) and pH (Potenzy hydrogen) values to ensure the fertility of soil in the field of agriculture to select the suitable crop and also the type of fertilizer to be used. Copper electrodes are used as sensor which measures the ionic particles present in the soil and converts it in to electrical signal. The electrical signal is amplified using signal conditioning and this amplified signal is sent to arduino in the form of digital signal from analog digital converter. The arduino plays a key role in processing data received from the sensor, where it compares the data already pre-stored with the sensor output signal. The arduino after comparison gives the output and the values are displayed on the LCD display. The output not only provides the information on fertility present in the soil but also suggests crops to be grown on that soil. The wireless trans-receiver transmits the data to a remote location or designated authority in the agriculture department for further analysis and suggestions.

Devika *et al*. (2014) had reported that they could develop an automatic plant watering system using arduino. The project uses Arduino board, which consists of ATmega328 Microcontroller. They had reported that it will sense the moisture level of the plants and supply the water if required. Normally, the plants need to be watered twice daily, morning and evening. So, the microcontroller has to be coded to water the plants in the greenhouse about two times per day. The system can report the status of its current conditions and also reminds the user to refill the water tank.

Pushpa *et al.* (2014) aims at providing a user friendly, reliable and automated water pumping system using arduino. The paper aims in designing a system which is capable of detecting moisture level in the soil and capable of taking the decision of switching ON/OFF of water pump. Arduino microcontroller is used to switch on/off the water pump automatically when the soil moisture sensor detects the water deficiency of the plant. The system also uses temperature sensor to detect the temperature and automatically controls the fan speed like coolants. The microcontroller, arduino forms the heart of the device and there are soil-moisture sensors, which are meant for detecting the moisture in the soil and is programmed with the arduino software.

Manoj *et al*. (2015) had reported about the application of soil moisture sensor in mixed farming. They had developed a device that detects the moisture level in the soil when the device is placed in the field. It works under three conditions wet, normal and dry conditions. If there is enough moisture in the soil, the device remains constant and it will not function. When the sensors detect a dry condition, the device which is interfaced with the water pump is turned on until the soil moisture reaches the normal condition. The system consists of an Arduino board, which is a microcontroller board based on the ATmega328. It has 14 digital input/output pins, 6 analog inputs, a USB connection, a power jack and reset button.

Jena *et al*. (2015) designed a system for data acquisition of Green house environment. In green house they used multiple sensors DHT11 sensor, soil moisture sensor etc. to make use of data for simulation or processing to achieve the better enhancement of growth in green house, this data has effect on the environment of green house, Graphical User Interface (GUI) had been used through LabVIEW Firmware of Arduino Uno as software and Arduino Uno board and sensors as hardware by using Arduino Uno board provides multiple analog input and digital I/O to made read data sensor easy to take temperature, humidity, CO2 gas, also measuring the soil moisture that needed for irrigation plants and the intensity of lights that applied for greenhouse. These parameters have the major effect on increase in growth of plants. The system for this purpose had been provided and given ability to control on environment of greenhouse.

2.3 SENSORS

There are a wide variety of applications available for Hall Effect sensor in all fields directly or indirectly

Kayal *et al.*(2013) studied about the design, integration and behaviour analysis for low power applications like position detection, current sensing, contactless switching etc. This type of sensor commonly uses CMOS technology which is also used in microcontroller, microprocessor, static RAM. Geometry of the sensor is responsible for the sensing contact length of the sensor. The geometry includes length(L) and width(W) of the sensor. If L/W ratio is 2.27 then sensing contact length is 8.8micrometer for basic structure.

Bolshakova *et al.*(2006) conducted a study on improvement of magnetic field measuring accuracy of hall sensor in radiation environment of thermonuclear reactor. It was proved that hall sensor based devices are malfunctioned instrument in irradiation conditions for magnetic field measurement. But it can be used for sensing of magnet but less efficient in measuring the field strength with certain microcontroller.

Jezny *et al.*(2013) studied about the use of hall sensor in position measurement. Hall effect sensor can react to magnetic array with change in analogue voltage. It can be also used to measure the velocity or directional movement. It can detect the presence of permanent magnet in different parts of a machine like wheels, shafts, tachometer, anti lock braking systems. The important parameter in detecting the magnet is the maintaining of effective operating air gap. Hall Effect sensors are frequently used for rotation sensing in DC brushless motors.

Ghosh *et al.*(2012) conducted a study on instantaneous measurement of power using hall sensor. As power is the product of current and voltage, by determining current and voltage it is easy to calculate the power. When a magnet come in contact with metal it will induce a current and due to this current a voltage is developed on the sensor, this voltage is called hall voltage. By applying this principle a CSN hall sensor can measure a current up to 1200amp. It can be used to measure AC, DC, and impulse current.

Mahesh kumbhar developed a system for monitoring controlled irrigation system in Indian agricultural field with a mobile by implementing Hall Effect sensor. A Hall Effect sensor is attached in the flow line and there is a pin wheel in which magnets are attached. The hall sensor counts the number of magnet on the pin wheel thereby calculate the amount water passed through the section. This flow can be controlled with a mobile device. It was also concluded that it is efficient to use an IC to monitors the valve condition which will reduce the manpower in fram work and also reduces the wastage of water. By utilizing this method it is easy to control irrigation from a distant field.

Buschbaum *et al.* (2007) used Hall Effect sensor for measuring the flap angle of tail rotor of the helicopter. He used HAL800 sensor the measurement of flap angle. The sensor measures the density of magnetic field and sends an equivalent output voltage. The sensor consists of a A/D converter and a D/A converter. The main rotor blade is equipped with a small movable flap and motion of the flap is measured by the hall sensor. The sensor is installed at the hinge of the blade and the magnet is fixed on the movable flap.

Siddiqui *et al. (*2017) constructed an automated guided vehicle using arduino and Hall Effect sensor. This vehicle is constructed to transports goods from one place to another through a path and this path is made of magnetic strip. This Hall Effect sensor will follow the path made of magnet. Arduino UNO is the controller used for this purpose. No human intervention is required for the execution. The safety measures are provided with fire sensor, obstacle sensor and with a buzzer to give alarm.

Chavhan *et al.* (2015) conducted a study in fault detection in power line using Arduino UNO and Hall Effect sensor. He used Hall Effect sensor to measure the current flowing through the power line and Arduino will convert analogue current into digital value and it will transmit the data into the transceiver. The measured value will be displayed on the LCD. When there is a change in current due to any fault produced then it will be displayed on the LCD and produce a buzz sound to indicate the fault.

Yuang *et al.* (1998) developed an on-line ferrographic analyser using a Hall Effect sensor for monitoring wear particles on oil. He allowed oil to flow in between two poles of the magnet. The magnetic flux will change when there is magnetic particle in between the magnetic pole. Thus voltage through the Hall Effect sensor changes. Thus amount of debris on oil can be determined by the deviation from standard voltage produced by the oil when there is no debris in between the magnetic pole.

Darbar *et al.* (2016) developed a Hall Effect sensor based text entry mechanism that effectively uses the 3D space around the smart watch for entering alphanumeric characters.

CHAPTER III

MATERIALS AND METHODS

This research work aims in developing a slip measuring instrument- slip-meter and comparing the automatic device with manual measurement of slip. The slip measuring methods, concepts of design, methodology adopted for the development of profile-meter are discussed in this chapter.

3.1 SLIP MEASURING METHODS

Slip can be defined in different ways and from each definition an equation can be developed for finding wheel slip. The magnitude of slip is thus dependent on how the zero slip is defined and measured. Some methods are as follows:

3.1.1 METHOD 1

In this method, wheel slip is calculated by counting number of revolutions of rear wheel under load and no load condition.

Procedure:

- Making distance constant
- Measure the number of revolution of rear wheel at load (Nl) and no load condition (Nn) using a hall sensor/ a counting mechanism.
- In this method slip at no load condition is considered to be zero
- A microcontroller is used to process the input data
- Then wheel slip is estimated using the equation

  Parameter: Number of revolution of rear wheel

$$1 - Nn/Nl \quad ..(3.1)$$

3.1.2 METHOD 2

Here, the slip is calculated by counting the number of revolutions of front and rear wheel simultaneously.

Procedure:

- The diameter of front and back wheel is measured at tarmacadam surface which is considered as the zero slip condition.
- Number of revolution of front and back wheel is measured using hall sensor fixed on wheel by means of extra setting on wheel.
- A microcontroller (Arduino) is used to process the input data.
- Then the wheel slip estimated from the equation:

$$\text{Wheel slip} = \frac{\text{distance travelled by rear wheel} - \text{distance travelled by front wheel}}{\text{distance traveled by rear wheel}}$$

$$= \frac{\pi NrD - \pi Nfd}{\pi NrD}$$

Dividing each term by πD

Then, wheel slip = $1 - \left(\frac{d}{D}\right) Nf/Nr$ ..(3.2)

Where Nr-Number of revolution of rear wheel

Nf-Number of revolution of front wheel

d- Diameter of front wheel

D-diameter of rear wheel

- Wheel slip is displayed digitally
- Parameter: Number of revolution of front and rear wheel, diameter of front and rear wheel

Note: It is assumed that d/D ratio is constant for a particular tractor at different working condition.

Among these the first method is more reliable and accurate. Here the rear wheel slip at no load condition is considered to be zero i.e. the zero slip condition.

3.1.3 Method 3

Here, wheel slip is calculated by measuring the distance travelled by the vehicle and the distance travelled by the rear wheel.

- Measure the distance travelled by the vehicle(say A)
- Measure the number of revolutions of the rear wheel(N) by a counting mechanism/hall sensor
- Determine the linear distance travelled by rear wheel (say $B=2\pi RN$ or by modifying the hodometer/survey wheel) on load condition
- A microcontroller is used to process the input data
- Then wheel slip is estimated using the equation

$$1 - A/B \quad ..(3.3)$$

Parameter: Radius of rear wheel, Number of revolution of rear wheel

The wheel slip is determined using the above mentioned method and the result is compared and analysed. Among these most reliable, easy and less time consuming method is adopted (METHOD 1 and METHOD 2). The wheel slip obtained by the adopted method is compared with the traditional method.

3.2 DESIGN OF SLIP METER

The concepts for the design and development of various components of a slip-meter are discussed in the following sub-sections.

3.2.1 CONCEPT OF DESIGN

Slip is the proportional measure by which the actual travel speed of a wheel falls short or exceeds the ideal or zero slip speed. The magnitude of slip is thus dependent on how the zero slip is defined and measured.

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. the Hall effect sensor should be attached to the tractor by means of an attaching component. The attaching component must hold the sensor in position. A metal sheet of diameter 50 cm having equal divisions of 10˚ marking was used to attach the magnets. The Hall Effect sensor should first count the number of magnets passing and thus can count the number of revolutions.

Thus the slip measurement can be achieved by using sensors, Microcontroller development board and suitable storing unit. The microcontroller is used to communicate and control the sensor.

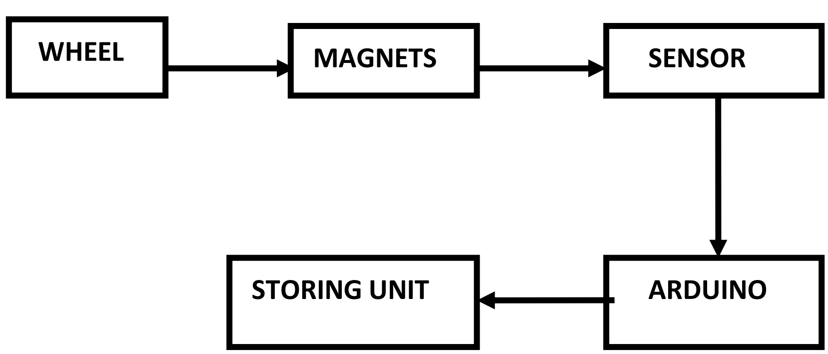


Fig 3.1 Block diagram of concept of design

The concept can be categorized into three categories:

1. Mechanical Design
2. Development of a program
3. Electrical circuit

3.2.1.1**Mechanical design**

3.2.1.1.1 ***Fixture for sensor***

The sensor should be able to count the number of magnets fixed on the rear wheel. For that the magnet should be fixed on the rear wheel directly or indirectly. Magnet can be fixed directly in the hub of the tractor. Indirectly, magnet can be fixed in a metal sheet in a specified distance or in specified angle, and then the metal sheet can be attached into the hub of the tractor with magnets itself. Clearance between the magnet and the sensor should not be greater than 1.5cm and should not be so close to the magnet.

The attaching component should have enough strength and it is better if the component is made of non magnetic material. If the material of attaching component is made of magnetic material then, enough space should be provided between the attaching component and the magnet so that the magnet should not get attracted by the component where we fix the sensor, at the same time the magnet should be sensed by the sensor. The spacing between the sensor and magnet as well as the attaching component and the magnet must be fixed correctly, in the case where we use magnetic material for attachment, and then chance of error will be high. The component should be flexible enough also.

It is necessary to attach the sensor in the tractor in such a way that the sensor must be stationary with respect to tractor. So that we need an attaching component from the tractor and the attaching component should have the capability to hold the sensor in correct position without much vibration and it should not obstruct the movement of the tractor. The component can be fixed to the tractor either be welding or with some removable nut and bolts arrangement which is already on the tractor.

Fig 3.2 3D Picture of fixture for sensor

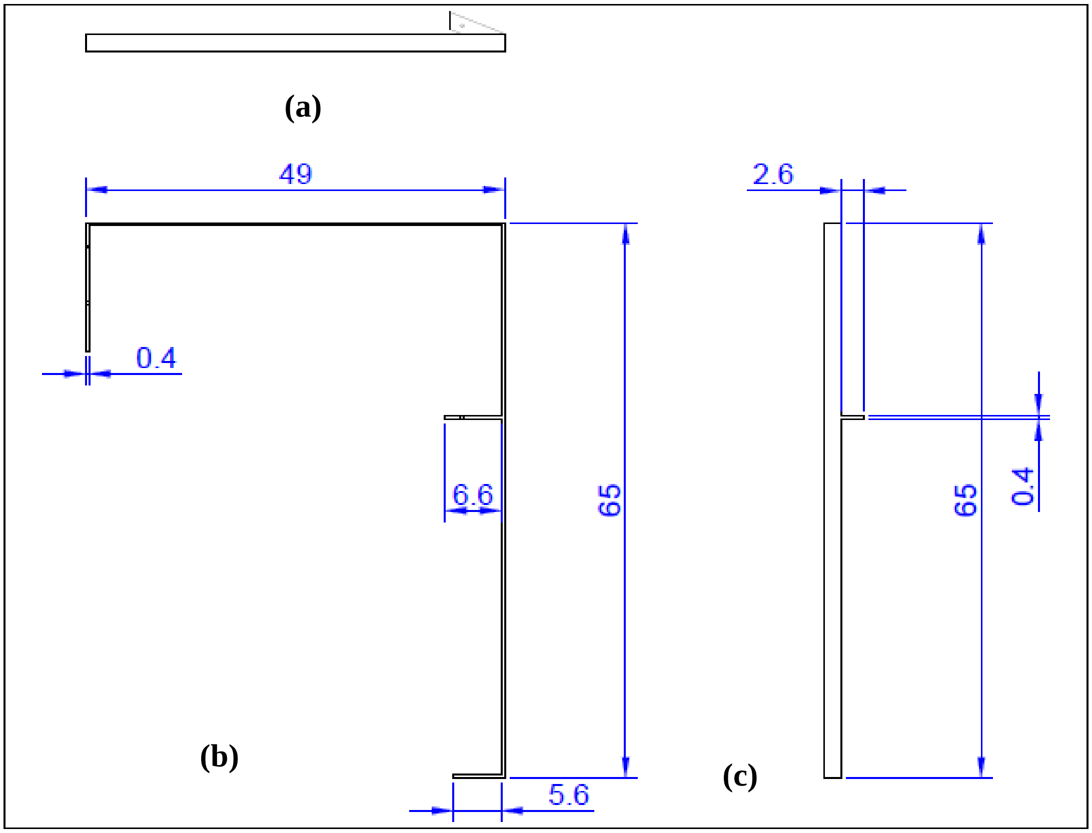


Fig 3.3 (a)Top view, (b) Front veiw, (c) Side view

3.2.1.1.2 ***Fixture for magnet***

3.2.1.1.2.1 ***Magnet***

The magnet is one of the important materials which determine the efficient working of a Hall Effect sensor. PAH sensors offer a programmable offset voltage (0.05-4.95V) and programmable gain of 0.45-14.0mV/Gauss. The magnet should have an intensity to produce a voltage that can be measured by the Hall Effect sensor. When using magnets and digital Hall Sensors, the size, shape, and material of the magnet will determine the gap range the sensor is able to detect. Although the sensor gains are fixed, magnetic fields increase/decrease exponentially as the gap changes from the pole. When using Analog Hall sensors and permanent magnets the fluctuation of intensity of magnet can be easily determined from the serial monitor (if we use Arduino as microcontroller). PAL1 sensors are our fastest responding Analog Hall Sensors with a 120 KHz response rate. They provide a 2.5V offset and a programmable gain of 1.3-2.9mV/G. PAL2 and PAL3 sensors are also available for applications requiring a higher gain.

Silver coloured round disc magnet having 10mm diameter and 1.5mm thickness is used for counting the number of revolution, with Hall Effect sensor and a micro controller. The intensity of the magnet is able to produce a measurable voltage. It can be further adjusted by the gap between the magnet and the sensor. The gap between the sensor and the magnet should not be greater than 1.5cm, otherwise the magnet will not be able to produce voltage that can be detected by the sensor.

Fig 3.4 Magnet

3.2.1.1.4 ***Metal sheet***

It is a metal formed by an industrial process into thin, flat piece. Metal sheets are one of the fundamental forms used in metalworking. It can be cut and bent into a variety of size and shapes. Thin sheets are considered as foil or leaf, and pieces thicker than 6 mm (0.25 inch) are considered as plate. Sheet metal thickness can be specified either in millimetres or in gauge. The larger the gauge number, the thinner the metal. There are many different metals that can be made into sheet metal, such as aluminium, brass, copper, steel, tin, nickel and titanium. Sheet metal is used in automobile, truck bodies, and many other applications. Sheet metal of iron and other materials with high magnetic permeability has applications in transformers and electric machines.

Here we use metal sheet to attach magnets at fixed position. So the metal selected should have enough strength to hold the magnets. The magnets must be fixed in such a way that it should be sensed by the sensor. This metal sheet is in turn attached to the tyre hub with the help of magnets with opposite poles.

3.2.1.1.5 ***Sticker***

The magnet must be fixed in the metal sheet and the metal sheet is further attached to the tractor wheel. It is important to fix the magnet at specific distance or specific angle (say 20˚). For making it more accurate it is better to mark angle on a sticker and this sticker is pasted to the metal sheet. A sticker is a type of label – a piece of printed paper, plastic, vinyl or other material with sticker with pressure sensitive adhesives on one side.

3.2.2 **Development of programme**

The uses of open source programs are being common now a days. Some of them are Raspberry pi, Teensy 2.0., Nanode etc. Based on the reviews, Arduino development board is selected for programming. It is simple and open source prototype platform. Arduino should able to control the movement of the instrument, to take the readings and to store the readings.

Arduino has so many types of boards like Arduino UNO, Arduino Mega, Arduino Due etc. From this Arduino UNO is selected for the programming because of its affordable cost, storing capacity and comparatively simple programming language.

3.2.2.1 ***Arduino***

Arduino is a small microcontroller board with a USB plug to connect to the computer and a number of connection sockets that can be wired up to external electronics, such as motors, relays, sensors, laser diodes, loudspeakers, microphones, etc. They can either be powered through the USB connection from the computer or from a 9V battery. They can be controlled from the computer or programmed by the computer and then disconnected and allowed to work independently. Arduino Uno, a microcontroller board based on the ATmega328 is used in this project. The hardware consists of a simple open hardware design for the Arduino board with an on-board input/output support. The software consists of a standard programming language compiler and the boot loader that runs on the Arduino board.The Arduino project provides the Arduino integrated development environment (IDE), which is a cross-platform application written in the programming language Java. It originated from the IDE for the languages Processing and Wiring. It was created for people with no profound knowledge of electronics. It includes a code editor with features such as syntax highlighting, brace matching, cutting-pasting and searching-replacing text, and automatic indenting, and provides simple one-click mechanism to compile and upload programs to an Arduino board. It also contains a message area, a text console, a toolbar with buttons for common functions and a series of menus. A program written with the IDE for Arduino is called a "sketch". Sketches are saved on the development computer as files with the file extension .ino. The Arduino IDE supports the languages C and C++ using special rules to organize code. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two functions, for starting the sketch and the main programs loop, that are compiled and linked with a program stub main() into an executable cyclic executive program with the GNU tool chain, also included with the IDE distribution. The Arduino IDE employs the program avrdude to convert the executable code into a text file in hexadecimal coding that is loaded into the Arduino board by a loader program in the board's firmware. A minimal Arduino C/C++ sketch, as seen by the Arduino IDE programmer, consists of only two functions:

• setup(): This function is called once when a sketch starts after power-up or reset. It is used to initialize variables, input and output pin modes, and other libraries needed in the sketch.

• loop(): After setup() is called, this function is called repeatedly by a program loop in the main program. It controls the board until it is powered off or is reset.

Table 3.1 Specifications of the Arduino UNO board

SPECIFICATION	VALUE
Microcontroller	ATmega328P
Operating Voltage	5 V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6

Analogue Input Pins	6
DC Current per I/O Pin	20 Ma
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by boot loader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Fig 3.5 Arduino

3.2.2.2 ***Sensors***

There are many sensors available for counting number of revolutions. Based on the reviews, hall effect sensor is found to be more suitable than other sensors.

Hall Effect Sensors are devices which are activated by an external magnetic field. Magnetic field has two important characteristics flux density and polarity (North and South Poles). The output signal from this sensor is the function of magnetic field density around the device. When the magnetic flux density around the sensor exceeds a pre-set threshold, the sensor detects it and generates an output voltage called the Hall Voltage, VH.

Hall Effect Sensors consist of a thin piece of rectangular p-type semiconductor material such as gallium arsenide (GaAs), indium antimonide (InSb) or indium arsenide (InAs) passing a continuous current through itself. When the device is placed within a magnetic field, the magnetic flux lines exert a force on the semiconductor material which deflects the charge carriers, electrons and holes, to either side of the semiconductor. This movement of charge carriers is a result of the magnetic force they experience passing through the semiconductor material.

As these electrons and holes move side wards a potential difference is created between the two sides of the semiconductor material by the build-up of these charge carriers. Then the movement of electrons through the semiconductor material is affected by the presence of an external magnetic field which is at right angles to it and this effect is greater in a flat rectangular shaped material. To generate a potential difference across the device the magnetic flux lines must be perpendicular to the flow of current and be of the correct polarity.

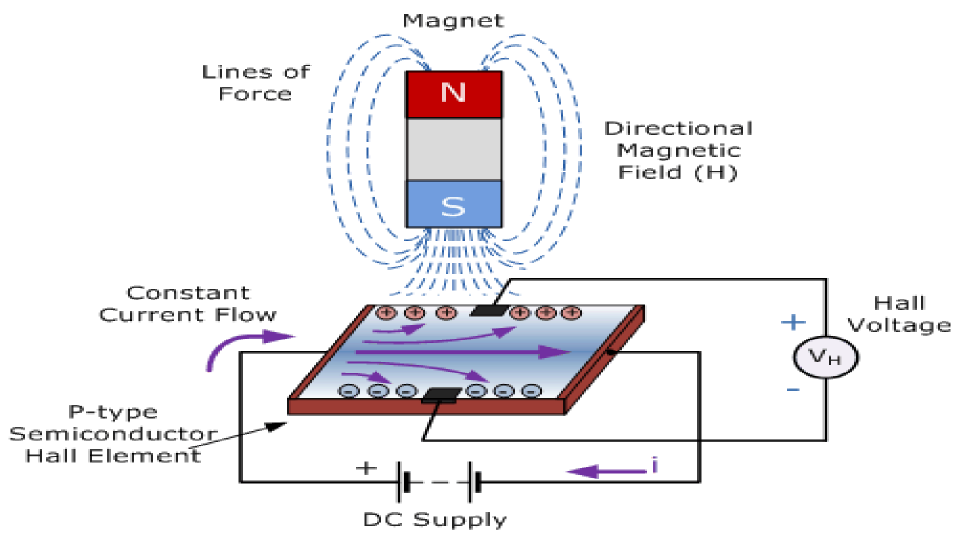
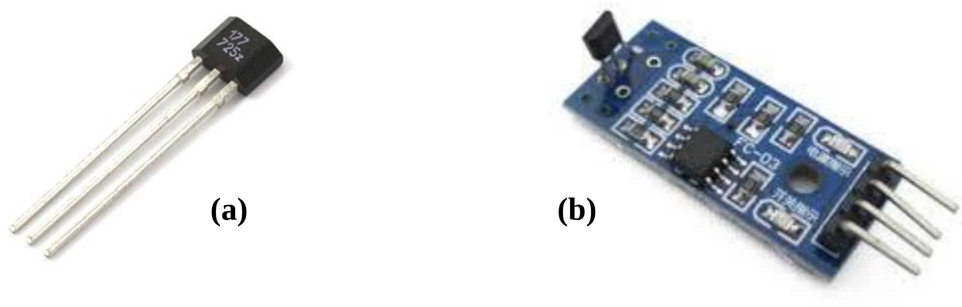


Fig 3.6 Working principle of Hall Effect sensor



(a) (b)

Fig 3.7 (a) Hall Effect sensor , (b) Hall Effect sensor module

The Hall Effect provides information regarding the type of magnetic pole and magnitude of the magnetic field. For example, a south pole would cause the device to produce a voltage output while a north pole would have no effect. Generally, Hall Effect sensors and switches are designed to be in the "OFF", (open circuit condition) when there is no magnetic field present. They only turn "ON", (closed circuit condition) when subjected to a magnetic field of sufficient strength and polarity.

This sensor has four pins: Vcc (voltage in), GND (ground), AO (Analogue output), DO (Digital output). The Vcc pin requires 5 V DC and the GND pin needs to be properly grounded.

3.2.2.3 ***MicroSD Card Adapter***

The SD library allows for reading from and writing to SD card. SD card adapter comes with a voltage regulator. Therefore, the Arduino's 5V and 3.3V pin can be used for the voltage supply. The module communicates via SPI (Serial Peripheral Interface) to the Arduino Uno. The communication between the microcontroller and the SD card SPI takes place on digital pins 11, 12, and 13. The following table shows the complete pin layout.

Table 3.2 Pin layout of MicroSD Card Reader

MICROSD CARD ADAPTER PIN	ARDUINO UNO PIN
CS	4
SCK	13
MOSI	11
MISO	12
VCC	5
GND	GND

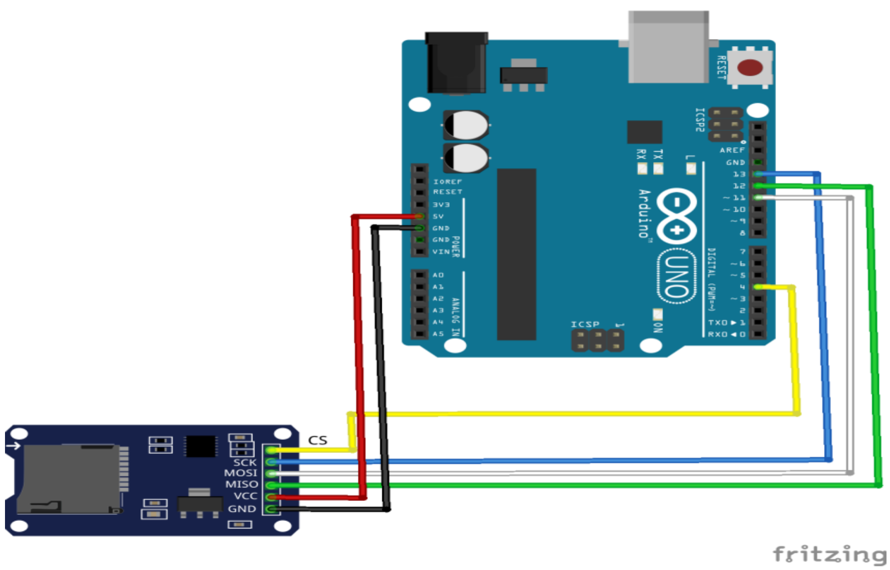


Fig 3.8 Connection diagram of micro SD card adapter

3.2.2.4 ***Programming concepts***

As the slip-meter is used to record slip of a tractor, for that we need number of revolutions of front and rear wheel at the same time. To count the number of revolutions we use Hall Effect sensors by sensing the number of magnet attached to the hub of the wheel. These reading should be recorded on the memory card.

The following things should be ensured while making the programme:

- All the recording things should work properly. i.e. Ensuring that components for data recording are working properly
- Ensuring reliability of working of sensors
- Sensors should take readings of desired points and record in the memory card.
- The program should stop when the tractor stop

This research work aims to develop program based on two methods (METHOD 1 and METHOD 2).

3.2.2.4.1 METHOD 1

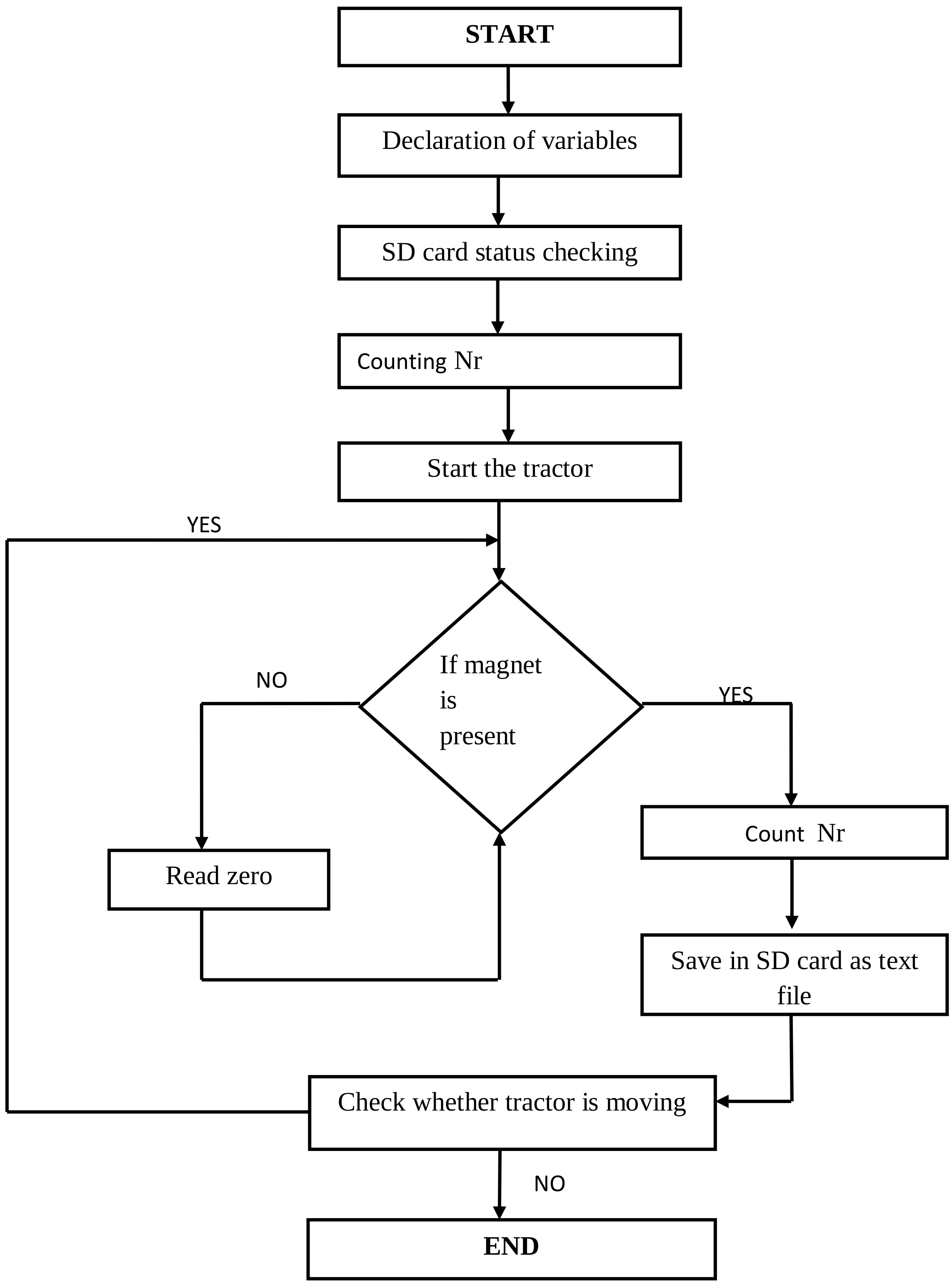


Fig 3.9 flow chart of programming concept of METHOD 1

3.2.2.4.2 METHOD 2

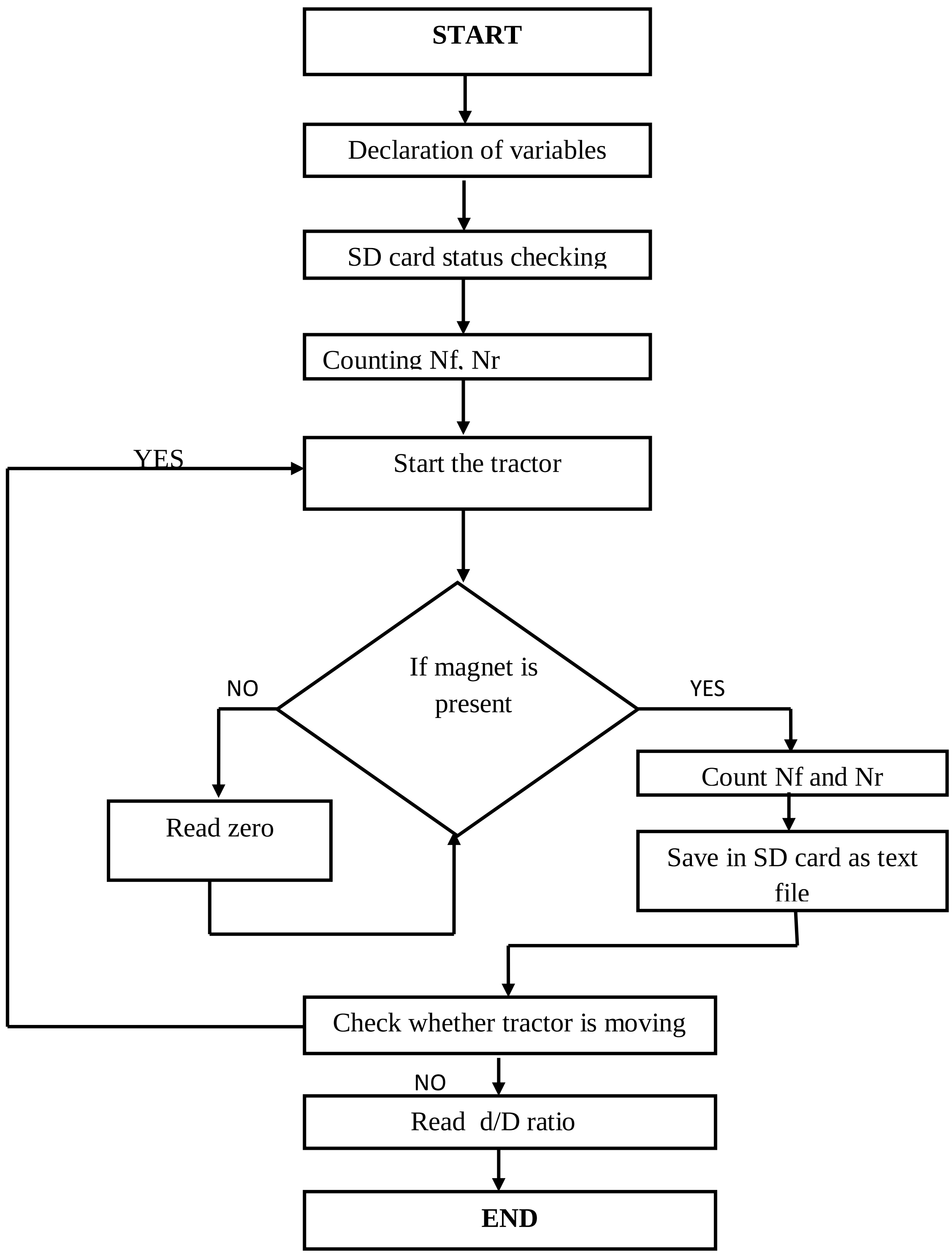


Fig 3.10 flow chart of programming concept of METHOD 2

3.2.3 **Electrical circuit**

For the working of Arduino board, 5V supply is needed. Following are the main components in electrical connections.

3.2.3.1 ***Bread board***

A breadboard is a solder less device for temporary prototyping of electronics and test circuit designs. The breadboards have strips of metal underneath the board and connect the holes on the top of the board. Top and bottom rows of holes are connected horizontally and the remaining holes are connected vertically. Here we use bread board to connect sensors and SD card adapter to Arduino.

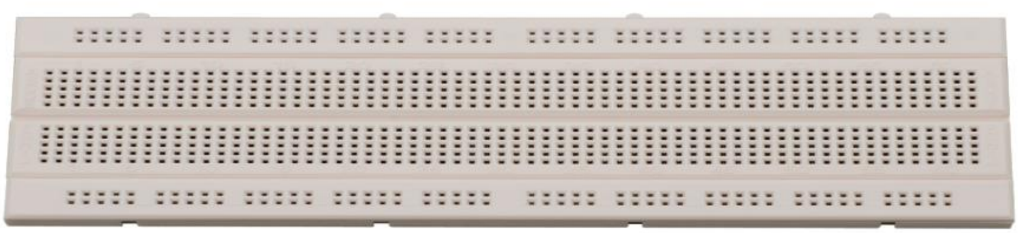


Fig 3.11 Bread board

3.2.3.2 ***Jump wire***

A jump wire (also known as jumper, jumper wire, jumper cable, DuPont wire) is an electrical wire or a group of wires in a cable with a connector or pin at each end. It is normally used to interconnect the components of a breadboard or other prototype or test circuit, internally or with other equipment or components, without soldering. They are used to transfer electrical signals from anywhere on the breadboard to the input/output pins of a microcontroller. Individual jump wires are fitted by inserting their "end connectors" into the slots provided in a breadboard and Arduino board.

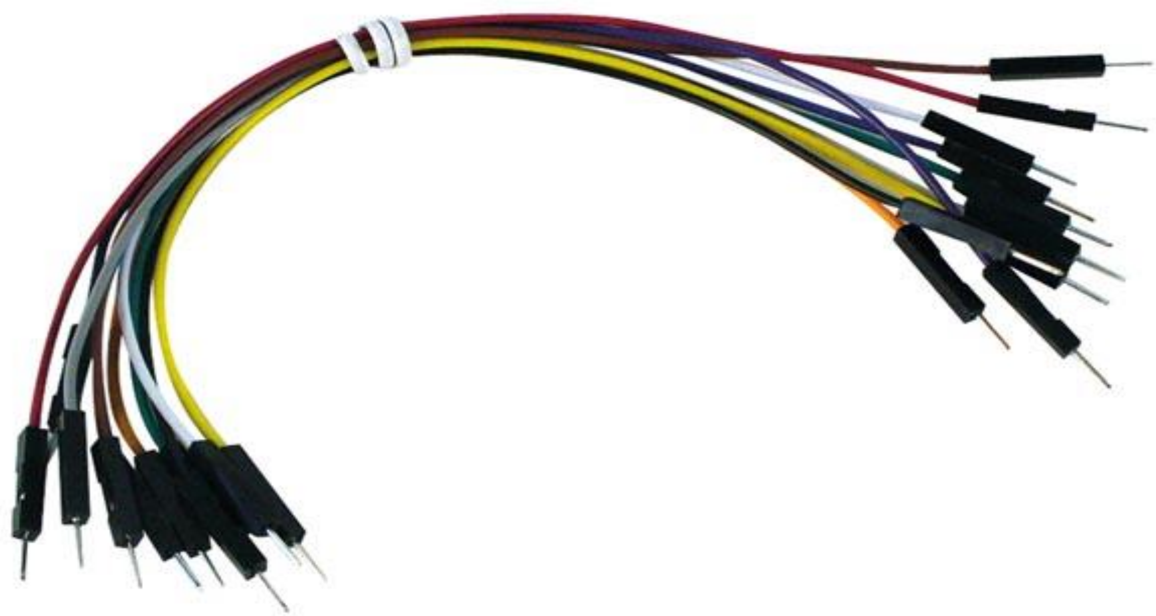


Fig 3.12 Jump wire

3.2.3.3 ***Power supply***

A power suppling device should be a portable device that can supply power from its built-in batteries through a USB port. They usually recharge with USB power supply.

We can give power to the Arduino through power bank. Recommended voltage value for Arduino is 7 to 12 volts and that of operating voltage value is 5 volts. Power bank is enough to provide the recommended voltage.

3.2.3.4 ***Wires***

A wire is a single, generally cylindrical, flexible strand or rod of metal. Wires are used to bear mechanical loads or electricity and telecommunications signals. Wire is commonly formed by drawing the metal through a hole in a die or draw plate. These are provided with proper insulations to use in electrical circuit. Different coloured insulations make the connection easier.

Here we use different coloured long wires to connect sensors to bread board.

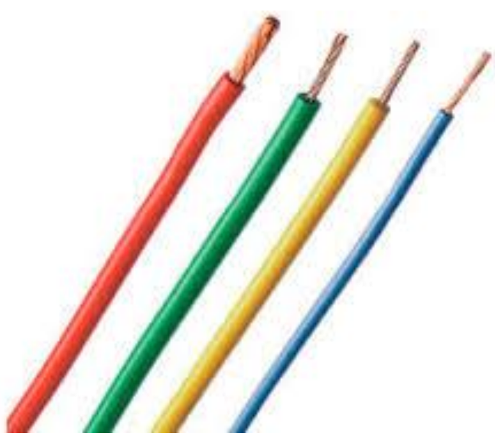


Fig 3.13 Wire

3.2 TESTING OF SLIP METER

3.3.1 ***Laboratory test***

The testing of the slip-meter was carried out in laboratory setup to check the accuracy of slip meter, for that testing we need a rotating shaft supported by bearing block with two metal discs on both sides. Each disc is fixed with a circular metal sheet, one having graduations from 0˚ to 360˚ (sheet 1) and the other is divided equally in to 36 parts (sheet 2). The circular sheets are fixed in to the disc by means of either magnets or double side tape. A handle is fixed on the shaft. Sheet 2 is fixed with magnet at the marked positions. The whole structure is supported on a stand.

(a)

(a)

Plate 3.1 (a) Graduated metal sheet (b) Metal sheet with magnets

Rotate the shaft and calculate the number of revolution of two sheets at the same time, one with sensor and the other with the graduations. Thus we get an actual and observed value of number of revolution.

3.3.2 ***Field test***

Testing of the slip meter was carried out in VST Mitsubishi Shakti Vt 224-1D in field with and without load(METHOD 2)

Table 3.3 Specifications of VST Mitsubishi Shakti Vt 224-1D

ENGINE	
Type	3 cylinder, 4 stroke, over Head valve
Bore	73mm
Stroke	78mm
Displacement (swept volume)	980 cu.cm
Max. Torque	5.5 kg-m
Output/Rated rpm.	22hp / 3000rpm (IS:10000)
S.F.C (specific fuel consumption)	225gm/hp-hr
Cooling system	Water cooled Radiator with compensatory tank
Dry weight	125kg
Starting system	Starter motor 12 Volt-1.6 KW
Air cleaner	3 Stage oil bath
FUEL SYSTEM	
Fuel	High Speed Diesel (H.S.D)
Tank capacity	18 liters
ELECTRICAL SYSTEM	
Lighting	12 volts, 35 watts
Alternator	12 volts, 40 Amps
Glow plug	12 volts, Quick heat type

TRANSMISSION	
Transmission	Selective sliding gear
Forward	6 speed
Reverse	2 speed
Travelling speed	1.31 (min) 19.29 (max) km/hr
Power take off (P.T.O)	1-3/8" – SAE std spline shaft, 2 speed 692, 1020 RPM at 3000 engine, rpm
Brake	Water proof internal expanding shoe type brake with parking brake
Tyres	Front 5-12, Rear 8-18 Track width : 890 (std), 740 (Adj)
Overall Dimension	Width 1085mm, Height 1250mm, Length 2540mm, Wheel Base 1420mm
Ground clearance	190mm
Turning Radius	Without Brake 2.5m With Brake 2.1m
Haulage	2 wheel Trailer, 3 Tonnes (Gross weight)
Tractor weight	740 kg (Without ballast weight)
ROTARY PERFORMANCE	
Rotary	Side drive type

Tilling width	900mm/1100mm
Number of tynes	20/28
Tilling depth	150mm
Plough depth	220mm
SPEED	
Forward	Low – 1.31km/hr High – 19.29km/hr
Reverse	Low – 1.67km/hr High – 7.37km/hr

Fig 3.14 VST Mitsubishi Shakti Vt 224-1D

3.3.2.2 Procedure

- Fix the attaching component on the tractor and circular metal sheet on the wheel hub with the help of magnets.
- Fix the magnets on the marked position on the metal sheet.
- Make the connection with the Arduino and sensor
- Fix the sensor properly on the attaching component
- Make sure that clearance between the sensor and magnet is enough to sense the magnets
- Fix a distance of 10m, mark the starting position and ending position
- Start the tractor without load and switch on the Arduino
- Stop the tractor at the ending position
- Repeat the procedure for load condition.
- Number of revolution of rear wheel under load and no load condition will be recorded on the inserted memory card.
- Insert the memory card on the system and the recorded value will be displayed in an excel file
- Slip will be displayed

The comparison between actual and measured value are done by using statistical methods. Chi square test is used for the comparison between actual and observed readings. For doing the chi square test , two set of data are taken at a time and found the chi square value. It is compared with the table value of chi square value corresponding to the degree of freedom and a level of significance of 5%. Since the calculated chi square value is always less than the table value of chi square, it can be concluded that there is no significant difference between the readings

Steps for the chi square test are as follows:

- Null hypothesis : Actual value = observed value

  Alternate hypothesis: Actual value > observed value

  Actual value< observed value

  Actual value $\neq$ observed value

- Test statistics

  $$\chi^2 = \frac{\sum(x_i - \ddot{x})^2}{\sigma^2}$$

- Find the table value or critical value by (n-1) degree of freedom and level of significance α (5% or below)
- If calculated value is less than table value is less than table value , we accept null hypothesis.

CHAPTER IV

RESULTS AND DISCUSSIONS

The work presented here is the development and testing of slip meter. Based on the materials and methods of study, the slip meter is fabricated.

4.1 DESIGN OF SLIP-METER

Slip meter is designed for method 1 and method 2. The details are as follows:

4.1.1 ***Development of program***

The programme should control read, store andindication of LED. Controlling is achieved by different pins. Each pin is assigned to different components. These pins are variable. Programming code starts with declaration of pins in Arduino board. In 14 digital pins, 3 pins are given for one sensors(method1) and 6 pins are given for two sensor(method 2). 4 pins are used for SD card reader and one pin for LED.

Table 4.1 Pin used for components

Pin number	Components/variable name
8	Sensor 1
9	Sensor 2

10	SD Card Reader(CS)
11	SD Card Reader(MOSI)
12	SD Card Reader(MISO)
13	SD Card Reader(SCK)

4.1.2 **Electrical connections**

The connection diagram for slip-meter is shown as below

4.1.2.1 METHOD 1

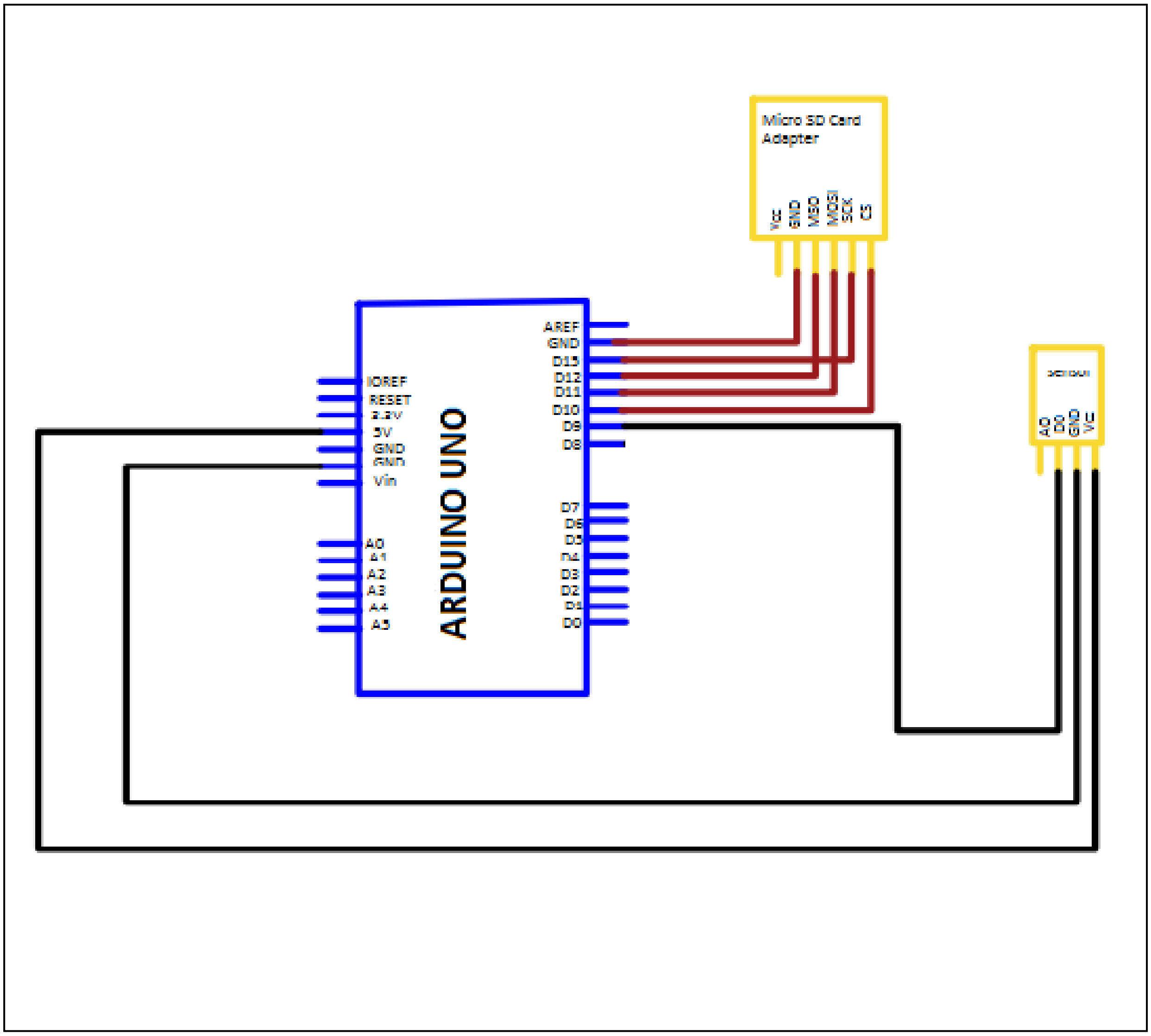


Fig 4.1 circuit diagram(METHOD 1)

4.1.2.2 METHOD 2

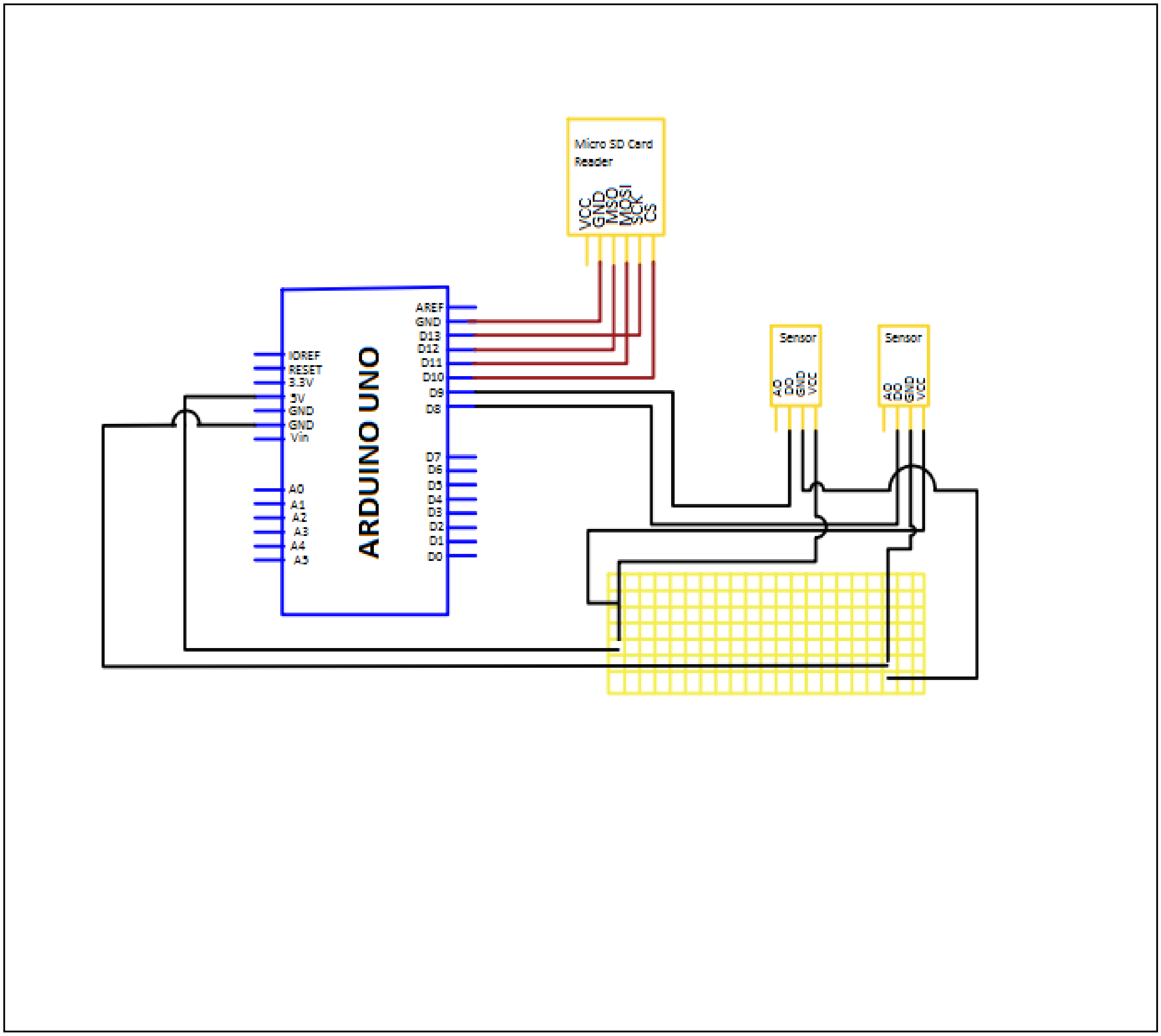


Fig 4.2 Circuit diagram (METHOD 2)

4.2 DEVELOPMENT OF SLIP-METER

The following flow chart shows the working of arduino program in slip meter.

4.2.1 METHOD1

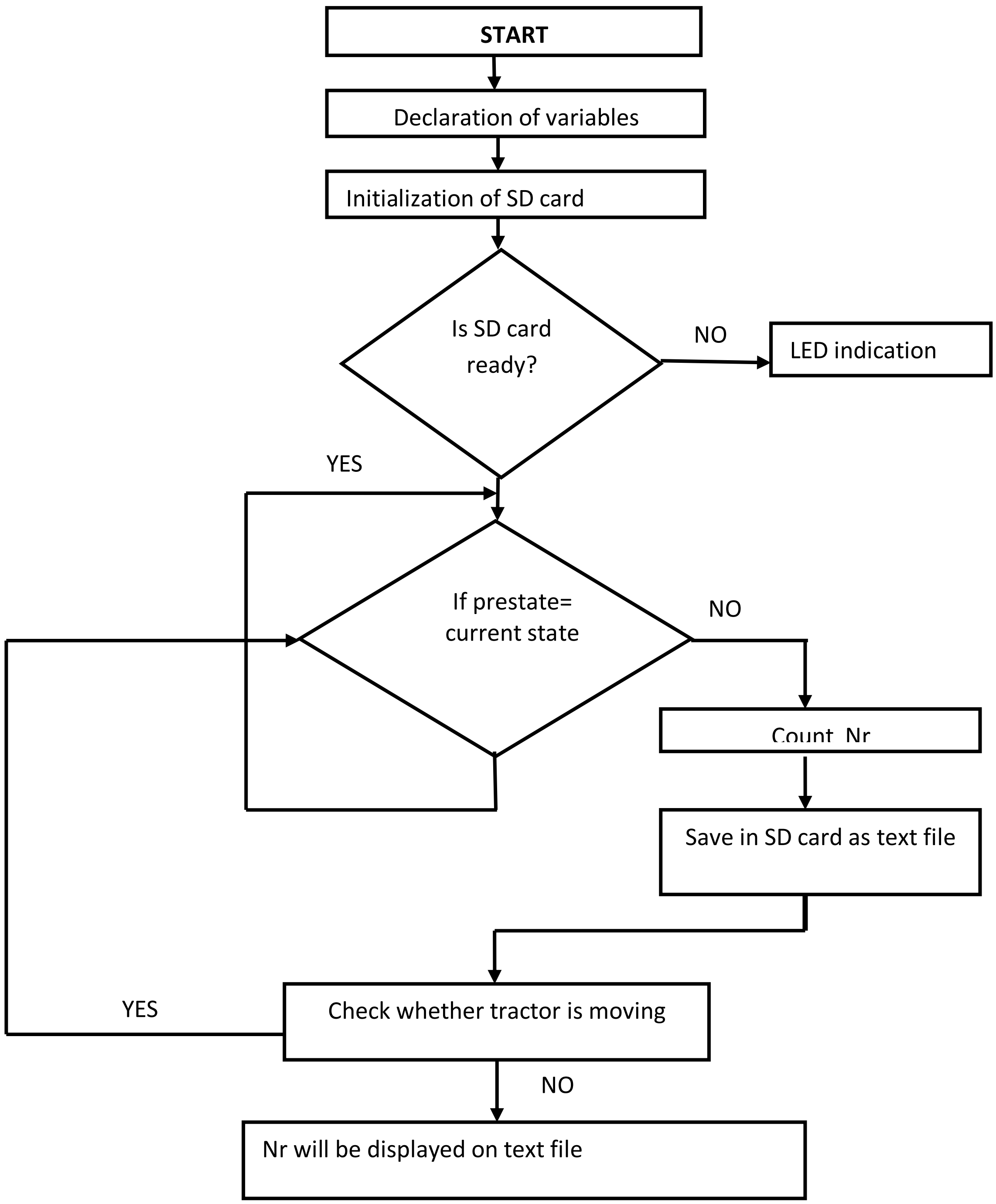


Fig 4.3 Flow chart of programming concept (METHOD 1)

4.2.2 METHOD 2

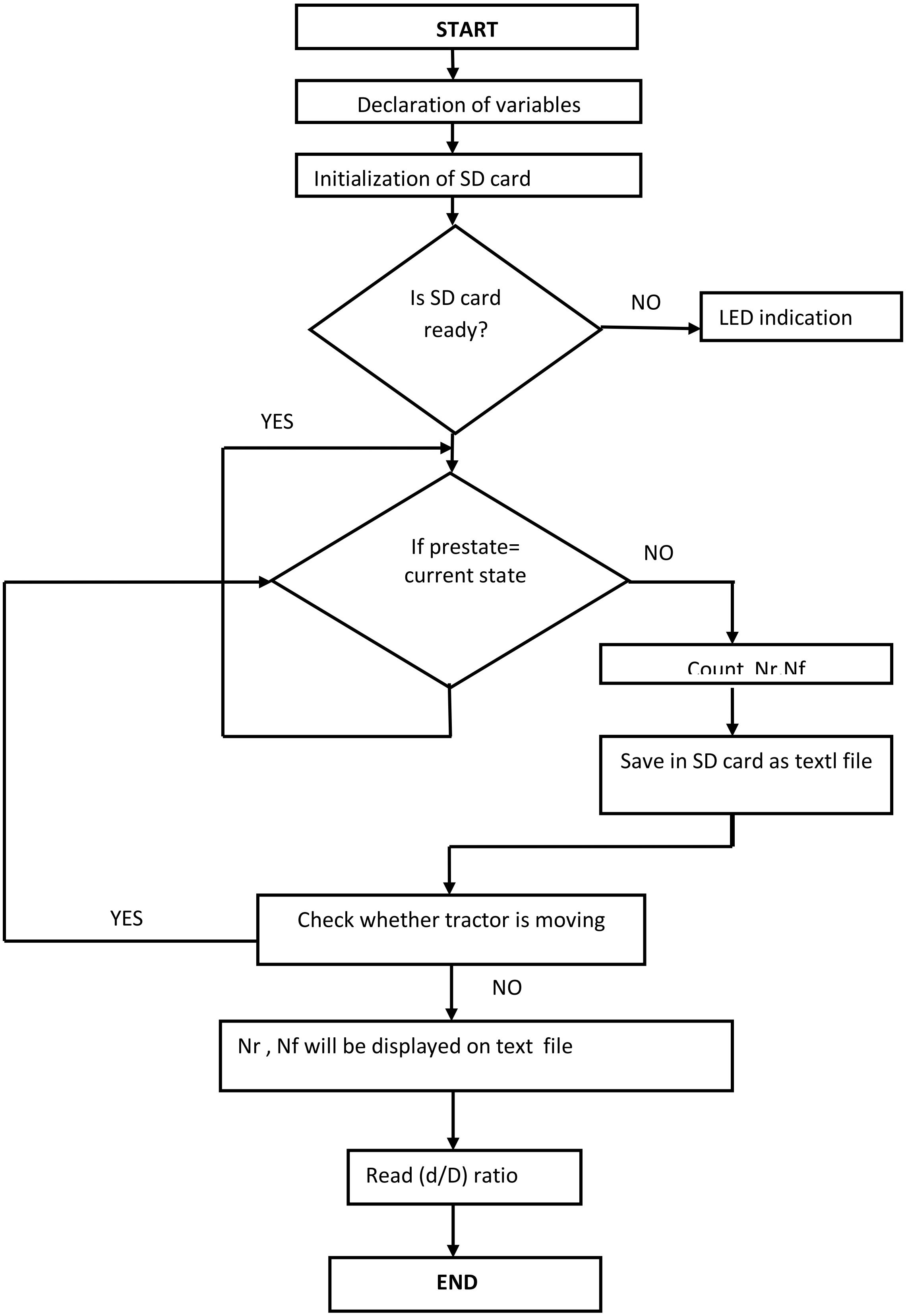


Fig 4.4 Flow chart of programming concept (METHOD 2)

4.3 COMPONENTS AND COST ESTIMATION

Table 4.2 components and cost estimation of METHOD 1

COMPONENTS	COST
Fixture for sensor	200
Fixture for magnets	500
Sensor	200
Arduino	450
Magnet	200
Sd card adapter	150
Miscellaneous	200
Total	1900

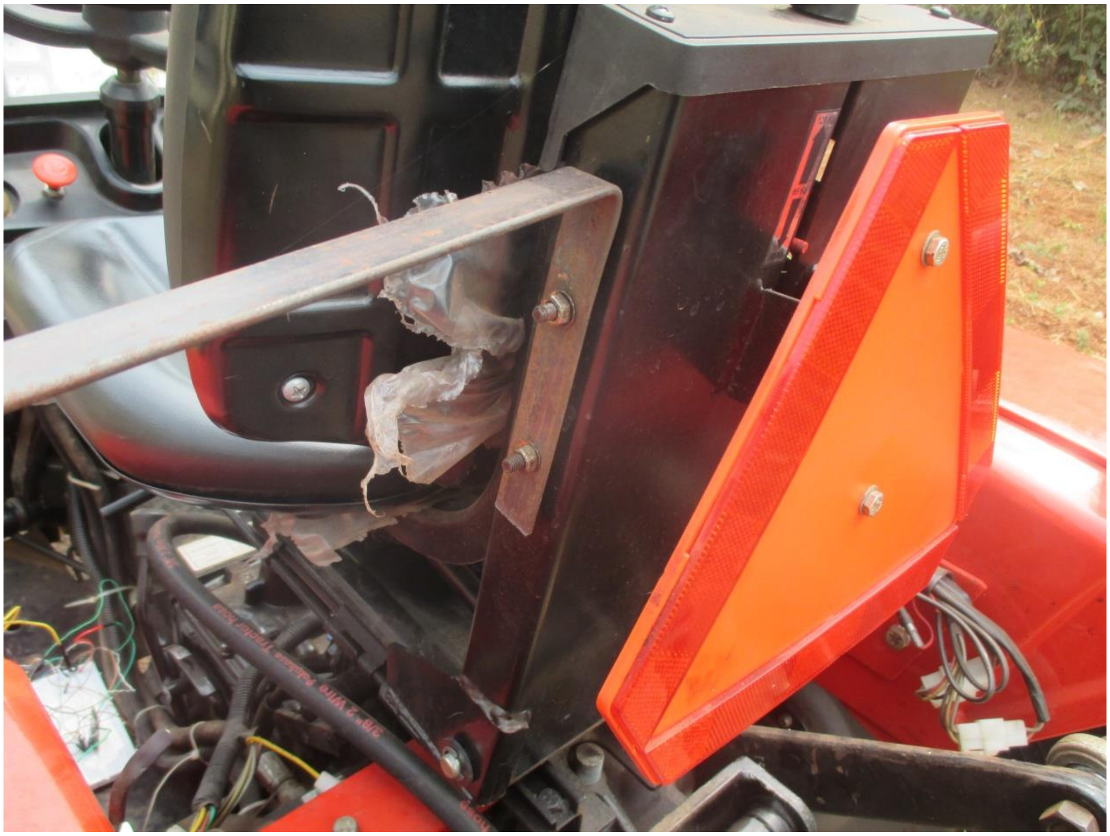


Plate 4.1 Fixture to tractor

Plate 4.2 working of slip meter under load condition

Table 4.3 components and cost estimation of METHOD 2

COMPONENTS	COST
Fixture for sensor	400
Fixture for magnets	1000
Sensor	400
Arduino	450
Magnet	400
Sd card adapter	150
Miscellaneous	200
Total	3000

Plate 4.3 slip meter (METHOD 2)

4.4 TESTING OF SLIP METER

4.4.1 LABORATORY TEST

Observed and actual values are compared using chi square test and found that there is no significant difference. Readings of test are given in appendix

Table 4.4 variance (Lab test)

Minimum variance	0
Maximum variance	0.42
Average variance	0.16

4.4.2 FIELD TEST

Slip measured manually and with slip meter are compared using chi square test and found that there is no significant difference. Readings of test are as follows

Table 4.5 Readings of field test

MANUAL

RPM	GEAR	NL	NNL	SLIP
1500	1	4.5	3.75	0.166667
1500	2	5	3.75	0.25
2000	1	4.15	3.75	0.096386
2000	2	5	3.75	0.25

SLIP-METER

RPM	GEAR	NL	NNL	SLIP
1500	1	4.36	3.86	0.1146
1500	2	5.05	3.83	0.241584
2000	1	4.39	3.83	0.127563
2000	2	5.06	3.83	0.243083

Table 4.6 Variance (slip meter)

Minimum variance	0.7
Maximum variance	5.2
Average variance	1.9

CHAPTER V

SUMMARY AND CONCLUSIONS

The development and testing of slip meter was conducted. Based on the design considerations and program, an automatic arduino based slip meter was developed. The summary of the results obtained from the experiments and conclusion drawn out from the study are presented in this chapter.

Slip meter can be used to obtain slip of the tractor. In terms of measurement, prediction, and presentation of tractor performance, slip is the single most important parameter. It is an indicator of right combination of tyre pressure, tractor weight(ballast) and operating speed resulting in correct traction for efficient performance and fuel saving. It can also determine wear and expected life time of a tractor drive train and tyres.

Slip measurement is acheived by using a micro controller and a sensor. The three main concepts for the design of slip meter are mechanical design, development of program and electrical circuit. Mechanical design includes fixture for magnet and fixture for sensor. Development of program includes the selection of micro controller, sensor etc. Arduino is selected as the micro controller because of its easiness and simplicity in use for beginners. Hall Effect sensor is used to count the magnet at the marked position. Electrical circuit design involves the electrical connection between power source, Arduino. SD card etc.

The fixture for sensor should have enough strength and it is better if the component is made of non magnetic material. If the material of attaching component is made of magnetic material then, enough space should be provided between the attaching component and the magnet so that the magnet should not get attracted by the component where we fix the sensor, at the same time the magnet should be sensed by the sensor. The spacing between the sensor and magnet as well as the attaching component and the magnet must be fixed correctly, in the case where we use magnetic material for attachment, and then chance of error will be high. The component should be flexible enough also.

we use metal sheet to attach magnets at fixed position. So the metal selected should have enough strength to hold the magnets. The magnets must be fixed in such a way that it should be sensed by the sensor. This metal sheet is in turn attached to the tyre hub with the help of magnets with opposite poles.

Arduino program controls the entire operations of slip meter. Conting the number of rotations and recording the values in the memory card are the various operations in the slip meter which is accomplished with the help of Arduino

The testing of the slip-meter was carried out in laboratory setup to check the accuracy of slip meter, for that testing we need a rotating shaft supported by bearing block with two metal discs on both sides. Each disc is fixed with a circular metal sheet, one having graduations from 0˚ to 360˚ (sheet 1) and the other is divided equally in to 36 parts (sheet 2). The circular sheets are fixed in to the disc by means of either magnets or double side tape. A handle is fixed on the shaft. Sheet 2 is fixed with magnet at the marked positions. The observed and actual values were compared by using chi square test. As per the results obtained from this statistical measure it can be concluded that the variations in the slip meter are insignificant.

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Appendix I

Programming Code

```
//This is the programme for the working of slip-meter (METHOD
1)
#include <SD.h>
//declaring all the pins
const int sdOutPin = 4;
int DR=9;
//declaring all the constants
int stater=0;
int prestater=0;
float r=1;float N=0.00;
void setup() {
// Open serial communications and wait for port to open:
Serial.begin(9600);
//declaring all the pinmode
pinMode(DR, INPUT);
pinMode(sdOutPin , OUTPUT);
//Checking the SD Card status
while(!SD.begin(sdOutPin))
{
Serial.println("sdcard not ready");
}
```

```
//creating files in SD card
writeData("rear.txt","START OF READING",HIGH);
}
//setup completed and loop begins
void loop() {
stater = digitalRead(DR);
if (stater!=prestater)
{
if (stater == LOW)
{
Serial.println(r++);
stater = digitalRead(DR);
}
}
prestater=stater;
//loop completed
prestatef=statef;
Serial.println("0");
Nr=(r-1)/36;
Serial.print("revolution of rear wheel=\t");
Serial.println(Nr);
writeData("rear.txt",String(Nr),LOW);
}
//This is the subprogram for writing files to SD card
void writeData (char *fileName, String Data, boolean nextLine)
{
```

```
File dataFile;
dataFile = SD.open(fileName, FILE_WRITE);
if (nextLine)
{
dataFile.println (Data);
}
else
{
dataFile.print (Data);
dataFile.print (",");
}
dataFile.close();
}
// End of the program
```

```
//This is the programme for the working of slip-meter(METHOD
2)
#include <SD.h>
//declaring all the pins
const int sdOutPin = 4;
int DR=9;
int DF=8;
//declaring all the constants
int statef=0;
int stater=0;
int prestatef=0;
int prestater=0;
float r=1;float Nr=0.00;
float f=1;float Nf=0.00;
void setup() {
// Open serial communications and wait for port to open:
Serial.begin(9600);
//declaring all the pinmode
pinMode(DR, INPUT);
pinMode(DF, INPUT);
pinMode(sdOutPin , OUTPUT);
//Checking the SD Card status

while(!SD.begin(sdOutPin))
{
```

```
Serial.println("sdcard not ready");
}
//creating files in SD card
writeData("rear.txt","START OF READING",HIGH);
writeData("front.txt","START OF READING",HIGH);
}
//setup completed and loop begins
void loop() {
stater = digitalRead(DR);
if (stater!=prestater)
{
if (stater == LOW)
{
Serial.println(r++);
stater = digitalRead(DR);
}
}
prestater=stater;
statef = digitalRead(DF);
if (statef!=prestatef)
{
if (statef==LOW)
{
Serial.println(f++);
statef = digitalRead(DF);
}
```

```
}
//loop completed
prestatef=statef;
Serial.println("0");
Nr=(r-1)/36;
Serial.print("revolution of rear wheel=\t");
Serial.println(Nr);
writeData("rear.txt",String(Nr),LOW);
Nf=(f-1)/36;
Serial.print("revolution of front wheel=\t");
Serial.println(Nf);
writeData("front.txt",String(Nf),HIGH);
}
//This is the subprogram for writing files to SD card
void writeData (char *fileName, String Data, boolean nextLine)
{
File dataFile;
dataFile = SD.open(fileName, FILE_WRITE);
if (nextLine)
{
dataFile.println (Data);
}
else
{
dataFile.print (Data);
dataFile.print (",");
```

```
}
dataFile.close();
}
// End of the program
```

Appendix II

Readings of laboratory setup

High speed

MEASURED VALUE	ACTUAL VALUE
2.67	3
2.94	3
2.58	3
2.97	3
3.03	3
4	4
3.92	4
3.86	4
3.75	4
3.75	4
4.86	5
4.86	5
4.75	5
4.58	5
5.89	6
6.78	7
6.64	7
7.92	8
7.78	8
8.89	9
8.78	9
8.89	9
8.92	9
9.92	10
9.78	10
9.89	10
11.92	12
11.81	12
11.84	12

Low speed

MEASURED VALUE	ACTUAL VALUE
4.97	5
5.97	6
5.94	6
5.81	6
6.89	7
6.97	7
6.94	7
7.94	8
7.92	8
7.94	8
7.86	8
9.94	10
9.97	10
10.94	11
10.89	11
10.83	11
10.86	11
10.97	11
12	12
11.97	12

Appendix III

Statistical analysis(χ^2 - test)

SAMPLE CALCULATION

High speed

MEASURED VALUE	ACTUAL VALUE	(Xi-Ẍ)^2
2.67	3	15.8816
2.94	3	13.8025
2.58	3	16.60703
2.97	3	13.58049
3.03	3	13.14187
4	4	7.049938
3.92	4	7.481166
3.86	4	7.812987
3.75	4	8.440024
3.75	4	8.440024
4.86	5	3.222643
4.86	5	3.222643
4.75	5	3.62968
4.58	5	4.306339
5.89	6	0.585488
6.78	7	0.015582
6.64	7	0.00023
7.92	8	1.59979
7.78	8	1.265238
8.89	9	4.994456
8.78	9	4.514894
8.89	9	4.994456
8.92	9	5.129446
9.92	10	10.6591
9.78	10	9.76455
9.89	10	10.46411
11.92	12	27.71841

11.81	12	26.57225
11.84	12	26.88244
	Ẍ=6.655172	Σ((Xi-Ẍ)^2)=261.7794

Variance$= \frac{\Sigma((Xi - \ddot{X})^2)}{n}$

$= \frac{261.7794}{29}$ =9.0268

$\chi^2 = \frac{\Sigma((Xi - \ddot{X})^2)}{\sigma 2}$

$= \frac{261.7794}{9.0268}$

=29

Taking $\propto = 5\%$

Degree of freedom=28

Table value of $\chi^2 = 41.337$

Low speed

MEASURED VALUE	ACTUAL VALUE	(Xi-Ẍ)^2
4.97	5	14.0625
5.97	6	7.5625
5.94	6	7.5625
5.81	6	7.5625
6.89	7	3.0625
6.97	7	3.0625
6.94	7	3.0625
7.94	8	0.5625
7.92	8	0.5625
7.94	8	0.5625
7.86	8	0.5625
9.94	10	1.5625
9.97	10	1.5625
10.94	11	5.0625
10.89	11	5.0625
10.83	11	5.0625
10.86	11	5.0625
10.97	11	5.0625
12	12	10.5625
11.97	12	10.5625
	Ẍ =8.75	Σ((Xi-Ẍ)^2)=97.75

Variance$= \frac{\Sigma((Xi-\ddot{X})^2)}{n}$

$= \frac{97.75}{20}$ =4.8875

$\chi^2 = \frac{\Sigma((Xi-\ddot{X})^2)}{\sigma 2}$

$= \frac{97.75}{4.8875}$

=20

Taking $\propto = 5\%$

Degree of freedom=19

Table value of $\chi^2 = 30.144$