DEVELOPMENT AND TESTING OF ARDUINO BASED PROFILE-METER

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PROJECT REPORT

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DECLARATION

We hereby declare that this thesis entitled **"DEVELOPMENT AND TESTING OF ARDUINO BASED PROFILE METER"** is a bonafide record of research work done by us during the course of academic programme in the Kerala Agricultural University and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this project report entitled **"DEVELOPMENT AND TESTING OF ARDUINO BASED PROFILE METER"** is a record of project work done jointly by Ms. Amrutha K, Ms. Anjana S R, and Ms. Rinju Lukose under my guidance and supervision and that it has not previously formed the basis for any degree, diploma, fellowship or associateship or other similar title of another University or Society.

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AMRUTHA K.

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Dedicated to the world of Research

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SYMBOLS AND ABBREVIATIONS

%	Percentage
2D	Two Dimensional
3D	Three Dimensional
A	Ampere
ATMEGA	Atmel megaAVR series
Avg	Average
cm	centimeter
CO2	Carbon dioxide
DC	Direct Current

EEPROM	Electrically Erasable Programmable Read Only Memory
e.g.	Example
et al.	and others
etc.	et cetera
g	gram
GND	Ground
GUI	Graphical User Interface
Hz	Hertz
i.e.	that is

ICSP	In Circuit Serial Programming
IDE	Integrated Development Environment
I/O	Input/Output
IR	Infrared
K	Potassium
KB	Kilobyte(s)
kg	kilogram(s)
LCD	Liquid Crystal Display
LDS	Laser Distance Sensor
LED	Light Emitting Diode

m	meter
mm	millimeter
m/s	metre per second
mA	milli Amperes
Max	Maximum
MHz	Mega Hertz
Min	Minimum
mm	millimeter
N	Nitrogen
No.	number

P	Phosphorous
PC	Personal Computer
pH	Potenzy Hydrogen
PTP	Portable Tillage Profiler
PWM	Pulse Width Modulation
RPM	Rotation Per Minute
SD	Secure Digital
SPI	Serial Peripheral Interphase
SRAM	Static Random Access Memory
US	Ultra Sonic

USB	Universal Serial Bus
V	Volt
VI	Visually Impaired
W	Watt

CHAPTER I
INTRODUCTION

Natural resources are being used more and more intensively as people attempt to fulfill the increasing demands of a growing population. This is leading to degradation of soil and water resources that farmers need. There is a strong demand to ensure that resources are used sustainably and there is a need to promote low cost soil and water conservation techniques, especially in developing countries. The maximum and minimum quantities of rainfall make cropping to be possible only with the use of special techniques of soil and water conservation. Ridge and Lister farming are the conventional systems of farming widely used by the farmers for the effective utilization of available water. In ridge farming, a ridge is constructed and the seed is planted in the elevated seedbed. Ridge or bed farming has been generally used in areas where high rainfall, tight soil or poor drainage limits the number of field working days in the spring and it will prevent damage to crops as a result of water logging. Ridge cultivation is also used for several crops such as root crops since the harvesting become easier due to the formation of bulb near to soil surface. In Lister farming, a furrow is made and the seed is planted in the furrow. It is generally used in areas with dry climate to conserve the moisture.

Mechanization in agriculture through modern power sources along with matching implements brings in added operational capacity, reduced dependence on labor, timeliness in field operations. This would lead to increased productivity and conservation of inputs, besides increase in profitability and sustainability of agriculture. Wide varieties of machines are available in India for the various farming operations.

Ridgers and furrowers are commonly used for the formation of bunds and furrows. Different designs of ridgers and furrowers suitable for different crop and cropping pattern are available in the market and used by farmers. Researches for developing crop and soil specific ridges and furrows are undertaken by various research organizations. To study about the performance parameters of ridgers and furrower, recording of profile is an important aspect.

Dimensions of various structures can be obtained by recording the profile. The measurement of profile helps in comparing the profile formed by different type of machines, variation of profile created by same machine in different soil conditions and also for checking whether the desirable profile is obtained.

Profile recording also helps to study about extent of soil erosion in the furrows before and after irrigation. Different studies on furrow irrigation have been carried out to reduce water losses and erosion related to furrow irrigation parameters such as furrow stream size, field slope, furrow length, soil type, plant coverage and soil density. High rainfall, runoff, water logging problems etc. are the main causes for soil erosion. Soil erosion results in washing out of available nutrients in the topsoil layer as the top soil is being rich in nutrient status. Study of variations in profile will help in identifying appropriate control measures in the field.

The methods or instruments which are currently in use for the profile recording are either less accurate or highly advanced technologies with high accuracy. The various existing methods for profile recording are pin-meter, shadow analysis, laser technology etc. Pin meter and shadow analysis are time consuming, less accurate methods which gives only an approximation of profile. Advanced methods like laser technology gives more accurate readings but the cost involved makes it less affordable for normal research works. Most of the existing instruments for profile measurement are used to obtain a 2-D view of the bunds and furrows. From a 2-D view, only a cross-sectional view can be obtained. 3-D view aids in a better way to study about shape of the structure and volume of the soil removed from an area. These factors highlight the necessity of low cost, portable instrument, which gives the profile of structures in field with less effort.

This research work aims in developing a soil profile meter for determining specific cross sections and furrow profiles in ditches and soil, new futures were added to soil meter to overcome some existing problems related to error measurement in fields.

The main objectives of this research work are following:

- To develop a low cost profile meter for automatic recording of bund and furrow profile.
- To fabricate and evaluate the profile meter.

CHAPTER II

REVIEW OF LITERATURE

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

2.1 PROFILE MEASURING DEVICES

Kuipers (1957) was one of the first researchers in the agricultural field to investigate the use of soil surface roughness measurements. He developed a relief meter which was used to measure heights of the soil surface relative to a datum line. The meter consisted of 20 small pins spaced 10 centimeters apart and free to slide up and down in a framework. The framework was placed over the surface to be measured and the dowel pins lowered to the soil surface. The distance each dowel pin moved from the reference line to the soil surface was read to the nearest centimeter from a scale mounted behind the dowel pins. The 20 height readings measured at a given location were corrected for the mean of the readings at that location.

Allmaras *et al*. (1966) also developed a random roughness index. They used a dowel pin system similar to that used by Kuipers (1957) to measure heights across the direction of tillage. Their relief meter had 20 pins spaced on 2 inch centers. The relief meter was used to measure 20 readings across the direction of tillage. Readings were taken at 20 relief meter settings spaced 2 inches apart in the direction of tillage, giving them 400 readings on a 40 x 40-inch sample area. Of the 400 readings recorded, the upper 10 percent and the lower 10 percent of the values were not used in the calculations because of the possibility of erratic height readings. An estimate of the standard error of these corrected heights was used as an index of random roughness.

An optical device was developed by Harral and Cove (1982) in which a laser diode, and position-sensing photo-detector, and appropriate lenses were utilized to determine the soil surface distance from the transducer. The device had a limited working range of about ± 150 mm from a point 600 mm from the source and receiver with a resolution of approximately ± 6 mm.

Romkens *et al.* (1982) developed a non-contact meter using a light source and a sensor at a constant height above the soil surface. The necessary location adjustment of the sensor to maintain that height was monitored and recorded automatically. A 250 point-per-meter transect, 1.52 m wide, was completed in about 4 min.

Pin meters are the devices most widely used for their simplicity. They consist in a single probe or a row of probes spaced at pre-established intervals and designed to slide up or down until the tip just touches the soil surface. Pin positions are recorded either electronically or manually (Romkens *et al*., 1986 and Wagner and Yiming, 1991). The chief disadvantage to this technique is its destructive impact on the soil surface while recording data in the field.

Wagner and Yiming (1991) developed a digitization procedure of pin-based profile meter photographs using a digitizing scanner to scan photographs and a custom-written computer program. This procedure allows more accurate data to be obtained, but requires several steps to take the data and two people to move the meter to different measuring locations. A common problem with steel pins is their heavy weight, which increases the weight of the meter and the accidental falling of the pins on the soil surface resulting in errors in depth measurements.

Image analysis techniques have recently been employed to measure different soil parameters e.g. two dimensional displacement vectors in soils obtained by a block-matching algorithm (Guler *et al.*, 1999), however, this algorithm is incapable of tracking individual particles, let alone their rotations.

Measuring soil profiles by Laser technology generates also had very good laboratory results, but its field use is limited because sunlight and hidden forms or shadows interfere with the readings, while high temperatures affect the performance of the sensitive measuring devices involved (Pardini, 2003; Darboux and Huang, 2003)

Raper *et al*. (2004) had developed a portable tillage profiler (PTP) which consists of a laser distance sensor, a linear actuator, a portable PC, and a lightweight aluminum frame that can quickly and accurately measure aboveground and belowground soil disruption caused by tillage.

Saeys et *al* (2004) stated that soil land measurement was started with measuring the profile of soil surface. The profile is measured using a set of laser beam and stake meter. Elevation was measured by placing one stake at each field corner for reference and then leveled. The stake meter was placed at 2, 4 up to 30 m length. The measurement was conducted at each tracks and the result was written on the table.

Kornecki *et al*. (2008) designed and tested a portable meter under typical field conditions; the tool can measure depths up to 500 mm and easily be modified for usage with large ditches. The device was successfully employed after rainfall events to assess soil erosion/deposition from quarter-drains.

Moreno *et al*. (2008) conducted study to develop a new method for measuring soil surface roughness that would be more reliable by using the principle underlying shadow analysis is the direct relationship between soil surface roughness and the shadows cast by soil structures under fixed sunlight conditions. They showed that shadow analysis yielded results significantly correlated to the pin meter findings, but with the advantage that the time invested in gathering field data was 12 to 20 times shorter.

Another work has been carried out by Borselli and Torri (2010) in order to reproduce reliable rough surfaces able to maintain stable, un-erodible surfaces to avoid changes of retention volume during tests by a set of roughness indices was computed for each surface by using roughness profiles measured with a laser profile meter, and roughness is well represented by quantiles of the Abbot–Firestone curve.

Hirschi *et al*. (2012) developed two surface profile meters which were developed for use in soil erosion research. Both were designed for use on 4.6 m wide field plots. Surface heights were measured electronically and stored on floppy disks. Meter pin spacing of 6.4 cm and 1.3 cm allowed measurement of plot characteristics and rill cross- sections. The accuracy of the meters was determined to be better than ±1 mm.

Hegazy (2013) recorded Soil Surface Profile using Portable Profile Meter with Image Processing and Tracking Technique. It is used to observe and measure changes occur in irrigation channels, small ditches and to quantify changes at specific cross sections within soil furrows. By using image processing and tracking system we can trace marked points in fixed level of meter pins. These pins can be vertically displaced and vary according to existing profiles and cross-sectional shape in different locations, which give us ability to record present form of different profiles. The recorded profiles heights for different locations gave us perspicuous knowledge about the geometry of furrows and ditches shapes before and after seasonal irrigation process. With ridge profiles, soil profile meter tracked variation in measured heights from 0 to 13.88 %, also, high percentage of variation obtained by studying flat top bed furrow changes, the largest percentage was 17.1 % at beginning of the furrow line.

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 Greenhouse 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 sensors available for distance measurement either directly or indirectly.

Kurt et al. (2008) stated that planar laser distance sensor (LDS) that has capabilities comparable to current laser scanners: 3 cm accuracy out to 6 m, 10 Hz acquisition, and 1 degree resolution over a full 360 degree scan. The build cost of this device, using COTS electronics and custom mechanical tooling, is under $30.

Mohammad et al. (2009) reported that the ultrasonic and IR sensors can measure distances more accurately. They also stated that the IR and US sensors can be used additionally to improve the overall vision systems of mobile robots.

Bach et al. (2012) reported the use of an Arduino microcontroller board to record the amount of time subjects spend in a particular location within a predefined distance between 2cm and 3m along with the date and stores each incident on a microSDcard. The data stored on the microSDcard can then be transferred to a computer for interpretation .They demonstrated the initial testing of the Arduino microcontroller board with an ultrasonic sensor as an accurate and anonymous method to measure proximity.

Mustapha et al. (2013) built an obstacle detection system is based on Ultrasonic (US) and infrared (IR) sensors. The system is intended for use by the elderly and people with vision impairment. The system also demonstrates good detection for different obstacle materials (e.g., wood, plastic, mirror, plywood and concretes) and colors. The minimum size of an obstacle that the system can detect is 5 cm x 5 cm. Ultrasonic sensor gives a linear output characteristic whereas infrared sensor shows a nonlinear output characteristic. Both sensors are able to detect an obstacle at the distances within their usable range with percentage of accuracy between 95% and 99%. The experimental result indicates that the US and IR sensors are able to provide reliable distance measurements even with different colors and materials of obstacles. It has been shown that IR sensor has slightly higher resolution than that of the US sensor, especially for small distance measurement within their usable ranges.

Vigneshwari et al. (2013) developed an electronic navigation system for the purpose of enhancing mobility for the blind and visually impaired pedestrian. Ultrasonic sensors are employed for obstacle detection. The real time signal reflected from the obstacles is collected by the sensor and Arduino Board processes the signal. Based on the processed data, appropriate decision is taken by the microcontroller in it. Accordingly a relevant message is invoked from the flash memory. Further this can be extended to communicate or deliver the decision to the subject via earphones.

Jamaluddin et al. (2014) developed simple method for non contact thickness gauge using Ultrasonic sensor and android Smartphone. This system is constructed using ultrasonic sensor HY-SRF05, microcontroller ATMEGA328, Bluetooth module and android smart phone. Ultrasonic sensor transmits ultrasonic pulses in the form of waves and receives back the pulses after the waves are reflected by an object. The time duration of ultrasonic between transmission and reception is calculated as distance between sensor and sample. The method of for thickness measurement adhere sample on holder in front of ultrasonic sensor. The Thickness measurement of sample is calculated based on distance between sensor to holder (fixed barrier) and sample to sensor. The zero position of measurement is distance of sensor to holder. The data of thickness is sent via Bluetooth and received by the Android application. Android Application uses to display measurement is designed base on MIT App Inventor for Android (AIA) platform.

Alattas (2014) developed a postuino which is used for posture correction by using Arduino Board and ultrasonic sensors. When a bad posture is detected, the user is notified. This system is designed specifically for computer users to prevent them from leaning too close to their computers' monitors. When the user leans to the computer, the distance between him / her, the computer, and the Postuino accordingly falls below a certain threshold. Then, an LED lights up and Piezo speaker plays chosen melody in order to alert the user to correct his/her posture.

Marathe et al. (2014) developed a portable automatic height detector which is basically designed to tackle the problem of 'accurate' height measurement. The IR sensor perceives the distance of the object whose height or any other dimension needs to be determined, the signal is then conditioned which makes the data suitable for further processing. The microcontroller Arduino Board is programmed to convert this input into the required height form for final display on the LCD. The LCD displays the height that is fed to it and provides the final output. They successfully measured and displayed the heights of various objects keeping an error margin of 2%.

Monisha et al. (2015) discusses the measurement of distance without making contact with the target. This is done by generating 40 kHz ultrasonic waves using ultrasonic transducers. Here the distance is calculated on the basis on time taken by the pulse generated by the ultrasonic transducer to travel to the target and return as reflected echo. This device also makes the use of microcontroller for calculating the distance and displaying it on a seven segment display. The distance up to 2.5m is calculated in air medium at ambient temperature.

Prabha et al. (2015) reported that the arduino with ultrasonic sensors can be used as accident avoidance system. They used ultrasonic sensors to detect any vehicle on both front and back side of the vehicle. The system comprises an idea of having safety while reversing a vehicle, detects any object within the following distance, and displays the distance between one vehicle and another vehicle to the driver using LCD. The safety can be maintained on crowded areas and in vehicle reversing process.

Ankit et al. (2016) reported that Ultrasonic sensor is most suitable for obstacle detection and it is of low cost and has high ranging capability. They had developed the obstacle avoidance robotics which is used for detecting obstacle and avoiding the collision. This is an autonomous robot. The design of obstacle avoidance robot requires the integration of many sensors according to their task. The obstacle detection is the primary requirement of this autonomous robot. The robot gets the information from surrounding area through mounted sensors on the robot. Some sensing devices used for obstacle detection are bump sensor, infrared sensor, ultrasonic sensor etc. This Arduino robot can be controlled by an android mobile or tablet, with the help of an android app that can be downloaded from Google Play store. The android application gets connected to the Bluetooth module and sends desired commands.

CHAPTER III

MATERIALS AND METHODS

This research work aims in developing a measuring instrument for the automatic recording of ridge and furrow profile and to plot the 3D profile of the structure. The concepts of design, methodology adopted for the development of profile meter are discussed in this chapter.

3.1 CONCEPT OF DESIGN

The distance measurement has three important factors i.e. medium, source and target. The source is a point from where distance is to be measured and target is the object whose distance is to be measured. The medium lies between source and target. The profile can be recorded by measuring its distance from a reference point. The distance can be measured by contact with surface and by non-contact measures. Surface contact measurements needs physical contact with the target whose distance is to be measured. The non-contact measures include the application of ultrasonic waves, laser technology etc.

Profile meter should measure form and critical dimensions as well as roughness of a ridge or furrow. The instrument should measure and record distances in X, Y and Z directions to obtain the 3-D view. The type and nature of the measuring instrument have a large effect the accuracy of data. For contact measurements, most obvious problem is that the stylus may disturb the measured surface or it may penetrate the soil and give inaccurate readings. This is especially true when measuring very smooth surfaces.

The non-contact measurement of profile can be achieved by using sensors, Microcontroller development board and suitable storing unit. The microcontroller is used to control the manipulator movements, as well as to communicate and control the sensor.

The concept can be categorized into three categories:

1. Mechanical Design
2. Development of programme
3. Electrical circuit

3.2 DESIGN OF PROFILEMETER

The concepts for the design and development of various components of 3-D profile-meter are discussed in the following sub-sections.

3.2.1 Mechanical design

A suitable prime mover is necessary for the manipulation of moving unit. Selection of prime mover and moving component is discussed in this section.

3.2.1.1 ***Selection of prime mover***

The selection criteria for the prime mover are following:

- Light in weight
- Portable
- Ability to start and stop at fixed intervals without much force of inertia
- High torque

Based on the criteria, the DC Motor is selected as the prime mover for the moving component. The Direct Current Motor is the most commonly used actuator for producing continuous movement and whose speed of rotation can easily be controlled, making them ideal for use in applications were speed control, servo type control, and/or positioning is required. A DC motor consists of two parts, a “Stator” which is the stationary part and a “Rotor” which is the rotating part. Normal DC motors have almost linear characteristics with their speed of rotation being determined by the applied DC voltage and their output torque being determined by the current flowing through the motor windings. The speed of rotation of any DC motor can be varied from a few revolutions per minute (rpm) to many thousands of revolutions per minute making them suitable for electronic, automotive or robotic applications. By connecting them to gearboxes or gear-trains their output speed can be decreased while at the same time increasing the torque output of the motor at a high speed.

Fig. 3.1 DC Motor

3.2.1.2 ***Moving component***

The profile-meter should be able to measure distances at various points. A lateral and transverse moving component is necessary for recording distances in X, Y and Z directions. The lateral component should design for measuring the span or width of the bund. Transverse component being smaller than lateral, can attached to latter. The height of lateral component can be fixed based on the height of bund. Normally the width of ridges and furrows for cultivation purposes varies between 30 cm to 100 cm and height a maximum of 100 cm. So, lateral part should be designed in such a way that it should cover the critical dimensions of the ridges and furrows. Lateral moving component should be able to carry the weight of transverse component. Both these components should be light in weight and should be able to move in both directions.

The conversion of rotary motion to linear motion can be achieved by using different types of mechanisms. Rack & pinion, slider crank mechanism, linear actuator are the some of the best mechanisms for the conversion. Since the space requirement for the rack & pinion and slider crank mechanisms are more, linear actuator is selected as the conversion mechanism for the profile-meter.

A linear actuator is an actuator that creates motion in a straight line, in contrast to the circular motion of a conventional electric motor. There are many types of linear actuators. Since the operation of electro-mechanical actuator can be automated, it is used for the working of profile-meter. In Electro-mechanical linear actuators, rotary motion of the motor is converted to linear displacement. The electric motor is mechanically connected to rotate a mild steel threaded rod using a gear. Big gear with 60 mm diameter is connected to the motor shaft directly. Small gears with 40 mm diameter are connected to the two threaded rods and are in mesh with the big gear. The rod has continuous helical thread with definite pitch. A nut having corresponding helical threads is threaded onto the rod. The nut is prevented from rotating freely with the rod, since it gets interlocked with the non-rotating part of the actuator. Therefore when the rod is rotated using the motor, the nut will be driven along the threads. The direction of motion of the nut depends on the direction of rotation of the rod. The motion can be converted to usable linear displacement by connecting linkages to the nut. The main principle is that the threads of a rod act as a continuous ramp that allows a small rotational force to be used over a long distance to accomplish movement of a large load over a short distance. Both lateral and transverse movement can be achieved by using linear actuators.

3.2.2 Development of programme

The uses of open source programs are being common now a day. 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 be 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.

Different types of sensors can be used with arduino for distance measurement. Some of them are ultrasonic sensors, infrared sensors, and proximity sensors. Considering the accuracy level and economic considerations, ultrasonic sensor is selected from these based on the reviews and affordable cost.

3.2.2.1 ***Arduino***

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pin, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. The Arduino Uno can be programmed with the Arduino Software (IDE). The Arduino/Genuino Uno board can be powered via the USB connection or with an external power supply. The board can operate on an external supply from 6 to 20 volts Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive 20 mA as recommended operating condition and has an internal pull-up resistor (disconnected by default) of 20-50k ohm. The ATmega328 has a memory of 32 KB (with 0.5 KB occupied by the boot loader).

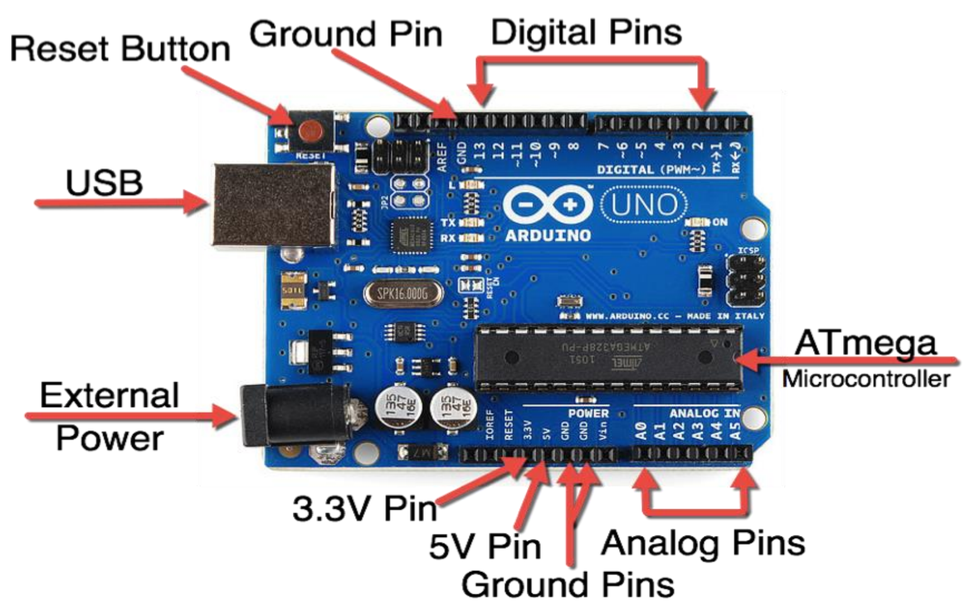


Fig. 3.2 Arduino Uno pin configuration

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

3.2.2.2 ***Sensors***

There are many sensors available for distance measurement. Based on the reviews, ultrasonic sensor is found to be more suitable than other sensors.

Ultrasonic sensor can be used as sensing component. Three sensors are necessary for taking X, Y, Z readings. Ultrasonic sensor account the amount of time taken by pulse to travel to a target and returns as reflected echo. The device calculates the distance up to 4m.System consists of a transmitter circuit and a receiver unit. Fig. shows the principle of ultrasonic distance meter.

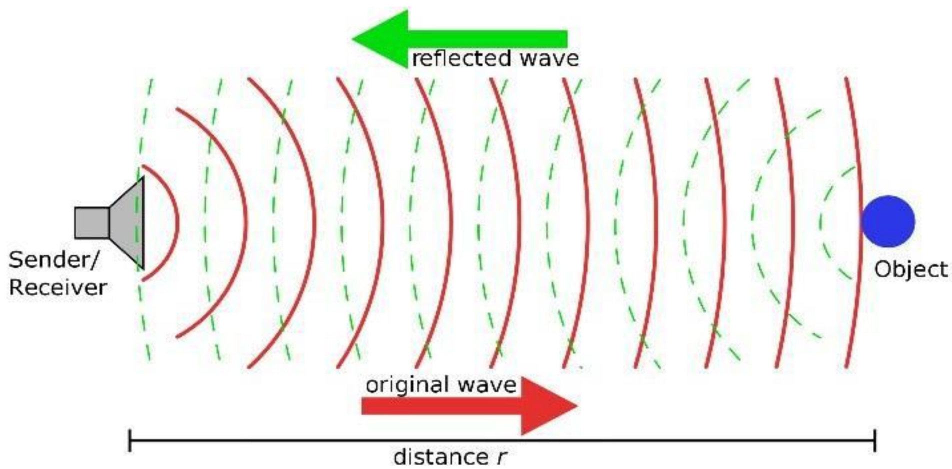


Fig 3.3 Principle of ultrasonic distance sensor.

Ultrasonic distance measuring sensors provide information on an absolute position of a target or moving object. Applications for ultrasonic distance measuring sensors include level detection, stack height control as well as absolute position feedback. Here uses the HC-SR04 ultrasonic sensor. This sensor has 4 pins: Vcc (Voltage in), Trig (Trigger), Echo, and GND (Ground). The Vcc pin requires 5 V DC and the GND pin needs to be properly grounded. The Trig pin receives a pulse to start ranging and sends out a burst of ultrasound. The Echo pin receives the signal and calculates the time between sending a signal and receiving it. Speed of sound in air generally taking as 340 m/s or 29 microseconds per centimeter. The sound wave or ping travels out and back, so to find the distance of the object we take half of the distance travelled. The following equation shows how the distance to an object is calculated.

$$Speed\ of\ sound\ waves\ in\ air = 340\ m/s$$

$$Distance\ travelled\ in\ centimeters = \frac{Time\ \ taken\ in\ microseconds}{29}$$

Since the time taken is the time taken by pulse to travel to a target and returns as reflected echo, actual time to reach the target is half of that.

$$Distance\ to\ target\ in\ centimeters = \frac{Time\ \ taken\ in\ microseconds}{58}$$

Fig 3.4 HC SR04 Ultrasonic Sensor

3.2.2.3 ***SD Card reader***

The SD library allows for reading from and writing to SD card e.g. on the Arduino Ethernet Shield. The communication between the microcontroller and the SD card SPI takes place on digital pins 11, 12, and 13. Additionally another pin must be selected to the SD card.

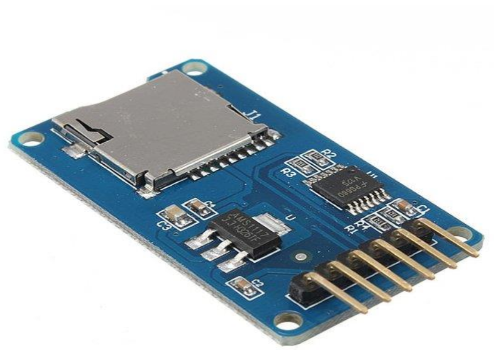


Fig 3.5 Arduino SD Card Reader

3.2.2.4 ***Programming concepts***

As the profile-meter is used to record X, Y and Z distances, three sensors are needed for the measurement. One sensor can be fixed as base point. Second and third sensors are movable with respect to the first sensor. Hence one sensor is fixed and other two are movable. Fixed sensor measures the distance in longitudinal direction. Movable sensors measure distance in transverse and vertical direction. Z distance indicates the depth to the desired points. It should subtract from the datum to get the height of the structure. These readings should record in 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
- The progamme should position the sensors properly
- Sensors should take readings of desired points and record in the memory card.
- The sensors should change direction according to extreme positions of transverse movement
- The programme should stop when the sensors attain the desired stopping position

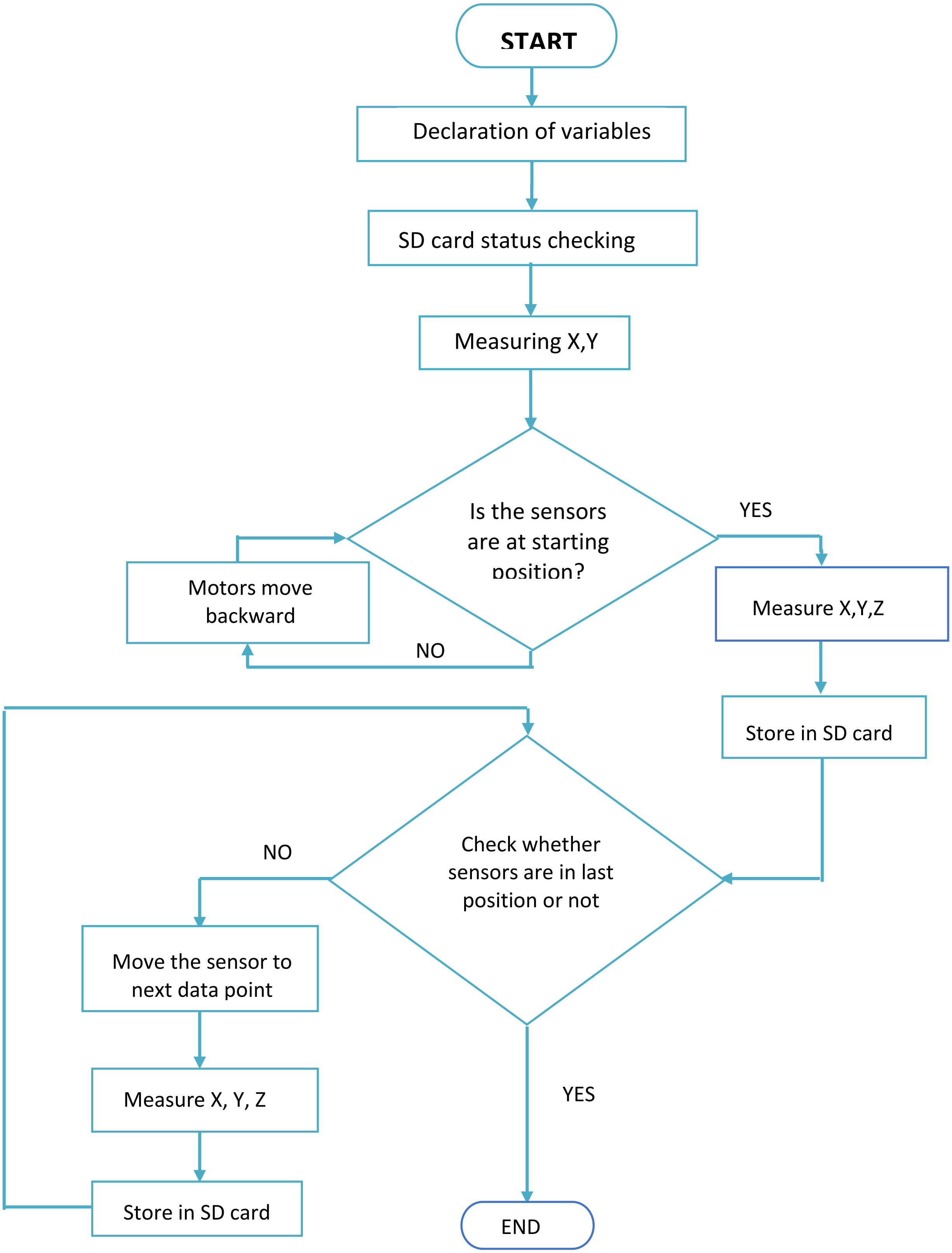


Fig 3.6 Flow chart of Programming Concept

3.2.3 ELECTRICAL CIRCUIT

For the working of Arduino Board, 5V supply is needed and for the working of DC motor, 12V supply is needed. Following are the main components in electrical connections:

3.2.3.1 MOTOR DRIVER

A motor driver is needed to control the DC motor. L293D is a typical Motor driver or Motor Driver IC which allows DC motor to drive on either direction. It is a 16-pin IC which can control a set of two DC motors simultaneously in any direction. It works on the concept of H-bridge. H-bridge is a circuit which allows the voltage to be flown in either direction. In a single L293D chip there are two H-Bridge circuit inside the IC which can rotate two DC motor independently. Due its size it is very much used in robotic application for controlling DC motors. There are two Enable pins on l293d, Pin 1 and pin 9, for being able to drive the motor. For driving the motor with left H-bridge it is necessary to make the enable pin 1 to high. And for right H-Bridge it is necessary to make the pin 9 to high. If anyone of these pins goes low then the motor in the corresponding section will suspend working.

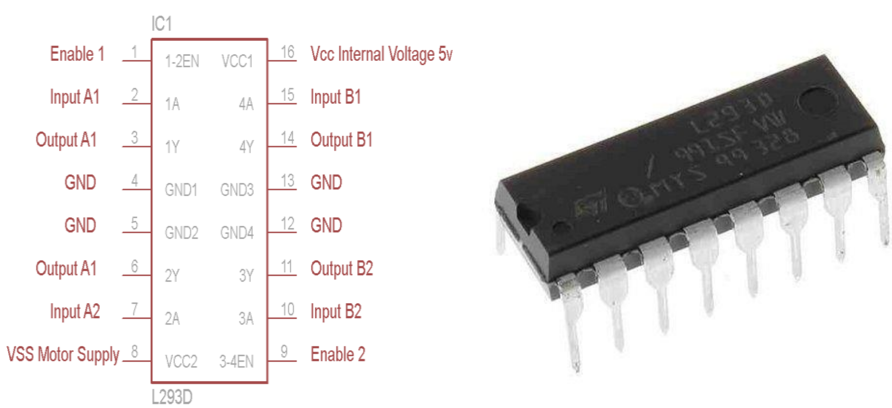


Fig 3.7 Motor Driver and pin configurations

3.2.3.2 ***Bread board***

A breadboard is a construction base for prototyping of electronics without having to solder them. It is used to build and test circuits quickly before finalizing any circuit design. The breadboard has many holes into which circuit components like ICs and resistors can be inserted. The bread board has strips of metal which run underneath the board and connect the holes on the top of the board.

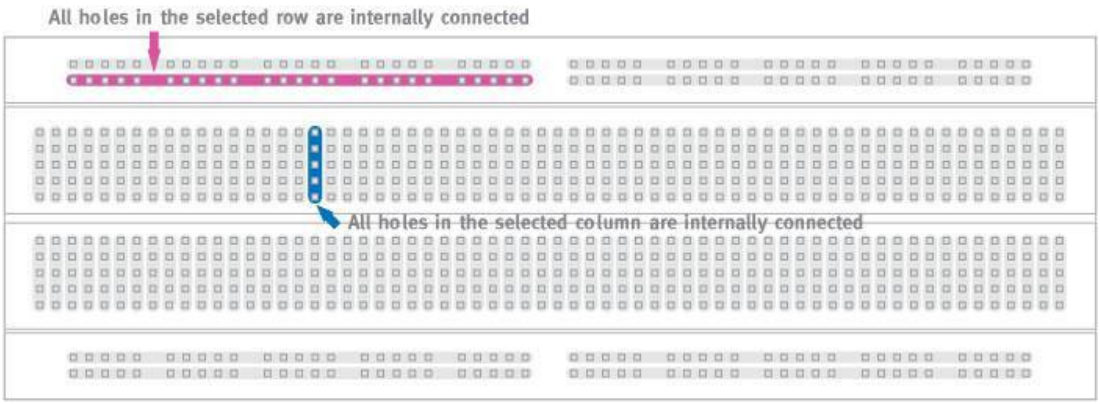


Fig. 3.8 Bread board Connections

3.2.3.3 ***Jumper wires***

A jumper wire (or simply jump wire) is a short electrical wire with a solid tip at each end (or sometimes without them, simply tinned), which is normally used to interconnect the components in a breadboard. They are used to transfer electrical signals from anywhere on the breadboard to the input/output pins of a microcontroller. Jump wires are fitted by inserting their end connectors into the slots provided in the breadboard that beneath its surface has a few sets of parallel plates that connect the slots in groups of rows or columns depending on the area. The end connectors are inserted into the breadboard, without soldering, in the particular slots that need to be connected in the specific prototype.

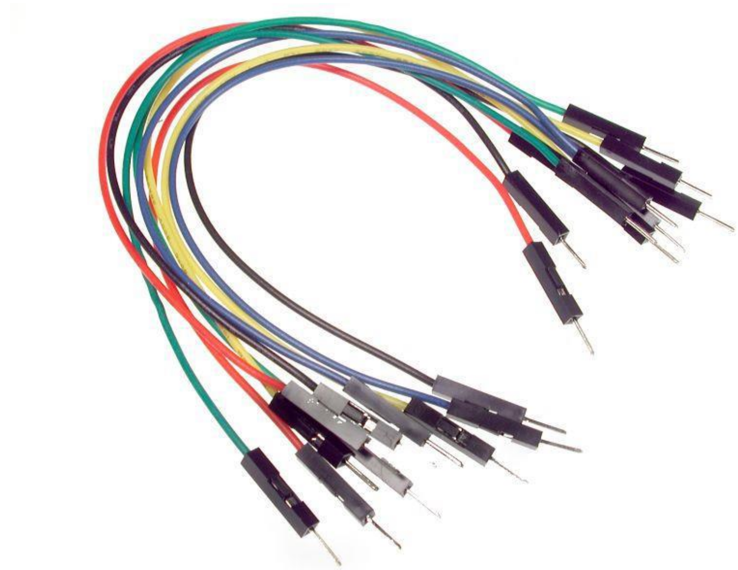


Fig. 3.9 Jumper Wires

3.3 DEVELOPMENT OF PROFILE-METER

Based on the subsystems identified and evolved design, a laboratory prototype was fabricated for analyzing the functionality. The components of the prototype are longitudinal unit, transverse unit, control unit and DC motors. The prototype was developed with wired programming control for the positioning of sensors and recording of readings.

3.3.1 **Lateral component**

An aluminium frame was used as supporting frame since it is lightweight and portable. Height of the unit is 100 cm. Two supporting frames are placed on steel plates of dimensions 15cm × 15cm for the stability of structure. Two end caps which are made up of wood are placed at the both ends of screw threads using ball bearings. At the top of end cap in one side, fixed sensor is positioned so that it would measure distance in X-direction. Motor for the working of linear actuator is fitted to one of the end cap. A bolt is screwed to the square nut of the lateral linear actuator. A hollow square pipe of 100cm × 2.5cm × 2.5cm is used as the cover for screw threads. Hydrostatic balance tool is attached to the square pipe to provide sufficient leveling. A rectangular plate1 which offers resistance to the fixed sensor and the inverted 'U' frame which supports the transverse component are attached to the vertical bolt with the help of lock nuts. Necessary numbers of washers are also used in between the contact surface for the smooth functioning of the components. Hence the wear and tear caused due to the movement can be reduced to a certain limit.

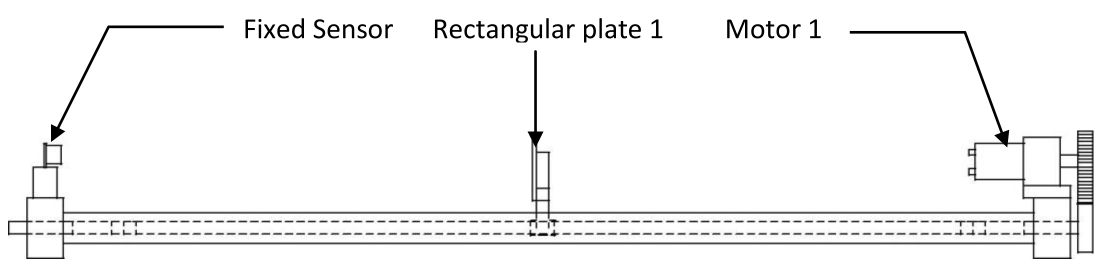


Fig. 3.10 Front View of Lateral Component (all dimensions are in mm)

3.3.2 **Transverse component**

Materials for construction are same as that of lateral component. Inverted U-frame from the vertical bolt is connected to the end caps of the transverse component. Screw thread is connected to the end caps as in lateral component. A hollow square pipe of 50cm × 2.5cm × 2.5cm is used as the cover for screw threads. Motor is fitted to one of the end caps. Movable sensor 1 is mounted on the end cap and it is facing towards the rectangular plate2.A downward facing bolt is screwed to the square nut of the transverse linear actuator. The rectangular plate2 which offers resistance to the fixed sensor2 is attached to the bolt. The sensor which reads distance in Z-direction is mounted on plate2. Hydrostatic balance tool is also attached to the square pipe.

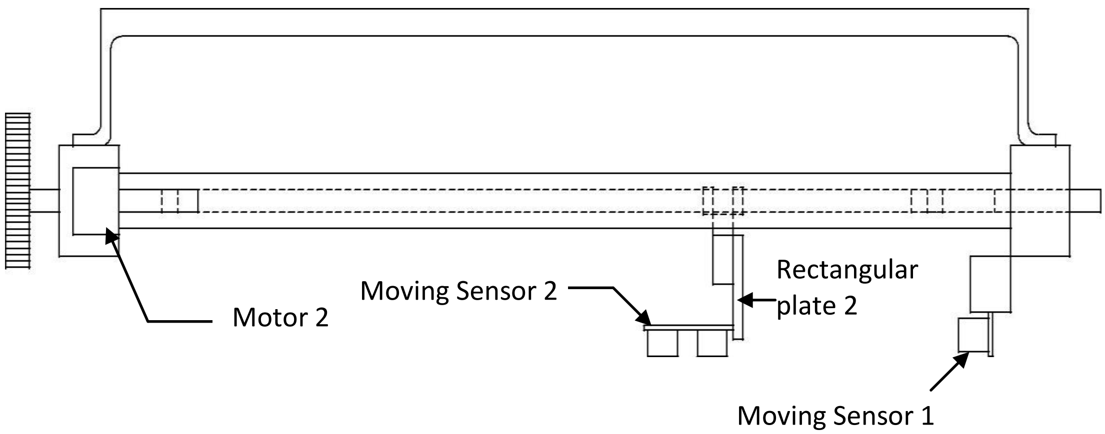


Fig. 3.11 Front View of Transverse Component (all dimensions are in mm)

3.4 TESTING OF PROFILE-METER

The testing of the profile-meter was carried out in a laboratory set up. For the testing, two structures are made by using wood and cardboard with known dimension. Shape of one structure is similar to semi-elliptical and shape of another structure is similar to rectangle. Actual dimensions of the structures are noted and then measured by using profile-meter. And two plots are created in AutoCAD, one using actual measurements and other using measured.

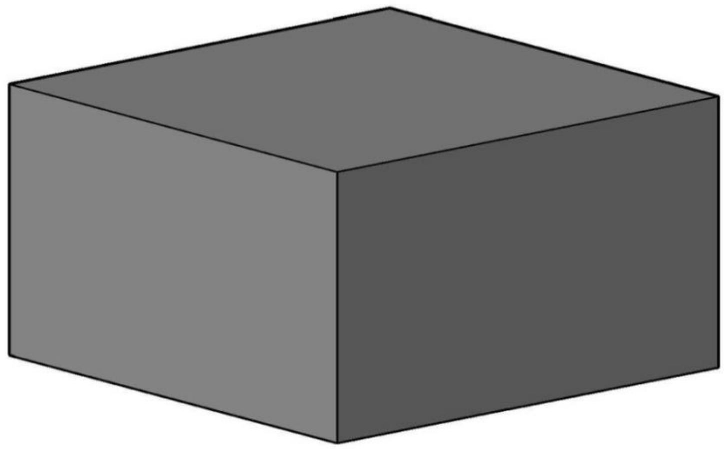


Fig 3.12 Isometric view of the structure made for testing (Rectangular)

(all dimensions are in mm)

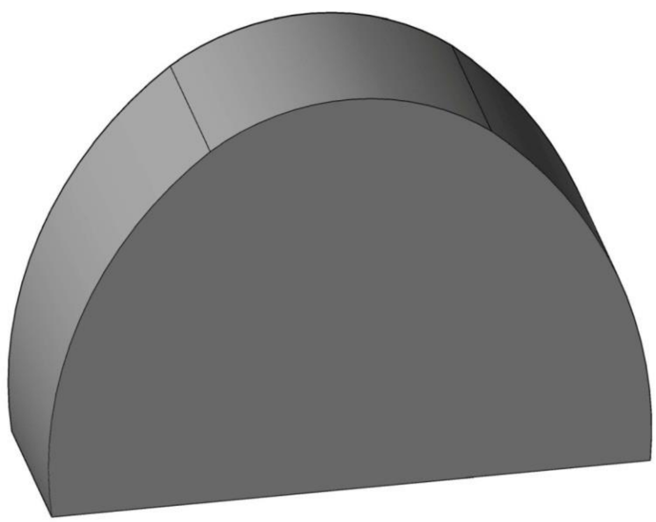


Fig 3.13 Isometric view of the structure made for testing (Semi elliptical)

(all dimensioms are in mm)

Plate 3.1 Testing of profile meter in laboratory setup (Semi elliptical Structure)

The comparison between actual and measured profile are done by using statistical methods. Paired t-test is used for the comparison between actual and observed readings. For a corresponding X-value,there are two Z-values in which one is obtained manually and other is obtained by using profilemeter.

For doing the paired t test, 121 set of data are taken at a time and found the t value. It is compared with the table value of t corresponding to the degree of freedom. Since the calculated t value is always less than the table value of t, it can be concluded that there is no significant difference between the readings. Sample calculation is given in annexure IV.

Steps for the paired t-test are following:

- Calculate the deviation between two z-values corresponding to each x-value .
- Calculate the mean value and standard deviation of the deviation values

$$Mean, \bar{z} = \frac{\sum_1^n z}{n}$$

$$Standard\ Deviation, \overline{SD} = \sqrt{\frac{\sum_1^n (z - \bar{z})^2}{n - 1}}$$

- Calculate the t-value using the following equation:

$$t\ value = \sqrt{n} \times \frac{\bar{z}}{\overline{SD}}$$

- Compare the calculated t-value with the table t-value which can be otbtained from the statistical table

CHAPTER IV

RESULTS AND DISCUSSION

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

4.1 DESIGN OF PROFILE-METER

Selection of various components is presented in this section.

4.1.1 Mechanical design

The moving system of profile-meter refers to the structure that helps in required movement. The measurement of different points by the sensor is achieved with the help of the moving system. Based on the preliminary studies, a moving system suitable for the profile-meter was selected and designed.

4.1.1.1 *Prime mover*

From analyzing the required movements, it was decided to use two motors for achieving motion. One motor is used for providing the rotation of screw thread in lateral component which gave motion in X direction. Another motor was used for giving a Y direction motion and Z direction motion of the unit. From the reviews studied so far, a 12 V DC motor which can produce a torque of 30 Kg.cm and a speed of 300 rpm was selected suitably for the design. The torque developed during the operation of the motor produces mechanical rotation and hence the motion

Table 4.1 Specifications of the motor

SPECIFICATION	VALUE
Type	DC
Shaft diameter	6 mm with M3 threaded hole
Rotation	300 rpm
Base RPM	18000 rpm
Input voltage	12V
Weight	250 g
Torque	30 Kg cm
No load current	800 Ma
Load current	Up to 7.5 A(Max)

4.1.1.2 ***Moving component***

The principle used for the mechanism is linear actuators. Two linear actuators are used for movement in different directions. In two linear actuators, one is placed in the X-direction and other is in the Y-direction. Length of linear actuator in X-direction is 100cm and in the Y-direction is 50cm.The diameter of thread is 1 cm. Two end caps are placed at the both ends of linear actuator. Ball bearings are placed at both ends for the smooth rotation of the rod. A square pipe of length 100cm and sides of 2.5cm is used to cover the threaded rod.

4.1.2 **Development of programme**

The programme should control read, store, motor rotation, indication 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, 6 pins are given for three sensors for their respective trig and echo pins, 4 pins are used for SD card reader and one pin for LED. In 6 analog pins, 4 pins are used for functioning of two motors.

Table 4.2 Pins used for the components

Pin Number	Component/Variable Name
Analog Pins	
2	Fixed Sensor (Trig Pin)
3	Fixed Sensor (Echo Pin)
4	Movable Sensor1 (Trig Pin)
5	Movable Sensor1 (Echo Pin)
6	Movable Sensor2 (Trig Pin)
7	Movable Sensor2 (Echo Pin)
9	LED
10	SD Card Reader (CS)
11	SD Card Reader (MOSI)

12	SD Card Reader (MISO)
13	SD Card Reader (SCK)
Digital Pins	
14	Xmotor (Forward Pin)
15	Xmotor (Reverse Pin)
16	Ymotor (Forward Pin)
17	Ymotor (Reverse Pin)

Other variables used in the programme are:

Table 4.3 Variables and their values used in the programme

VARIABLE NAME	DESCRIPTION	INITIAL VALUE	WHETHER VARIED DURING RUN
minX	Starting point of longitudinal movement	150	NO
minY	Starting point of transverse movement	100	NO
maxX	End point of longitudinal movement	850	NO
maxY	End point of transverse movement	400	NO
noSamples	Total number of readings taken at a point	30	NO
XDist	Mode value of distance from Fixed Sensor		YES
YDist	Mode value of distance from Movable		YES

	Sensor2		
ZDist	Mode value of distance from Movable Sensor2		YES
XMotorForward	Movement of Xmotor	LOW	YES
YMotorForward	Movement of Ymotor	LOW	YES
XChangeDir	Direction Changing of Xmotor	LOW	YES
YMotorRotate	Rotation of Ymotor	LOW	YES

The variable noSamples which is given at the time of coding the programme represents the number of readings taken for measuring a particular distance. This has been set to 30 for the present programme consideration based on the accuracy levels and time required. Starting position for movement in X-direction is fixed at 150mm from fixed sensor for the current programme and it is indicated in the programme by the variable minX. And ending position, which is represented by variable maxX is fixed at 850mm from fixed sensor. Starting position for movement in Y-direction is fixed at 100mm from moving sensor1 and it is indicated in the programme by the variable minY. And ending position i.e. maxY is fixed at 400mm from movable sensor2.

A number of operations have to be incorporated. Some of these activities are measuring distance, writing measured data, rotation of motor in specified direction etc. are repeated actions to be performed based on the current position of the sensor. In order to perform these operations, five different sub functions were identified which has to be done in both setup and loop.

Table 4.4 Sub functions used in the programme and output

Sl no.	Sub function	Input variable	Output
1	motorRun	state of motor, motor direction and time for rotation	rotation of motor
2	getDistance	Pin numbers for trig pin and echo pin and number of samples	distance value from sensors
3	getInteger	Distance value from sensors	decimal values are rounded to integer values
4	getMode	Integer values of distance	Mode calculation
5	writeData	Mode value of distance	Storing of values into the memory card

As some of the sensors are attached to a moving component, the time taken by the sensor to be in rest position and environmental failures like wind speed may influence the accuracy of distance measured. In order to obtain an accurate measurement, 30 samples (which correspond to the variable noSamples) are taken for a particular point and the mode of these is taken for the actual calculation of the distance. If a unique mode was not obtained, the readings were neglected and fresh readings are taken until a constant mode is obtained. This method minimizes the chances of error.

As a result of writeData function, 4 files are created in the memory card, one each for X, Y, and Z readings respectively and the remaining one for X, Y, Z readings.

The file with X, Y, Z readings are saving as script files. By dragging these files into AutoCAD, 3-D view of the structure can be obtained.

4.1.3. **Electrical connections**

The connection diagram for 3-D profile-meter is shown as below:

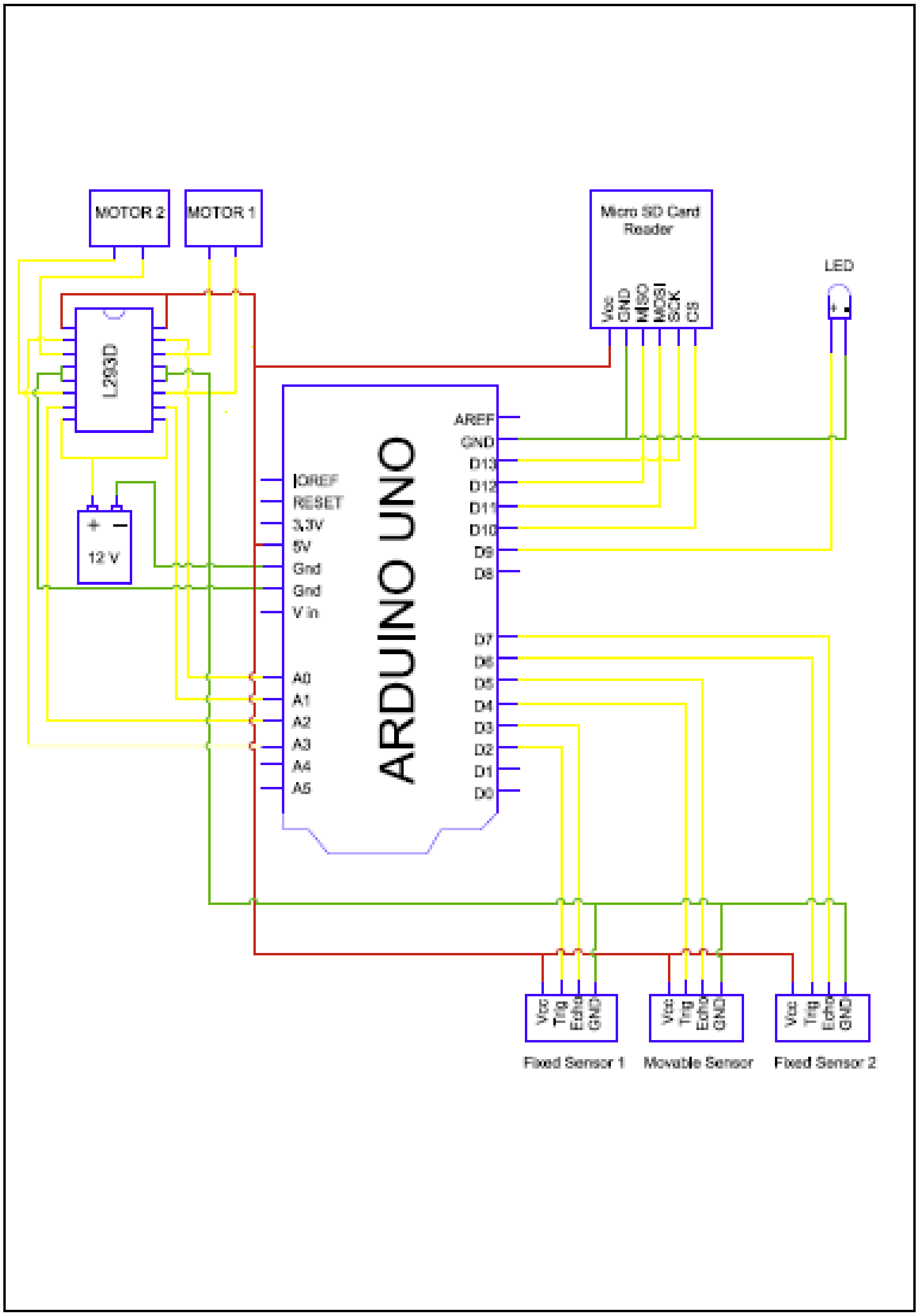
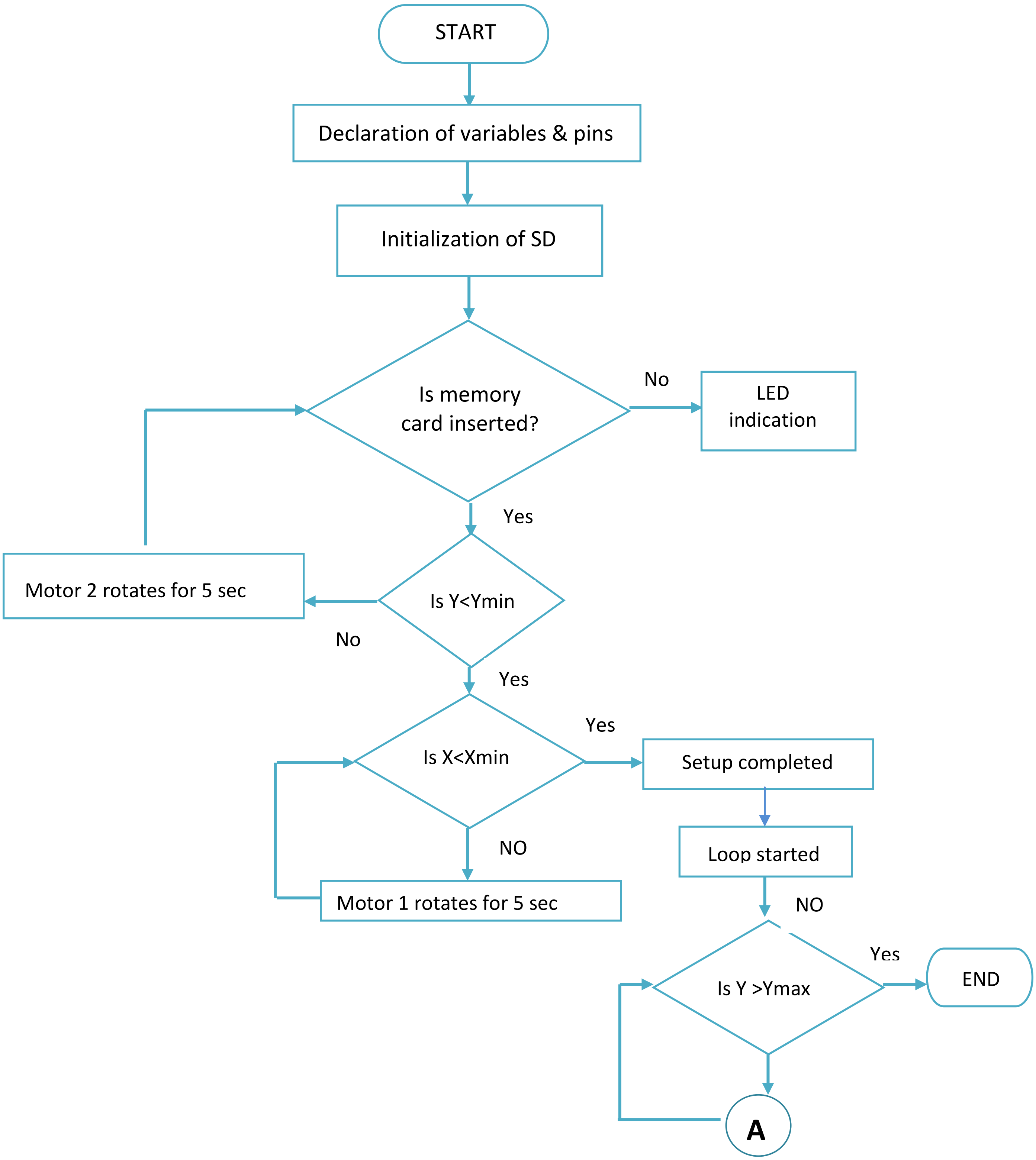


Fig. 4.1 Circuit diagram

4.2 DEVELOPMENT OF PROFILEMETER

The following flow chart shows the working of Ardunio Programme in Profile-meter:



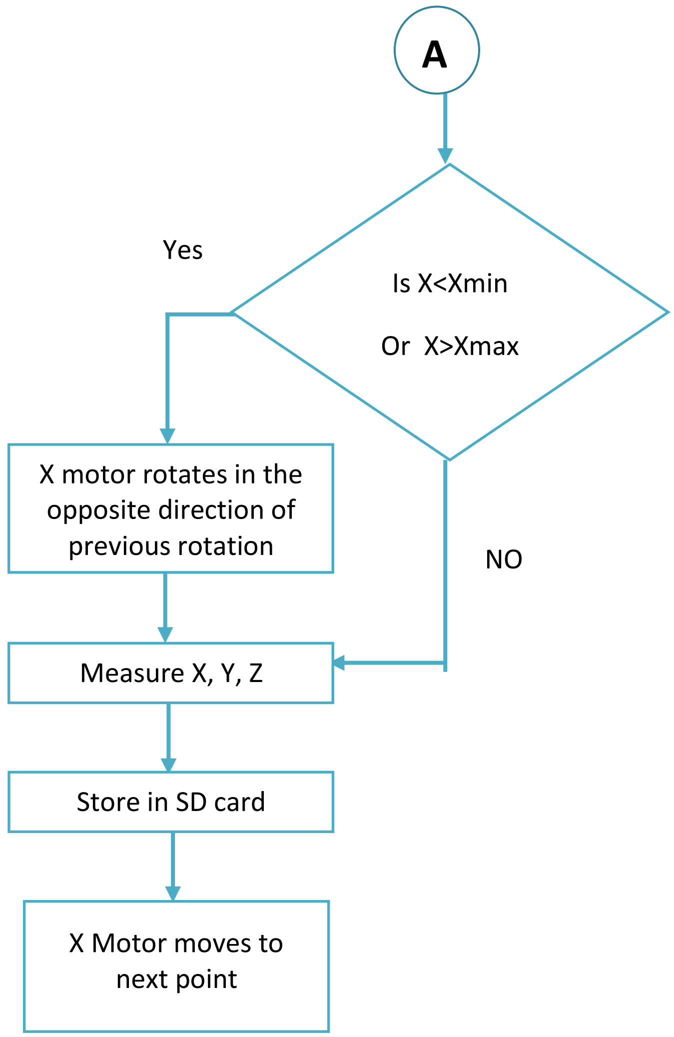


Fig 4.2 Flow chart of working of Profile-meter

The measurement of various points is achieved by linear actuator with the help of rotation of two threaded rods. Mild steel threaded rod with 1 cm diameter is used for this. The rod is fixed at both ends by end cap and is surrounded by a square hollow pipe.

The length of rod for lateral component is 100 cm and that for transverse component is 50 cm.

Plate 4.1 Profile-meter

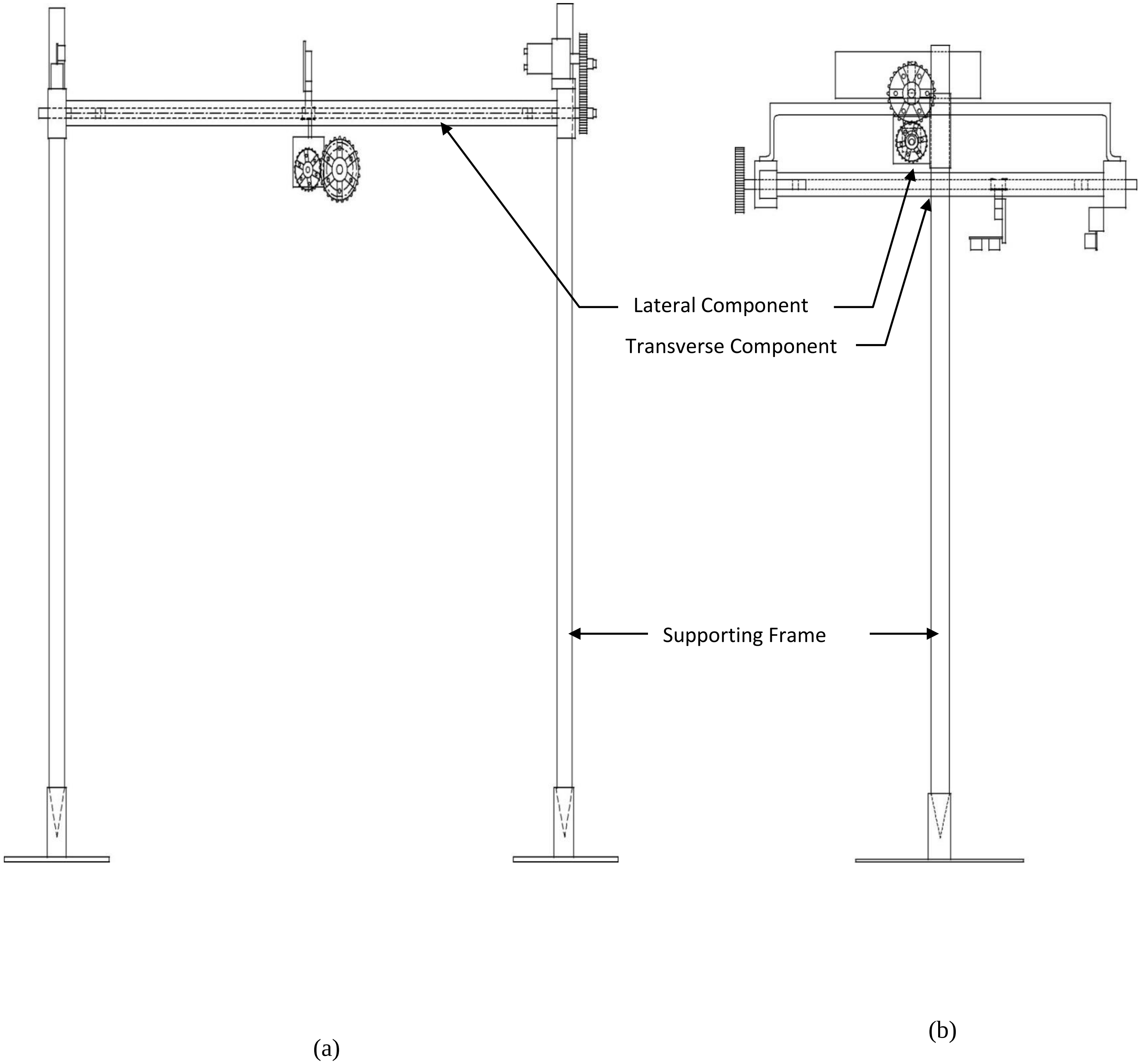


Fig 4.3 (a) Front View, and (b) Side View of the Profile meter

(all dimensions are in mm)

Table 4.5 Specifications of the threaded rod

THREADED ROD	
Outer diameter	10 mm
Inner diameter	8.5 mm
Mean diameter	9 mm
Pitch	1.5 mm

Motor drive for giving to and fro motion of sensor is mounted at the side of the both lateral and transverse component. The motor drive is transmitted to the threaded rods through gears. Big gear with 6 cm diameter is connected to the motor shaft directly. A small gear with 4 cm diameter is connected to the threaded rod and is in mesh with the big gear.

Table 4.6 Specifications of the gears

Large gears	
Addendum circle diameter	60.00 mm
Dedendum circle diameter	53.00 mm
Larger width of tooth	2.90 mm
Smaller width of tooth	1.30 mm
Thickness	12.00 mm
Number of teeth	38

(Table 4.6 continues.)

Small gears	
Addendum circle diameter	40.00 mm
Dedendum circle diameter	33.00 mm
Larger width of tooth	2.60 mm
Smaller width of tooth	1.20 mm
Thickness	12.00 mm
Number of teeth	25

The overall weight of the Profile meter is 3 kg and has a cost around 6000 rupees.

The details of cost are given in the following table.

Table 4.7 Details of cost

PARTICULARS	COST
Arduino, sensors, memory card reader and memory card	1250
Motors	2200
Connecting wires, motor driver and breadboard	300

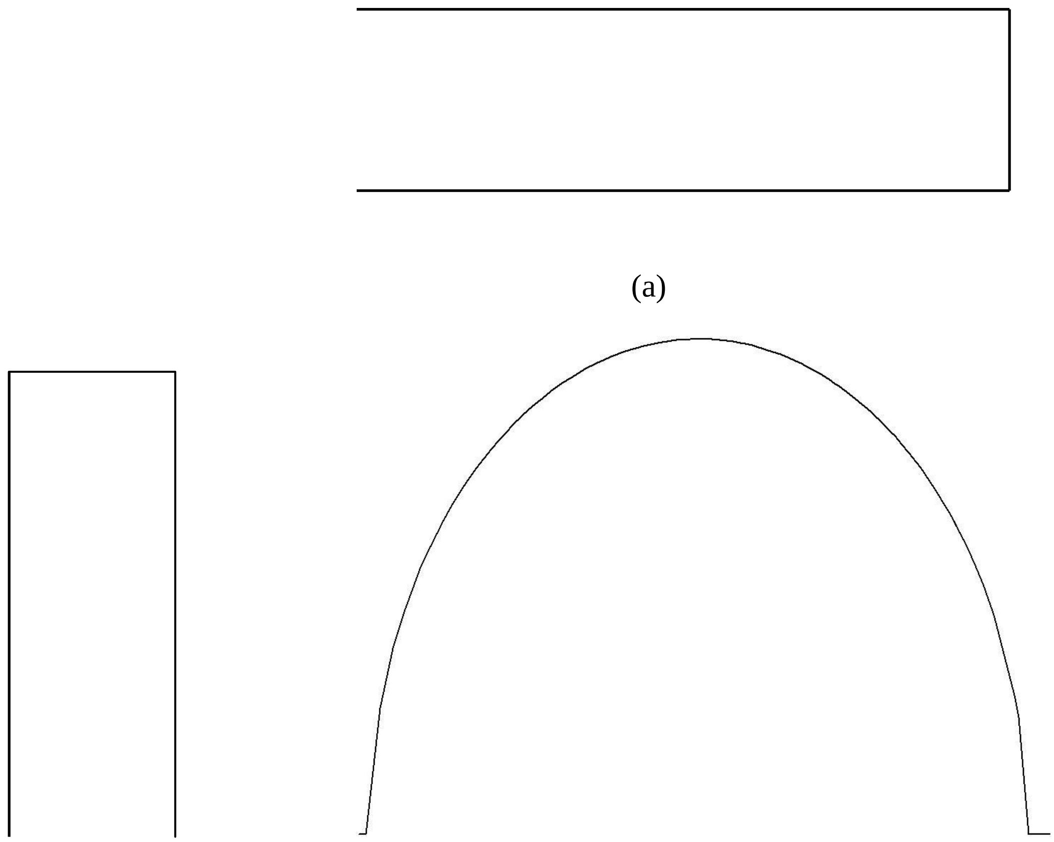
Frame, screw rod, bearings	1500
Fabrication cost	500

4.3 TESTING OF PROFILE METER

The laboratory prototype fabricated based on the design was tested at laboratory set up to check the functionality of its parts. The parts showed a successful functioning in the laboratory environment. The vertical unit and horizontal unit were found operating in smooth condition, but the time taken for the longitudinal and lateral movement was very much great. In order to overcome this issue, it is recommended to use a screw rod of higher pitch value.

4.3.1 **Semi-elliptical Structure**

The profile of a semielliptical structure of known dimension is measured using profilemeter. The result obtained is:

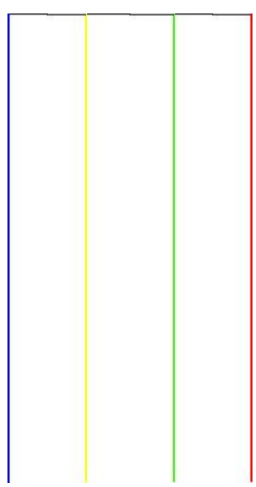


(a)

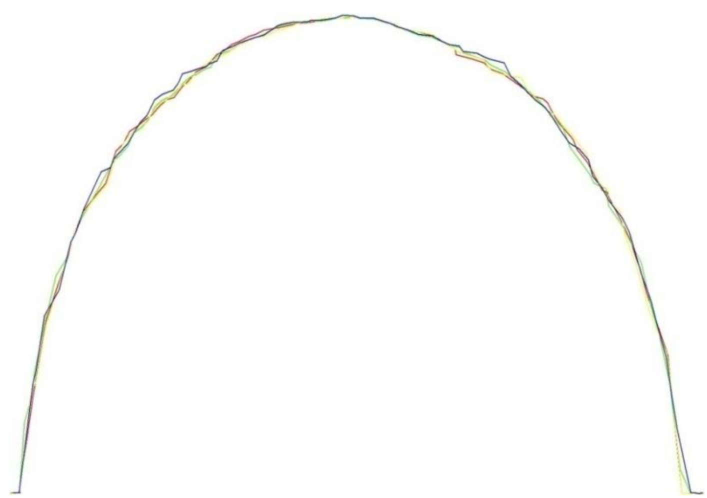
(b) (c)

Fig 4.4 (a) Top View, (b) Side View and (c) Front view of the structure with actual measurement

(a)



(b)



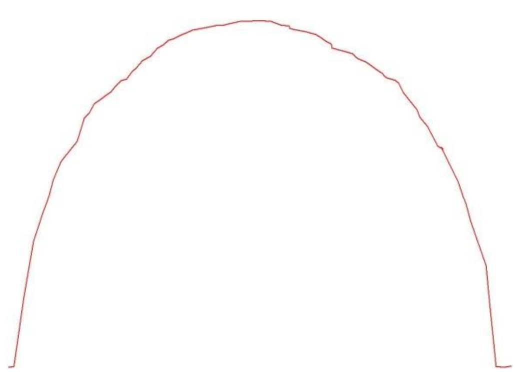
(c)

Fig. 4.5 (a) Top View, (b) Side View and (c) Front view of the structure measured by profilemeter

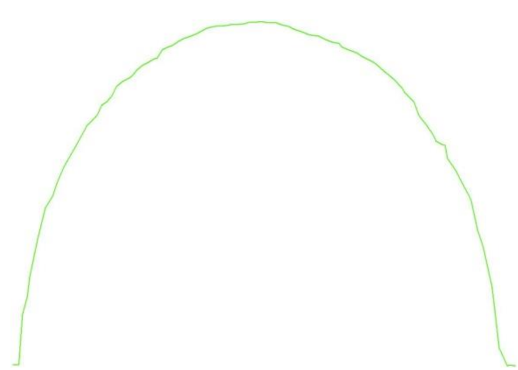
The isometric view of the measured profile is given below. Each layer is given in separate colour.

Fig. 4.6 Isometric view of the measured profile

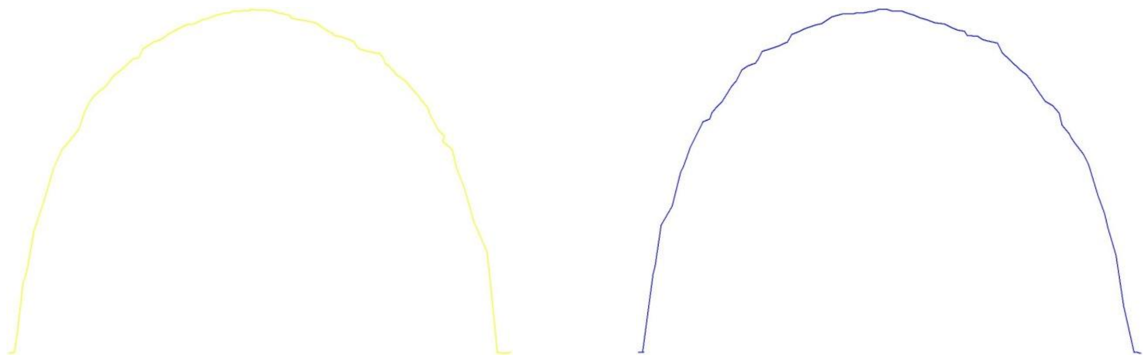
The front view of each layer separately is given below:



(a)



(b)

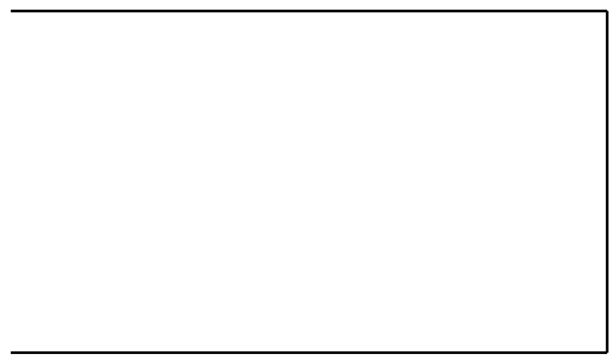


(c) (d)

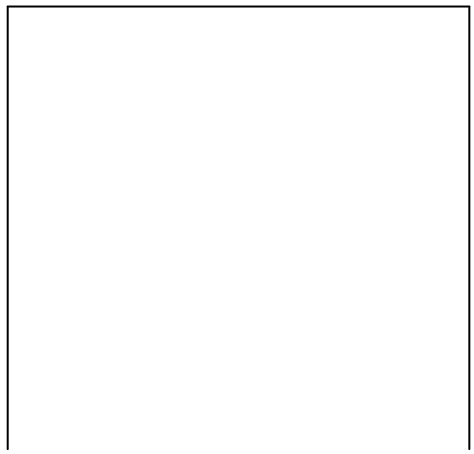
Fig 4.7 Front view of (a) Layer 1, (b) Layer 2, (c) Layer 3 and (d) Layer 4 of the measured profile

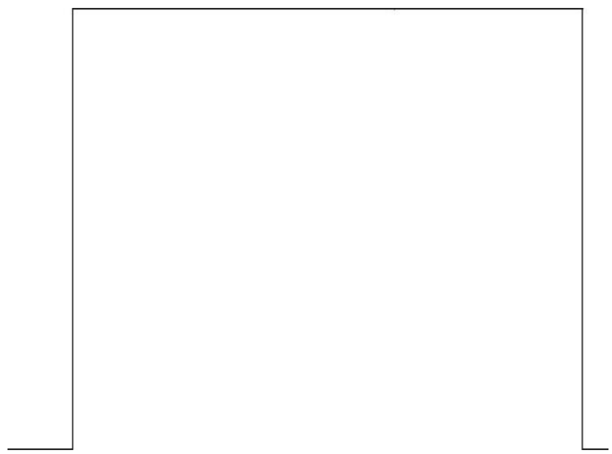
4.3.2 **Rectangular Structure**

A rectangular structure having known dimension is made and its profile is measured using profile meter. The result obtained is:



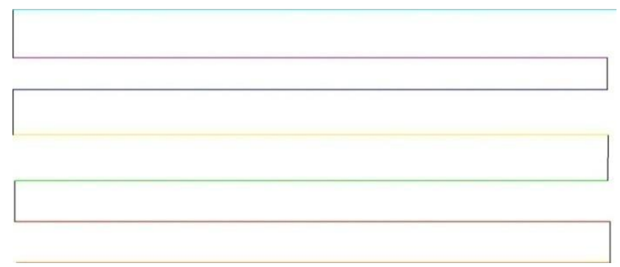
(a)



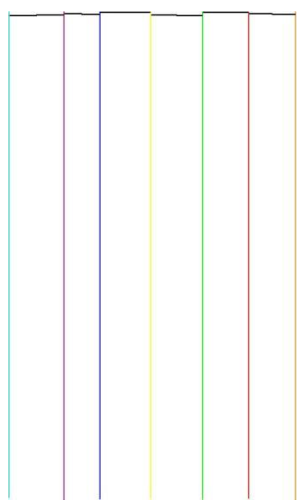


(b) (c)

Fig 4.8 (a) Top View, (b) Side View and (c) Front view of the structure with actual measurement



(a)



(b) (c)

Fig. 4.9 (a) Top View, (b) Side View and (c) Front view of the structure measured by profile-meter

The isometric view of the measured profile is given below. Each layer is given in separate colour.

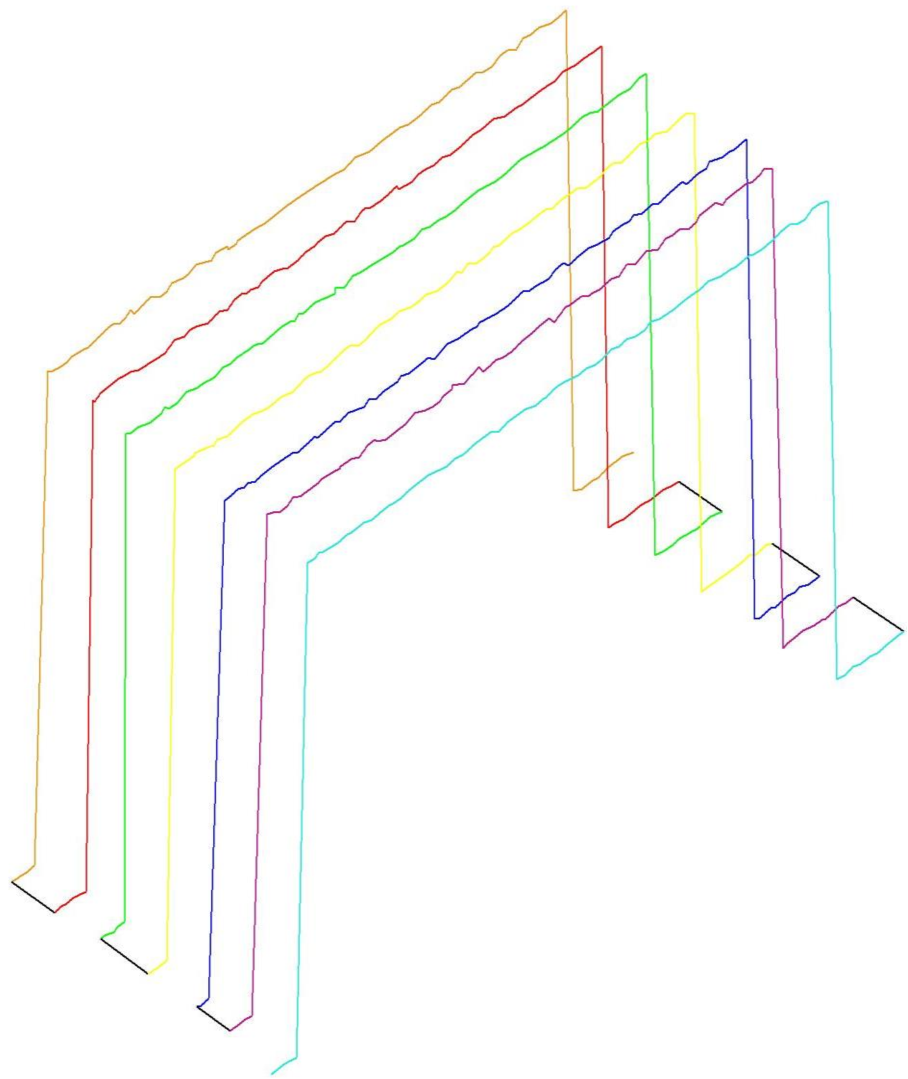
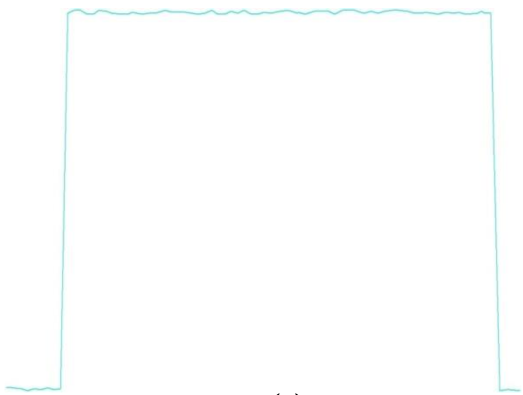
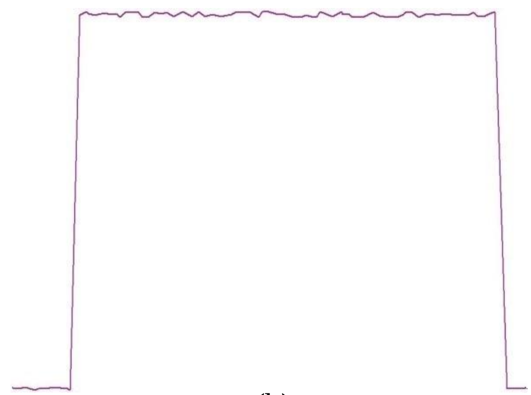


Fig. 4.10 Isometric view of the measured profile

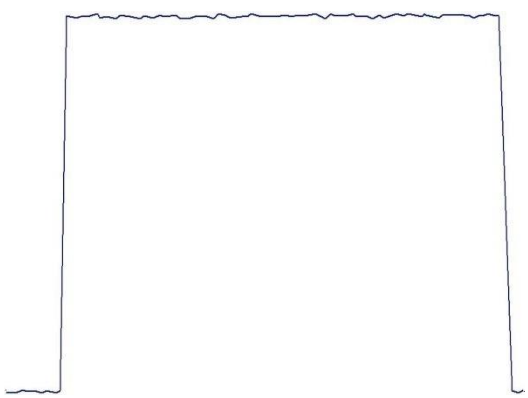
The front view of each layer separately is given below:



(a)

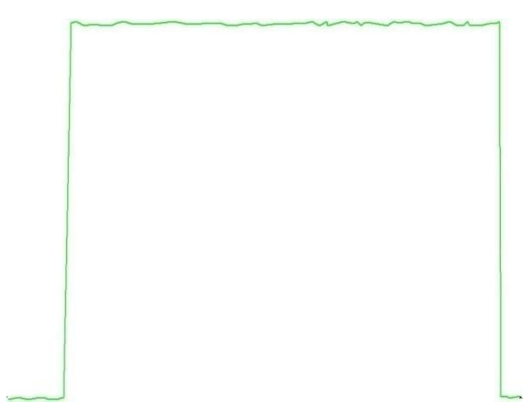


(b)

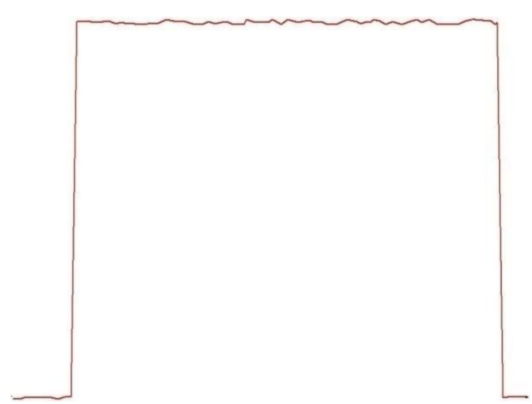


(c)

(d)



(e)



(f)

(g)

Fig. 4.11 Front view of (a) Layer 1, (b) Layer 2, (c) Layer 3, (d) Layer 4, (e) Layer 5, (f) Layer 6, and (g) Layer 7 of the measured profile

As a result of paired t-test, it can be concluded that there is no significant difference between actual and measured profile.

CHAPTER V

SUMMARY AND CONCLUSIONS

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

Profile meter can be used to obtain a 3D profile of bunds and furrows. Profile of bunds and furrows are very necessary to evaluate the performance of various ridgers and furrowers. It can also be used to compare the profile formed by different types of machines, variation of profile created by same machine in different soil conditions and also for checking whether the desirable profile is obtained. 3D view of the bunds and furrows also helps to study about the shape of structure and volume of soil removed from the area.

Profile meter is a non-contact type measuring instrument. The non contact type measurement is achieved by using a microcontroller, and a sensor. The three main concepts for the design of profile meter are mechanical design, development of programme and electrical circuit. Mechanical design includes the selection of prime mover and moving component. A dc motor of 12V is selected as the prime mover. Linear actuators are used as the moving mechanism. Development of programme includes the selection of microcontroller, sensors etc. Arduino is selected as the microcontroller because of its easiness and simplicity in use for beginners. Ultrasonic sensor is used to read the distance to the various points. Electrical circuit design involves the electrical connections between power source, Arduino, motor driver, sd card etc.

Profile meter mainly consists of a lateral component and a transverse component. Lateral component covers the width of bund and furrow. Transverse component measures the roughness of the structure. Length of the lateral component is 100 cm and that of the transverse component of 40 cm. Three ultrasonic sensors are incorporated in the profile meter. One sensor is fixed and other two sensors are movable relative to the fixed sensor. Fixed sensor measures the distance in X direction. Movable sensor measures the distances in Y and Z direction. Recording of various points in the structure were achieved by the to and fro movement of ultrasonic sensors. The movement was obtained by using DC motor and a linear actuator. Sensor takes 30 readings at a point and a mode of these values is calculated. This mode value is taken as the distance to the point so that more accurate values were obtained. Readings at every point were recorded in the SD card.

Arduino programme controls the entire operation of the profile meter. Various sub functions are used for the working of profile meter. The positioning of sensors at the desired points, taking the readings and recording the values in the memory card are the various operations in the profile meter which is accomplished with the help of Arduino. Arduino programme ensures that the sensors are at starting position at the beginning of the operation. Then, sensors were moved for 5 seconds and took the corresponding X, Y, and Z readings and then sensors were moved to the next data point. When the sensor reaches at the end, the entire operations were terminated.

Testing of the profile meter was done by comparing the actual profile and measured profile of a known structure. Actual profile was drawn by using the readings taken by manually. Measured profile was drawn by using the readings taken by profile meter. The two profiles were then compared by using paired t test. As per the results obtained from this statistical measure, it can be concluded that variations in the profile are insignificant.

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APPENDICES

Appendix I

Programming Code

```
//This is the programme for the working of Profile-meter

#include <SD.h>

//declaring all the pins

const int XTrigPin = 2;
const int XEchoPin =3;

const int ZTrigPin = 4;

const int ZEchoPin = 5;

const int YTrigPin = 6;

const int YEchoPin = 7;


const int ledPinRed = 9;

const int sdOutPin = 10;

const int XMotorPinF = 14;
const int XMotorPinR = 15;

const int YMotorPinF = 16;

const int YMotorPinR = 17;


//declaring all the constants
```

```
const int noSamples = 30;

const int minX = 150;
const int maxX = 850;
const int minY = 100;
const int maxY = 400;
int n = 0;
int XDist;
int YDist;
int ZDist;

boolean XMotorForward = LOW;
boolean YMotorForward = LOW;
boolean XChangeDir = LOW;
boolean YMotorRotate = LOW;

void setup()
{
  // Open serial communications and wait for port to open:
  Serial.begin(9600);

  //declaring all the pinmode
  pinMode(XTrigPin , OUTPUT);
```

```
  pinMode(XEchoPin , INPUT);
  pinMode(YTrigPin , OUTPUT);
  pinMode(YEchoPin , INPUT);
  pinMode(ZTrigPin , OUTPUT);
  pinMode(ZEchoPin , INPUT);

  pinMode(ledPinRed , OUTPUT);
  pinMode(sdOutPin , OUTPUT);

  pinMode(XMotorPinF , OUTPUT);
  pinMode(XMotorPinR , OUTPUT);
  pinMode(YMotorPinF , OUTPUT);
  pinMode(YMotorPinR , OUTPUT);

 //Checking the SD Card status
  while(!SD.begin(sdOutPin))
  {
    digitalWrite(ledPinRed, HIGH);
    Serial.println("sdcard not ready");
    }
//waiting for 1 second
  delay(1000);
```

```
  //checking whether Z sensor is in starting position
  while(MeasureDist(2)>minY)
  {
    motorRun(YMotorPinF,YMotorPinR,LOW,5000);
  }
 delay(1000);

//checking whether X sensor reads Minimum fixed distance
 while(MeasureDist(1)>minX)
  {
    motorRun(XMotorPinF,XMotorPinR,LOW,3000);
   }
//creating files in SD card
  writeData("data.txt","START OF READING",HIGH);
  writeData("X.txt","START OF READING",HIGH);
  writeData("Y.txt","START OF READING",HIGH);
  writeData("Z.txt","START OF READING",HIGH);
  writeData("Profile.scr","LINE",HIGH);
}
//setup completed and loop begins
void loop()
{
//checking whether Z sensor is in the end position
```

```
  while(MeasureDist(2)<maxY)
  {
     XDist=MeasureDist(1);
    if (((XDist < minX) || (XDist > maxX)) && !XChangeDir )
{
  XMotorForward = !XMotorForward;
  YMotorRotate=HIGH;
  XChangeDir=HIGH;
}
else
{
  XChangeDir = LOW;
  YMotorRotate = LOW;
   }
YDist=MeasureDist(2);
ZDist=10000-MeasureDist(3);

 writeData("data.txt",String(XDist),LOW);
 writeData("data.txt",String(YDist),LOW);
 writeData("data.txt",String(ZDist),HIGH);

 writeData("X.txt",String(XDist),HIGH);
 writeData("Y.txt",String(YDist),HIGH);
```

```
 writeData("Z.txt",String(ZDist),HIGH);


 writeData("Profile.scr",String(XDist),LOW);

 writeData("Profile.scr",String(YDist),LOW);

 writeData("Profile.scr",String(ZDist),HIGH);


if (YMotorRotate)

{

motorRun(YMotorPinF, YMotorPinR,LOW,3000);

}

 motorRun(XMotorPinF,XMotorPinR,XMotorForward,3000);

 }

 if( YDist > maxY)

  {

    If (n==0)

    {

      n = n+1;

    Serial.println("END OF READING");

     writeData("data.txt","END OF READING",HIGH);

     writeData("X.txt","END OF READING",HIGH);

     writeData("Y.txt","END OF READING",HIGH);

     writeData("Z.txt","END OF READING",HIGH);

     writeData("Profile.scr"," ",HIGH);
```

```
    }
    digitalWrite(ledPinRed, HIGH);
    delay(1000);
    digitalWrite(ledPinRed, LOW);
}
}
//loop completed

//This is the subprogram for motor run.
void motorRun(int motorPin1,int motorPin2,boolean motorDir,int
delayTime)
{
  digitalWrite(motorPin1,motorDir);
  digitalWrite(motorPin2,!motorDir);
  delay(delayTime);
  digitalWrite(motorPin1,LOW);
  digitalWrite(motorPin2,LOW);
  }

//This is the subprogram for reading distance.
int getDistance(int TrigPin,int EchoPin)
{
  int i;
```

```
  int dist[noSamples];


  float duration;

  float distance;

  for (i = 0;i<= (noSamples-1); i++)

  {

    digitalWrite(TrigPin,LOW);

    delayMicroseconds(1000);

    digitalWrite(TrigPin, HIGH);

    delayMicroseconds(1000);

    digitalWrite(TrigPin, LOW);

    duration= pulseIn(EchoPin, HIGH);

    distance = duration /28 /2 ;

    dist[i] = getInteger(distance);

  }

  delay(1000);

  return getMode(dist);

}

// This is the subprogramme for rounding the decimal values to
nearest integer

int getInteger(float myNum)

{

  int myRem;
```

```
  myRem = (int(myNum *100) % 10);
  if (myRem >= 5)
  {
    return int(myNum*10) + 1;
  }
  else
  {
    return int (myNum*10);
  }
}
//This is the subprogram for calculating mode
int getMode(int numbers[])
{
  int i;
  int j;
  int maxNumb;
  int maxCount;
  int maxRepeat = 0;
  int count[noSamples];

  for (i=0; i<(noSamples); i++)
  {
    count[i] = 0;
```

```
  for (j=0; j<(noSamples); j++)
  {
    if (numbers[i] == numbers[j])
    {
      count [i] = count[i]++;
    }
  }
}
maxNumb = numbers[0];
maxCount = count[0];
for (i=1; i<(noSamples); i++)
{
  if (count[i] > maxCount)
  {
    maxNumb = numbers[i];
    maxCount = count [i];
   }
 }
for (i=0; i<(noSamples); i++)
{
  if (maxCount == count[i])
  {
    maxRepeat++;
```

```
    }
  }
  if (maxCount == maxRepeat)
  {
    return maxNumb;
  }
  else
  {
    return 0;
  }
}
//This is the subprogram for writing the readings
int MeasureDist (int drn)
{
  int TrigPin;
  int EchoPin;
  int MeasuredDist = 0;

  switch (drn) {
    case 1:
      TrigPin = XTrigPin;
      EchoPin = XEchoPin;
    break;
```

```
    case 2:
      TrigPin = YTrigPin;
      EchoPin = YEchoPin;
    break;
    case 3:
      TrigPin = ZTrigPin;
      EchoPin = ZEchoPin;
    break;
  }
  while (MeasuredDist == 0)
  {
    MeasuredDist = getDistance(TrigPin, EchoPin);
  }
  //Serial.println(MeasuredDist);
  return MeasuredDist;
}
//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 the test structure (Semi elliptical), mm

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
12,197,3	12,197,0
21,197,4	21,197,0
27,197,42	27,197,58.1
39,197,124	39,197,152
43,197,158	43,197,172
56,197,220	56,197,224
71,197,267	71,197,271
84,197,301	84,197,304
91,197,328	91,197,321
104,197,360	104,197,348
121,197,381	121,197,379
133,197,395	133,197,399
155,197,445	155,197,431
164,197,461	164,197,443
173,197,467	173,197,455
183,197,475	183,197,466
193,197,482	193,197,477
201,197,491	201,197,486
211,197,501	211,197,496
221,197,504	221,197,505
231,197,517	231,197,514
239,197,524	239,197,520
249,197,536	249,197,528
263,197,543	263,197,538
268,197,553	268,197,542
276,197,558	276,197,547
286,197,563	286,197,553
295,197,571	295,197,558
304,197,574	304,197,563
318,197,581	318,197,570
327,197,584	327,197,574
337,197,589	337,197,578
355,197,592	355,197,584
360,197,595	360,197,586
379,197,597	379,197,591

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
440,197,604	440,197,599
448,197,606	448,197,599
459,197,605	459,197,599
467,197,605	467,197,599
477,197,604	477,197,598
486,197,601	486,197,597
495,197,598	495,197,596
509,197,596	509,197,594
510,197,592	510,197,593
519,197,590	519,197,592
537,197,587	537,197,587
556,197,582	556,197,581
574,197,570	574,197,573
584,197,565	584,197,569
585,197,558	585,197,568
607,197,552	607,197,557
621,197,548	621,197,549
626,197,543	626,197,546
631,197,539	631,197,542
645,197,534	645,197,533
668,197,518	668,197,515
673,197,515	673,197,510
678,197,509	678,197,506
683,197,506	683,197,501
697,197,502	697,197,488
703,197,497	703,197,482
712,197,480	712,197,472
721,197,468	721,197,462
736,197,451	736,197,443
741,197,438	741,197,437
754,197,422	754,197,419
773,197,387	773,197,389
782,197,382	782,197,374
778,197,386	778,197,381
796,197,351	796,197,348

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
858,197,179	858,197,168
863,197,129	863,197,141
876,197,4	876,197,0
891,197,3	891,197,0
898,197,4	898,197,0
903,197,4	903,197,0
903,253,3	903,253,0
892,253,4	892,253,0
888,253,3	888,253,0
874,253,34	874,253,41.13
861,253,142	861,253,152.7
856,253,163	856,253,177.3
836,253,241	836,253,251
824,253,295	824,253,284.9
808,253,324	808,253,323.3
799,253,342	799,253,342.4
782,253,367	782,253,374.5
778,253,389	778,253,381.5
774,253,390	774,253,388.2
762,253,396	762,253,407.4
757,253,407	757,253,414.9
745,253,424	745,253,431.9
732,253,441	732,253,448.8
723,253,465	723,253,459.8
714,253,474	714,253,470.2
706,253,482	706,253,478.9
701,253,490	701,253,484.1
688,253,504	688,253,497
670,253,519	670,253,513.3
656,253,531	656,253,524.8
648,253,536	648,253,530.9
630,253,545	630,253,543.5
622,253,551	622,253,548.6
613,253,554	613,253,554.1
595,253,561	595,253,563.9

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
536,253,583	536,253,587.5
523,253,588	523,253,591
510,253,592	510,253,593.9
501,253,597	501,253,595.6
488,253,600	488,253,597.5
479,253,603	479,253,598.6
460,253,604	460,253,599.8
453,253,606	453,253,599.9
439,253,604	439,253,599.7
430,253,604	430,253,599.3
421,253,602	421,253,598.6
408,253,600	408,253,597
399,253,601	399,253,595.6
394,253,599	394,253,594.7
382,253,598	382,253,592.2
373,253,598	373,253,590
364,253,596	364,253,587.5
355,253,594	355,253,584.8
337,253,584	337,253,578.4
324,253,579	324,253,573
315,253,576	315,253,568.9
306,253,571	306,253,564.5
293,253,563	293,253,557.5
284,253,560	284,253,552.3
276,253,556	276,253,547.4
268,253,542	268,253,542.2
262,253,540	262,253,538.1
249,253,533	249,253,528.6
241,253,529	241,253,522.4
232,253,521	232,253,515
223,253,511	223,253,507.2
219,253,507	219,253,503.6
205,253,500	205,253,490.2
196,253,492	196,253,481
188,253,476	188,253,472.4
178,253,465	178,253,461
169,253,459	169,253,450.1

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
138,253,415	138,253,407.4
125,253,391	125,253,386.6
102,253,351	102,253,344.4
90,253,323	90,253,318.8
82,253,300	82,253,300.1
69,253,279	69,253,265.8
55,253,222	55,253,221.4
41,253,158	41,253,163
37,253,124	37,253,141.5
28,253,92	28,253,71.16
22,253,4	22,253,0
11,253,4	11,253,0
11,316,3	11,316,0
21,316,4	21,316,0
27,316,42	27,316,56
36,316,126	36,316,135.6
43,316,145	43,316,172.7
56,316,216	56,316,224
72,316,267	72,316,274.2
83,316,301	83,316,302.5
91,316,328	91,316,321.1
105,316,360	105,316,350.3
123,316,381	123,316,383.2
135,316,395	135,316,402.7
146,316,428	146,316,419.2
156,316,446	156,316,433.2
164,316,456	164,316,443.8
174,316,465	174,316,456.2
183,316,471	183,316,466.8
196,316,489	196,316,481
201,316,494	201,316,486.2
211,316,501	211,316,495
221,316,511	221,316,505.4
232,316,520	232,316,515
241,316,522	241,316,522.4
249,316,538	249,316,528.6
264,316,547	264,316,539.4

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
295,316,564	295,316,558.6
305,316,570	305,316,563.9
318,316,576	318,316,570.3
327,316,580	327,316,574.3
338,316,581	338,316,578.7
355,316,589	355,316,584.8
360,316,590	360,316,586.3
380,316,597	380,316,591.8
393,316,600	393,316,594.5
403,316,601	403,316,596.3
408,316,603	408,316,597
422,316,604	422,316,598.6
439,316,605	439,316,599.7
440,316,607	440,316,599.8
448,316,606	448,316,599.9
459,316,605	459,316,599.8
467,316,605	467,316,599.5
479,316,604	479,316,598.6
486,316,601	486,316,597.8
495,316,599	495,316,596.6
509,316,596	509,316,594.1
510,316,592	510,316,593.9
518,316,590	518,316,592.2
538,316,587	538,316,586.9
556,316,583	556,316,581
564,316,576	564,316,578
574,316,570	574,316,573.8
584,316,565	584,316,569.3
586,316,562	586,316,568.4
607,316,556	607,316,557.5
621,316,551	621,316,549.2
625,316,544	625,316,546.7
631,316,538	631,316,542.8
646,316,533	646,316,532.3
668,316,529	668,316,515
673,316,523	673,316,510.7
678,316,511	678,316,506.3

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
712,316,482	712,316,472.4
721,316,471	721,316,462.1
736,316,455	736,316,443.8
740,316,449	740,316,438.6
754,316,432	754,316,419.2
755,316,425	755,316,417.8
771,316,395	771,316,393.2
782,316,384	782,316,374.5
779,316,375	779,316,379.8
796,316,361	796,316,348.4
804,316,327	804,316,332
817,316,293	817,316,302.5
825,316,265	825,316,282.3
834,316,234	834,316,257.1
857,316,181	857,316,172.7
864,316,124	864,316,135.6
876,316,4	876,316,0
892,316,3	892,316,0
897,316,4	897,316,0
900,316,4	900,316,0
900,372,3	900,372,0
894,372,4	894,372,0
888,372,4	888,372,0
870,372,86	870,372,91.76
863,372,128	863,372,141.5
856,372,175	856,372,177.3
842,372,224	842,372,231.8
836,372,248	836,372,251
824,372,281	824,372,284.9
808,372,334	808,372,323.3
799,372,352	799,372,342.4
782,372,374	782,372,374.5
778,372,381	778,372,384
773,372,390	773,372,389.9
761,372,404	761,372,408.9
756,372,425	756,372,416.3
744,372,439	744,372,433.2

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
705,372,485	705,372,480
698,372,493	698,372,487.2
687,372,501	687,372,498
669,372,519	669,372,514.2
655,372,531	655,372,525.5
647,372,548	647,372,531.6
629,372,552	629,372,544.1
621,372,555	621,372,549.2
612,372,560	612,372,554.7
594,372,562	594,372,564.5
589,372,569	589,372,567
576,372,571	576,372,573
566,372,575	566,372,577.2
554,372,582	554,372,581.7
536,372,584	536,372,587.5
523,372,589	523,372,591
510,372,593	510,372,593.9
501,372,597	501,372,595.6
488,372,601	488,372,597.5
479,372,604	479,372,598.6
460,372,605	460,372,599.8
453,372,607	453,372,599.9
439,372,608	439,372,599.7
430,372,605	430,372,599.3
421,372,603	421,372,598.6
408,372,601	408,372,597
399,372,602	399,372,595.6
394,372,600	394,372,594.7
382,372,599	382,372,592.2
373,372,599	373,372,590
364,372,597	364,372,587.5
355,372,595	355,372,584.8
337,372,583	337,372,578.4
326,372,580	326,372,573.8
314,372,576	314,372,568.4
306,372,573	306,372,564.5
298,372,569	298,372,560.3

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
262,372,543	262,372,538.1
252,372,540	252,372,530.9
242,372,537	242,372,523.2
232,372,534	232,372,515
226,372,521	226,372,509.8
220,372,513	220,372,504.5
206,372,508	206,372,491.2
196,372,501	196,372,481
186,372,481	186,372,470.2
178,372,473	178,372,461
170,372,460	170,372,451.3
161,372,445	161,372,439.9
151,372,435	151,372,426.3
143,372,426	143,372,414.9
139,372,415	139,372,408.9
127,372,410	127,372,389.9
105,372,364	105,372,350.3
94,372,333	94,372,327.7
88,372,321	88,372,314.3
73,372,261	73,372,276.9
54,372,228	54,372,217.8
43,372,158	43,372,172.7
39,372,141	39,372,152.7
21,372,4	21,372,0
23,372,4	23,372,0
13,372,4	13,372,0

Appendix III

Readings of the test structure (Rectangular),mm

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)	MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)	MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
147,98,1	147,98,0	514,98,400	514,98,400	841,147,3	841,147,0
160,98,4	160,98,0	524,98,400	524,98,400	834,147,4	834,147,0
169,98,4	169,98,0	528,98,400	528,98,400	826,147,3	826,147,0
178,98,3	178,98,0	534,98,400	534,98,400	819,147,2	819,147,400
187,98,1	187,98,0	534,98,400	534,98,400	811,147,400	811,147,400
196,98,2	196,98,0	543,98,400	543,98,400	809,147,398	809,147,400
206,98,1	206,98,0	565,98,398	565,98,400	802,147,402	802,147,400
215,98,4	215,98,0	579,98,400	579,98,400	781,147,403	781,147,400
224,98,402	224,98,400	597,98,400	597,98,400	776,147,403	776,147,400
233,98,400	233,98,400	599,98,398	599,98,400	768,147,402	768,147,400
242,98,400	242,98,400	608,98,398	608,98,400	759,147,399	759,147,400
246,98,398	246,98,400	609,98,401	609,98,400	738,147,398	738,147,400
255,98,403	255,98,400	622,98,402	622,98,400	729,147,398	729,147,400
264,98,402	264,98,400	627,98,398	627,98,400	718,147,403	718,147,400
273,98,403	273,98,400	645,98,404	645,98,400	707,147,400	707,147,400
281,98,397	281,98,400	654,98,400	654,98,400	701,147,403	701,147,400
291,98,402	291,98,400	659,98,400	659,98,400	694,147,402	694,147,400
299,98,402	299,98,400	672,98,402	672,98,400	680,147,398	680,147,400
309,98,398	309,98,400	678,98,398	678,98,400	667,147,401	667,147,400
318,98,398	318,98,400	686,98,398	686,98,400	658,147,398	658,147,400
327,98,402	327,98,400	697,98,403	697,98,400	650,147,402	650,147,400
333,98,401	333,98,400	715,98,398	715,98,400	641,147,403	641,147,400
345,98,399	345,98,400	719,98,404	719,98,400	637,147,400	637,147,400
354,98,402	354,98,400	725,98,400	725,98,400	632,147,401	632,147,400
368,98,398	368,98,400	731,98,399	731,98,400	623,147,399	623,147,400
377,98,401	377,98,400	739,98,402	739,98,400	618,147,401	618,147,400
391,98,398	391,98,400	744,98,402	744,98,400	605,147,403	605,147,400
395,98,398	395,98,400	767,98,397	767,98,400	592,147,399	592,147,400
404,98,398	404,98,400	772,98,398	772,98,400	591,147,398	591,147,400
413,98,400	413,98,400	786,98,399	786,98,400	578,147,398	578,147,400
418,98,397	418,98,400	792,98,397	792,98,400	569,147,401	569,147,400
433,98,399	433,98,400	799,98,397	799,98,400	559,147,400	559,147,400
447,98,397	447,98,400	809,98,398	809,98,400	555,147,402	555,147,400

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
464,98,401	464,98,400
477,98,397	477,98,400
478,98,398	478,98,400
487,98,399	487,98,400
505,98,400	505,98,400
497,147,400	497,147,400
484,147,400	484,147,400
475,147,401	475,147,400
466,147,403	466,147,400
463,147,399	463,147,400
448,147,398	448,147,400
441,147,400	441,147,400
432,147,400	432,147,400
423,147,399	423,147,400
414,147,401	414,147,400
405,147,398	405,147,400
401,147,401	401,147,400
392,147,399	392,147,400
379,147,402	379,147,400
370,147,401	370,147,400
356,147,403	356,147,400
352,147,403	352,147,400
343,147,399	343,147,400
330,147,399	330,147,400
321,147,398	321,147,400
312,147,399	312,147,400
303,147,399	303,147,400
294,147,400	294,147,400
286,147,399	286,147,400
277,147,402	277,147,400
272,147,401	272,147,400
261,147,400	261,147,400
252,147,401	252,147,400
243,147,401	243,147,400
233,147,401	233,147,400
225,147,3	225,147,400
216,147,3	216,147,0

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
828,98,4	828,98,0
836,98,2	836,98,0
854,98,3	854,98,0
854,147,2	854,147,0
848,147,4	848,147,0
154,147,1	154,147,0
145,147,1	145,147,0
145,196,1	145,196,0
158,196,3	158,196,0
164,196,3	164,196,0
173,196,1	173,196,0
183,196,2	183,196,0
193,196,3	193,196,0
201,196,1	201,196,0
211,196,1	211,196,0
221,196,3	221,196,400
231,196,402	231,196,400
239,196,403	239,196,400
249,196,399	249,196,400
263,196,400	263,196,400
268,196,399	268,196,400
276,196,399	276,196,400
286,196,399	286,196,400
295,196,402	295,196,400
304,196,403	304,196,400
318,196,400	318,196,400
327,196,400	327,196,400
337,196,400	337,196,400
346,196,401	346,196,400
355,196,402	355,196,400
360,196,402	360,196,400
374,196,403	374,196,400
379,196,402	379,196,400
393,196,400	393,196,400
403,196,400	403,196,400
408,196,400	408,196,400
421,196,402	421,196,400

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
537,147,400	537,147,400
523,147,403	523,147,400
514,147,398	514,147,400
506,147,402	506,147,400
501,147,403	501,147,400
495,196,399	495,196,400
509,196,400	509,196,400
510,196,401	510,196,400
519,196,400	519,196,400
537,196,401	537,196,400
556,196,402	556,196,400
565,196,403	565,196,400
567,196,402	567,196,400
574,196,399	574,196,400
584,196,403	584,196,400
585,196,399	585,196,400
607,196,403	607,196,400
621,196,401	621,196,400
626,196,403	626,196,400
631,196,399	631,196,400
636,196,402	636,196,400
645,196,402	645,196,400
668,196,399	668,196,400
673,196,402	673,196,400
678,196,403	678,196,400
683,196,402	683,196,400
697,196,403	697,196,400
703,196,401	703,196,400
712,196,402	712,196,400
721,196,399	721,196,400
736,196,400	736,196,400
741,196,400	741,196,400
754,196,403	754,196,400
764,196,399	764,196,400
773,196,399	773,196,400
778,196,403	778,196,400
782,196,399	782,196,400

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
836,196,2	836,196,0
846,196,4	846,196,0
851,196,4	851,196,0
852,251,3	852,251,0
842,251,3	842,251,0
831,251,4	831,251,0
821,251,401	821,251,0
808,251,401	808,251,400
799,251,401	799,251,400
799,251,403	799,251,400
782,251,400	782,251,400
778,251,398	778,251,400
774,251,402	774,251,400
762,251,398	762,251,400
757,251,399	757,251,400
745,251,402	745,251,400
732,251,402	732,251,400
723,251,399	723,251,400
714,251,398	714,251,400
706,251,399	706,251,400
701,251,400	701,251,400
688,251,398	688,251,400
676,251,401	676,251,400
670,251,402	670,251,400
661,251,400	661,251,400
656,251,398	656,251,400
648,251,399	648,251,400
630,251,403	630,251,400
622,251,403	622,251,400
613,251,398	613,251,400
604,251,399	604,251,400
595,251,402	595,251,400
590,251,403	590,251,400
577,251,402	577,251,400
573,251,402	573,251,400

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
536,251,401	536,251,400
523,251,398	523,251,400
510,251,399	510,251,400
501,251,403	501,251,400
496,251,399	496,251,400
488,251,403	488,251,400
479,251,398	479,251,400
465,251,399	465,251,400
460,251,402	460,251,400
453,251,400	453,251,400
439,251,403	439,251,400
430,251,402	430,251,400
421,251,401	421,251,400
408,251,403	408,251,400
399,251,403	399,251,400
394,251,400	394,251,400
382,251,402	382,251,400
373,251,402	373,251,400
364,251,402	364,251,400
355,251,398	355,251,400
346,251,399	346,251,400
337,251,399	337,251,400
333,251,402	333,251,400
324,251,403	324,251,400
315,251,398	315,251,400
306,251,400	306,251,400
293,251,403	293,251,400
284,251,401	284,251,400
276,251,403	276,251,400
268,251,400	268,251,400
262,251,398	262,251,400
249,251,401	249,251,400
241,251,402	241,251,400
232,251,398	232,251,400
223,251,1	223,251,400

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
178,251,3	178,251,0
169,251,4	169,251,0
161,251,1	161,251,0
151,251,3	151,251,0
151,251,4	151,251,0
143,251,1	143,251,0
143,305,1	143,305,0
156,305,1	156,305,0
166,305,4	166,305,0
171,305,2	171,305,0
180,305,3	180,305,0
193,305,1	193,305,0
198,305,3	198,305,0
212,305,1	212,305,0
217,305,3	217,305,0
226,305,401	226,305,400
240,305,399	240,305,400
245,305,400	245,305,400
254,305,400	254,305,400
268,305,403	268,305,400
271,305,399	271,305,400
281,305,400	281,305,400
294,305,398	294,305,400
299,305,402	299,305,400
313,305,400	313,305,400
327,305,398	327,305,400
332,305,401	332,305,400
345,305,399	345,305,400
354,305,402	354,305,400
359,305,400	359,305,400
368,305,401	368,305,400
377,305,401	377,305,400
382,305,398	382,305,400
396,305,399	396,305,400
405,305,401	405,305,400

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
451,305,399	451,305,400
466,305,400	466,305,400
474,305,400	474,305,400
479,305,403	479,305,400
489,305,401	489,305,400
497,305,400	497,305,400
511,305,400	511,305,400
529,305,402	529,305,400
532,305,400	532,305,400
538,305,401	538,305,400
545,305,401	545,305,400
553,305,401	553,305,400
567,305,403	567,305,400
581,305,398	581,305,400
588,305,403	588,305,400
592,305,402	592,305,400
610,305,401	610,305,400
619,305,403	619,305,400
623,305,400	623,305,400
639,305,400	639,305,400
646,305,398	646,305,400
655,305,402	655,305,400
661,305,399	661,305,400
679,305,403	679,305,400
688,305,401	688,305,400
694,305,403	694,305,400
714,305,400	714,305,400
717,305,403	717,305,400
719,305,402	719,305,400
737,305,399	737,305,400
741,305,402	741,305,400
760,305,402	760,305,400
771,305,402	771,305,400
779,305,401	779,305,400
784,305,399	784,305,400

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
819,305,401	819,305,400
837,305,3	837,305,0
846,305,1	846,305,0
851,305,3	851,305,0
851,343,2	851,343,0
846,343,2	846,343,0
843,343,2	843,343,0
835,343,3	835,343,0
826,343,2	826,343,0
809,343,404	809,343,400
802,343,402	802,343,400
794,343,399	794,343,400
786,343,399	786,343,400
780,343,403	780,343,400
774,343,401	774,343,400
772,343,400	772,343,400
751,343,400	751,343,400
747,343,402	747,343,400
734,343,401	734,343,400
726,343,400	726,343,400
726,343,402	726,343,400
713,343,401	713,343,400
704,343,398	704,343,400
695,343,403	695,343,400
687,343,404	687,343,400
683,343,401	683,343,400
674,343,398	674,343,400
656,343,399	656,343,400
652,343,399	652,343,400
641,343,403	641,343,400
629,343,399	629,343,400
621,343,398	621,343,400
613,343,398	613,343,400
608,343,401	608,343,400
599,343,401	599,343,400

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
555,343,399	555,343,400
549,343,400	549,343,400
541,343,398	541,343,400
531,343,398	531,343,400
519,343,401	519,343,400
510,343,401	510,343,400
497,343,404	497,343,400
488,343,404	488,343,400
483,343,398	483,343,400
470,343,404	470,343,400
466,343,403	466,343,400
452,343,404	452,343,400
444,343,400	444,343,400
439,343,400	439,343,400
431,343,399	431,343,400
418,343,401	418,343,400
409,343,399	409,343,400
400,343,404	400,343,400
391,343,399	391,343,400
378,343,404	378,343,400
378,343,404	378,343,400
365,343,399	365,343,400
356,343,403	356,343,400
348,343,402	348,343,400
339,343,403	339,343,400
330,343,398	330,343,400
321,343,399	321,343,400
317,343,403	317,343,400
299,343,404	299,343,400
291,343,398	291,343,400
287,343,401	287,343,400
274,343,402	274,343,400
265,343,402	265,343,400
257,343,400	257,343,400
248,343,402	248,343,400

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
209,343,3	209,343,0
200,343,4	200,343,0
187,343,2	187,343,0
178,343,2	178,343,0
174,343,1	174,343,0
160,343,4	160,343,0
151,343,2	151,343,0
143,343,3	143,343,0
143,401,4	143,401,0
151,401,4	151,401,0
164,401,3	164,401,0
173,401,1	173,401,0
182,401,3	182,401,0
192,401,2	192,401,0
201,401,4	201,401,0
210,401,2	210,401,0
219,401,3	219,401,0
229,401,399	229,401,400
238,401,402	238,401,400
247,401,402	247,401,400
256,401,398	256,401,400
265,401,398	265,401,400
273,401,402	273,401,400
283,401,401	283,401,400
291,401,399	291,401,400
305,401,398	305,401,400
314,401,398	314,401,400
319,401,400	319,401,400
333,401,398	333,401,400
342,401,399	342,401,400
351,401,399	351,401,400
361,401,401	361,401,400
366,401,402	366,401,400
375,401,400	375,401,400
384,401,400	384,401,400

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
431,401,402	431,401,400
439,401,398	439,401,400
449,401,398	449,401,400
458,401,401	458,401,400
467,401,399	467,401,400
476,401,402	476,401,400
486,401,398	486,401,400
495,401,398	495,401,400
504,401,400	504,401,400
513,401,399	513,401,400
527,401,401	527,401,400
537,401,402	537,401,400
542,401,401	542,401,400
551,401,399	551,401,400
552,401,400	552,401,400
561,401,398	561,401,400
574,401,401	574,401,400
594,401,401	594,401,400
603,401,398	603,401,400
608,401,400	608,401,400
613,401,402	613,401,400
631,401,402	631,401,400
639,401,400	639,401,400
644,401,399	644,401,400
654,401,401	654,401,400
663,401,399	663,401,400
673,401,401	673,401,400
683,401,402	683,401,400
692,401,402	692,401,400
705,401,401	705,401,400
715,401,399	715,401,400
725,401,399	725,401,400
729,401,400	729,401,400
739,401,399	739,401,400
748,401,398	748,401,400

MEASURED VALUE(X,Y,Z)	ACTUAL VALUE(X,Y,Z)
803,401,399	803,401,400
808,401,401	808,401,400
813,401,399	813,401,400
821,401,399	821,401,0
834,401,1	834,401,0
843,401,2	843,401,0
848,401,2	848,401,0
862,401,1	862,401,0

Appendix IV

Statistical Analysis (Paired t-test)

SAMPLE CALCULATION

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7
X (mm)	Y (mm)	Z(measured) (mm)	Z(actual) (mm)	| Z (measured) – Z (actual) |	Col. 5 - Mean of Col.5	$(\text{Col. }6)^2$
147	98	1	0	1	-0.74	0.5476
160	98	4	0	4	2.26	5.1076
169	98	4	0	4	2.26	5.1076
178	98	3	0	3	1.26	1.5876
187	98	1	0	1	-0.74	0.5476
196	98	2	0	2	0.26	0.0676
206	98	1	0	1	-0.74	0.5476
215	98	4	0	4	2.26	5.1076
224	98	402	400	2	0.26	0.0676
233	98	400	400	0	-1.74	3.0276
242	98	400	400	0	-1.74	3.0276
246	98	398	400	2	0.26	0.0676
255	98	403	400	3	1.26	1.5876
264	98	402	400	2	0.26	0.0676
273	98	403	400	3	1.26	1.5876
281	98	397	400	3	1.26	1.5876
291	98	402	400	2	0.26	0.0676
299	98	402	400	2	0.26	0.0676
309	98	398	400	2	0.26	0.0676
318	98	398	400	2	0.26	0.0676
327	98	402	400	2	0.26	0.0676
333	98	401	400	1	-0.74	0.5476
345	98	399	400	1	-0.74	0.5476
354	98	402	400	2	0.26	0.0676
368	98	398	400	2	0.26	0.0676
377	98	401	400	1	-0.74	0.5476
391	98	398	400	2	0.26	0.0676

395	98	398	400	2	0.26	0.0676
404	98	398	400	2	0.26	0.0676
413	98	400	400	0	-1.74	3.0276
418	98	397	400	3	1.26	1.5876
433	98	399	400	1	-0.74	0.5476
447	98	397	400	3	1.26	1.5876
451	98	400	400	0	-1.74	3.0276
464	98	401	400	1	-0.74	0.5476
477	98	397	400	3	1.26	1.5876
478	98	398	400	2	0.26	0.0676
487	98	399	400	1	-0.74	0.5476
505	98	400	400	0	-1.74	3.0276
514	98	400	400	0	-1.74	3.0276
524	98	400	400	0	-1.74	3.0276
528	98	400	400	0	-1.74	3.0276
534	98	400	400	0	-1.74	3.0276
534	98	400	400	0	-1.74	3.0276
543	98	400	400	0	-1.74	3.0276
565	98	398	400	2	0.26	0.0676
579	98	400	400	0	-1.74	3.0276
597	98	400	400	0	-1.74	3.0276
599	98	398	400	2	0.26	0.0676
608	98	398	400	2	0.26	0.0676
609	98	401	400	1	-0.74	0.5476
622	98	402	400	2	0.26	0.0676
627	98	398	400	2	0.26	0.0676
645	98	404	400	4	2.26	5.1076
654	98	400	400	0	-1.74	3.0276
659	98	400	400	0	-1.74	3.0276
672	98	402	400	2	0.26	0.0676
678	98	398	400	2	0.26	0.0676
686	98	398	400	2	0.26	0.0676
697	98	403	400	3	1.26	1.5876
715	98	398	400	2	0.26	0.0676
719	98	404	400	4	2.26	5.1076
725	98	400	400	0	-1.74	3.0276
731	98	399	400	1	-0.74	0.5476
739	98	402	400	2	0.26	0.0676
744	98	402	400	2	0.26	0.0676

767	98	397	400	3	1.26	1.5876
772	98	398	400	2	0.26	0.0676
786	98	399	400	1	-0.74	0.5476
792	98	397	400	3	1.26	1.5876
799	98	397	400	3	1.26	1.5876
809	98	398	400	2	0.26	0.0676
813	98	401	400	1	-0.74	0.5476
828	98	4	0	4	2.26	5.1076
836	98	2	0	2	0.26	0.0676
854	98	3	0	3	1.26	1.5876
854	147	2	0	2	0.26	0.0676
848	147	4	0	4	2.26	5.1076
841	147	3	0	3	1.26	1.5876
834	147	4	0	4	2.26	5.1076
826	147	3	0	3	1.26	1.5876
819	147	2	400	398	396.26	157021.9876
811	147	400	400	0	-1.74	3.0276
809	147	398	400	2	0.26	0.0676
802	147	402	400	2	0.26	0.0676
781	147	403	400	3	1.26	1.5876
776	147	403	400	3	1.26	1.5876
768	147	402	400	2	0.26	0.0676
759	147	399	400	1	-0.74	0.5476
738	147	398	400	2	0.26	0.0676
729	147	398	400	2	0.26	0.0676
718	147	403	400	3	1.26	1.5876
707	147	400	400	0	-1.74	3.0276
701	147	403	400	3	1.26	1.5876
694	147	402	400	2	0.26	0.0676
680	147	398	400	2	0.26	0.0676
667	147	401	400	1	-0.74	0.5476
658	147	398	400	2	0.26	0.0676
650	147	402	400	2	0.26	0.0676
641	147	403	400	3	1.26	1.5876
637	147	400	400	0	-1.74	3.0276
632	147	401	400	1	-0.74	0.5476
623	147	399	400	1	-0.74	0.5476
618	147	401	400	1	-0.74	0.5476
605	147	403	400	3	1.26	1.5876

592	147	399	400	1	-0.74	0.5476
591	147	398	400	2	0.26	0.0676
578	147	398	400	2	0.26	0.0676
569	147	401	400	1	-0.74	0.5476
559	147	400	400	0	-1.74	3.0276
555	147	402	400	2	0.26	0.0676
546	147	402	400	2	0.26	0.0676
537	147	400	400	0	-1.74	3.0276
523	147	403	400	3	1.26	1.5876
514	147	398	400	2	0.26	0.0676
506	147	402	400	2	0.26	0.0676
501	147	403	400	3	1.26	1.5876
497	147	400	400	0	-1.74	3.0276
484	147	400	400	0	-1.74	3.0276
475	147	401	400	1	-0.74	0.5476
466	147	403	400	3	1.26	1.5876
TOTAL				610		157183.5396

Sum of deviations = Sum of Col. 6

= 610

Total number of readings = 121

$$\text{Mean, } \bar{z} = \frac{\sum_1^n z}{n}$$

= 610/121

= 5.041322314

$$Standard\ Deviation, \overline{SD} = \sqrt{\frac{\sum_1^n (z - \bar{z})^2}{n-1}}$$

$$= \sqrt{\frac{157183.5396}{121-1}}$$

= 36.19202716

$$t\ value \ = \ \sqrt{n} \ \times \ \frac{\bar{z}}{\overline{SD}}$$

$$= \sqrt{121} \times \frac{5.041322314}{36.19202716}$$

$$= 1.532230986$$

Table value of t = 1.98

DEVELOPMENT AND TESTING OF ARDUINO BASED PROFILE METER

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ABSTRACT

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IN

AGRICULTURAL ENGINEERING

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2017

ABSTRACT

Ridge and lister farming are widely used conventional cultivation practice especially for the effective utilization of available water. Ridges and furrows of different size and shapes are recommended based on the crop, soil conditions, and agronomical practices etc. As mechanization has become inevitable in all agricultural operations, machines / implements for the preparation of ridges and furrows are also becoming popular and number of research and developmental works are being undertaken in this sector. In order to study the suitability of ridges and furrows formed and to compare the performance of different implements recording of furrow profile is highly essential. The methods or instruments currently used for profile recording are either less accurate or high cost, highly accurate depriving researchers to record the profile with reasonable accuracy at affordable cost. This work has been undertaken to develop a low cost profile-meter for the automatic recording of ridge or furrow profile.

The designed profile-meter can measure form and critical dimensions as well as roughness of a ridge or furrow. The instrument should measure and record distances in X, Y and Z directions to obtain the 3-D view. The measurement of distance is achieved by using ultrasonic sensors and Arduino microcontroller board. Arduino board controls the entire operation of the profile-meter. Movement of sensor for taking measurements of different points is achieved with the help of DC motor and linear actuator. All the readings will be stored in SD card in both script file and text file formats. The script file can be directly dragged to AutoCAD for the direct plotting of profile. The tool can measure the soil profile having width up to 100 cm and can take roughness along lengthwise up to 50 cm. The statistical analysis of the measurements

obtained from the designed profile-meter with the actual measurements indicated that there is no significant difference between the actual profile and measured profile. Hence it is concluded that the instrument is working successfully. Overall weight of the instrument is 3 kg and has a cost of around 6000 rupees.