चारा कुट्टी मशीन में चोट निवारण के लिए सवेंदक-आधारित सुरक्षा चेतावनी प्रणाली का विकास

DEVELOPMENT OF SENSOR-BASED SAFETY ALARM SYSTEM FOR INJURY PREVENTION IN FODDER CUTTER MACHINE

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DEVELOPMENT OF SENSOR-BASED SAFETY ALARM SYSTEM FOR INJURY PREVENTION IN FODDER CUTTER MACHINE

A Thesis

By

ASHA K R

Submitted to the Faculty of Post-Graduate School,
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CERTIFICATE

This is to certify that the thesis entitled '**Development of sensor-based safety alarm system for injury prevention in fodder cutter machine**' submitted to the Post-Graduate School, ICAR–Indian Agricultural Research Institute, New Delhi, in partial fulfillment of the requirements for the award of the degree of **Master of Technology in Agricultural Engineering**, embodies the results of *bonafide* research work carried out by **Ms.Asha K. R. (Roll No. 20767)** under my guidance and supervision, and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help availed during the course of investigation as well as source of information have been duly acknowledged by her.

Date: June, 2018

Place: New Delhi, India

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LIST OF ABBREVIATIONS

ADC	Analog to Digital converter
AMOLED	Active Matrix Light Emitting Diode
BIS	Bureau of Indian Standards
CMRR	Large Common Mode Rejection Ratio
DC	Direct Current
FAO	Food and Agriculture Organization
FET	Field Effective Transducer
GDP	Gross domestic product
GND	Ground
GOI	Government of India
ICAR	Indian Council of Agricultural Research
IARI	Indian Agricultural Research Institute
IC	Integrated Circuit
ILO	International Labour Organization
IR	Infrared
LED	Light Emitting Diode
LCD	Liquid Crystal Display
OLED	Organic Light-Emitting Diode
PCB	Printed Circuit Board
PIR	Passive Infrared
PMOLED	Passive Matrix Light Emitting Diode
PTO	Power Take-off
RSM	Response Surface Methodology
SCL	Serial clock
SD	Standard Deviation
SDL	Serial Data
CV	Coefficient of Variance
USB	Universal Serial Bus
VIN	Voltage Input
NLM	National livestock mission

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Chapter 1

INTRODUCTION

Since human civilization, agriculture is considered as an oldest occupation of human beings. In Asian countries, workforce engaged with agricultural operations is approximately two billion (Pandey and Manwani, 2014). Agriculture is considered as one of the most hazardous industries, having very high risk of fatal and non-fatal injuries to the farmers (NIOSH, 2018). In India, agriculture (back bone of Indian economy) is the single sector which is providing employment to more than 50 percent of total workers (Arjun *et al.*, 2013) with 17-18% contribution to GDPs (India economic survey, 2018). Now a day's increasing rate of Indian farm mechanization as per the farm and farmer needs which is consequentially becoming the main reason of increasing occupational health hazards on Indian farms. This leads to many problems and impact productivity of farm workers, health, safety and their economic status.

In a year, a total of 120 million occupation hazards with 12 million permanent disabilities to the work force was estimated in the world by the International Labor Organization (ILO). Farm accidents in the age group of 40-60 (13 percent) and below 40 years (12 percent) of the total agriculture workforce were observed in the survey conducted in India during the period of 2011-2017 (NFS: National Farm Survey, 2018).

Several potential hazards are associated with working on machinery and equipment. Working parts of machine are accident prone such as crush points, free-wheeling parts, shear points, slip and falls in fast moving machineries, and careless adjustment/repair/ servicing of agricultural machines. Several times, due to poor design of machines or faulty procedure or lack of safety system and awareness, number of accidents take place causing injuries to workers resulting in permanent disability. Entanglement hazards may also arise when limb of a worker (e.g., hand or foot) or loose clothing worn by him/ her comes into direct contact with a moving machine component. In general, entanglement may involve: contact with a single rotating surface or in gaps and hands being caught in between counter-rotating parts (fodder cutter machine). India has largest livestock population (19th Livestock census, 2012:

GOI, 2014). Working and possession fodder cutter machines is necessary to feed these animals. In Southern states of the country long unchopped fodder is fed to animals hence fodder cutter machines are not commonly used (Misra *et al*., 2010) but chopped fodder is commonly practiced in Northern part of India for feeding the animals.

Existence of Fifty manufacturing units of fodder cutter machine was reported by Indian agricultural machinery manufacturing association in the year 2011. The total number of fodder cutter machines increased from 5367 (Agricultural engineering data book-CIAE, 2008) to more than 8000 which includes 600 hand operated and 7522 power driven fodder cutter machines reported in National action plan on fodder and feed security programme under National livestock mission 2016-17.

Fodder cutter machine is simple and owned by most of the families, used to cut green or dry fodder crops (chaff), straw, hay in to small pieces of uniform length. It can be directly feed to the animals individually mixing with other forages**.** This aids in saving the time of feeding the animals, improved fodder condition, increased feed palatability, improve digestion of animals, animals, and increase the consumption by animals.

Generally, hand operated fodder cutter machines are equipped with flywheel, cutting blades, feeding tray, handle and cutting head. Fodder cutting machine associated with many injury problems to operator working with the machine and to children playing with the machine due to its large availability (Kumar *et al.* 2012) and accessibility in the rural households. The epidemiological study conducted in North India reported that maximum agricultural accidents (11 to 31% upper limb injuries) were caused by fodder cutter machine, most of the victims were younger in age (below 15 years) (Mohan *et al.* 2004 and S.K. Patel *et al.* 2010). The highest percentage of chaff cutter injuries occurred up to year 2006 was reported in a survey conducted in Haryana as 37.24% of total observed injuries (Kumar *et al*. 2012). A survey conducted in Punjab, Northern India during 2007 to 2012 reported that fodder cutter was responsible for major farm injuries (crush injury) happened due to improper assembly of machine parts (Vaishnav *et al*. 2017).

Injuries with fodder cutter machine occur at inlet tray while pushing the fodder with greater force by the operator results in hands entanglement resulting in crushing of fingers and hand in between the feed rollers. Sometimes slipping of hand while rotating the flywheel of the machine may also cause cut injuries. Ergonomic intervention had been developed to reduce the fodder cutter machine injuries and enhanced the safety of workers, such as providing wooden warning roller at the feed tray where the fodder is pushing towards feed rollers which hits the worker hand if enters in the danger area, providing blade guards, flywheel lock helps in safer operation with the machine (Kumar *et al.,* 2013).

In agriculture operations, there is a need to adopt proper measures to safeguard the farm workers by adopting design modifications and interventions for safety in farm machineries (engineering), limits for danger zones in working area(enforcement) and helping farmers by providing trainings to operate and work with farm machines(education) which is the moral responsibility of nation ("3–E's" termed by Lubinus and Peterson, 1956).

An active real time sensing device or warning system which will prevent access to dangerous parts of the operation by detecting the human presence as the body part comes in vicinity of identified dangerous area by installing the device on machine at proper position and provides warning signal. The warning signal may be audible (sirens/alarm), visual (flashing lights) or a combination of both. This will forewarn the workers that he/she is in danger and make them aware of the situation by which they can take necessary action or adopt a safe position away from the machine.

The knowledge of current position of the movable part and the prior knowledge of the vacant condition can help to develop system which senses the human presence and prevent injury to the operator (Neumayer *et al*., 2010). A single PIR (passive infrared or pyro electric infrared) sensor could achieve more than 92% accuracy in classifying the direction, speed of movement, the distance interval and identifying human (Jaeseok *et al*., 2014). PIR sensors are effective in target detection and comparatively has good performance (Xin *et al*. 2012).

To make the agricultural worker more attentive about the potential hazard of injury in the work environment, an active real-time warning alarm system need to be developed. This system could sense the motion of human body, which comes in the vicinity of moving machine parts and has the potential to cause injury.

The system will forewarn the operator and people around with a warning sound (alarm) and flashing light, make them conscious and prevent the injury while working on the machine. Considering the above facts, a study was undertaken with the following objectives.

1. Response study of Passive Infra-red (PIR) sensor with respect to human hand and fodder
2. Development of a sensor based audio-visual warning system
3. Evaluation of the developed system on fodder cutter machine

Review of Literature

Chapter 2

REVIEW OF LITERATURE

This chapter deals with the previous work done on human safety in operation of agricultural machines and application of safety measure in agricultural machines. The review of literature done for this study is presented under the following sub headings

1. Global and Indian agriculture
2. Injuries associated with Agricultural machinery
3. Accidents/ injuries with fodder cutter machine
4. Hand anthropometry data
5. Application of Electronics for machine safety
6. Passive Infra-Red (PIR) Sensor based security systems

2.1 Global and Indian agriculture

In the world about 37.26 percent of land area is under agriculture (FAO, 2015). At present the total world population is 7.6 Billion and an addition of 2.3 to 3 billion is expected by the end of 2050 (FAO, 2009). This will lead to increased food demand to feed the global population. This could only be achieved by higher agricultural production with intensive agricultural practices and farm mechanization.

India's total geographical area is 3.28 million sq.km (2.2% of total world land area) with population of 132.42 crores. Increasing population of the country also demands increased food production and is majorly depends on agriculture sector, farm power availability, farm mechanization with enhanced safety aspects and etc.

Agriculture is a back bone of Indian economy with 17-18 % contribution to country's GDP (India economic survey, 2018). It is the single sector providing employment to more than 50 percent of total workers (Arjun *et al.*, 2013). About 54.6% of total workers are in agriculture sector. It might decrease to 33% by 2020 (Census, 2011).

2.1.1 Farm power availability

Farm power is a basic input to agriculture (Singh and Singh, 2017). The major sources of farm power are humans, draft animals, mechanical and electrical sources. For performing various field operations, operating irrigation system and to operate farm equipment/ machinery, farm power is the basic requirement (Soni, 2010). At present, the farm power availability per unit cultivable area in India is 2.02kW/ha. It expected to be 2.2 kW/ha in 2020 (Mehta *et al.,* 2014).

2.1.2 Farm mechanization and occupational health hazards

Farm mechanization is the availability of mechanical power per unit cultivated area. Improving farm worker efficiency using farm tools and machines in farm operations. This will result in quality work, timeliness of operations, reducing human and animal drudgery. The ultimate aim of mechanization is to enhance the cropping intensity with efficient management practices for agricultural inputs. Increasing farm production with lowest production cost (Verma, 2006) can be achieved.

Increased rate of Indian farm mechanization is also associated with occupational health hazards for the farm workers. This will affect productivity of workers, health, safety and their economic status. It is important to improve the working environment of farm workers. This could be achieved with ergonomic design of agriculture equipment and, integrating safety devices in the farm tools and equipment.

2.2 Injuries associated with agricultural machinery

Selvan and Rangaswamy (2001) carried out a study on farm machinery related injuries in Tamilnadu. They concluded that majority of injured victims were between 35 to 50 years old. The majority of injured victims were labors and they did not have adequate training.

Kumar *et al.* (2002) studied the injuries caused by grain threshers and has proposed ergonomic design modifications to prevent the limb crush injuries. The study reported that injured victims under age of 16 years (4%), 16 - 45 years (82%) and above 45 years (14%). The causal factors were smaller chute opening height, higher crop pushing force with hands near to threshing drum. The authors proposed ergonomic modifications which were considered under standards by Bureau of Indian Standards (BIS) for safer operation. The machine should be provided with hand- warning roller at chute mouth, proper posture, increased chute height and covering length.

Tiwari *et al.* (2002) carried out a study in Madhya Pradesh (eight districts of different agro-climatic zones) and gathered information on farm injuries for five-year period. Total incidents reported were 76. About 77.6% (59) injuries with agricultural machinery and 11.8% (9) injuries with hand tools were reported. This case also reported that threshers (14.5%), sickles (10.5%) and chaff cutters (4%). Maximum number of victims were male workers (92.7 %) followed by female workers (7.3%). The highest injuries were observed in 30-44 years (45.1%) age group, followed by 15-29 years (32.9%). Accurate data on farm injuries are important for designing a safe farm equipment to reduce injuries.

Gite *et al*. (2010) reported survey of seven states (Tamil Nadu, Orissa, Madhya Pradesh, Punjab, Rajasthan, Arunachal Pradesh and West Bengal) from 2004-07. Data on farm machinery accidents were collected to develop farm safety programme. Total accidents observed were 698 in number. The total accidents rate was estimated as 333 accidents per 100,000 workers per year and 18.3 accidents per 100,000 workers fatality rate per year. The results were represented as the percentage of accidents with farm machinery: 30.5% (chaff cutters: 9%, threshers: 14% etc.), hand tools: 34.2%, and other sources as 35.3% respectively. It was reported that 94.4% (7,55,000) accidents were non-fatal (95.7 per 100,000 workers per year) in nature and 5.6% (45,000) were fatal (5.7 per 100,000 workers per year). The estimated cost of human life was 11 lakhs, Rs. 5700 and Rs. 5400 crores per year were figured average costs for fatal injury and total costs of accidents respectively. This study suggested development of built in safety devices in chaff cutter, and in cane crushers, shielding rotating parts of machines and educating people through trainings will help in reducing the farm machinery accidents.

Kumar *et al*. (2012) conducted study in Haryana and has collected population data of farm machineries in the year 1995-96, 2000-01 and 2005-06 to figure out the total accidents (percentage of fatal and non-fatal accidents) with different farm machines. It was reported that a total of 15, 808 incidents in the year 2000-01, highest accidents were with chaff cutter (41.76%), tractors (31.96%) and others (7.84%). The total number of accidents identified in the year 2005-06 were 17,227 and highest percentage was with chaff cutters

(37.24%), tractors (36.90%), threshers (11.54%) and others (10.00%). It was reported that 90.87% of injuries were non-fatal in nature where as 9.13% were fatal. It was recommended to adopt suitable safety measure for agricultural workers reduce the farm machinery accidents it is important.

Patel *et al.* (2010) conducted a survey in 22 villages of Etawah district of Uttar Pradesh in India to collect the informative data related to agricultural injuries (1996–2000). The study revealed that out of 1.4 million population of the state, 0.75 million were engaged with farming activities. The survey revealed that in 22 villages, total of 27,125 people engaged in agricultural work. Total economic burden of fatal injuries was US $ 730,000 in the year 2000. The total cost of non -fatal injuries in the study was calculated as the product of loss in income during recovery time of injury and average medical treatment expenses. The data collected shows that total agricultural injuries identified were 106 during the survey period. 57 (56%) injuries are due to farm machinery with injury happening rate of 0.8 workers / 1000 years. Maximum (22) farm machinery injuries were associated with fodder-cutter, by threshers (12), cuts (6), struck body parts in machines by loose cloths (12). By nature of injuries maximum injuries happened due to crushing, cut, amputation, fractures and laceration. 43 (41%) injuries are by hand tools, 9 % of injuries were fatal and 91 % were non-fatal. Highest injured persons were male 79% (84 in numbers) and 21% (22) injuries were identified with female workers and maximum workers injured were in the age group of 30-44 years. It was observed that the children with age group of 0-15 years were injured chaff cutter and other machines because of playing with those. They suggested that the use of ergonomically designed hand tools, providing locking system on fodder cutter machine to avoid children injuries in unused condition, providing shields or guards to the rotating parts of various farm machines used and awareness trainings to the labors was able to prevent the injuries.

Shaw (2010) reviewed 100 incident investigation reports in the UK spanning the period 2002–2007 and identified a number of contributory causes. The review revealed that inadequacies in design, failures to isolate (lockout), lack of protection system, inadequate fault reporting or maintenance were major contributors to the accidents.

Sarkar *et al*. (2012) conducted a comprehensive study in Karnataka state to understand the effect of modern agricultural practices on human health. Occupational health hazards were identified and categorized in percentage of injury or hazard type. It was reported that 85% cut injuries were observed during study period, which may be due to entanglement chances such as caught in moving machine parts, threshers, stucking parts and other machines.

Das (2014) surveyed six villages of Hooghly district where a greater number of people were engaged in farm activities in West Bengal (India) during 2006-2010. This study reported that the total number injuries during that surveyed period with respect to gender (male:214, female:109), source of injury (hand tools: 209 or 64.70%, farm machinery: 94 or 29.10%), nature of injury (196 minor injuries: 129 in male and 67 in female) and also with some specific agricultural machines (threshers: male 47.50% and female 77.10%, winnower: male 10.30% and female 21.70%). Total 124 injured subjects and 323 farm injuries were identified and recorded during the survey period. The occurrence rate of were farm machinery: 2.48/1000 workers per year (male), 2.53/1000 workers per year (female), Winnower: highest accident rate such as 1.18/1000 workers per year(male), 1.95/1000 workers per year (female). Total injury occurrence rate in male was 8.99/ 1000 workers per year and in female 7.89/1000 workers per year. Study suggested that to increase the productivity of workers and to improve their working conditions: increase in number of short rest periods, reducing total working hours, using low cost protective devices and providing education to farm workers was helpful.

Ravikumar *et al*. (2017) conducted a study from October 2017 to April 2017 to know the physical and psychological impacts of agricultural injuries and to analyze the recovery pattern of agricultural hand injuries. It was observed that hand injuries (73%) were most common, 27% patients were with right hand cut injuries and 73% were left hand. 11.25% of total upper extremity problems were agriculture upper limb injuries. Males affected (83.64%) more. Maximum number of patients were with age of 21-50 and most of them were right handed individuals. This study reported that covering the moving or rotating parts of farm machines, educating workers, avoiding children entry near to such machines and by working hour adjustments of farm workers can reduce agricultural upper limb injuries.

Patel *et al.* (2018) conducted study in Arunachal Pradesh (2010-2013) to collect the demographic data of farm injury and characteristics (body part injured, type and tools caused injury). Maximum accidents were with farm machinery and farm tools 144 (60%), most injured parts were foot and legs. The highest number of injuries occurred on upper limb parts (29%: shoulder, elbow, forearm), followed by lower limb (26%), hand (19%: fingers and wrist), knees (14%), foot and dorsal surfaces (9%). The estimated farm injury occurrence rate per year was 589 per 1,00,000 workers, accidents with male workers (78%, 462 per1,00,000 workers per year) were more (3.6 times) than female workers (22%).

2.3 Accidents/ injuries with fodder cutter machine

Dinesh and Patel (1992) conducted an ergonomical study to determine the main causes of injuries among farmers in 9 villages in the state of Haryana in Northern India. The study revealed that the largest number of traumatic injuries was caused by fodder cutting machines and threshers. The designs of these machines have been made safer using ergonomics principles.

Mittal *et al.* (1996) carried out a similar study in Punjab and reported data on 36 accidents in a year from 12 villages. 47per cent of the accidents occurred while using sprayers/ pesticides, 25 per cent from tractors, 14 per cent from electric motors and 8 per cent each from chaff cutter and threshers.

Mohan *et al.* (2004) conducted an epidemiological study in North India. Study was conducted in two phases. Authors stated that fodder cutter machines were used every day by farmers and their families in India for preparation of fodder to feed the livestock. They reported that fodder cutter was responsible for maximum injuries (64 or 11% in phase I and 87 or 31% in phase II). Maximum injuries were observed for younger one's (age below 15) from chaff cutter while playing with machine and it was concluded that all age groups sustain fodder cutter injuries while operating the machine. A detailed study of injuries and machine characteristics resulted in a safer fodder cutter design. This paper reported the process of the community-based study and the safer design features of fodder-cutter machine. Engineering interventions were developed like warning roller, blade safety guard etc. to reduce the agricultural injuries by fodder cutting. The design changes were cost effective and could be incorporated in both existing and new fodder cutter machines.

Kumar *et al.* (2012) conducted a survey in five villages of Ghaziabad district of Uttar Pradesh (a northern state of India) to determine the causal factors responsible for chaff cutter injuries. A total 36 fodder cutter related injury were observed in that, 20 % were female. Hand injuries were maximum in younger persons. It was observed that major injuries were caused during children playing with the machine and workers feeding the fodder in to the chute. Based on the survey results and mechanism of injuries, three safety interventions were developed to prevent the injuries. These interventions can be retrofitted on old machines and can be incorporated in new machines as well. Experiments were conducted using different fodder crops to observe difficulty in chaff cutting with the safety interventions. It was observed that incorporation of the interventions had no effect on performance of chaff cutting operation. These were retrofitted on existing machines at different locations and the response found was very positive.

Vaishnav *et al*. (2017) reported the rare fatal head injury and crush injury to leg by an improperly assembled fodder cutter. Survey was conducted during 2007-2012 in Punjab regarding the farm machinery accidents. It was reported that farm machinery accidents were common in north-west region of India. In Punjab. 70.7 % of accidents were due to machinery like tractor, harvester, thresher and chaff cutter. Among the district of the Punjab, farm machinery accidents were maximum in Sangrur and least in Nawanshar and Kapurthala. maximum number of accidents happened with chaff cutter.

2.4 Hand anthropometry data

Human hand anthropometric data such as palm area, palm thickness, palm width and hand length are useful in designing the safety system which helps in reducing amputations or injuries to hand.

Kar *et al.* (2003) suggested the use of hand anthropometry data which can help in the proper designing of equipment for better efficiency and comfort. Eight hand dimensions were identified which were considered more useful for designing agricultural hand tools. Right and left-hand dimension were collected from 200 male and 204 female workers of West Bengal and eastern India. It was noted that there were significant differences ($P<0.001$) in hand measurements between the right and left hands as well as between right and left hands as well as between male and female workers. However, the percentages of differences in the measurements right and left hands was small (0.10 % to 3.49%) than those between the men and women (7.1 % to 11.96 %).

Nag *et al.* (2003) studied the hand breadth, circumference and depth and found normal distribution, with some deviation in case of finger lengths. Hand length was significantly correlated with the fist, wrist and finger circumferences. The fist and wrist circumference, in combination, was better predictors of the hand length. The hand lengths, breadths and depths, including finger joints of Indian women studies were smaller than those of American, British and West India women. The hand circumferences of the Indian women were also smaller than the American women. The handgrip strengths of the present women were much less (20.36) were less than those of American, British and west Indian women. Grip strength was found to be significantly correlated with three hand dimensions (6, 18, 48). Grip strength of India women (20.36) were less than those of American, British and West India women. The women who are forced to frequently use cutters, strippers, which are not optimally designed to their hand dimensions and strength range, might have higher prevalence of clinical symptoms and disorders of the hand.

Chandra *et al.* (2009) surveyed eight hundred and seventy-eight male industrial workers for analyzing thirty-seven hand anthropometric characteristics of the Haryana state. Minimum, maximum, mean, standard deviation, skewness, coefficient of variation 5th, 50th, and 95th, percentile for each hand anthropometric dimension calculated. The maximum and minimum hand lengths were 170 mm and 202 mm respectively and the counter values for the hand circumference were 225 mm and 244 mm respectively. Coefficient of variation among the thirty-seven hand dimensions ranged from 3.32 to 15.12% with 34 of them below 10%.

Sahu *et al.* (2013) obtained information on the body dimensions, which may be used ergonomic design of farm equipment. In this study difference in hand dimensions of right and left hand of 200 female agricultural workers have been collected. It was noted that there were significant differences in hand measurement between left and right hand of agricultural female workers. The 200 female workers were categorized in four different age groups (18-25, 26-35,36-45,46 to above) whose mean, SD, CV, range were computed according to age groups. Percentile values (5th, 25th, 50th, 95th) of the anthropometric dimension were also computed separately for different age groups. The percentage difference in the measurement between right and left hands was small (0.05% to 0. 22%).

2.5 Application of electronics for machine safety

Backstrom and Doos (2000) reported problems related to safety devices from 76 accidents in automated production obtained from 21 work sites in over a two-year period (1988–1990). The study reveals that a production installation should not be regarded as safe simply because it possesses safeguards. The latter include barriers, interlocks, hold to run control, two hand controls and presence sensing device. The study identifies four levels of problems namely (i) no or low level of safeguarding, (ii) non-use of safeguards (remove, circumvent, defeat, decouple), (iii) failure of safeguards to stop all machine movements in the danger zone (residual energy, inertia) and (iv)failure of safeguards to provide protection under all prevailing circumstances (e.g. work requiring machine to be energized). It is shown that all types of safeguards have associated problems. Safeguards do not always function adequately in conjunction with the handling of production disturbances.

Shutske *et al.,* (2001) worked with a multi-sensor human-existence identifying system, using microwave and passive infrared sensors to provide protection to agricultural machine operators from the moving or hazardous rotating machine parts. They evaluated the system with rotating PTO power shaft. The detection range was 92 to 227 cm per second. It was reported that in 822 warm climate trials sensors performed better in identifying human presence comes closer to the rotating shaft and was able to raise timely alarm (between 0.5 and 1.0 seconds) without any lags. But in cold conditions additional control has to be taken for some hardware problems. The study suggested that using more than one sensor makes the system more precise and reduces the false detections. further studies were reported in order to prevent the entanglement injuries with machines by development of automatic shutdown systems and warning systems.

Guo *et al.,* (2002) has developed a conceptual security alert system with two ultrasonic sensors for farm machineries to alert operators with real time warning signals. Test results were validated and it was reported that the developed sensor system had ability of adopting in outdoor environments to detect the moving objects comes in sensor detection area and to warn worker or person approaching machine parts.

Charpentier (2005) retrieved 457 automation accidents covering a period of 20 years from the French database. Study reported the type of industry, characteristics of injuries, factors leading to the accidents, protective devices existing on the equipment and prevention or corrective measures adopted. The nature of injuries suffered by victims of automation accidents were amputation (27%), fractures (28%), various wounds and injuries (30%) and bruises (10%). The activities involved in the accidents were: usage or operation (36%), handling (8%), assembly (9%), adjusting (7%), supervising (12%), repairs (9%), cleaning (10%) and informing, testing and inspecting (5%). Safeguards being absent accounted for 32% of the accidents. Guards (i.e. fixed, moveable with or without locking, moveable with timed opening, automatic) and safety devices (i.e. light curtains, pressure mats, and other presence sensing devices) were present in 45% of the accidents. Emergency stops, lockout procedures and other preventive measures were present in 20% of accident cases. The reasons behind accidents occurring were inadequate guards or improperly dimensioned, installed and utilized (35%), bypassed guards (30%) and malfunctioning of guards (15%). In 82% of cases, corrective measures following the accidents were to use safeguards.

2.6 Passive infra-red (PIR) sensor-based security systems

PIR or Passive infrared sensor is passive as it purely senses the infrared radiation energy emitted by the warm-blooded living beings. When human being or animals comes within its detection field of view, there occurs a sharp increase in radiation energy which is invisible to human eye.

Hashimoto *et al*. (1997) conducted a study that, people counting system with human information sensors using multi-sensing application which were used for detecting the number of passing persons and their moving directions. The sensor head module of sensing system consists of 1-dimensional 8-element array detectors fabricated by sheet forming method of pyroelectric PbTi03 ceramics, IR-transparent lens and oscillating mechanical chopping parts. By using this method 95% accuracy was detected.

Shankar *et al.* (2006) developed a human tracking system using a low-cost sensor cluster consisting of PIR sensors and Fresnel lens arrays to implement the desired spatial segmentations. The sensor system can detect human motion for large areas at distances of 12 m. Pyroelectric detectors are in expensive and normally used in motion detectors for security or home automation systems. They characterized the behavior of the dual-element pyroelectric detector. The data extracted to obtain velocity information and the direction of motion. By using multiple sensor clusters in different orientations, demonstrated human motion tracking.

A study on Robust Sensing of Human Proximity for Safety Applications was conducted by Neumayer *et al*., (2010), A system was developed with proximity sensor for detecting the presence of a human in the vicinity of dangerous working areas of a power tool. They used current position of movable part and prior knowledge of a vacant condition. Developed a system sensed the human presence and enabled the control unit of power tool to move in backward or forward direction to avoid injury to operator.

A study was conducted Xin *et al.,* (2012) to monitor human activities (pedestrian motion and detection of intruders) in a secure region. Target detection and classification seismic sensor and PIR sensors were used to extract symbolic features. They found that PIR sensors were very good for target detection and performed better as compared to seismic sensor for the same work.

Benopezeth *et al*., (2011) carried out a study on Vision-based system for human detection and activity analysis in indoor environment. They studied the changes in detection with respect to background and variations with the environment, tracking moving objects and to know nature of objects present in the scene. The evaluation gives detection rate of 97% whereas static position of people was not being identified properly.

Chowdhury *et al.,* (2011) developed a Low-cost security system using PIR sensor made with a microcontroller. The developed microcontroller-based system sensed the pulse generated. The detection of unauthorized person will occur at any time instant, which activates the sensor system to make alarm and though GSM (Global System for Mobile Communication). The modem alarm is controlled to make sound for predefined time until motion occurs in its field of view. Fresnel lens made of special plastic material which condenses light, the lens will provide extended range of sensing area and focuses infrared radiation towards sensor. A warm body (human, animal) moves in to the area, in first capture PIR sensor shows the positive differential change between two elements and if intruder leaving the area negative differential change will occurs. If there is no motion or intruder presence, sensor will settle to idle position and both elements of sensor detect the almost same quantity of radiation with respect to ambient condition of area. This system is highly responsive and has low calculative needs, used in observation systems, industrial applications and smart environments.

Prasanna *et al*., (2013) carried out a study on Automated Intelligent Power Saving System and Security System. The study was planned to save the power used in places like. Libraries, Staircases, Parking, Gardens etc. The use of PIR sensor in security systems which save energy when it is compared with convectional security systems without PIR sensors was discussed. These PIR sensors were reported to consume less power and achieve high efficiency. Comparison between security systems with PIR sensors and system without PIR sensors was discussed. It was evident from the studies that IR sensors also can be used in security systems but have a disadvantage of low range distance. This disadvantage could be overcome by the use of PIR sensor. About 25% of the total operational hours can be reduced with the help of the PIR sensor. The total consumption of power is also reduced by 25% with the use of PIR sensor. The total amount paid per month is also reduced by 25 percent.

Jaeseok *el al*., (2014) conducted study on Human movement detection and identification Using Pyroelectric infrared sensors. A data collection module having two pairs of PIR (passive infrared) sensors with modified Fresnel lenses was developed. The application of PIR sensor in determining the movement of the person from one place to another was studied. It was carried out by various different factors like going straight and forth, changing the speed of the person's movement. More than 92% correct detection of direction and speed was reported. It was reported that single PIR sensor could achieve up to 92% accuracy in classifying direction and speed of movement and more than 94% accuracy in classifying speed and distance of identifying subjects.

Kapre *et al*., (2014) carried out a study on Advanced Security Guard with PIR Sensor for Commercial and Residential use. The major goals of the study were to provide security to shops, residential areas, factories, banks and to cover all the area meant for protection and not to restrict the view to any single area of entrance. Gas sensor, PIR sensor, Main fuse failure Detector and Smoke sensor were used in the study. The controlling device used was microcontroller. This setup is connected to the user through a GSM module. The device had two modes of working as internal and external. In the internal mode, the sensors present were inactive and vice versa. The study upholds the fact that the existing devices used for the security system had so many drawbacks. The technology used in this system used the PIR sensor to sense the person entering. It signals to the camera and Camera will take the picture of the person entering the premises.

Sravani *et al*., (2014) developed a human motion detecting system using passive infrared sensor. The detected input signal was converted to generate the alarm. PIR sensor was used which worked on the principle of pyroelectricity sensing the presence (motion) of human or animals. It developed a change in the infrared radiation with respect to surrounding that was detected by PIR sensor, which triggered the system to make alarm sound. Microcontroller used for continuous monitoring of the system output obtained from the unit and to make the buzzer to sound accordingly to create message for intruder alert. The system finds application to provide security in places like roofed parking places, shopping malls, garden lighting, in outdoor lights and also in-home automation requirements. It was a low cost and reasonable, can be adopted for as low power requirement system, portable and easy usage with minimum maintenance.

Kumar *et al.,* (2015) and team has worked to develop Human Detection Robot using PIR sensor. Robot can detect the presence of human, sends the signal and notifies to the user by continuous buzzer sound.

Nwalozie *et al*., (2015) and team has been worked for developing and enhancing home security using SMS-base Intruder Detection System for the smart home. The main aim of this project is to implement a smart home system by controlling the electronic devices at home remotely with the help of a mobile device and getting alerts on intrusion or movement around the restricted premises. The SIM900-GPRS module and the microcontroller are used to communicate between the mobile phone and the devices and sensors installed at home. The major drawback of the project is that it is limited to the area with the GSM network available and the whole system does not work without the network.

Abdellatif *et al.,* (2016) developed a Human detection robot to detect the human being within the 4 to 5 m in disaster areas. A PIR sensor was used in robot for detection of movements.

From the above literatures, it was clear that injury was caused by farm machines which reduces the worker's productivity temporarily or permanently (in case of induced disability). Hand injuries, cut and crush injuries are common in fodder cutter machine. These injuries are non-fatal in nature and create permanent disability to the worker. A number of ergonomic interventions were developed to reduce the injuries in fodder cutter machine. A low-cost safety alarm for human body or body part detection can be an effective preventive measure. PIR electronic sensor can be used for human motion detection. Many studies reported PIR sensors and their performance for the suitability of sensor in human motion detection. A fore warn safety alarm system can provide enhanced safety by warning the workers whenever they assess injury prone area.

Materials and Methods

Chapter 3

MATERIALS AND METHODS

This chapter deals with the description of materials used and method followed in the research work. Response study was conducted to assess the sensor effectiveness to differentiate human hand in different orientations and distances, and hand movement along with biological material (fodder), to obtain the reference values for design variables. Developing program with the values obtained in Arduino software, electronic circuit design and integration of circuit to develop safety alarming system.

The Programme of research work plan sequence:

1. Response study of Passive Infrared (PIR) sensor with respect to human hand and fodder on experimental setup in the lab, identifying and defining the reference values of responses for hand and fodder parameters (distance from sensor, hand orientation, speed of hand movement, fodder type).
2. Development of algorithm and program for microcontroller based on reference values.
3. Configuration of electronic circuit and Integration of software (microcontroller program).
4. Test-evaluation of developed microcontroller-based system.
5. Development of PIR sensor-based Audio warning system for fodder cutter machine.
6. Statistical analysis of the experimental data.

3.1 Development of PIR sensor safety device

The following materials were used in development of Passive infrared sensor-based safety warning system

3.1.1 Arduino Nano (ATmega328P), Arduino Uno

Arduino is an open-source electronic platform called as brain of electronics projects. It contains a microcontroller and works on set of instructions (Program code) communicated with the help Arduino software in C language. There are many different Arduino boards used for projects. In present study, Arduino Nano and Arduino Uno boards were used for the development of sensor warning system.

The Arduino Nano is a small, complete, breadboard friendly, compacted board. It can be powered with Mini-B USB cable with 6-20V unregulated external or 5V regulated external power supply and lacks only in DC power jack. Arduino Uno will perform the same function as Arduino Nano. It is bigger in size than Arduino Nano.

Many facilities are provided for communicating with hardware's such as computer, or with other microcontroller or Arduino. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. A Software Serial library allows for serial communication on any of the Nano's digital pins.

In the study 5V, GND, Analog pins (A0, A1, A2) and Digital pin 13 (D13) are used. 5V pin is give a power input, GND pin for ground, any one analog pin out of three used to get sensor output. Digital pin 13 is selected to produce buzzer and LED output.

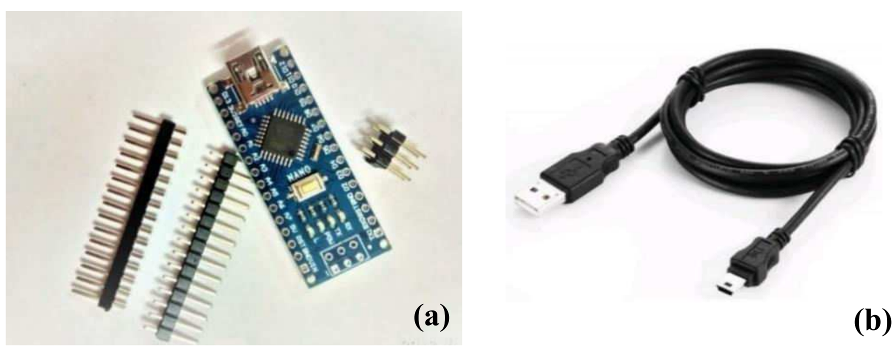
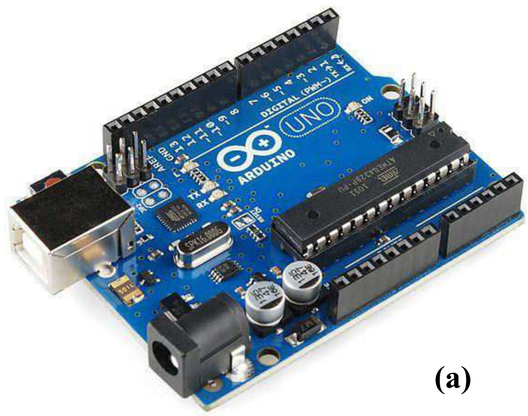


Plate 3.1 (a) Arduino Nano ATmega328P (b) data Cable

Table 3.1 Specifications of Arduino Nano

Parameters	Specification
Microcontroller	ATmega328P – 8-bit (AVR family)
Operating Voltage	5V (Input voltage 7-12V)
Analog Input Pins	6 (A0 – A5)
Digital Input/output Pins	14 (Out of which 6 provide PWM output)
DC Current on I/O Pins	40 mA
DC Current (3.3V Pin)	50 mA
Flash Memory	32 KB (2 KB is used for Bootloader)
Frequency (Clock Speed)	16 MHz
Communication	IIC, SPI, USART



(a)

(b)

Plate 3.2 (a) Arduino Uno (b) Micro USB Cable

Table 3.2: Specifications of Arduino Uno

Particulars	Specifications
Microcontroller	ATmega328P – 8-bit AVR family microcontroller
Operating Voltage	5V
Input Voltage	7-12V
Input Voltage Limits	6-20V
Analog Input Pins	6 (A0 – A5)
Digital I/O Pins	14 (Out of which 6 provide PWM output)
DC Current on I/O	40 mA
DC Current on 3.3V	50 mA
Flash Memory	32 KB (0.5 KB is used for Bootloader)
Frequency (Clock Speed)	16 MHz

3.1.2 Capacitors

Capacitors consists of electric conductors. These are used to store electric charge as well as filters in some applications. Connecting capacitors in parallel will help to increase the total chare storage capacity with same voltage in each capacitor.

Capacitors may be polar or non-polar type. Polar capacitors or electrolytic capacitors made of dielectric electrolyte and having positive and negative terminals. Small leakage of current occurs while allowing high capacitance. Polar capacitors can be used as filters in power supply systems. Non-polar capacitors, made of mica and ceramic material capacitors without positive/negative poles. Very less current leakage may occur in non-polar type and they can able to maintain capacitance in both directions (bias). Capacitance of 0.01µF, 10µF and 100µF were used in the study as a signal filter (Plate 3.3).

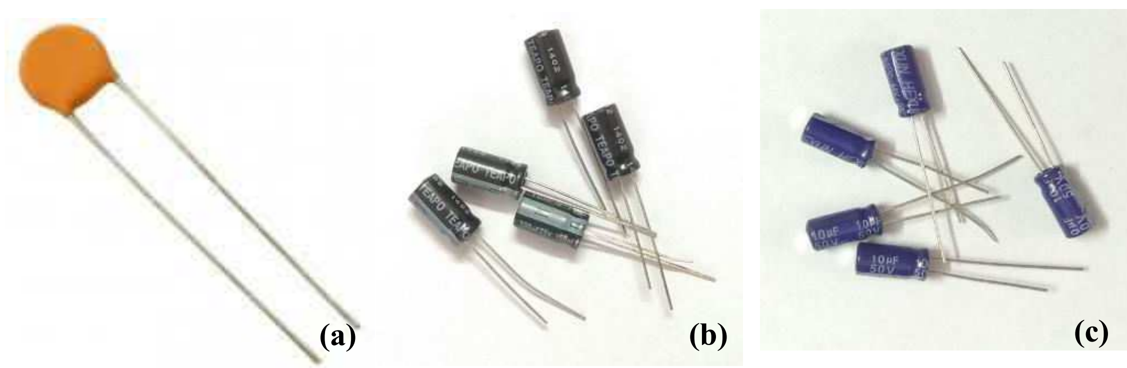


Plate 3.3 Capacitors of value (a) 0.1µF, (b) 10µF and (c) 100µF

3.1.3 Resistors

Resistor are the electronic components, they oppose the flow of electrons or electric current in an electric circuit. They are made up of ceramic coating with nickel alloy or metal oxides (tin oxide). Resistors when connected in series, same current will flow through them and sum of each resistors will give the total resistance. Likewise, parallelly connected resistors will have same voltage across them and total current is the sum of current in individual resistors. In this study 1 M ohm, 10 k ohm and 47 k ohm resistors are used (Plate 3.4).

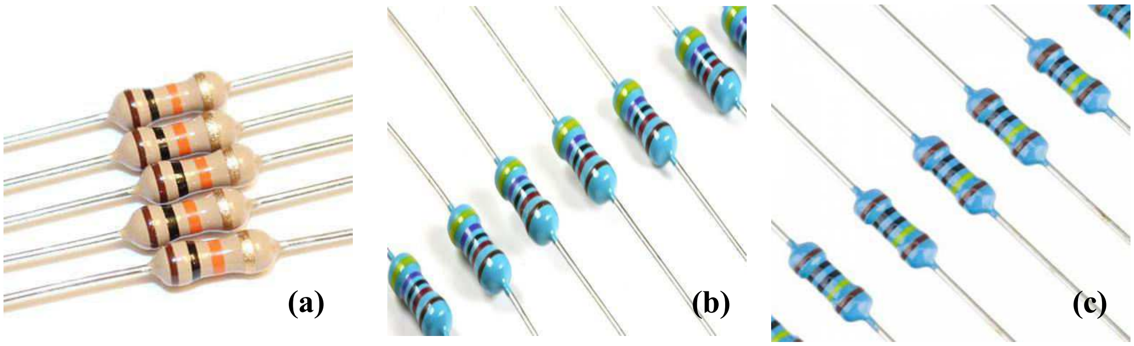


Plate 3 .4 Resistors of value (a)10k, (b) 47k and (c) 1M ohm resistors

3.1.4 Transistors

Transistors helps in transfer of electric charge or signal across the resistors. Transistors are small in size and solid-state electronic devices. They made up of semiconductor material (germanium), having minimum of three electrodes or pins named as Collector: current flows in through collector, Base: controls the biasing of transistor and Emitter: current drains out through emitter. In the present study BC547 transistor was used.

In this study transistor (BC 547) was used as a signal amplifier. Transistor when operated in active region, can amplify current, voltage and power in different conditions. Different amplification circuits have common emitter amplifier, common collector amplifier and common base amplifier. Among them common emitter type is generalized one. DC gain of an amplifier is obtained with relation to “DC Current Gain = Collector Current / Base Current”. This type of amplification circuits can be used in LED driver, Relay module driver, in audio and signal amplification modules, *etc*.

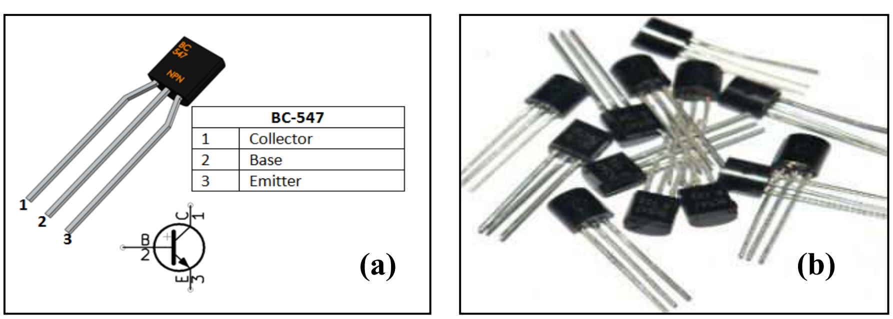


Plate 3.5 BC 547 NPN Transistor (a) Pins configuration (b) BC547 Transistor

3.1.5 OLED

OLED is an organic light emitting diode, composed of a film of organic compound (emissive electroluminescent layer), which is placed in between two electrodes and one of them should be transparent, it emits the light according to an electric current. An OLED display is driven by a specific control scheme that is PMOLED (passive-matrix LED: a one by one row or line display control) or AMOLED (active-matrix LED: allowing for higher resolution and larger display).

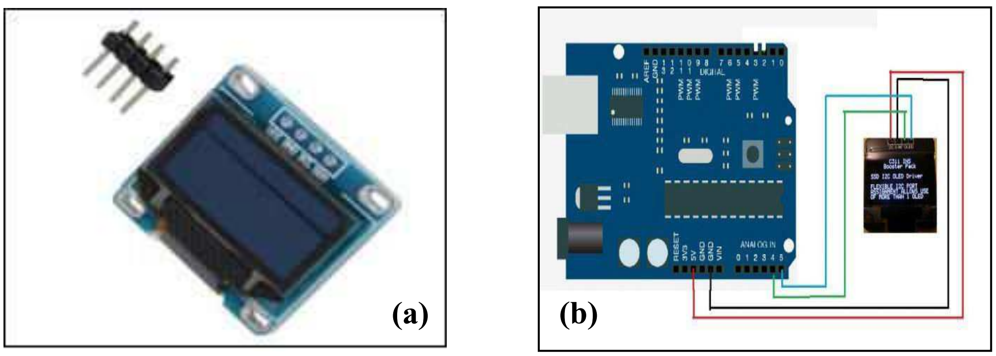


Plate 3.6 (a) Four pin OLED (b) OLED connection with Arduino board (Uno)

OLED can emit visible light and can works without backlight. In low ambient light conditions (such as a dark room), an OLED screen can achieve a higher contrast ratio than an LCD. OLED are used as for digital display of real time data, in computer monitors, mobile phones etc. In present study 4 pin OLED (plate 3.6) has been used and is supported by Arduino power supply. The connections are made in such a way that the OLED input VCC pin connected to 5V Arduino pin, OLED GND pin to Arduino GND pin, SCL and SDA pins connected to Arduino analog input pins A4 and A5.

3.1.6 Integrated circuit

An integrated circuit (IC), electronic chip, made up of semiconductor material (silicon), which is integrated with many small transistors, tiny resistors, capacitors. It can be used as an amplifier, oscillator, computer memory or microprocessor, timer, counter. Two different ICs have been used to check the suitability for the present study namely LM324 and LM741(plate 3.7 and 3.8).

The LM324 ICs are cost effective with four operational amplification circuits in it. They are able to give true differential inputs. These are very much useful compare to other standard circuits. The range of operating voltage is 3V to 32V.

LM741 ICs are general-purpose operational amplifiers. It helps in overload Protection on the Input and Output voltage. The specification of ICs LM324 and IC LM741 are given in Table .3.3.

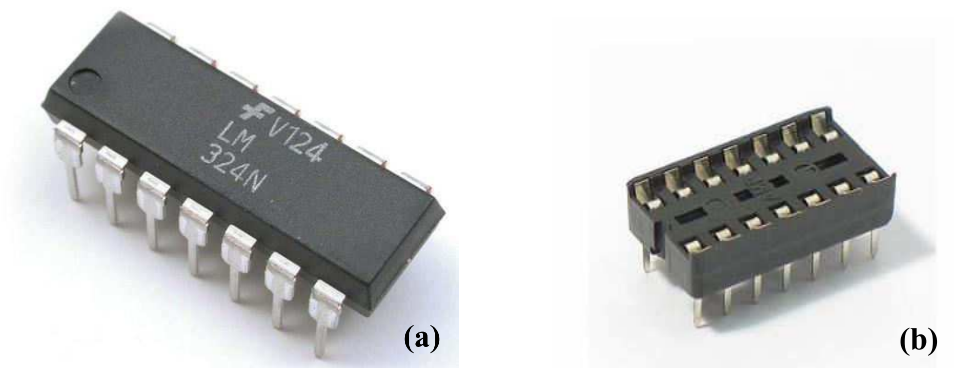


Plate 3.7 (a) LM 324 ICs (b) 14 pin bases

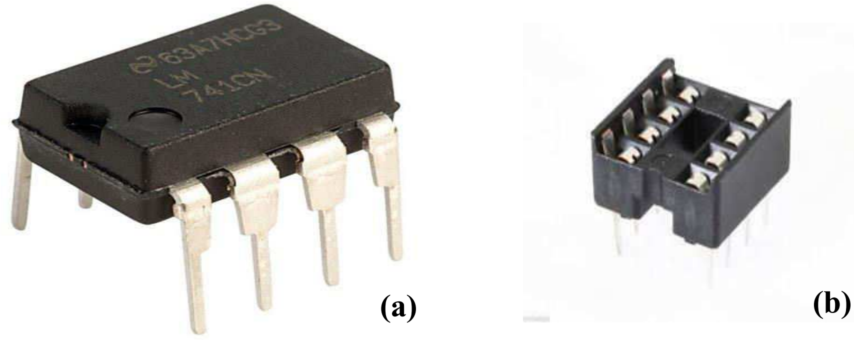


Plate 3.8 (a) LM 741 IC (b) 8 pin bases

Table 3.3: Specifications of Integrated circuits

Name	Specification
LM324	1. Short circuited protected outputs 2. True differential input stage 3. Single supply operation: 3.0 v to 32 v 4. Low input bias current: 100 nA maximum 5. Four amplifiers per package 6. Common mode range extends to negative supply 7. Industry standard pinouts
LM741	1. Short circuit and overload protection provided. 2. Low power consumption. 3. Large common mode rejection ratio (CMRR) and differential voltage ranges. 4. No external frequency compensation is required. 5. Simplifies circuit design and minimizes the number of components used.

3.1.7 Power source/ Battery, LEDs, Buzzer and connection wires

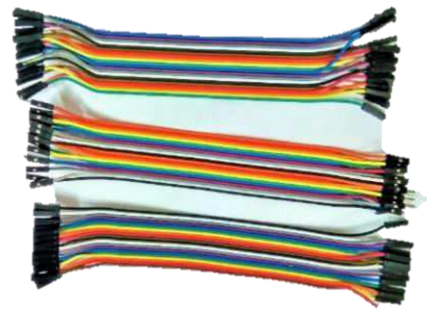
A 9V battery was used to power the Arduino Uno and Nano for different circuitry. An LED and buzzer were used to give warning signal when human body signal was detected by PIR sensors. Jumper wire of different colors were used to connect the components in the circuit.

(a)

(b)

(c)

(d)



(e)

Plate 3.9 (a) 9V battery, (b) Battery power jack, (c) Buzzers, (d) LEDs (e) jumper wires

3.1.8 Passive infrared sensor (PIR Sensor):

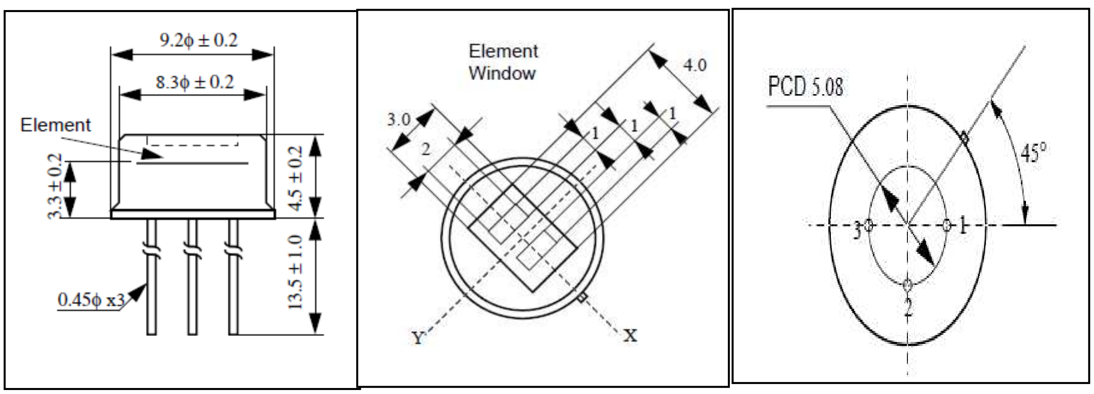
Objects with body temperature more than zero-degree celsius will emit radiation. PIR sensors are semiconductor elements, which detect infrared radiation of wavelength 5 to 14 micrometer, emitted from the object or body and produce signals in waveforms. It is usually called motion detection sensor. PIR sensor contains two active sensing elements arranged in such a way that series differential balance is exists between them. These are having high sensitivity to small changes in temperature of surroundings. Microwatt thermo signals are sufficient for triggering and change in output voltage. With the help of PIR sensor direction of heated object movement can also be observed (Table 3.4).

RE200B is a passive infrared sensor, with wavelength range up to 10microns (plate 4.0). When the elements exposed to temperature change, then there will be a development of separate electric charges across the elements. J-FET will control the voltage across sensors. Optical transfer characteristics of windows can control the spectral sensitivity of the sensor for optimized sensing of radiation from human body.

Plate 3.10 Passive infrared sensor

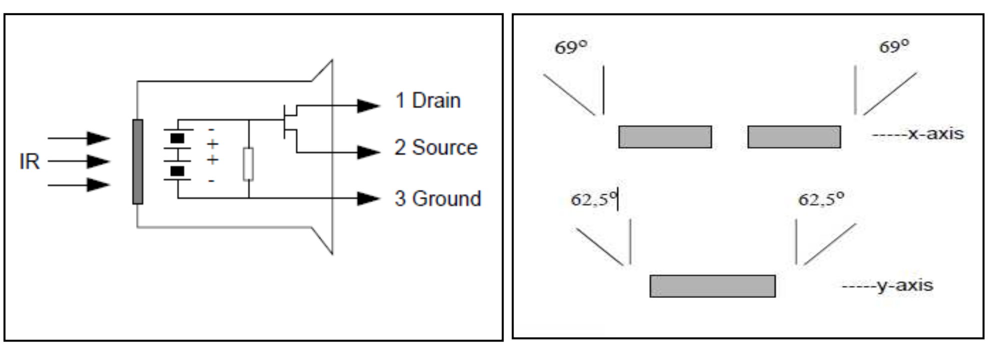
Table3.4: Specifications of RE200B PIR Sensor

Passive Infrared (PIR) Sensor	
Particulars	**Specifications**
Detection range	up to 10 m / 30 ft
Spectral response	5-14 µm
Operating temperature	-20 °C to +70 °C
Storage temperature	-30 °C to +80 °C
Operating voltage	3 to 15 V
Viewing angle	95-110 degree



(a) (b) (c)

Figure 3.1: Sensor element of RE200B (dimensions, window, base view)



(a) (b)

Figure 3.2 (a) Circuit Configuration of PIR sensor, (b)Field of view of PIR sensor

3.1.8 Infrared thermometer

Non - contact type infrared thermometers (Laser thermometers, temperature measuring gun) were used to measure an infrared radiation emitted from a body. In the present study the Fluke 59 MAX+ infrared thermometer was used to measure the hand temperatures of subjects. This instrument can measure the quantity of infrared radiation on the target surface area in terms temperatures units (Table 3.5).

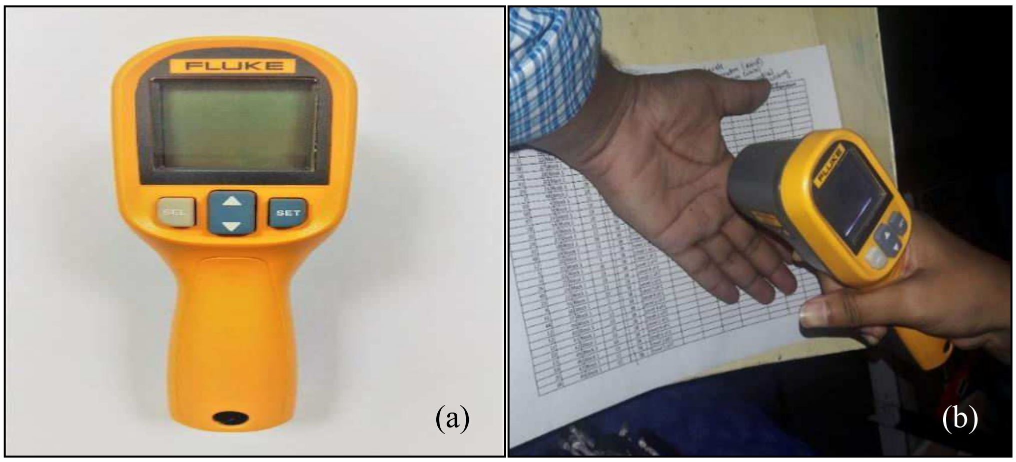


Plate 3.11 (a) Infrared Thermometer and (b) Hand temperature measurement with IR thermometer

Table3.5: Specifications of infrared thermometer

Particulars	Specifications
Temperature Range	-30 °C to 350 °C (-22 °F to 662 °F)
Response Time (95 %)	<500 ms (95 % of reading)
Spectral Response	8 mm to 14 mm
Emissivity	0.10 to 1.00
Distance to Spot Ratio	8:1 (calculated at 90 % energy)
Display Resolution	0.1 °C
Battery Life	12 hours with laser and backlight on
Weight	220 g
Size	(156 x 80 x 50) mm
Operating Temperature	0 °C to 50 °C (32 °F to 122 °F)

Storage Temperature	-20 °C to +60 °C (-4 °F to 140 °F, without battery)
Operating Humidity	10 % to 90 %

3.1.9 Design of Sensor Mounting Box on Fodder cutter chute

Rectangular shaped mild steel sheet frame with required dimensions is attached to the chute. The frame with dimensions 22cm height from the top of chute and 23.5cm width was used in the study (Plate 3.4).

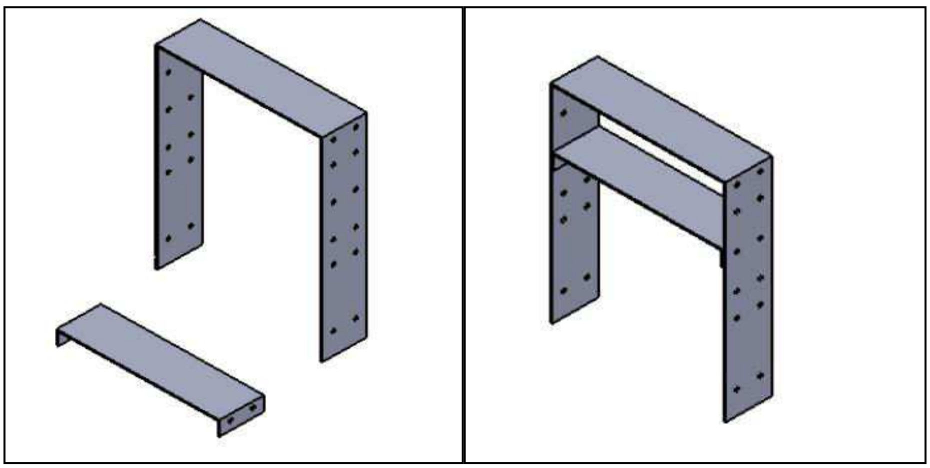


Plate 3.12 Mild steel frame attached with feed chute of fodder cutter

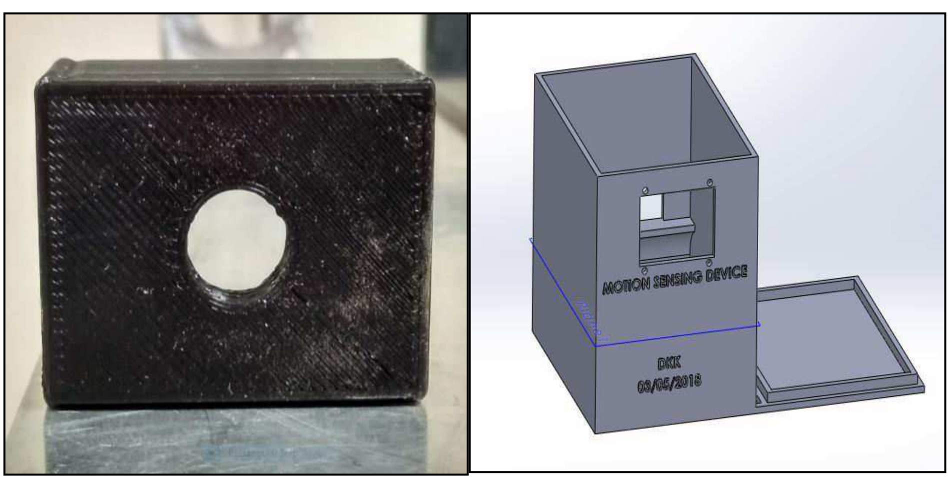


Plate 3.13 3D printed boxes for sensor system

3.1 Programme for PIR sensor setup and integration of components to the circuit

To program the microcontroller of the system developed, code has been written in an open source of Arduino software. The flow diagram of the program is given in fig. 3.3.

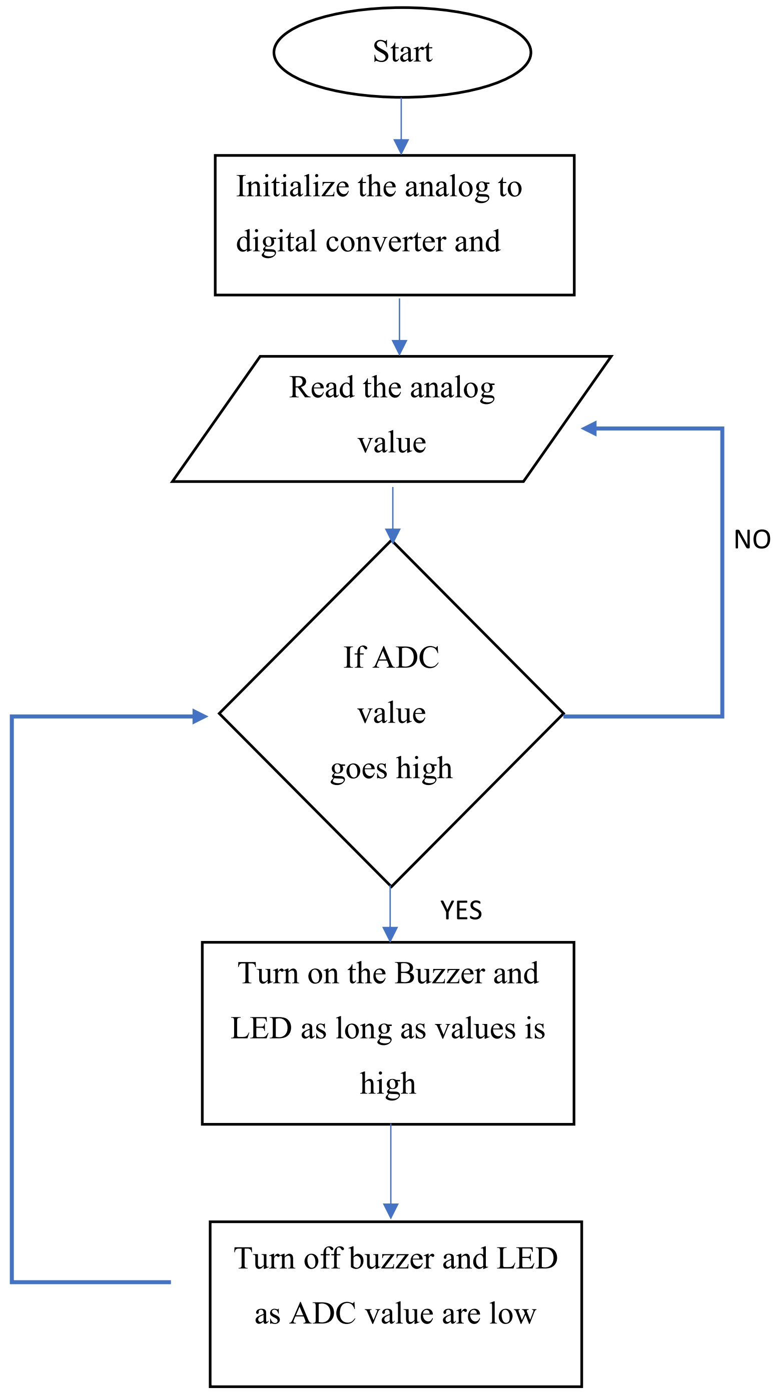


Figure 3.3 Flowchart for PIR sensor safety system for fodder cutter machine alarming system

3.1.1 Integration of circuit

Data collection circuit model was prepared using PIR sensor, four pin OLED and Arduino Uno. PIR sensor has three pins, VCC, GND and OUT pins connected to Arduino VCC, GND and A0 pins respectively. The four pins of OLED VCC, GND, SCL and SDA also connected to 5V, GND, A4 and A5 pins in the Arduino.

The audio - visual warning system was developed using PIR sensor, LM324IC, BC547 transistor, resistors capacitors, Arduino Nano, buzzer, LED and connection wires. The connections were for the circuit (Fig 3.4).

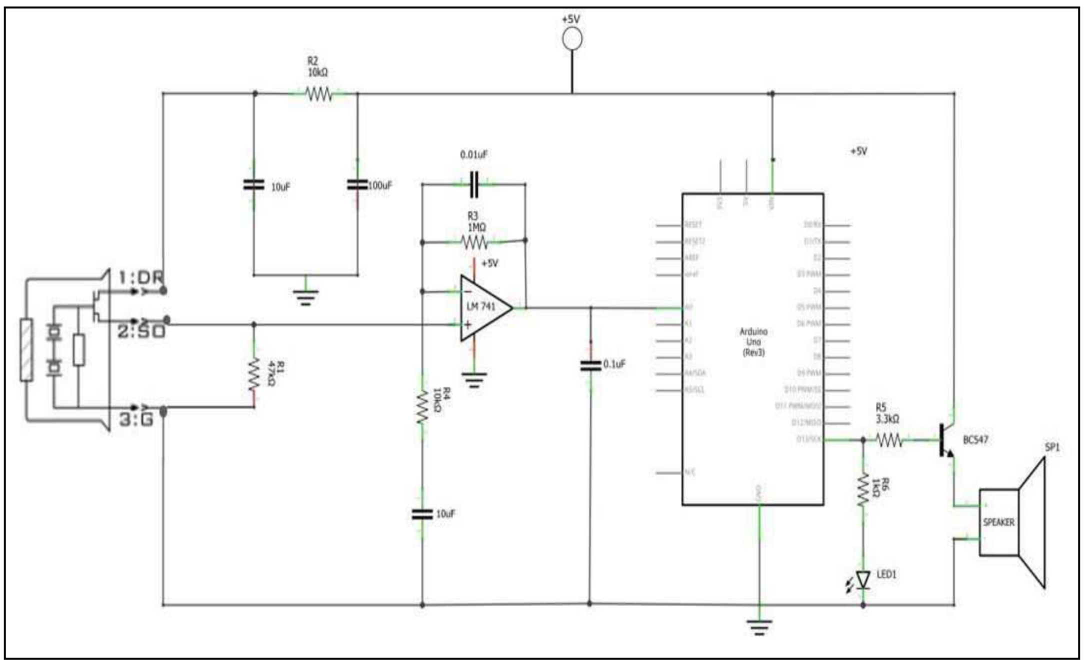


Figure 3.4 Circuit Diagram of sensor System

3.2.4 Experiment Design for development of PIR sensor-based safety alarm system

The development and evaluation was carried out using central composite design in response surface methodology with 4 independent factors at 5 levels. The independent variables were distance, hand orientation, hand speed, ambient temperature and its ranges were 5-20 cm, Pronation, supination, vertical and holding hand positions/ orientations, 450-900 mm/min and 18-30^{0}C respectively. The actual and levels of variables are given in Table 3.6. The ranges of variables were decided on basis of review of literature and initial preliminary experimental trials. Total experimental run is shown in Table 3.2. The experiments were carried out at the Division of Agricultural Engineering, ICAR-IARI, New Delhi.

Table 3.6 Plan of Experiment

Independent variables	Levels	Values	Dependent Variable
Distance, cm	5	5, 8, 12.5, 17 and 20 cm	Sensor Response (V in digital analog value)
Hand orientation	4	Supination Pronation Vertical Holding	
Speed of hand motion	3	450, 650 and 940 mm/min	
Temperature	5	18, 20, 24, 27.5 and 30°C	
Replications	3		

3.2.5 Experimental procedure adopted for evaluation of PIR sensor-based system

1. Hand anthropometric measurements (palm area, hand width and length, thickness) were taken for the selected five subjects of different age.
2. Experiment was done at different room temperatures.
3. Experiment was conducted with five subjects and fodder (Maize fodder)
4. Sensor system was fixed at desired level on the frame attached to the chute of fodder cutter machine such that the distance can be varied (from 5 to 20cm).
5. Hand temperature of subjects at both sides was readed with the help of Infrared thermometer.
6. The subject was guided to move his hand similarly fodder and sensor data for each movement data for fodder movement alone and with both hands along with fodder has taken.
7. The experiment was repeated for different hand orientations. The four different hand orientations were considered here. While feeding fodder to the fodder cutter machine the worker intended to push the fodder to chop. He may push the fodder in different

hand positions. Exposure area of hand in the sensing zone of sensor for different hand positions may be different. By studying sensor response for different hand orientations, it is possible to suggest good hand orientation to work with the machine.

8. The data collected was analyzed by Response Surface Methodology to obtain the desired values for developing Arduino program for the system.

3.3 Response surface methodology:

Response surface methodology (RSM) is an experimental method, which is an assemblage of many mathematical and statistical techniques, used in development of empirical models to study the unknown relationship that exists between various input (independent) and output or response (dependent) variables (Khuri and Mukhopadhyay, 2010). Graphical representation of response with three-dimensional contour plots is very helpful in picturing response surface.

In the present study with help of RSM, using numeric and categoric factors according to number of levels, experimental run (series to perform test) was obtained. Accordingly, the following experiments was conducted.

3.3.1 Determination of sensor response with respect to distance and hand orientation

A mild steel sheet frame was fixed on the chute of fodder cutter machine, at a height of 22cm from the top level of chute. Distance or heights to mount the sensor, on mild steel sheet, markings were made at 5cm, 8.04cm, 12.5cm, 16.9cm and 20cm on vertical frame. By fixing PIR Sensor and connecting with OLED and programmed Arduino board on the horizontal frame at proper marked distances, which can be powered by battery from the computer. Sensor was fixed on the frame in such a way that it should face the feeding chute area. The experiment was conducted at room temperature.

Before starting experiment human hand temperature on both sides of hand was measured using infrared fluke thermometer. The subjects were guided to move their hand towards the sensing area with normal speed. The data for human hand motion for five different subjects at different distances and for different hand orientations was collected by continuous video recording of OLED display. Then data was extracted from video source and arranged according to the experimental plan.

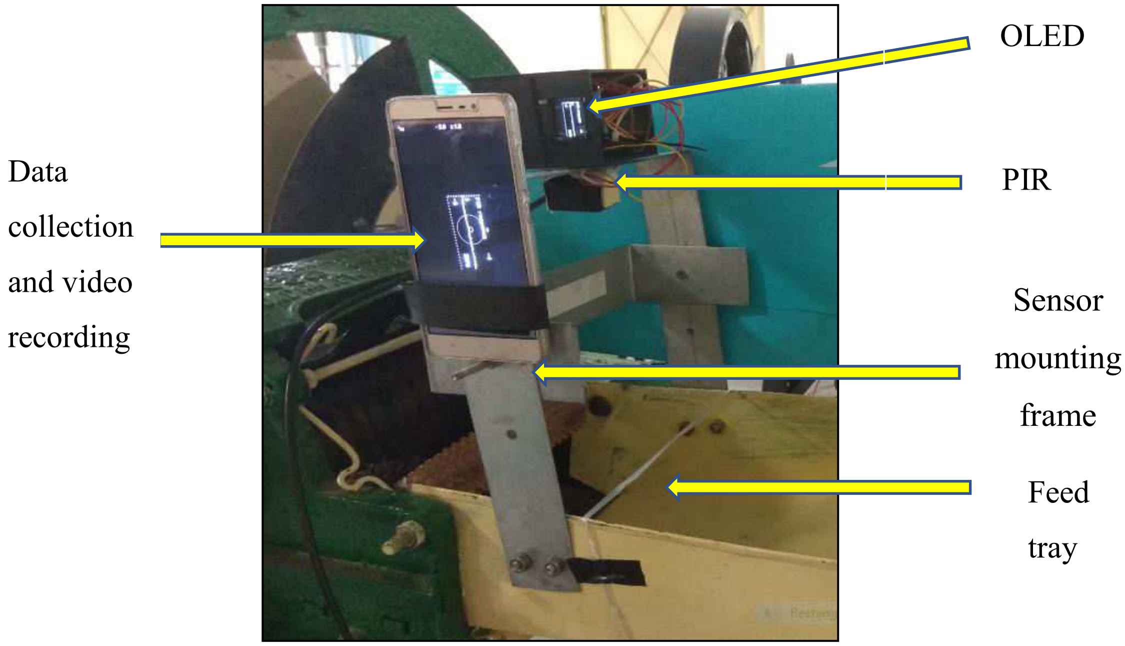
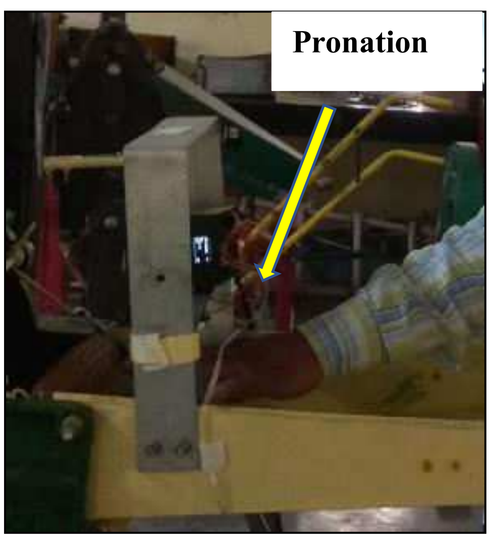
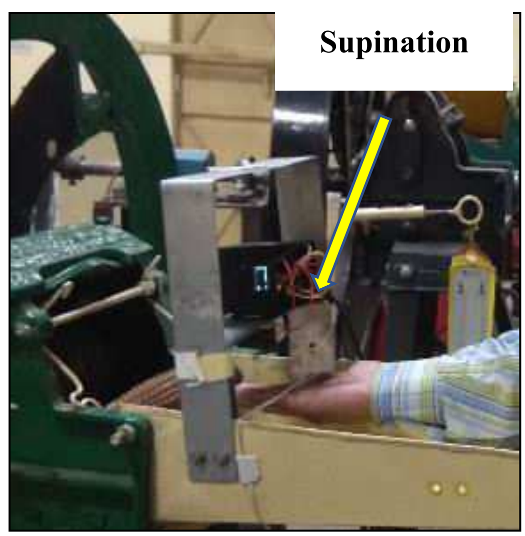


Plate 3.14 Setup fixed to chute of fodder cutter machine sensor evaluation

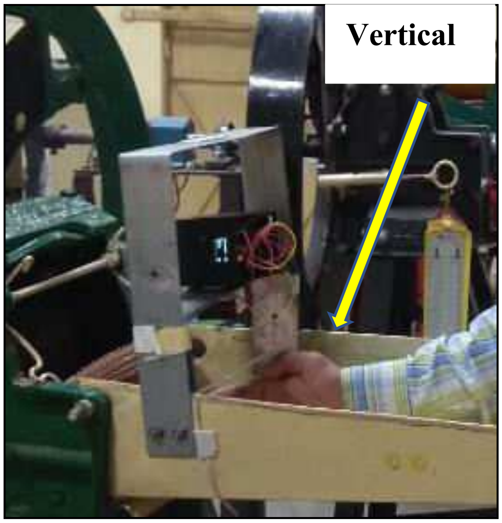


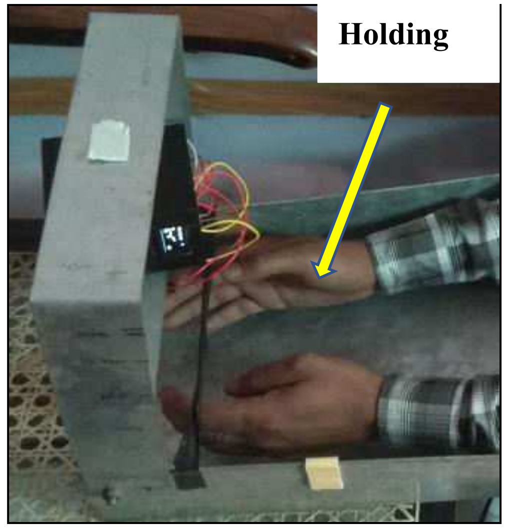
(a)



(b)

Plate 3.15 Pronation and Supination





(c) **(d)**

Plate 3.16 Vertical and holding position

3.3.2 Determination of sensor response with respect to distance, hand orientation and room temperature

The experimental setup similar to experiment section 3.3.1 was made on separate chute and placed the whole system in an enclosed cold camber with temperature controlling system. The HTC-1 temperature/ humidity clock was used to observe the temperature ranges in cold chamber. The same procedure of experiment 01 was followed. The temperatures of 18°, 20°, 24°, 27.5°, and 30° was maintained with settings of controlling system. By setting a particular temperature in cold chamber data has been collected for an individual subject at time with same procedure followed in experiment no. 01 for different distances, hand orientation. The same method has been followed for other subjects.

3.3.3 Determination of sensor response with respect to distance, hand orientation, fodder and room temperature

This experiment used the same procedure of section 3.3.2, the sensor data collected for the combined movement of fodder and subjects' hand in holding position at five different temperatures and five distances.

3.3.4 Determination of sensor response with respect to distance, room temperature along with fodder

The same experimental setup used in section 3.3.2 was used here with same procedure, here the sensor data for only fodder movement at five different room temperatures and for five distances has been collected.

Plate 3.17 Sensor system setup in cold room

3.3.5 Effect of speed of hand movement on sensor response

The system was fixed to the feeding tray of fodder cutter machine, by moving hand towards sensor, with help of setup for control the speed. The set was made with two 3D printed gear units attached with thread. The setup was programmed to maintain five speed ranges. Hand movement by following the thread speed the data was collected.

Plate 3.18 Setup to study the speed of hand movement

Results

Chapter 4

RESULTS

The results of experiments conducted to study the response of sensor with respect to various parameters namely hand position, distance, temperature and hand movement are presented in this chapter.

4.1 Effect of distance and hand orientation on sensor response

The experiment was conducted as per the research methodology discussed in chapter III. The data was analyzed using the design expert software and ANOVA table for Response Surface Quadratic Model as given in Table 4.1. From the table it was found that the obtained model for the experiment was significant at 5% level of significance and the model terms A (distance), B (subjects), C (hand orientation), AB, A^2, B^2 are also significant.

The regression equations for four hand orientation obtained from the statistical analysis (RSM methodology) are given below.

Pronation position of hand (Level 1 of C)

$+V = -19.4958 - 5.98368\,A + 0.058240\,A\,B + 0.11719\,A^2$

Supination position of hand (Level 2 of C)

$+V = -12.3643 - 6.05563\,A + 0.058240\,A + 0.11719\,A^2$

Verical position of hand (Level 3 of C)

$+V = -25.5023 - 5.71859\,A + 0.058240\,A\,B + 0.11719\,A^2$

Holding position of hand (Level 4 of C)

$+V = -18.2164 - 5.89712\,A + 0.058240\,A + 0.11719\,A^2$

where

+V is the sensor response (digital value after ADC conversion) = $\frac{\text{(Digital value) (5 levels)}}{1024}$

A = Distance hand between hand and PIR sensor,

B = subjects and

C = Hand orientation.

4.1.1 Effect of distance for different hand orientation on sensor response

3D graph obtained from the design expert software for interaction between distace (between hand and sensor) with respect to hand orientations are given in Figure 4.1a, 4.1b, 4.1c and 4.1d. The sensor response was found to be the inverse of distance in all hand orintation cases.

Table 4.1 ANOVA for sensor response with respect to distance and hand orientation

ANNOVA for Response Surface Quadratic Model

Analysis of variance table [classical sum of squares - Type II]

Source	**Sum of Squares**	**df**	**Mean Square**	**F**	**p- value**	
Model	5238.702	14	374.193	10.633	<0.0001	Significant
A- Distance	534.74	1	534.741	15.195	0.0004	
B-Subjects	238.552	1	238.552	6.778	0.00132	
C- Hand Orientation	846.183	3	282.061	8.015	0.0003	
AB	195.37	1	195.3705	5.551	0.0239	
AC	14.261	3	4.753	0.135	0.9385	
BC	26.668	3	8.889	0.256	0.859	
A^2	302.303	1	302.303	8.59	0.0058	
B^2	2783.756	1	2783.756	79.104	<0.0001	
Residual	1302.059	37	35.196			
Lack of Fit	1302.053	21	62.002	193758.027	<0.0001	Significant
Pure error	0.0051	16	0.003			
Total	6540.761	51				

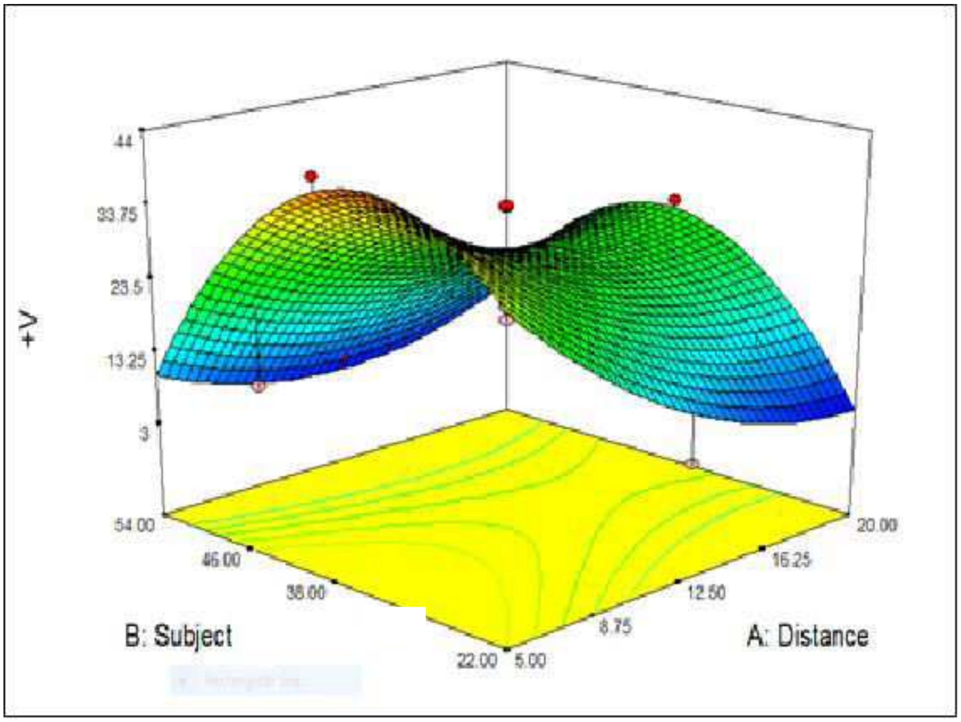


Fig. 4.1a Sensor response of hand oreintation (level 1 of C, Pronation)

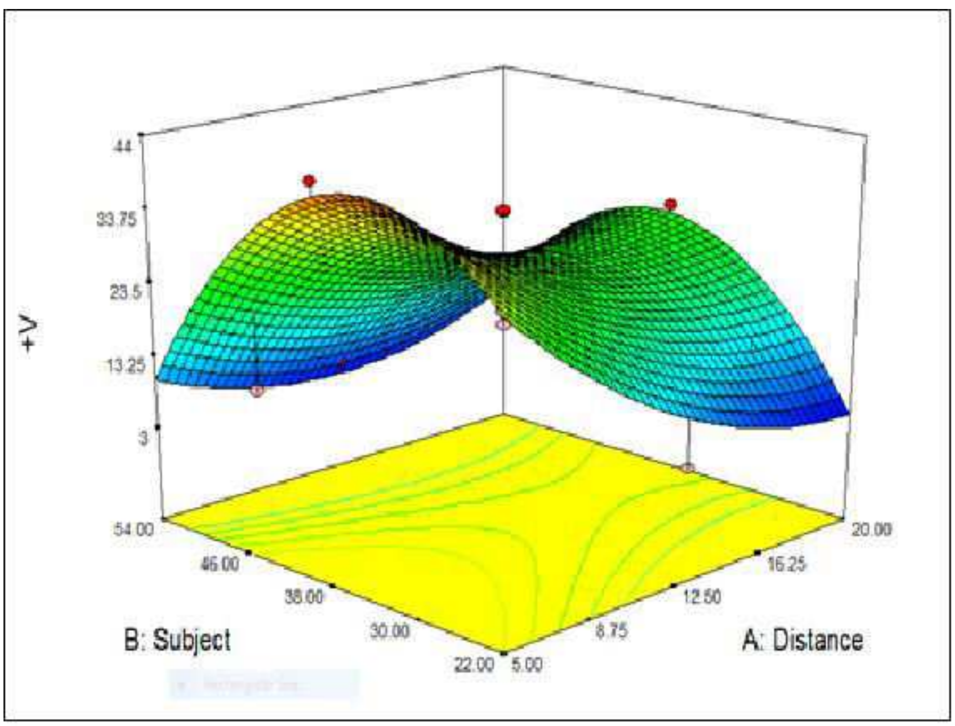


Fig. 4.1b Sensor response of hand oreintation (level 2 of C, Supination)

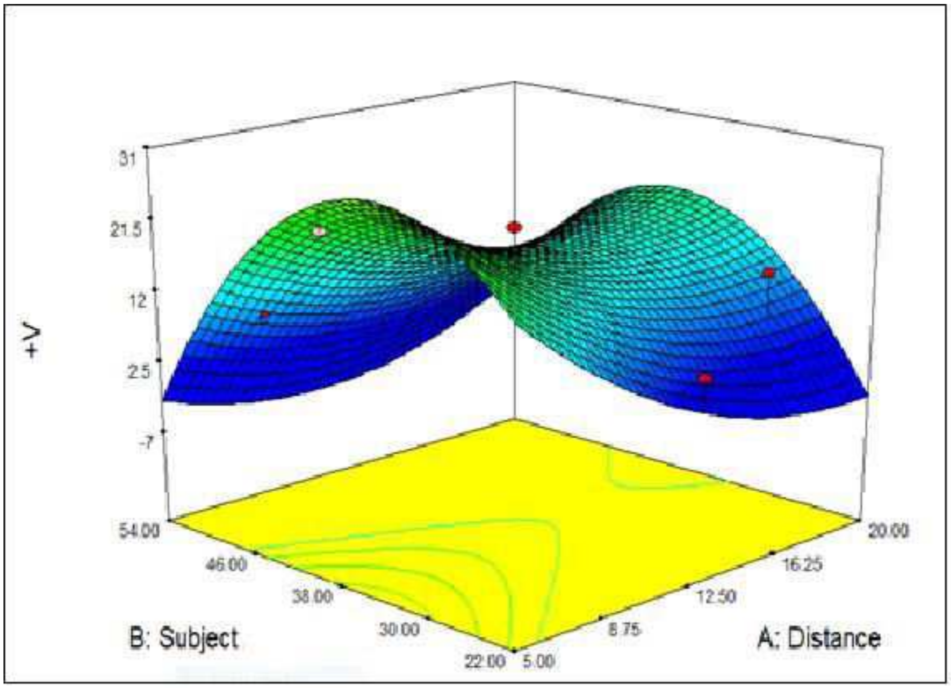


Fig. 4.1c Sensor response with hand oreintation (level 3 of C, Vertical)

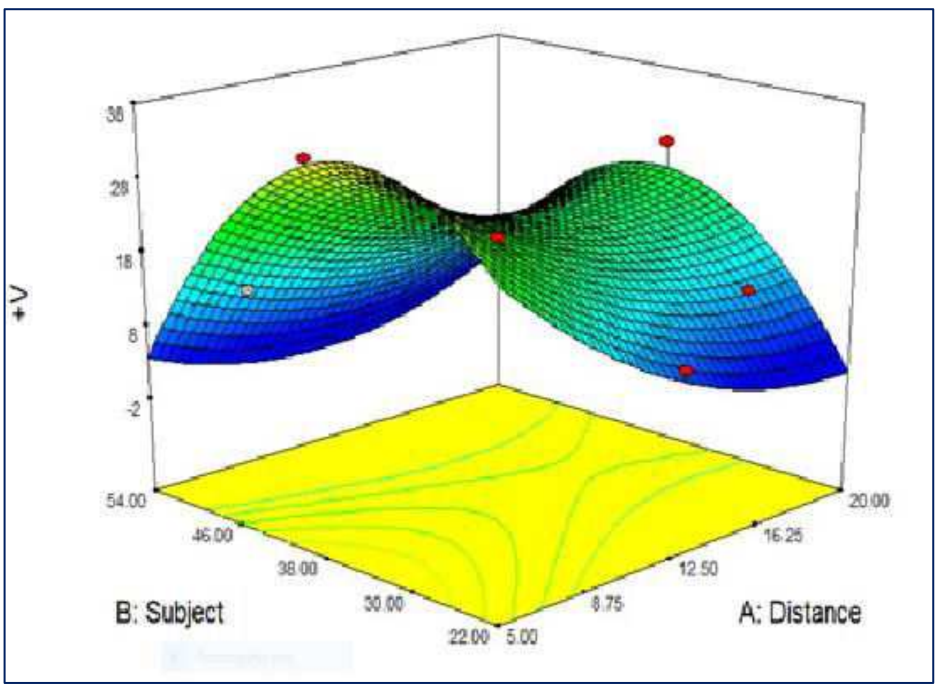


Fig. 4.1d Sensor response with hand oreintation (level 4 of C, Holding)

Fig. 4.1 Effect of distance and subjects for different hand orientations on sensor response

4.1.2 Effect of hand orientation and distance on sensor response

The 2D graph obtained from the design expert software for interaction between distace (between hand and sensor) and hand orintation is given in Fig. 4.2. In all hand orientation positions the sensor response was changing with the distance. For C1, C2 hand orienation levels sensor response was almost similar and higher than other levels of hand orienations. The C3 (vertical) hand orienation level was low among all and C4 (hoding) level the sensor response was observed among the other three levels.

The surface area of hand exposed to sensor field of view may be influencing sensor output. Since surface area of hand orientations C1 and C2 exposed to sensor was highest, hence the senosor output was observed to more than other hand orientations. The sensor response for C3 hand orientation level was minimum due to lower surface area of hand. However the sensor response for C4 hand orientation was slightly higher due to higher surface area.

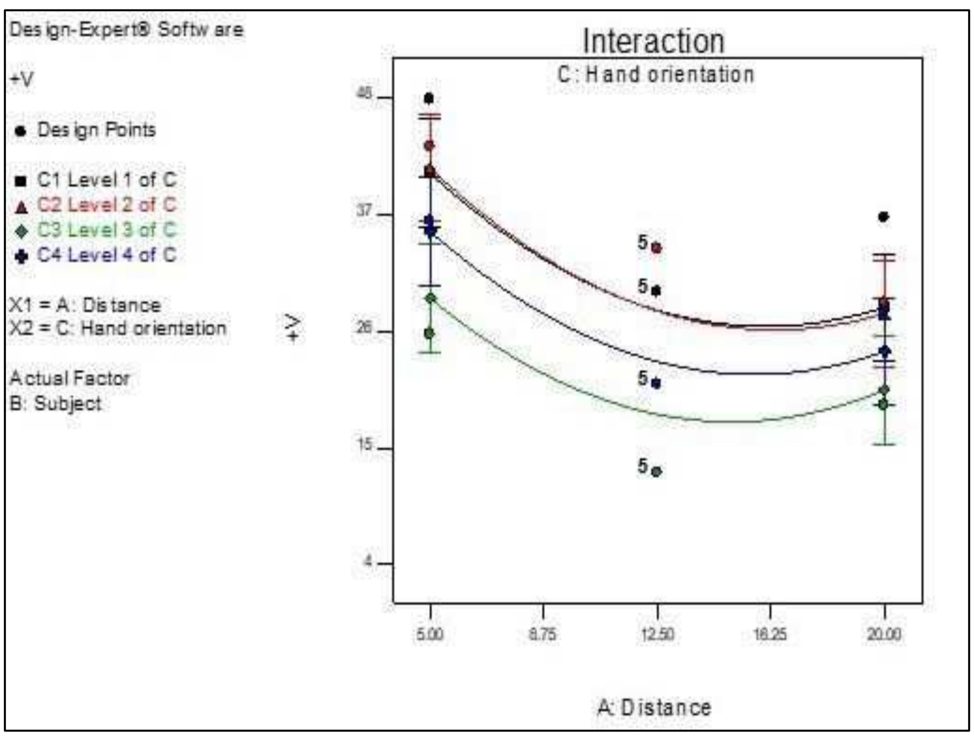


Fig. 4.2 Effect of hand orientation and distance on sensor response

4.1.3 Effect of hand orientation and subject age on sensor response

Interaction between subjects hand orintation for mean distance of 12.5cm is given in Fig. 4.3. Effect of hand orientation levels C1 and C2 was highest followd by C4 and C3. This may be due to larger and smaller exposure area of hand in sensor field of view.

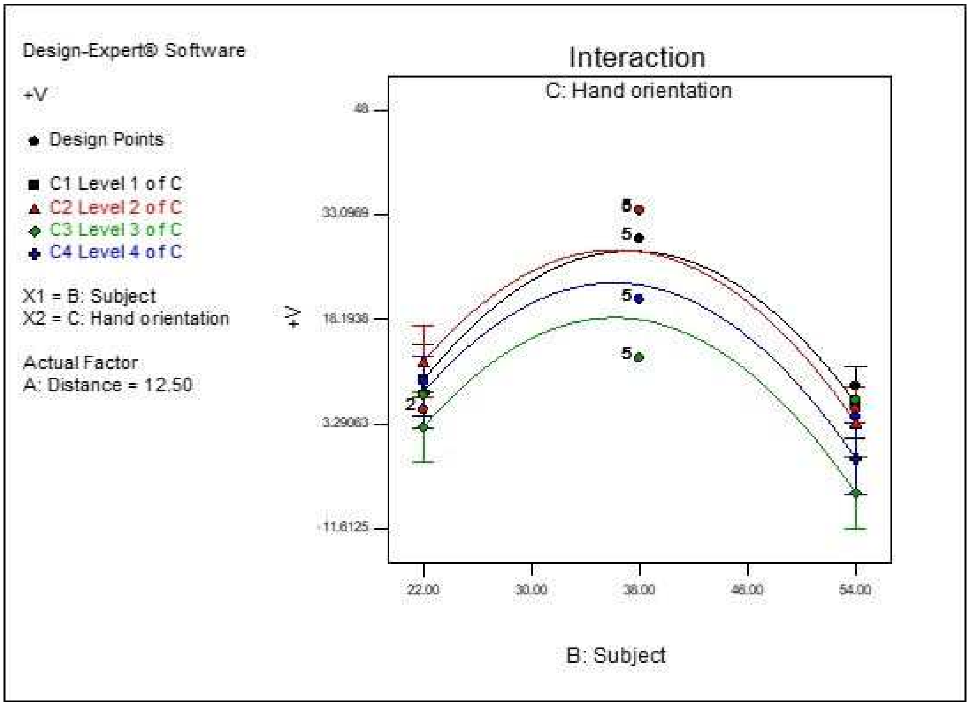


Fig. 4.3 Effect of hand orientation on sensor response

4.2 Sensor response with respect to distance, hand orientation and ambient temperature

The data was analyzed using the design expert software and ANOVA table for Response surface quadratic model is given in Table 4.2. From the table it was found that the obtained model for the experiment was significant at 5% level of significance and the model terms A (distance), B (subjects), C (hand orinetation) , AB, B^2, C^2 were also significant.

The regression equations obtained for four hand orientations from the statistical analysis (RSM methodology) are given below.

Pronation of hand

$+V = +7.9835 - 5.46635\ A + 3.83449\ C + 0.19573\ AC + 0.027260\ A + 4.59435E - 003C - 0.026901A^2 - 0.15429\ C^2$

Supination of hand

$+V = +\ 1.08133 - 5.36241A + 4.33876\ D + 0.19573\ AD + 0.027260\ A + 4.59435E - 003\ D - 0.026901\ A^2 - 0.1542C^2$

Vertical of hand

$+V = -9.8779 - 5.43089A + 4.3834\ C + 0.19573\ AC + 0.027260\ A + 4.59435E - 003\ D - 0.026901A^2 - 0.15429D^2$

Holding Position of hand

$+V = -11.9121 - 5.29210A + 4.79074D + 0.19573\ AD + 0.027260\ A + 4.59435E - 003D - 0.026901A^2 - 0.15429\ D^2$

Where

+V is the sensor response (digital value after ADC conversion)$+V = \frac{\text{(Digital value)(5 levels)}}{1024}$.

A = Distance beween hand sensor and hand

C = hand orientation and

D = ambient temperature at which the experiment is conducted

4.2 ANOVA for sensor response with respect to distance, hand orientation and ambient temperature

ANOVA for Response Surface Quadratic Model

Analysis of variance table [Classical sum of squares - Type II]

Source	Sum of Squares	d f	Mean Square	F Valu	p-value Prob > F	
Model	1967.714	21	93.70	2.89	0.0007	Significant
A-Distance	116.171535	1	116.1715	3.58	0.0631	
D- ambient Temperature	139.415759	1	139.4158	4.30	0.0424	
B-Subjects	110.227358	1	110.2274	3.40	0.0701	
C-Hand orientation	517.504905	3	172.5016	5.33	0.0026	
AB	310.316328	1	310.3163	9.58	0.0030	
AC	42.8043781	1	42.80438	1.32	0.2548	
AD	4.84235738	3	1.614119	0.04	0.9851	
BC	0.77812812	1	0.778128	0.02	0.8773	
BD	80.0563622	3	26.68545	0.82	0.4856	
CD	98.6674033	3	32.88913	1.01	0.3921	
A^2	16.4982868	1	16.49829	0.50	0.4781	
B^2	222.304232	1	222.3042	6.86	0.0112	
C^2	375.686759	1	375.6868	11.6	0.0012	
Residual	1876.90421	58	32.36042			
Lack of Fit	1876.90421	38	49.39222			
Pure Error	0	20	0			
Total	3844.618995	79				

4.2.1 Effect of sensor response to distance, ambient temperature and hand orientation

The 3D graph obtained from the design expert software for interaction between distace (between hand and sensor) and ambient temperature with respect to hand orientation is given in relative Figure 4.4a, 4.4b, 4.4c and 4.4d. The sensor response was found to be the inverse of distance in all hand orintation cases. The minimum and maximum tempperature ranges was taken as 18 °C and 30 °C. At low temperature range the sensor performed satisfactorily, as the temperature increases the variation in sesnor respose was observed.

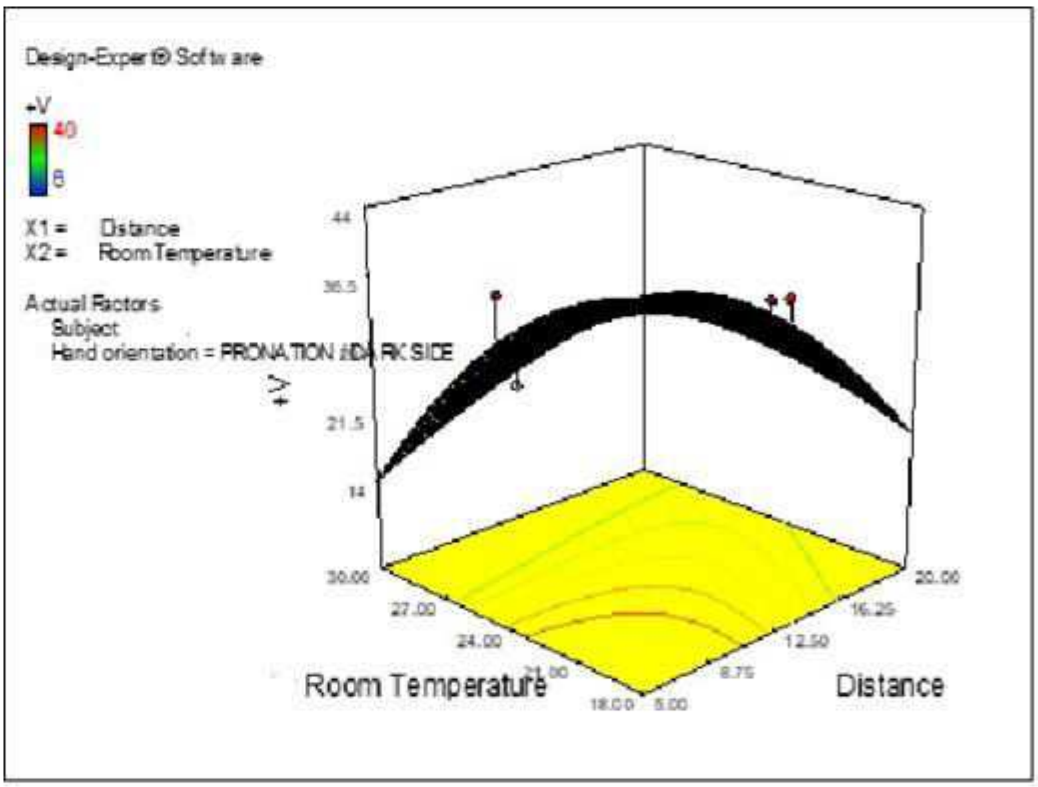


Fig. 4.4a Sensor response for hand orinetation leve1 C1

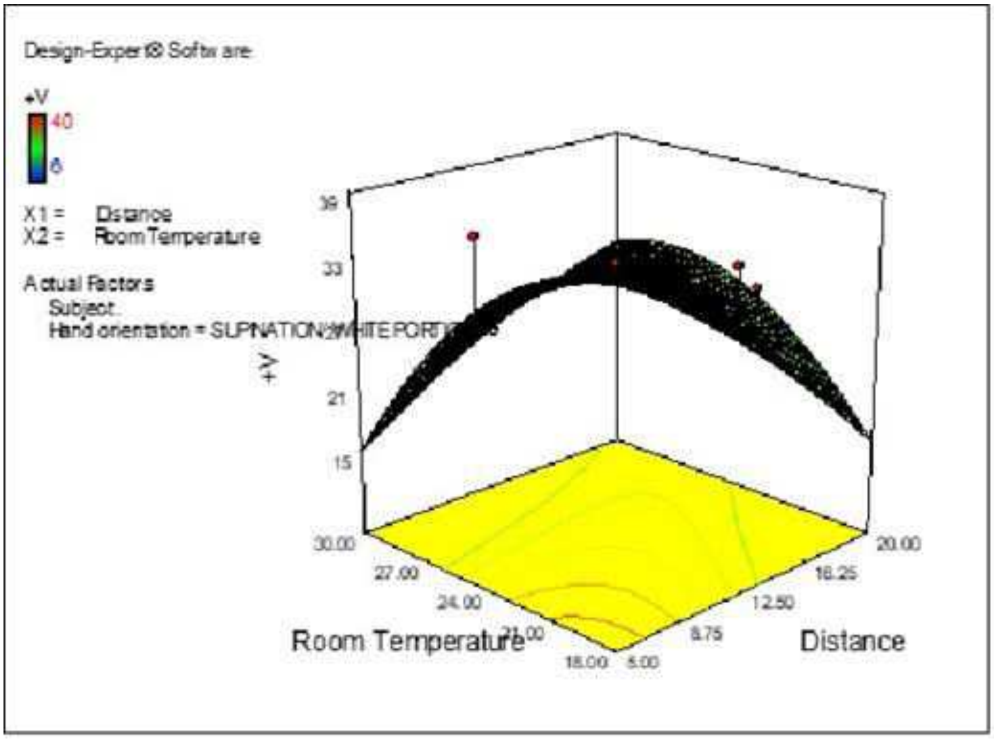


Fig. 4.4b Sensor response for hand orinetation leve1 C2

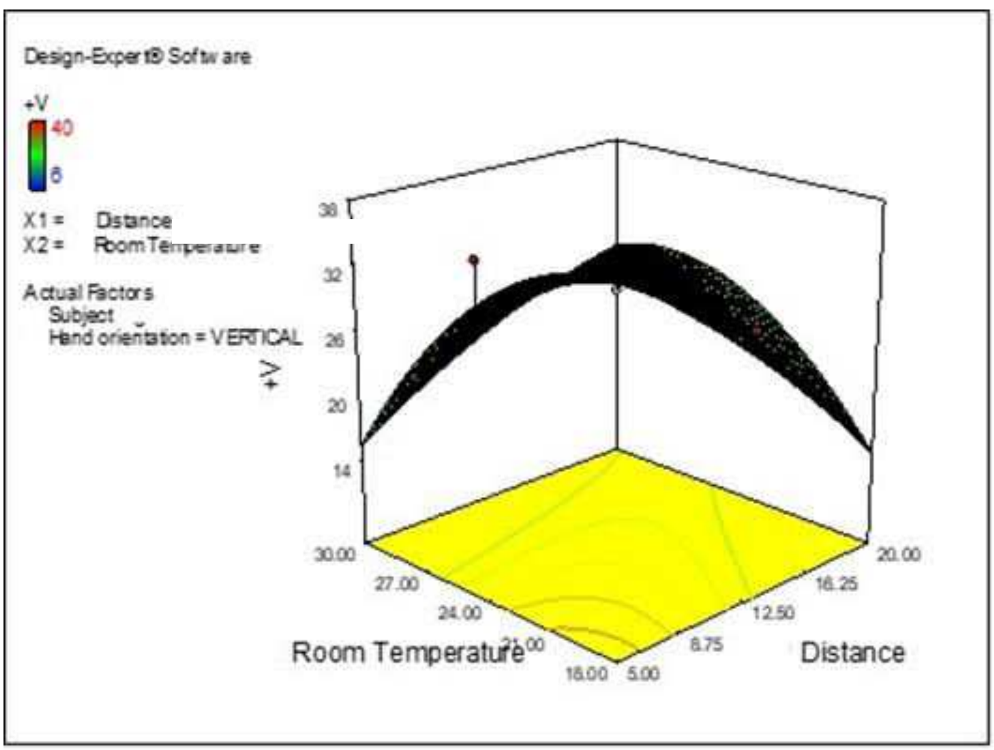


Fig. 4.4c sensor response for hand orinetation leve1 C3

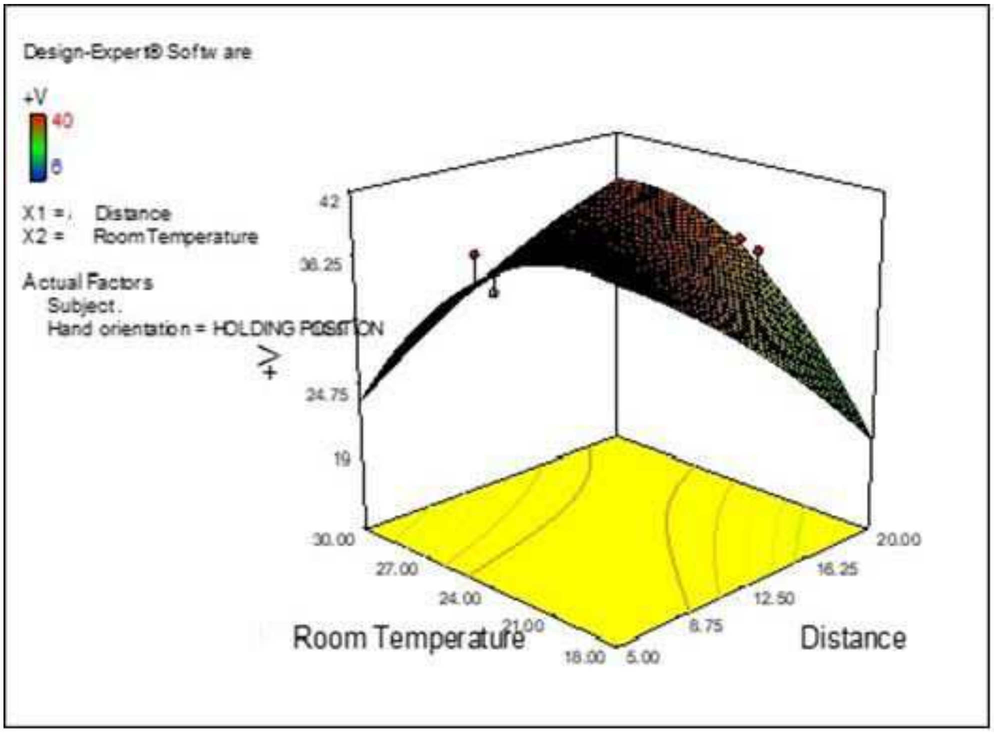


Fig. 4.4d Sensor response for hand orinetation leve1 C4

Fig. 4.4 Effect of sensor response to distance, ambient temperature and hand orientation

4.2.2 Effect of hand orientation and distance on sensor response

The 2D graph obtained from the design expert software for interaction between distance (between hand and sensor) and hand orintation for mean temperature of 24 °C given in Fig. 4.5 For all hand orientations the sensor response was inversly proportional to the distance. It was observed that the sensor gave good response to the holding hand orientation level as compared other levels. This may happen due to combined hand radiation fo both hands in holding position or hand orienation.

4.2.3 Effect of hand orinatation on sensor response

Sensor response of hand orintation for mean distance of 12.5cm and mean temperature of 24 °C is given in Fig. 4.6. Effect of hand orientation levels holding position was more than other levels. This may due to exposure of both hand in viewing area of sensor and sensor may active at larger amount of radiation emitted by hand.

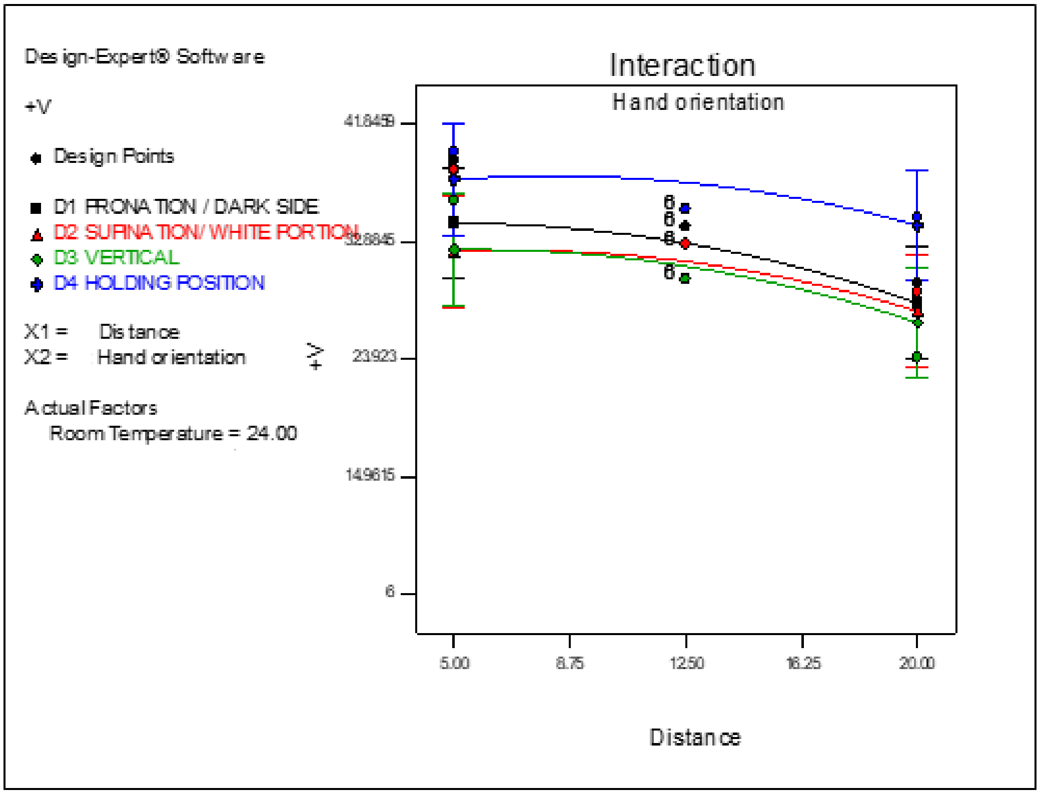


Fig. 4.5 Effect of hand orientation and distance on sensor response

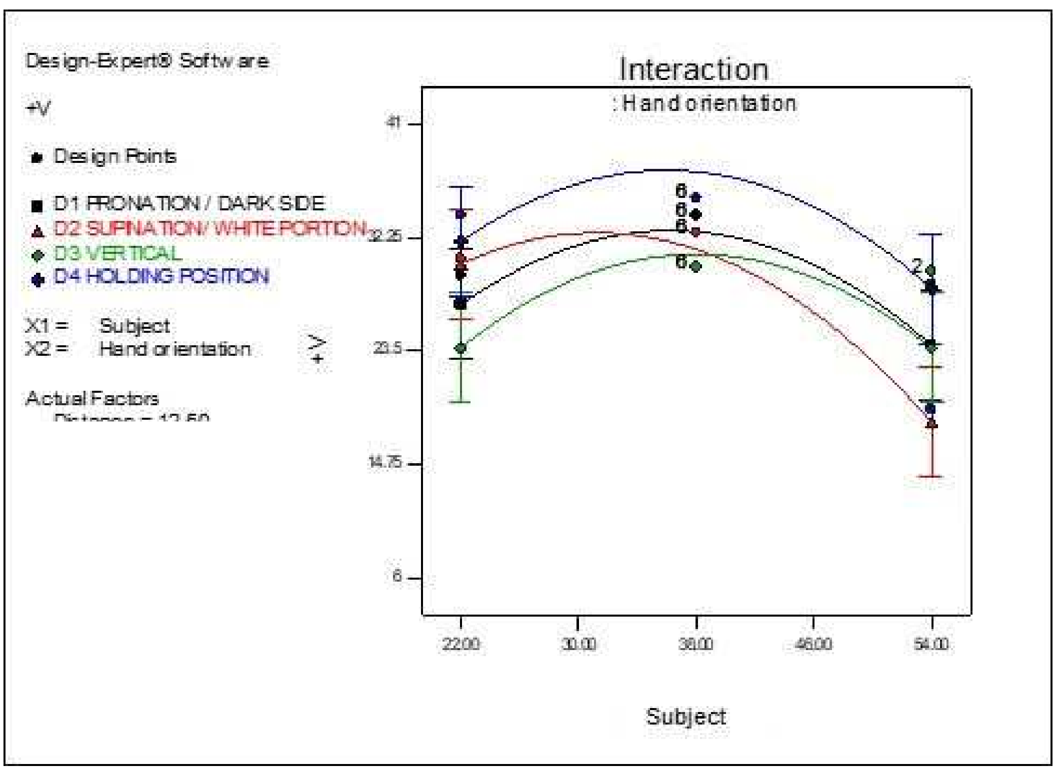


Fig. 4.6 Effect of hand orinatation on sensor response

4.3 Effect on sensor response with respect to distance, ambient/fodder temperature, hand orientation along with fodder

The data was analyzed using the design expert software and ANOVA table for Response surface quadratic model is given in table 4.3. From the table it was found that the obtained model for the experiment is significant at 5% level of significance but the model terms B, D, B^2, D^2 are significant. Where B = subjects and D = ambient/fodder temperature.

The regression equations obtained from the statistical analysis (RSM methodology) are given below.

Regression equation for hand orientation in holding position

$+V = -124.4701 - 2.23808\,A + 14.38119\,D + 0.10213\,AD + 0.041717\,A + 0.020842\,D - 0.079131\,A^2 - 0.35989D^2$

Where A = distance, D = fodder temperature.

Table 4.3 ANOVA for sensor response with respect to distance, ambient temperature along with fodder

Source	Sum of Squares	Mean Square	F Value	p-value Prob > F	
Model	627.874841	69.7638	8.25263193	0.0022	Significant
A-Distance	7.19711712	7.19711	0.85137417	0.3802	
D-Fodder Temperature	96.8306194	96.8306	11.4544598	0.0081	
B-Subjects	77.2377364	77.2377	9.13674366	0.0144	
AD	15.3227565	15.3227	1.81258677	0.2111	
AB	18.1794396	18.1794	2.15051460	0.1766	
BB	2.90417704	2.90417	0.3435460	0.5722	
A^2	34.6385932	34.6385	4.0975300	0.0736	
D^2	293.475448	293.475	34.716319	0.0002	
B^2	134.963414	134.963	15.965332	0.0031	
Pure Error	0	0			
Total	703.9566105				

4.3.1 Effect of distnace, fodder temperature on sensor response

The 3D graph obtained from the design expert software for interaction between distace (between hand and sensor) and fodder temperature with respect to C4 level of hand orientation is given in Fig 4.7. As already mentioned that in this case also sensor response was found to be the inverse of distance in all hand orintations. The minimum and maximum tempperature ranges was taken as 18 °C and 30 °C and distance between and sensor ranges was taken as 5 to 20 cm.

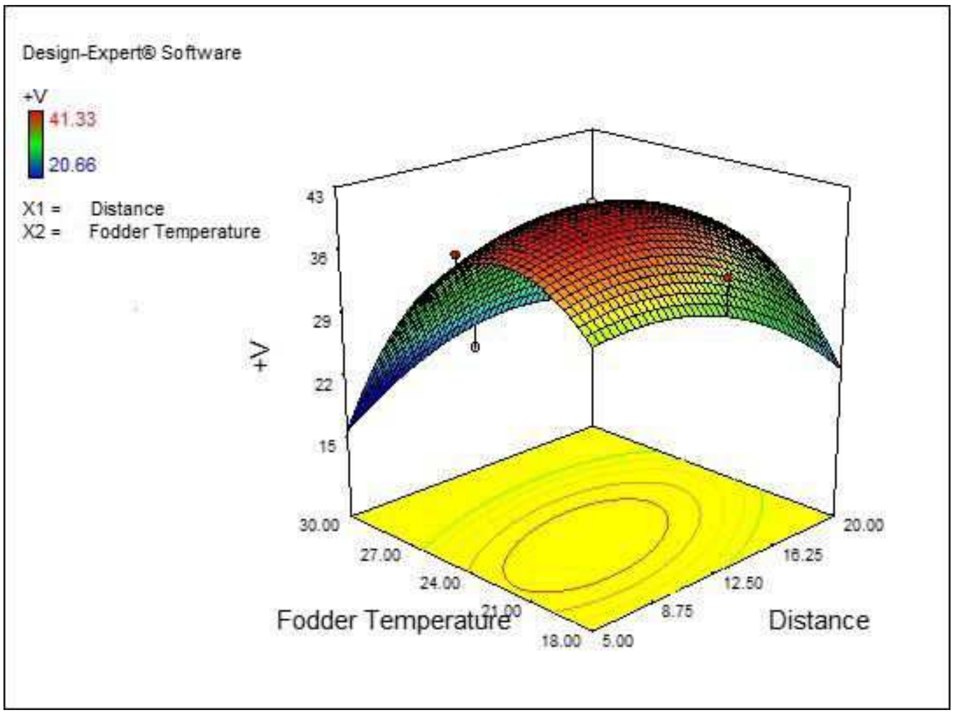


Fig. 4.7a Effect of fodder temperature and distance on sesnor output

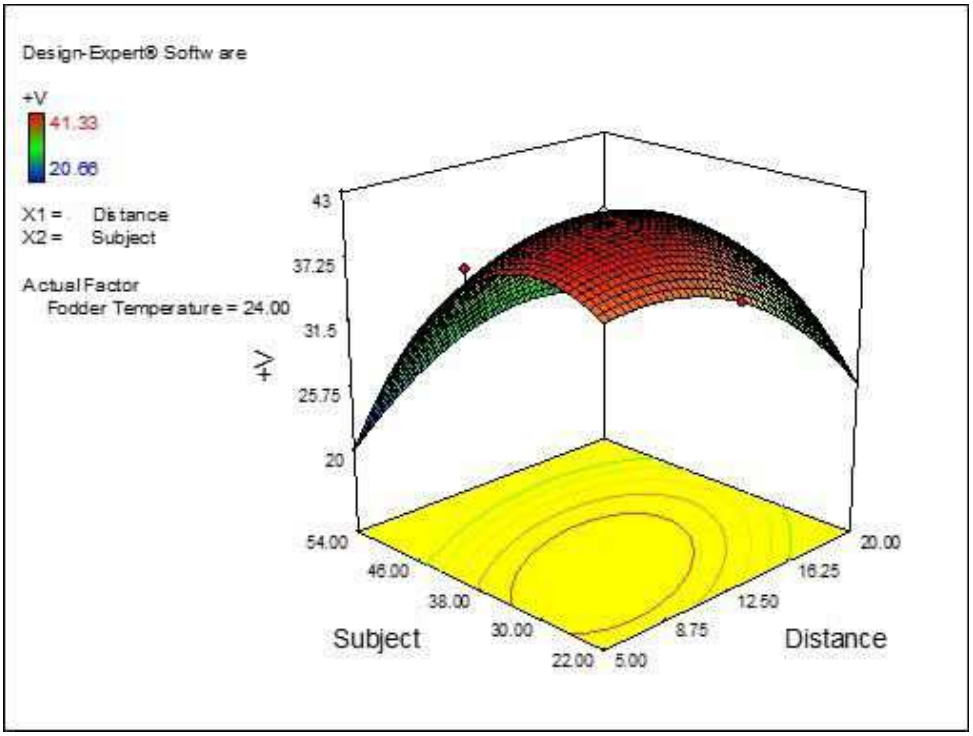


Fig: 4.7b Effect of distance on sesnor response

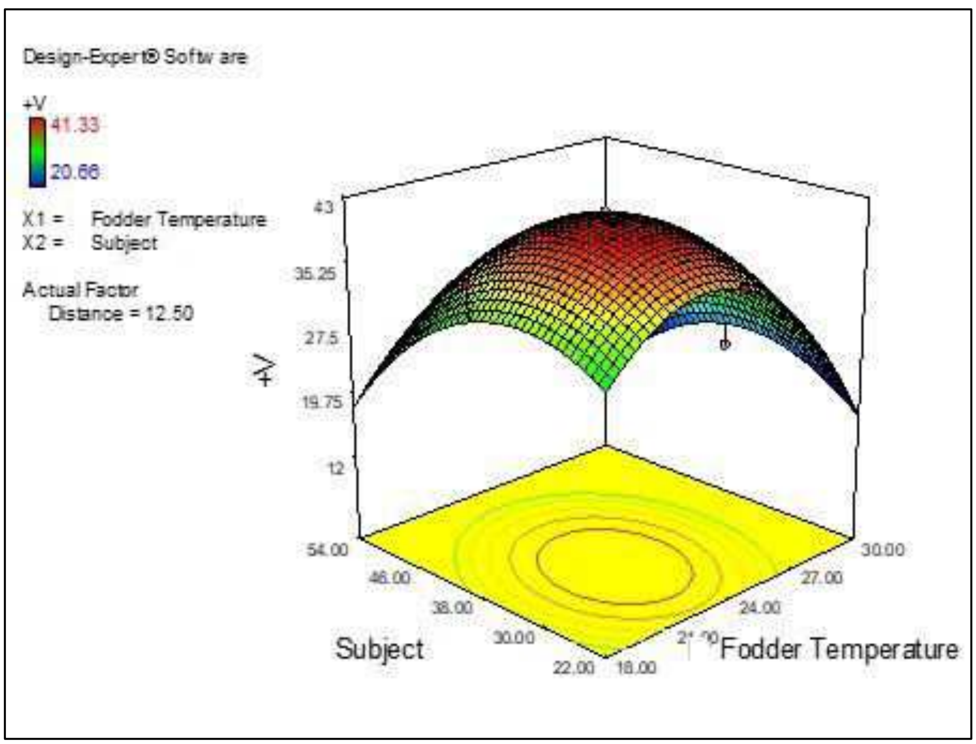


Fig: 4.7c Effect of fodder temperature on sesnor response

4.4 Effect on sensor response with respect to distance, fodder and ambient temperature

The data was analyzed using the design expert software and ANOVA table for Response surface quadratic model is given in table 4.4. From the table it was found that the obtained model for the experiment is significant at 5% level of significance and the model terms A, D, AD, A^2, D^2 are significant.

Table 4.4: ANOVA for Effect on sensor response with respect to distance, fodder and ambient temperature

ANOVA for Response Surface Quadratic Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	D f	Mean Square	F Value	p-value Prob > F	
Model	235.9407	5	47.188	17.947	< 0.0001	Significant
A-Distance	64.6051	1	64.605	24.571	0.0002	
D-Fodder Temperature	12.9054	1	12.905	4.9084	0.0438	
AD	74.0544	1	74.054	28.165	0.0001	
A^2	64.1011	1	64.101	24.379	0.0002	
D^2	27.11799	1	27.118	10.313	0.0063	
Pure Error	0	11	0			
Cor Total	272.7504	19				

The regression equations obtained from the statistical analysis (RSM methodology) are given below.

$+V = + 42.77052 + 1.46377A – 3.02972 D -0.19123 AD + 0.10552 A^2 + 0.10724 D^2$

Where A= disntace in cm and

D = fodder temperature in °C

4.4.1 Effect of Fodder Temperature and Distance on Sensor Response

The 3D graph obtained from the design expert software for interaction between distace (between hand and sensor) and fodder/ ambient temperature is given in Fig. 4.8. The sensor response was found to be the inverse of distance in all hand orintation cases. But as the temperature increases the drastic increase in sensor response was observed. This shows that incresed ambient temperature was creating unable to differentiating between the human hand and fodder.

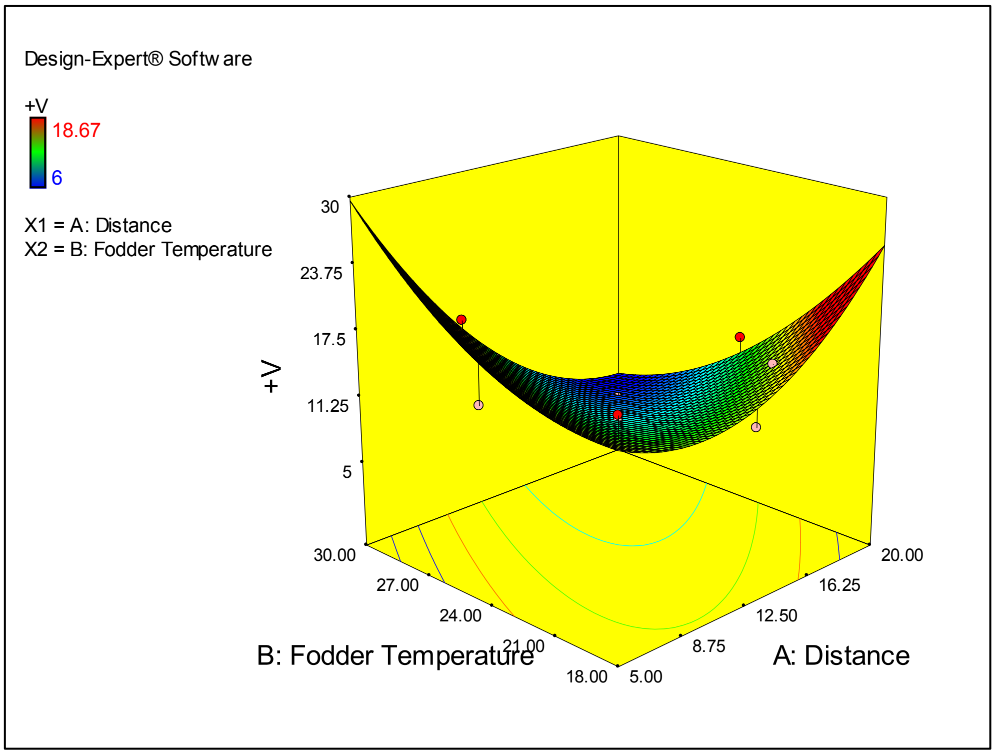


Fig. 4.8 Effect of Fodder Temperature and Distance on Sensor Response

4.4.2 Effect of speed of hand movement with change in distance on sensor response

The sensor response for different speed of hand movement with change in distance was observed. Pronation and supination hand orineations were considered to study the sensor response. Observable values of sensor response was found within the hand speeds of 650 to 940 mm/min. Sensor was giving poor response at hand speeds higher than 940 mm/min and at very low hand speeds (less than 450 mm/min). It was found that at slow hand movement (less than 50rpm speed of fodder cutter machine), sensor response was very less.

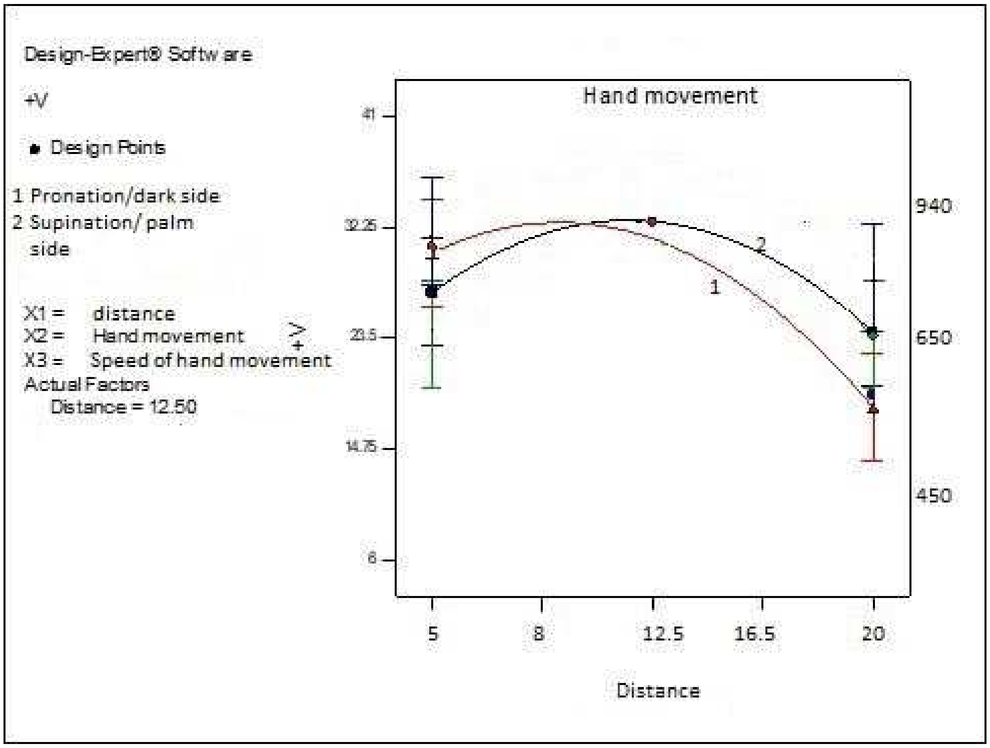


Fig 4.9 Effect of speed of hand movement with change in distance

4.5 Developed sensor based safety alarm system for fodder cutter machine

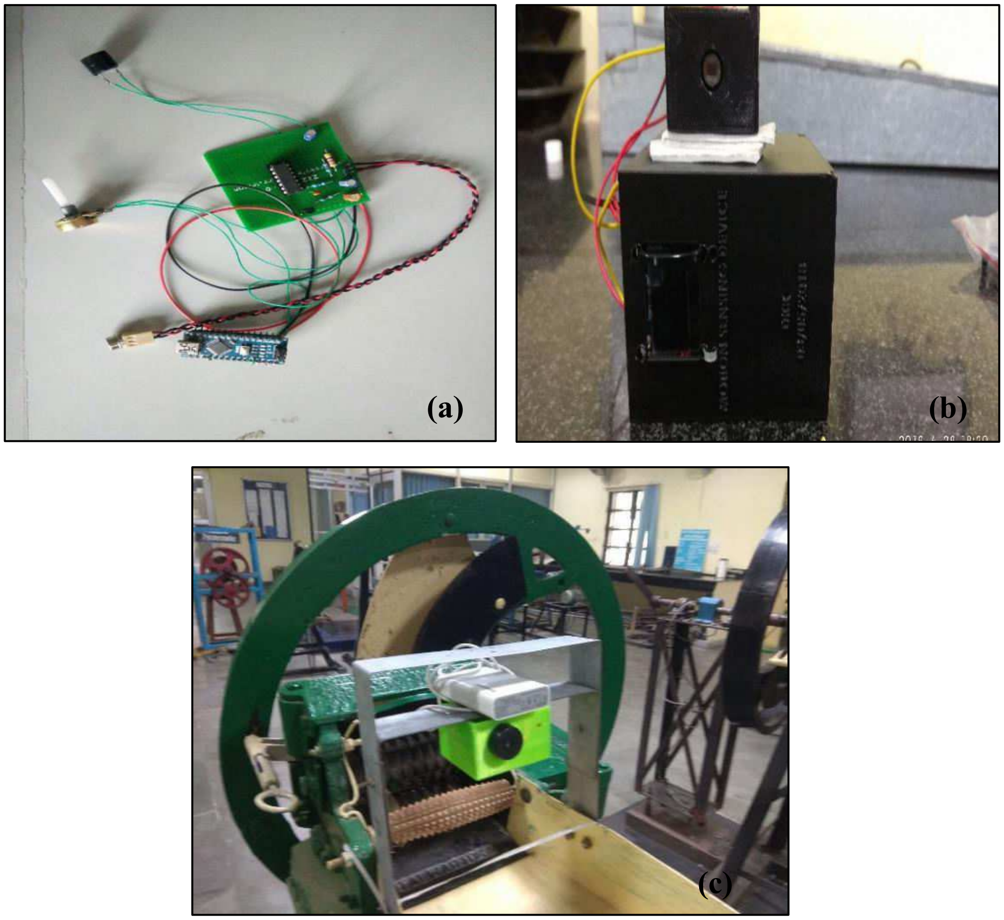


Plate 4.1 Senosr based safety alarm system (a) Circuit of system, (b) system with setup (b) Senosor system mounted on fodder cutter machine

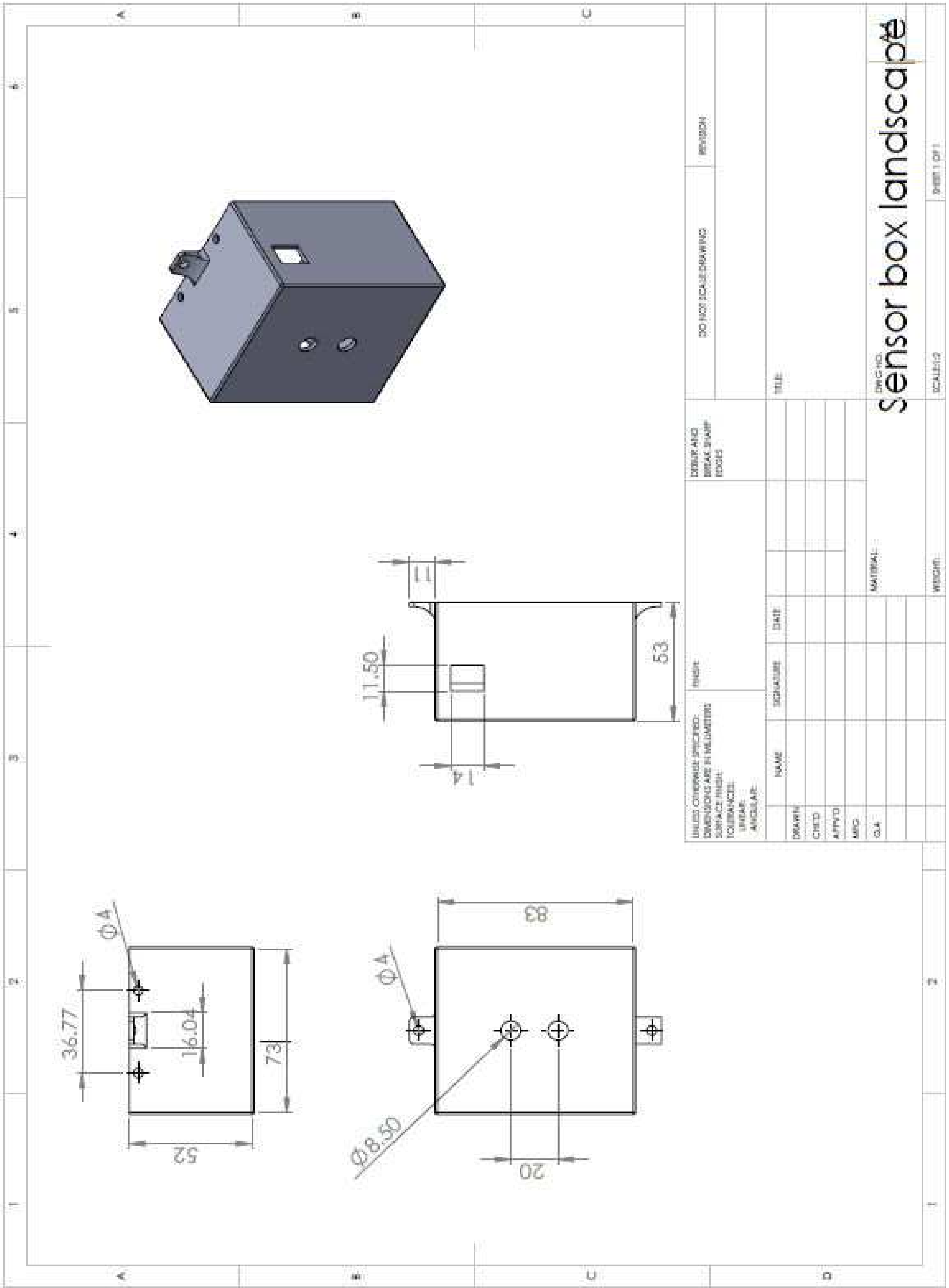


Plate 4.2 Dimensions of final setup box

Discussion

Chapter 5

DISCUSSIONS

Discussion of the results presented in chapter 4 is made in this chapter. Supporting reasons for variation in results are elaborated.

5.1 Effect of distance and hand orientations on sensor response

The effect of distace (between hand and sensor) and different hand orinetations was required be investigated to know sesnor behaviour. The interaction effect of these variables at five levels of distnace (5cm, 8cm, 12.5cm, 17cm and 20cm), and four levels of hand orientation (pronation, supination, verical and holding) was analysed using RSM methodology.

It was observed that the sensor response was inversly proportional to the distance. This might be due to the increase in intesity of heat radiation emitted from subject hand while moving towards sensor. For the hand orintations of pronation and supination(C1, C2), the sensor response was higher followed by holding (C4) position. Low sensor response observed for vertical (C3) hand orientation. This might be due to skin condition or blood circulation.

Exposed hand surface area to sensor field of view might influence sensor output. Since surface area of hand orientations C1 and C2 exposed to sensor was highest, hence the senosor output was observed to be more than other hand orientation levels. The sensor response for C3 hand orientation level was minimum due to less exposed surface area of hand. However, the sensor response for C4 hand orientation is slightly higher due to more surface area compare to C3. sensor response was observed to be maximum at mean distance of 12.5cm the.

5.2 Effectof ambient temperature, distance and hand orientation on sensor response

To determine the suitable working temperature of sensor system study was conducted at five different ambient temperatures (18, 20, 24, 27.5 and 30°C). The response of sensor was observed to be higher in temperature range of 18 to 27 °C.

As the ambient temperature increased the response of the sensor was affected in terms of fluctuation in voltage output (DAC value). There is need of temperature compensation mechanism. Sensor output varied continuously when there was no motion due to warm environment, and radiation from the surroundings might be the cause for this fluctuation.

At different distances sensor gave good response (47 to 59 DAC value of voltage) under 24°C. The C4 hand orientation level or holding position, sensor response was higher than other hand orientation levels. This may happen due to exposure of both hand (more area) in viewing area of sensor and sensor may active at larger amount of radiation emitted by hand.

5.3 Effect of distance and fodder temperature on sensor response

To program the developed warning sensor system, the range of response values have to be determined for fodder movement. By fixing those values such that the system should not produce any warning signal while fodder in motion. Experiment was conducted to recognize the senosr response for fodder alone at difffernt temperatures with varying distance.The minimum and maximum temperature ranges was taken as 18 °C and 30 °C and distance between and sensor ranges was taken as 5 to 20cm.

The senosor response of fodder movemnt is very low compare to human hand movemnt at moderate temperature and distances. Increasing ambient conditions will change the sensor resposne as the fodder temperature was increased.

5.4 Effect of ambient temperature, Distance and hand orientation on Sensor Response

Interaction between distace (between hand and sensor) and fodder/ room temperature for different hand orinetations were studied to investigate the sensor detection capacity for combined movement of hand.The sensor response was found to be in inverse relationship to the distance in all hand orintation cases. However, as the temperature increases the drastic increase in sensor response was observed. This shows that the incresed temperature may not be properly able to differentiate the human hand and fodder. It might be due to higher wavelength of radiation detected by the sensor element in the surroundings.

5.5 Effect of speed of hand movement on sensor response

The sensor response for different speed of hand movement at different distances with subject was analyzed by RSM methodology. Observable values of sensor response was found within the hand speeds of 650 to 940 mm/min. It was observed that for selected hand speeds sensor was not able to recognize the hand movement continuously at higher distances between hand and sensor. Sensor was giving poor response at hand speeds higher than 940 mm/min and at very low hand speeds (less than 450 mm/min). The hand chaff cutters were operated maximum of up to 50 rpm of flywheel (950mm/min). From the statistical analysis it was obtained that there is no much significant sensor response at particular speed of hand movement. The speed of 950mm/min, the sensor response was little observable for hand movement at 8 to 16 cm distances.

Summary & Conclusion

Chapter 6

SUMMARY AND CONCLUSIONS

Injurie are natural hazards occurs to human beings while working in the farm due to multiple factors, e.g. machine, toxic chemicals or environmental factors. The injury occurred to the worker is not intentional but a result of unsafe act, unsafe machine or unsafe environment. Increasing rate of Indian farm mechanization as per the farm and farmer needs which is consequentially becoming the main reason of increasing occupational health hazards to the farm workers which leads to many problems and has impact on productivity of farm workers, health, safety and their economic status.

Other than farm mechanization, India having largest livestock population in the world (Annual Report of Indian Livestock production, 2016-17). Livestock management is an integral part agriculture, and feeding those animals depending on agriculture fodder crop production (Kumar and Singh, 2008). Feeding chopped fodder to animals is commonly followed by farmers. In rural areas fodder chopping is done with fodder cutter machine to make the fodder more palatable, to help in curing fodder, for storage and to reduce stored fodder spoiling. Hand injury risks are also associated with the machine. Proper attention should have to give to reduce health hazards. The safety operation with increased worker comfort while using different farm implements and machines will increase the efficiency of farm worker. Thus, there is necessity of development of safety warning system.

This thesis work presents the development of sensor-based safety alarm system for injury prevention in fodder cutter machine. With the aim to fore warn the operator or worker working with the fodder cutter machine (feeding fodder at chute) when his or her hand enters the identified danger zone at the chute. The sensor system was mounted at the chute on a metal frame at a distance of about 15cm away from the area where pair of fodder crushing rolls were moving in opposite direction may considered as potential zone to cause crush injury to hand and fingers to the worker in the fodder cutter machine.

PIR sensor used in the alarm rising warning system for fodder cutter machine. It is important to take handling precaution for the sensor because the sensor element was delicate. Problem of circuit burn may occur due to high voltage input, so that the circuit should not be loaded.

Initially a data collection sensor setup was developed to study the sensor response to different parameters such as distance, room temperature, fodder movement, hand orientation and data has been collected. Selected different electronic components were integrated to make a circuit to develop a sensor-based safety alarm system for injury prevention in fodder cutter machine. The experiments were conducted to obtain the optimum values for independent variables to write program code for sensor system. The sensor response was checked for distance between sensor and hand movement in five levels (5, 8, 12.5, 17 and 20cm), five levels of room/fodder temperatures (18, 20, 24,27.5 and 30°C) and four levels of hand orientations (pronation, supination, vertical and holding position).

Based on the analysis of the results, the following conclusions could be drawn

i. Optimum value of distance obtained is 12.5 cm form the top of chute between sensor and hand movement.
ii. The sensor system was able to work properly in moderate temperatures of up to 27.5°C, but in warm environment it may fail to recognize the subject due to compensation heat waves from surrounding.
iii. The hand orientations of pronation, supination and holding positions sensor response was higher than vertical position.
iv. The sensor response was negligible at very slow hand movement, however at 950mm/min the sensor response was observable.

1

Abstract

Development of Sensor-Based Safety Alarm System for Injury Prevention in Fodder Cutter Machine

ABSTRACT

Agricultural activities are considered as one of the most hazardous occupation. It is having high risk of fatal and non-fatal injuries contributing factor. Increased farm mechanization is one of the contributing factors to occupational health hazards among farm workers. This adversely impact the productivity of farm workers, health, safety and their economic status. Chaff cutter is used to chop the fodder by farmers to make the fodder more palatable, to help in curing fodder, for storage and to reduce spoiling in fodder storage. Hand injury are associated with this machine. With the objective of providing forewarn signal to the worker in dangerous working (injury prone area) zone of chaff cutter feeding chute, a micro controller-based alarming system was developed. Passive infrared (PIR) sensor was used as a motion detection element sensing infrared radiation emitted by the human body. The system was designed to give sound an alarm as the hand motion is detected in danger zone. The performance characteristics of PIR sensor were studied under varying conditions of distance, hand orientation and ambient conditions for different subjects.

The effects of distance between sensor and human hand (5, 8, 12.5, 17 and 20cm), hand orientation (pronation, supination, and fodder holding position), room temperature and/or fodder temperature (18, 20, 24, 27.5 and 30°C) for five subjects of different age groups were studied. The regression equations for sensor response to different hand orientations as functions of distance, age and room or fodder temperature were obtained using Response Surface Methodology. The optimum distance for mounting system on feeding chute was obtained as 12.5 cm ahead of identified dangerous area. hand orientations pronation and supination, the sensor gave high response under different temperature conditions followed by holding position. The optimum working temperature for best usage of sensor system was in the range of 24 to 27°C. The worker response to audible frequencies was also studied with speed of hand movement.

Key words: PIR sensor, pronation, supination, Response surface methodology.

चारा कुट्टी मशीन में चोट निवारण के लिए सवेंदक-आधारित सुरक्षा चेतावनी प्रणाली का विकास

सारांश

कृषि को सबसे खतरनाक उद्योगों में से एक माना जाता है, जिसमें किसानों को घातक चोटों का बहुत अधिक खतरा होता है। भारतीय कृषि मशीनीकरण की बढ़ती दर भी श्रमिकों के व्यावसायिक स्वास्थ्य के खतरे में वृद्धि का कारण बन रही है। इससे कृषि श्रमिकों की उत्पादकता, स्वास्थ्य, सुरक्षा और उनकी आर्थिक स्थिति पर असर पड़ता है। चारा कुट्टी का उपयोग किसानों द्वारा चारा को काटने के लिए किया जाता है ताकि चारा को आसानी से खाने योग्य और उचित भंडारण में मदद मिल सके। कुट्टी मशीन के द्वारा हांथों के चोटिल होने के की संभावना लगातार बानी रहती हैं। अतः चारा कुट्टी मशीन के फीड ट्रे के खतरे के क्षेत्र में कार्यकर्ता को पूर्व चेतावनी प्रदान करने के उद्देश्य से, एक माइक्रो नियंत्रक-आधारित खतरे को आगाह करने की प्रणाली विकसित की गई। इस प्रणाली में, निष्क्रिय इन्फ्रारेड (पीआईआर) सेंसर का उपयोग मानव के शरीर द्वारा उत्सर्जित अवरक्त विकिरण को पहचानने के रूप में प्रयोग किया गया। खतरे के क्षेत्र में चालक का हाथ आते ही, प्रणाली को अलार्म ध्वनि देने के लिए बनाया गया है ।

पीआईआर सेंसर की क्षमता विशेषताओं का अध्ययन विभिन्न दूरियों, हाथ के अभिविन्यासों , व्यक्ति की आयु और परिवेश की विभिन्न परिस्थितियों किया गया। सेंसर और मानव हाथ (5, 8, 12.5, 17 और 20 सेमी) के बीच दूरी के प्रभाव, हाथ के विभिन्न अभिविन्यास, कमरे और चारे के तापमान (18, 20, 24, 27.5 और 30 डिग्री सेल्सियस) और विभिन्न आयु के पांच व्यक्तियों के लिए अध्ययन किया गया। अलग-अलग हाथ उन्मुखताओं के लिए सेंसर प्रतिक्रिया के लिए प्रतिगमन समीकरण को प्रतिक्रिया सतही पद्धति का उपयोग करके दूरी, विषय आयु और कमरे या चारा तापमान के रूप में प्राप्त किए गए। खतरे वाले क्षेत्र से 12.5 सेमी पूर्व दूरी पर चेतावनी प्रणाली के सवेदक को स्थापित करना इष्टतम पाया गया | प्रवण और प्राप्ति हाथ उन्मुखता के लिए, संवेदक सेंसर द्वारा विभिन्न तापमान स्थितियों में उच्चतम प्रतिक्रिया पायी गयी | संवेदक प्रणाली के सर्वोत्तम उपयोग के लिए इष्टतम तापमान 24 से 27 डिग्री सेल्सियस की सीमा में पाया गया ।

मुख्य शब्द: P I R सेंसर, रिस्पॉन्स सतह कार्यप्रणाली

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Appendices

Appendix – I

Hand temperature of subjects measured by infrared thermometer

Subject Age (Years)	Pronation T1 (°C)	Supination T2(°C)
22	37	35.9
27	34.4	33.9
38	35.6	34.5
49	36.4	34.8
54	36.5	36.1

Appendix-II

Microcontroller program for sensor-based safety alarm system

//Specify digital pin on the Arduino that the positive lead of piezo buzzer is attached.

```
int piezoPin = 4;
int signalPin=A4;
int value=0;
int referenceValue;
int diffValue=0;
int referenceValue1;
int i=0;
int ledPin=13;
void setup()
{
 Serial.begin(115200);
  pinMode(signalPin, INPUT); // sts the analog input as pin 4
 pinMode(ledPin, OUTPUT);  // sets the digital pin 13 as output
 digitalWrite(ledPin, LOW);
delay(5000);
 while( i<10)
 {
 referenceValue1=referenceValue+analogRead(signalPin);
i++;
```

```
Serial.println(i);
delay(500);
 }
 referenceValue1=referenceValue/10;
 Serial.println("referenceValue");
 Serial.println(referenceValue);
  delay(1000);
}
//close setup
void loop()
{
  value=analogRead(signalPin);
Serial.println(value);
  diffValue=(referenceValue1 -value);
  if(diffValue<0)
  {
    diffValue=diffValue*(-1);
}
////Serial.println ("Current Value:");
// //Serial.println(value);
// Serial.print(" ");
//// Serial.print(" ref_Value:");
// Serial.print(referenceValue);
```

```
//  Serial.print(" ");
// Serial.print(" Diff_Value:");
//Serial.print(",");
 //Serial.println(diffValue);
  // Serial.print(",");
//// Serial.print(" Currt_Value:");
// Serial.println(value);
 if((diffValue)>5)
 {
  digitalWrite(ledPin, HIGH);
  //tone(piezoPin, 4000, diffValue*20+100);
  tone(piezoPin, 4000, 100);
 }
//  Tone needs 2 arguments, but can take three
//    1) Pin
//    2) Frequency - this is in hertz (cycles per second) which determines the pitch of
the noise made
//    3) Duration - how long teh tone plays
//  tone (piezoPin, 1000, 500);
 //delay(2000-(diffValue*150));*/
//delay (500);
   DigitalWrite (ledPin, LOW);
}
```

APPENDIX -III

Sensor Response Data for Holding Hand Ordination for difference distance and ambient temperature

RUN ORDER	DISTANCE (cm)	ROOM/FODDER TEMP (degree Celsius)	SUBJECT of different age	VOLTAGE (V, ADC Value)
1	8	27.6	47.5	27
2	12.5	24	38	41.33
3	12.5	24	38	41.33
4	5	24	38	39.67
5	12.5	24	38	41.33
6	8	20.4	47.5	28
7	12.5	24	38	41.33
8	17	20.4	28.5	31
9	12.5	18	38	37.33
10	8	27.6	28.5	31
11	17	27.6	28.5	33.67
12	12.5	24	38	41.33
13	12.5	24	38	41.33
14	8	20.4	28.5	17.33
15	17	27.6	47.5	29
16	12.5	30	38	20.66
17	20	24	38	35.33
18	12.5	24	22	37
19	12.5	24	54	29.33
20	17	20.4	47.5	31.25

APPENDIX -IV

Sensor Response Data for different distance and ambient temperature

RUN ORDER	DISTANCE (cm)	FODDER TEMP (Degree Celsius)	VOLTAGE (V, ADC value)
1	8	27.6	18.67
2	12.5	24	9
3	12.5	24	9
4	5	24	15
5	12.5	24	9
6	8	20.4	15
7	12.5	24	9
8	17	20.4	14.5
9	12.5	18	13
10	8	27.6	18.67
11	17	27.6	6
12	12.5	24	9
13	12.5	24	9
14	8	20.4	15
15	17	27.6	6
16	12.5	30	10.85
17	20	24	13
18	12.5	24	9
19	12.5	24	9
20	17	20.4	14.5