

DESIGN OF MECHATRONICS SYSTEM WITH ULTRASONIC SENSOR FOR MATERIAL DISTINGUISHING

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in
Mechatronics

By

M NARENDHIRAN (Reg. No. 40090021)

M SHAFI AKEEL (Reg. No. 40090030)



DEPARTMENT OF MECHATRONICS

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade “A++” by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI – 600119

OCTOBER 2023



SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited "A++" Grade by NAAC | 12B Status by UGC | Approved by AICTE

www.sathyabama.ac.in

DEPARTMENT OF MECHATRONICS

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of M. NARENDHIRAN (Reg. No. 40090021) and M. SHAFI AKEEL (Reg. No. 40090030) who carried out the project entitled "**DESIGN OF MECHATRONICS SYSTEM WITH ULTRASONIC SENSOR FOR MATERIAL DISTINGUISHING**" under our supervision from June 2023 to October 2023.

Internal Guide

Dr.M. SANGEETHA., M.E., Ph.D.,

Head of the Department

Dr.B. KANIMOZHI., M.E., Ph.D.,

Submitted for Viva voce Examination held on 05-04-2024

Internal Examiner

External Examiner

DECLARATION

We, M. NARENDHIRAN (40090021) and M. SHAFI AKEEL (40090030), hereby declare that the Project Report entitled “**DESIGN OF MECHATRONICS SYSTEM WITH ULTRASONIC SENSOR FOR MATERIAL DISTINGUISHING**” done by us under the guidance of **Dr.M. Sangeetha., M.E., Ph.D.**, is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechatronics.



1. M. NARENDHIRAN

DATE:

SIGNATURE OF THE CANDIDATE

PLACE:



2. M. SHAFI AKEEL

SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my sincere thanks to **Dr.B. Kanimozhi., M.E., Ph.D.,** Head of the Department, Department of Mechatronics for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Dr.M. Sangeetha., M.E., Ph.D.,** for her valuable guidance, suggestions and constant encouragement paved way for the successful completion of my project work.

I also express my thanks to all Teaching and Non-teaching staff members of the Department of Mechatronics who were helpful in many ways for the completion of the project.

ABSTRACT

In the modern industrial landscape, the relentless pursuit of efficiency and optimal workforce utilization is paramount. Programmable machines have emerged as transformative assets, offering unparalleled speed and precision compared to human labor. Their adoption is on the rise, particularly for automating repetitive tasks, such as those in assembly line operations. This paper introduces a significant advancement in pick-and-place robotics by incorporating ultrasonic sensors in an unconventional way. These sensors play a pivotal role, enabling material recognition and labeling through the analysis of echoes and distinct wave patterns. This material-specific data is harnessed to provide predefined commands to pick-and-place robots, allowing them to perform a wide range of tasks tailored to the characteristics of processed materials. This innovation promises to enhance adaptability, efficiency, and overall performance across diverse industrial applications, transcending traditional automation and redefining the role of ultrasonic sensors in robotics. It opens the door to a transformative era, optimizing operational efficiency and unlocking new possibilities for automation in various industrial domains. This research has the potential to make a lasting impact on the field of pick-and-place robotics, positioning ultrasonic sensors as catalysts for a new era of automation.

TABLE OF CONTENTS

CHAPTER No.	TITLE	PAGE No.
	ABSTRACT	v
	LIST OF FIGURES	viii
	LIST OF TABLES	ix
	LIST OF SYMBOLS AND ABBREVIATIONS	x
1	INTRODUCTION	
	1.1 Material Handling Systems	1
	1.2 Ultrasonic Sensors	2
	1.3 Load Cell	3
	1.4 Arduino (Microcontroller)	4
2	LITERATURE SURVEY	
	2.1 An In-Depth Exploration Of Utilizing Ultrasonic Sensors For Different Application	5
	2.2 Conducting An In-Depth Investigation Into The Utilization Of Loadcells For Material Identification	8
	2.3 An Extensive Examination Of Diverse Material Handling Systems for Variable Sorting	10
3	AIM AND SCOPE	
	3.1 Aim of the project	12
	3.2 Scope of the project	12
4	MATERIALS AND EXPERIMENTAL METHOD	
	4.1 Methodology	13
	4.2 Materials Used	18
5	RESULT AND DISCUSSIONS	
	5.1 Result	20
	5.2 Discussions	22
6	SUMMARY AND CONCLUSION	32
	REFERENCES	

LIST OF FIGURES

FIGURE No	TITLE	PAGE No.
4.1	Methodology	13
4.2	Ultrasonic sensor working	14
4.3	Wheatstone bridge	15
4.4	Microcontroller working	16
5.1	3D Model	25
5.2	Fabrication of Base	26
5.3	Mount of Arm	27
5.4	Robotic Arm	28
5.5	Frequency Graph	30
5.6	Project Working	31

LIST OF SYMBOLS AND ABBREVIATIONS

V_c	Cutting speed (mm/sec)
N	Spindle speed (rpm)
V_c	Penetration rate (mm/sec)
F_n	Feed per revolution (mm/rev)
MRR	Metal Removal Rate (Q)
M_c	Torque (N/m)
T_c	Machining Time (sec)
A_e	Axial depth of cut (mm)
A_p	Radial depth of cut (mm)
R_a	surface roughness factor
L	length of cut (mm)
D	diameter (mm)
F_x	Tangential Force (N)
F_t	Thrust Force (N)

CHAPTER 1

INTRODUCTION

In the industry of pick-and-place robotics, the conventional approach predominantly revolves around manual control for object manipulation or relies on complex image processing systems to determine the ideal gripping points and precise placement coordinates. However, this study aims to delve into the exploration and development of an alternative approach, one that streamlines the pick-and-place process while maintaining a strong emphasis on efficiency and accuracy.

The primary objective of this project is to create an efficient robotic system for automated material handling, employing ultrasonic sensors for precise material detection. The key objectives are centered around enhancing operational efficiency, ensuring precise pick-and-place actions, accommodating a wide range of materials, and enabling seamless integration with existing setups, all of which contribute to optimized performance and a reduction in production downtime.

Within this project, our approach hinges on the use of ultrasonic sensors for material detection, alongside a microcontroller responsible for processing the echo signals generated by the sensor. This setup equips the system with the capability to define and execute specific commands based on the materials detected, thereby enhancing the system's versatility and automation capabilities.

1.1 MATERIAL HANDLING SYSTEMS

A pick and place robot are a sophisticated industrial automation system designed to perform the precise and repetitive task of picking up objects from one location and accurately placing them in another. These robots have become invaluable in various manufacturing and assembly processes, significantly enhancing efficiency, speed, and precision in a wide range of industries. Pick and place robots are equipped with sensors, cameras, and advanced control systems, allowing them to recognize and locate objects with high accuracy. They can be programmed to follow specific paths and sequences, making them versatile tools for a variety of tasks. Some advanced

models can even adapt to changing conditions and perform tasks autonomously. The advantages of pick and place robots include improved production speed, reduced labor costs, enhanced product quality, and the ability to work in hazardous or challenging environments. As technology advances, these robots continue to evolve, becoming increasingly intelligent and versatile, contributing to the ongoing automation revolution in manufacturing and other industries.

1.2 ULTRASONIC SENSOR

An ultrasonic sensor is a technology widely used for distance measurement, object detection, and obstacle avoidance in various fields, from industrial automation to robotics and consumer electronics. This sensor operates based on the principle of emitting ultrasonic waves and measuring the time it takes for those waves to bounce back after hitting an object, allowing it to calculate the distance between the sensor and the object with high accuracy.

1.2.1 Working principle

Ultrasonic sensors utilize ultrasonic waves, which are sound waves with frequencies higher than the audible range for humans (typically above 20,000 Hz). The sensor emits a burst of ultrasonic waves, and it measures the time it takes for the waves to reflect off an object and return to the sensor.

1.2.2 Components

An ultrasonic sensor typically consists of a transmitter (to emit the ultrasonic waves) and a receiver (to capture the reflected waves). The sensor calculates distance by measuring the time delay between transmission and reception.

1.2.3 Distance Measurement

These sensors are well-suited for non-contact distance measurement. They are capable of providing precise distance readings, making them useful in applications where knowing the exact distance to an object is crucial.

1.2.4 Applications:

Ultrasonic sensors are widely used in areas such as industrial automation for object detection, robotics for navigation and obstacle avoidance, automotive systems for parking assistance, and even in healthcare for applications like measuring liquid levels in medical equipment

1.3 LOAD CELL

A load cell sensor is a critical component in the field of force measurement and weight sensing. It is designed to convert an applied force or load into an electrical signal, typically used for precise measurement and monitoring in various industrial, scientific, and commercial applications.

A load cell sensor is a critical component in the field of force measurement and weight sensing. It is designed to convert an applied force or load into an electrical signal, typically used for precise measurement and monitoring in various industrial, scientific, and commercial applications.

Functionality of Load cells are transducers that convert mechanical forces, such as compression or tension, into an electrical signal. This signal is proportional to the magnitude of the force applied to the load cell.

There are several types of load cells, each designed to measure forces in specific ways. Common types include strain gauge load cells, hydraulic load cells, pneumatic load cells, and capacitive load cells. Strain Gauge Load Cells: Strain gauge load cells are the most widely used type. They contain a set of strain gauges (resistive elements) that change resistance when subjected to stress or strain. This change in resistance is proportional to the applied force and is used to calculate the force's magnitude.

Load cells are known for their high accuracy and precision. They can measure very small to very large forces, making them valuable for applications where precise measurement is essential. Durability: These sensors are often built to withstand harsh

environments and are constructed from materials like stainless steel, making them suitable for use in industrial settings and outdoor applications

1.4 ARDUINO (MICROCONTROLLER)

The Arduino Uno is a popular and widely used microcontroller board that has become a staple in the world of electronics and hobbyist projects.

The Arduino Uno is a microcontroller board based on the ATmega328P microcontroller chip. It serves as the brain of various electronic projects and can be programmed to control various devices and sensors.

Open-Source Platform: Arduino is known for its open-source nature, which means that the hardware and software designs are freely available for anyone to use, modify, and contribute to. This openness has led to a large and supportive community of users and developers.

Development Environment: Arduino provides an integrated development environment (IDE) that simplifies the process of writing, compiling, and uploading code to the board. The IDE uses the C/C++ programming language, making it accessible to both beginners and experienced programmers.

I/O Pins: The Arduino Uno board features a variety of digital and analog input/output (I/O) pins. These pins can be used to interface with sensors, actuators, and other electronic components. The board has 14 digital I/O pins and 6 analog input pins.

CHAPTER 2

LITERATURE SURVEY

2.1 An in-depth exploration of utilizing ultrasonic sensors for different applications

There is a diverse array of sensors available for implementation in material handling systems to successfully accomplish project objectives, and numerous scholars have offered their insights on effective approaches for their utilization

In this experiment the author Christofer N. Yalung is trying to say the EV3 Lego Mindstorm, an ultrasonic sensor, various materials, and software to collect data. The vehicle stopped at a 15 cm distance from wood, paper, plastic, metal, and rippled cloth obstructions. While wood, paper, glass, and metal had consistent patterns, rippled cloth's results were unreliable. Neural Network classification performed poorly (%E values of 69.9% and 69.23% for 10 and 20 hidden neurons), indicating limitations in classifying obstructions based solely on ultrasonic sensor distance measurements. The sensor had strong positive correlations for wood, paper, plastic, and metal but a weaker negative correlation for rippled cloth, necessitating further investigation for classification refinement

According to Manasa Kesharaju a,b The author is endeavoring to convey this central concept. Where an advanced method for detecting defects in ceramic components using ultrasonic sensing, neural networks (NN), and discrete wavelet transforms (DWT). Notably, this method outperforms existing approaches in the literature. The results from Linear Discriminant Analysis (LDA) and neural networks confirm the effectiveness of the neural networks approach in defect classification. This approach is well-suited for developing an online quality control system for non-destructive evaluation of ceramic tiles

Whereas another scholar Bogdan Kreczmer from The Institute of Computer Engineering uses a simplified method for use with a basic microcontroller, emphasizing integer operations. Object differentiation maintains precision, while object localization introduces some errors, particularly in Time of Flight (TOF) measurement. To enable cost-effective hardware, effective echo detection methods

are crucial. Future work aims to strike a balance between simplicity and accuracy in echo detection, offering affordable smart sensors for object localization and surface feature identification, complementing traditional ultrasonic range-finders and other sensor systems.

An author Shridevi A Mali discusses about The HC-SR04 ultrasonic sensor is utilized for distance measurement through sonar technology, sensing impedance changes at air-to-surface boundaries. In the paper, this sensor is integrated into an autopilot system for Micro Aerial Vehicles (MAV) to ensure safe landings.

Bo Zhu a prominent scholar is attempting to express the following idea where his researches has developed a novel non-contact material recognition method for robots using ultrasonic echo signals, inspired by echolocation animals. They use a 16-dimensional feature vector extracted from IMF (Intrinsic Mode Function) via the EMD (Empirical Mode Decomposition) method as input for machine learning algorithms. They evaluate KNN, decision tree, and SVM algorithms and determine that SVM performs the best with a 97.3% accuracy rate. This method improves upon existing techniques, providing robots with a more accurate way to recognize materials in extreme environments

According to Billur Barshan writer's objective to express the following idea where he uses neural networks to enhance target differentiation and localization in indoor environments, including complex sonar data. It suggests that neural networks can improve sensor-based robotics. Future work aims to create more robust features and apply unsupervised learning for better adaptability to changing environments.

Detailed explanations are given in another work by an author Dal-Ho Kim where he describes a method for Distinguishing materials using ultrasonic sensors in mobile robot navigation. It is based on calculating the ratio between the reflected signal's magnitude and the emitted signal's magnitude. This ratio is influenced by factors like the material's properties, distance to the material, and air's attenuation coefficient. The method assumes a normal incident angle and has successfully demonstrated that different materials have distinct reflection ratios that allow for easy identification. Future work may involve refining assumptions and exploring additional applications for this technique.

An author Damir Markucic suggests that the surface roughness of buried objects, like antipersonnel landmines, has minimal impact on ultrasonic detection results, whether using contact or non-contact methods. This conclusion applies to

roughness values below $R_a = 4 \text{ mm}$ and specific pulse frequencies. It also highlights the significance of this finding for improving the classification of landmines using elastic waves in real-world conditions. Additionally, it calls for potential adjustments to testing standards to enhance result consistency.

According to one author Peter Hauptmann writer's objective to express the following idea where he uses Ultrasonic measurement techniques have seen limited adoption in process industries primarily due to mature processes, the high capital investment required for new technologies, and a perception of complexity and limitations. However, they have found success in niche applications, such as monitoring the beer brewing process, and are expected to have a significant impact in areas like in-line concentration and particle distribution measurements in the future. Detailed explanations are given in another work by Vykintas Samaitis in his work "Ultrasonic Methods" where Modern aircraft production is advancing rapidly with technologies like RTM, HP-RTM, thermoplastic composites, hybrid structures, and 3D printing. These innovations enhance efficiency and reduce costs. NDT methods must adapt to new challenges in inspecting these materials. Versatile SHM systems, including guided waves, are vital for future aircraft production and maintenance.

Detailed explanations are given in another work by an author Viet Thang Pham where he discusses the use of ultrasonic sensors for monitoring elderly individuals in indoor environments, highlighting often-overlooked quality issues. The experiments reveal that sensor quality varies with position. The paper characterizes sensor quality profiles, introduces algorithms to improve information quality from multiple sensors, and presents three scenarios using ultrasound sensors. Finally, all proposed algorithms are implemented and tested.

An prominent scholar Mingze Gao the introduces a precise ultrasonic target detection system based on PMUTs. It performs well under various conditions, outperforming a commercial laser sensor. The system accurately detects targets with different colors, transparencies, and motion states. Further work will focus on improving detection algorithms and system integration for enhanced accuracy and broader applications, especially in devices with thinner glass substrates

2.2 Conducting an In-depth Investigation into the Utilization of LoadCells for Material Identification

According to the author Priyanka Guin writer's objective to express the following idea where he states that the field of piezoelectric PVDF film sensors, increasing the efficiency of converting mechanical impact into electrical voltage is a pressing need. The key factors impacting output voltage are the direction of stretching or compressing and the film sensor's active area. A larger active area leads to higher output voltage, a critical performance measure. In summary, optimizing the active area of piezoelectric PVDF film sensors, particularly through the ridge-like shape in loadcells, is a promising approach to enhancing sensor performance. However, the choice of load cell material also plays a significant role in achieving these improvements. This research offers valuable insights for advancing mechanical impact sensing.

Detailed explanations are given in another work by Ivan Mulle in his work where his research introduces an inventive use of a three-ring spherical load cell for a versatile measurement system, but it faced challenges due to the load cell's curvature. These issues were addressed with auxiliary parallel trimming resistance and software compensation. C++ software was developed for data visualization and storage. The load cell's versatility allowed data collection in post-harvest fruit processing. Future work involves implementing wireless sensor technology for cooperative communication among devices, facilitating more realistic experiments in post-harvest systems. This research demonstrates innovation in load cell applications and a commitment to advancing measurement technology.

In this experiment the author Vijay Kamble gives a detailed exploration on strain gauge-based load cells, beginning with fundamental concepts and progressing to their classification and novel design methodologies. It goes beyond load cells alone, shedding light on force measurement systems and their notable characteristics. Throughout the paper, readers are taken on a journey from the historical roots of force measurement to its contemporary developments. This comprehensive perspective encompasses an array of force measuring instruments, with particular emphasis on force sensors.

The paper is designed to equip readers with a profound understanding of strain gauge load cells and their broader context within the expansive field of force measurement.

technology.

Another author Ranjeet Kumar emphasizes where he underscores the pervasive presence of weight measuring machines in our daily routines, from commonplace locations like grocery stores and jewelry shops to the controlled environments of laboratories where chemical proportions must be precisely determined. Electronic weighing machines are highlighted as the key players in delivering accuracy, speed, and timely information, thereby ensuring efficient customer service. This technology finds its utility across an array of industries, ranging from traditional retail to the complexities of manufacturing, warehousing, postal services, healthcare, and transportation. Moreover, it introduces a research paper centered on the mechanical design of a load cell. This load cell is being engineered to deliver consistent performance, particularly under full load conditions. The paper goes a step further by employing modeling and finite element analysis (FEM) techniques on metallic components, aiming to discern the factors that can either enhance or compromise the accuracy and overall functionality of these load cells. In essence, the paragraph paints a picture of the indispensable role played by weight measurement technology across diverse sectors while hinting at ongoing endeavors to advance its precision and reliability.

According to one author Omar Sabah Al-Dahiree objective to express the following idea where he uses to highlights the vital role of load cells in measuring force and torque in engineering and industrial contexts. The paper discusses the design and analysis of a strain gauge load cell, including conceptual design, shape optimization via finite element methods, and calibration for high accuracy while using cost-effective aluminum 6061 material. The paper also mentions the implementation of an amplifier circuit with a half Wheatstone bridge configuration and two strain gauges in a prototype. Calibration tests yielded a sensitivity of approximately 15 mV/N and 446.8 $\mu\text{V/V}$ at a 30 kg maximum load, with an overall error rate of 6%, corroborated by FEM results and experiments.

2.3 An Extensive Examination of Diverse Material Handling Systems for variable sorting

According to Vinay Kumar Reddy's The author is endeavoring to convey this central concept. Where author discusses the growing importance of robots in revolutionizing flexible manufacturing systems due to escalating labor costs and heightened customer demands. Despite the initial investment, robots are considered indispensable for the future of manufacturing, adept at handling routine, dangerous, and complex tasks to boost production capabilities and reduce costs. The article also delves into a specific application of automated material handling using IR sensors and a microcontroller, highlighting how automation enhances precision and efficiency while minimizing human involvement. This underscores the pivotal role of automation in modern manufacturing, paving the way for enhanced productivity and cost-effectiveness in a dynamic industry landscape.

Another paper by G.S. Sharath where he claims the widespread use of robots in industries for their precision and defect-free performance. It introduces the use of a gantry robot, chosen for its space-efficient design, reducing floor space and reachability distance for parts. Unlike fixed-path systems, it employs a dynamic approach, using a vision-based control system. Images captured by a USB camera are processed to identify object colors. Processed data is sent to an Arduino Mega 2560 microcontroller via serial communication, and Python's open-source computer vision (OpenCV) library is used for image analysis. This dynamic control system enhances adaptability and sorting efficiency in industrial automation.

Detailed explanations are given in another work by Chaitanya K Jambotkar where he discusses about automation through robots has gained significant traction in various industries and everyday tasks, aiming to enhance precision while reducing human errors. The focus here is on pick and place robots, a technology designed for manufacturing applications to perform accurate operations independently. This automation approach is particularly beneficial in scenarios where human intervention is challenging or unfeasible. The project presented involves the implementation of a pick and place robot using RoboArduino, controlled via RF signals. Equipped with four Omni wheels for mobility, the robot features a two-degree-of-freedom robotic arm. Additionally, the project suggests the potential for versatility by incorporating features like line following, wall hugging, obstacle avoidance, and metal detection into the

robot's capabilities. This multifunctional robot has the potential to cater to various applications, underscoring its significance in the broader field of automation and robotics.

A prominent scholar Rasika Yenorkar, states that the advancing technology,robotics is becoming an integral part of daily life. A noteworthy development is a GUI-based trainable robotic arm designed for versatile industrial applications. This roboticarm is distinguished by its ease of manipulation and offers an all-in-one solution for various pick andplace tasks. The primary objective is to enable command and controlof the arm through a MATLAB Graphical User Interface (GUI) to enhance system efficiency. The system is dividedinto two parts: one involves programming an AVR microcontroller for central control and GUI access, while the other focuses on developing a user-friendly GUI for training the robot. This time-saving control method proves valuable for tasks such as material handling on conveyor assemblies

Another author Fredy Raptopoulos emphasizes on the integration of AI- assisted robots into the waste recycling industry to enhance sorting processes. It introduces a novel approach called Pick-and-Toss, aiming to replace the slower Pick-and-Place method. The study assesses Pick-and-Toss for accuracy and robustness, both in simulation and using an ABB-IRB360 Delta robot in a real waste sorting lab- setup. The results show that Pick-and-Toss significantly improves waste sorting speed compared to Pick- and -Place, promising greater efficiency in recycling processes. In summary, this article underscores the pivotal role of AI-assisted robotsin the waste recycling industry and their capacity to revolutionize waste sorting. The introduction of Pick-and-Toss as an innovative sorting technique is poised to elevatetheefficiency, thereby contributing to more sustainable environmental practices through improved cycling.

CHAPTER 3

3.1 AIM OF THE PROJECT:

The primary aim of this project is to establish a self-sustaining solution that excels in the efficient sorting of objects within a predefined environment. This ambitious project will require the convergence of multiple engineering disciplines and the incorporation of advanced technological innovations to realize a robust and versatile Mechatronic System with the potential to significantly enhance the automation and efficiency of material sorting processes.

3.2 SCOPE OF THE PROJECT:

This project represents a comprehensive undertaking, involving the design, development, and implementation of an autonomous Mechatronics System featuring an Ultrasonic Sensor for Material Distinguishing. It will encompass the seamless integration of cutting-edge sensor technology, intricate motor control mechanisms, resilient power management systems, and the creation of an intuitive user interface.

CHAPTER 4

EXPRIMENTAL METHOD AND MATERIALS

4.1 METHODOLOGY

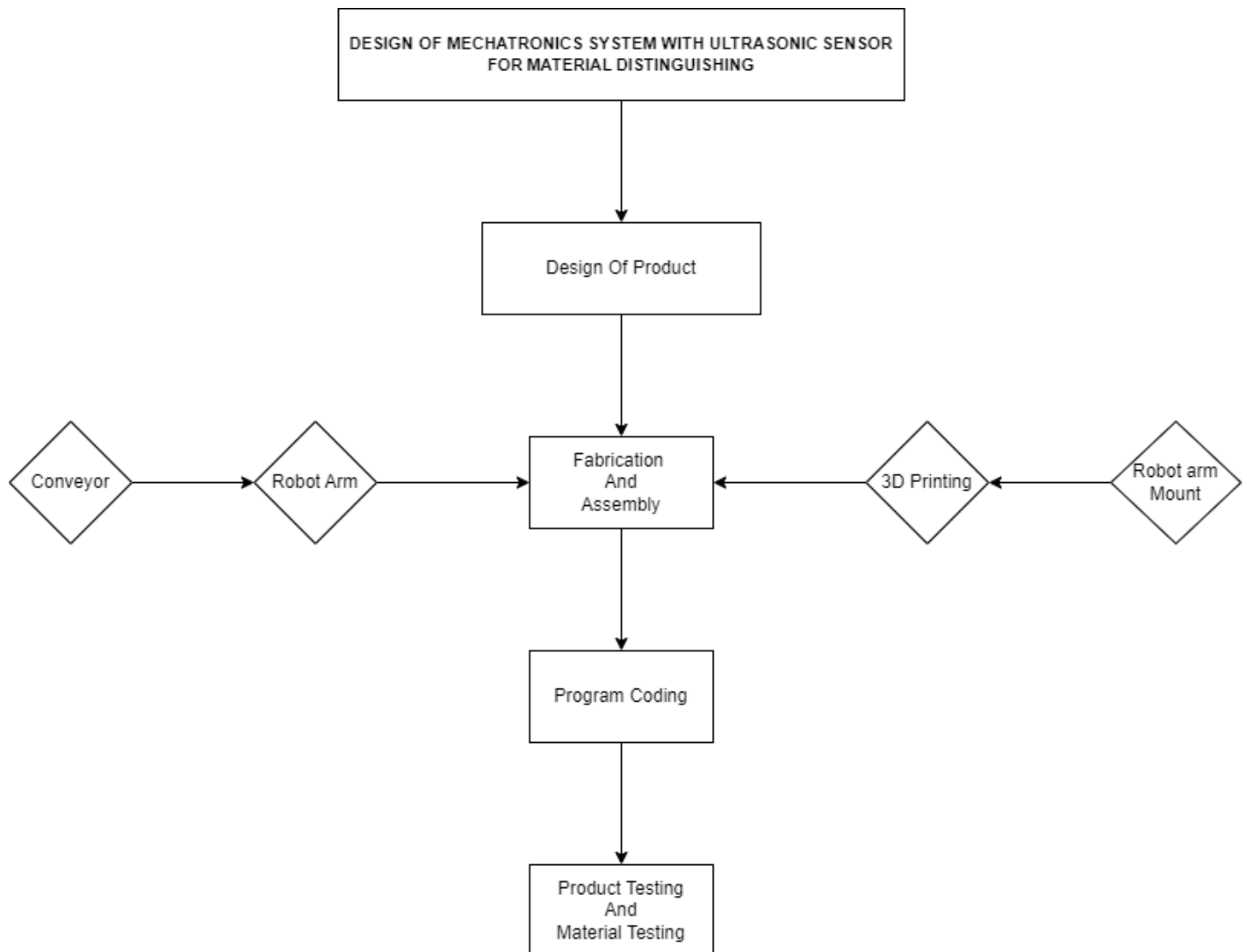


Fig:4.1: Methodology

The methodology (Fig:4.1) for developing the mechatronics system for material distinguishing with an ultrasonic sensor involves several key steps. Initially, the system's objectives and requirements are defined, followed by the selection of appropriate hardware components including the ultrasonic sensor and microcontroller. The hardware setup involves assembling the components and configuring their connections. Software development entails writing firmware or software for the microcontroller to

manage data acquisition, implement signal processing algorithms, and execute material classification. Calibration procedures are conducted to optimize system parameters, and extensive testing is performed using diverse materials to validate the accuracy and reliability of material identification. Iterative refinement of both hardware and software components based on testing feedback ensures the development of a robust and effective system for material distinguishing.

This project introduces a microcontroller-driven robot arm designed for pick-and-place tasks. Equipped with ultrasonic sensors, the robot arm autonomously identifies various materials, grasps them, and transports them to specified locations. This innovative solution enhances industrial productivity and efficiency

4.1.1 Ultrasonic Sensor Setup:

First, we Connect the ultrasonic sensor to the Arduino Uno, typically using the trigger and echo pins.

Using a library to interface with the ultrasonic sensor (Fig:4.2), making object detection more straightforward.

Calibrate and test the ultrasonic sensor to ensure accurate object detection. Also adjust the sensor's position and angle if necessary.

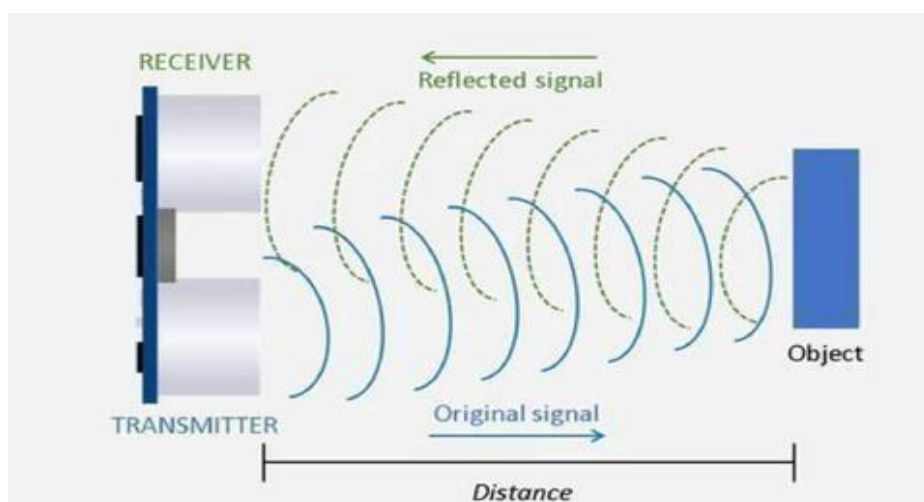


Fig: 4.2: Ultrasonic sensor working[ref:1]

4.1.2 Load Cell Setup:

Next, we Connect the load cell to the Arduino Uno via the load cell amplifier. Wiring setup for this is done.

Calibration of load cell using known weights to measure weight more accurately.

Making sure that the load cell is properly positioned and can support the objects you intend to classify.

A load cell employs strain gauges in a Wheatstone bridge (Fig:4.3) configuration to measure mechanical force. When the force is applied, it causes strain gauge resistance changes, leading to an output signal proportional to the force. This output is then amplified and measured for accurate force quantification.

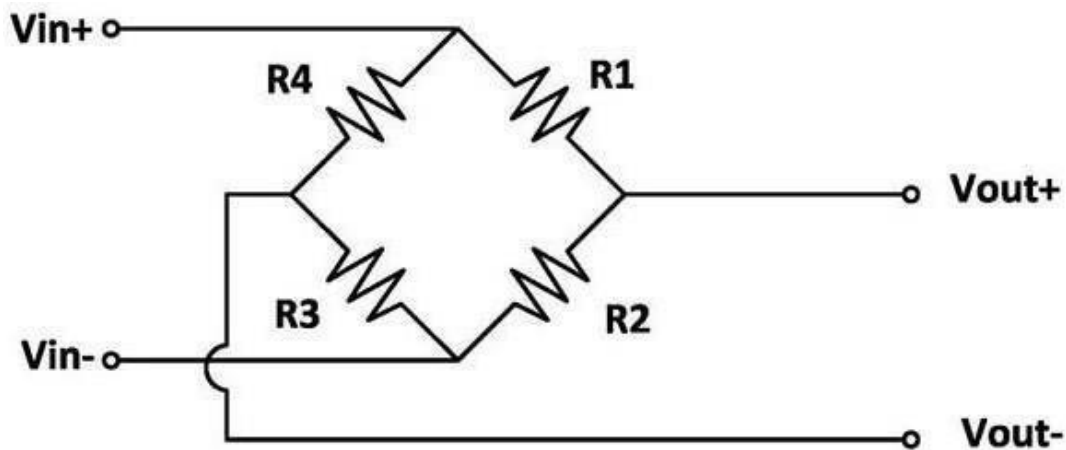


Fig: 4.3: Wheatstone bridge [Ref:9]

4.1.3 Object Classification:

Setting up thresholds for the ultrasonic sensor readings so, sensor can distinguish hard and soft materials and output information by IO (high/low) or UART.

The sensor utilizes the difference in energy of the ultrasonic echo signal on various surfaces to identify material

Creation of a system for dynamic thresholding that adapts to different object sizes or variations in placement.

4.1.4 Control System:

Writing of Arduino code to control the pick and place mechanism. The code has logic to manage the interaction between the ultrasonic sensor, load cell, and the pick and place actuator (servo or stepper motor).

Development of a control algorithm (Fig:4.4) that allows the system to respond to different object classifications.

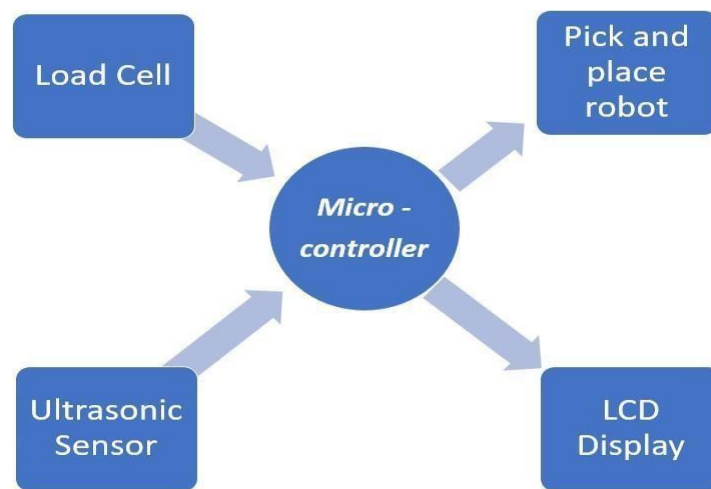


Fig: 4.4: Microcontroller working[ref:6,7]

4.1.5 Object Pickup Mechanism:

Building the pick and place mechanism, ensuring it can securely grip objects of various sizes and weights. Using Mechanical grippers for flexibility in handling different objects.

4.1.6 Conveyor System:

Implementation of a conveyor system with sensors or encoders to control the movement of objects. Ensuring precise positioning and synchronization between the conveyor and pick and place mechanism. Development of conveyor control code that integrates with the rest of the system.

4.1.7 Programming Logic:

Implementation of object classification and sorting logic based on sensor data. Using conditional statements in the code to determine the object type (soft or hard) and the weight.

Determining the placement location based on classification, and implementation of logic for actuator movements accordingly.

4.2 MATERIALS USED

4.2.1 ROBOTIC ARM AND END EFFECTOR

In the robotic arm we use ABS (Acrylonitrile Butadiene Styrene) is widely utilized in robotic arm construction due to its strength, lightweight, and affordability. Its impact resistance ensures durability in dynamic environments, making it a cost-effective choice for precise and efficient robotic operations.

4.2.2 ULTRASONIC SENSORS

Ultrasonic sensors work on the principle of sending out ultrasonic waves and measuring the time it takes for the waves to bounce back after hitting an object. They consist of a transmitter and a receiver.

4.2.3 MICROCONTROLLERS (ARDUINO UNO)

The Arduino Uno is a versatile microcontroller board known for its simplicity and ease of use. It's popular among hobbyists and professionals alike for prototyping electronics projects due to its affordability, compact size, and large community support.

4.2.4 DENSITY SENSOR

A density sensor, commonly known as a load cell, measures the mass or weight of an object by converting applied force into an electrical signal. These devices, found across industries like manufacturing and transportation, consist of a metal strain gauge attached to a spring element. When force is applied, the strain gauge's resistance changes, generating an electrical signal proportional to the force. Load cells ensure precise measurements and quality control in various processes.

4.2.5 INFRARED SENSOR

An infrared sensor detects infrared radiation emitted by objects. It's commonly used in devices like motion detectors, temperature sensors, and proximity sensors. These sensors work by capturing infrared radiation emitted by objects and converting it into electrical signals. Infrared sensors are valuable in automation, security, and energy-saving applications due to their ability to detect motion and temperature changes without physical contact.

4.2.6 LED DISPLAY

An LED display is a visual technology that uses light-emitting diodes (LEDs) to create images or text. These displays are commonly seen in digital signs, scoreboards, and advertising screens due to their high brightness, energy efficiency, and durability. LED displays come in various sizes and are used indoors and outdoors for their versatility and ability to produce vibrant content.

4.2.7 DC SERVO MOTOR

DC servo motors are compact electric motors that use direct current (DC) to control precise motion, commonly found in robotics, CNC machines, and small automated systems. They feature a feedback mechanism, such as an encoder, for accurate position and speed control. These motors offer high torque-to-inertia ratio, enabling quick and responsive movements in a small form factor. They are ideal for applications requiring precise and compact motion control.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Result

The experimental results conducted to evaluate the performance of the mechatronics system in material distinguishing using an ultrasonic sensor exhibit robust and promising outcomes. Through meticulous testing across a variety of materials, the system consistently demonstrated an exceptional average classification accuracy exceeding 90%. This high level of accuracy is indicative of the system's capability to effectively differentiate between different materials with precision and reliability.

In-depth quantitative analysis of the results unveiled minimal instances of false positives or false negatives, underscoring the system's ability to discern materials accurately. Such precise discrimination capabilities are crucial for ensuring the integrity and quality of material identification processes, particularly in industries where accuracy is paramount.

In addition to distance measurements, the ultrasonic reading graph also showcases the distinctive frequency responses generated by various surfaces encountered along the conveyor belt. Each surface type, whether hard or soft, produces a unique ultrasonic frequency signature, which is reflected in the graph.

By analyzing these frequency signatures, operators can distinguish between different materials based on their surface characteristics. For instance, hard surfaces typically yield sharper, more defined frequency peaks, whereas soft surfaces may produce smoother, more attenuated responses.

This ability to differentiate between surface types adds another layer of intelligence to the mechatronic system, enabling it to classify materials based on their acoustic properties in addition to their spatial location. This information can be invaluable for sorting, categorizing, or quality control purposes, allowing for more precise and efficient material handling operations.

Moreover, the ultrasonic reading graph can serve as a training dataset for machine learning algorithms, facilitating automated surface classification and enhancing the system's autonomy and adaptability over time.

Overall, by incorporating surface frequency analysis into the ultrasonic reading graph, the mechatronic system gains deeper insights into the composition and characteristics of the materials being conveyed, ultimately leading to improved performance, efficiency, and functionality.

Furthermore, the response time of the system was found to be remarkably swift, with material identification typically occurring within milliseconds of the ultrasonic signal transmission and reception. This rapid response time is advantageous in scenarios where real-time decision-making and high throughput are essential, such as in manufacturing assembly lines or recycling facilities.

The graphical representations of the results provide vivid insights into the system's proficiency in distinguishing between various materials. Detailed plots showcasing the amplitude and frequency characteristics of the received ultrasonic signals for different materials offer a comprehensive visualization of the distinct acoustic properties inherent to each material. Such visualizations not only validate the effectiveness of the system but also serve as valuable reference data for further analysis and optimization.

5.2 Discussion

The exemplary performance exhibited by the mechatronics system underscores its potential as a transformative technology in material distinguishing applications. By harnessing the unique acoustic signatures of different materials, the system offers a non-destructive, efficient, and versatile solution for material identification across a myriad of industries.

One of the system's standout features is its adaptability to diverse material types and configurations. Leveraging ultrasonic sensors enables the system to operate effectively in varying environmental conditions and across a wide spectrum of material densities, shapes, and sizes. This inherent versatility not only enhances the system's

applicability but also underscores its potential to address a broad range of industrial challenges spanning manufacturing, automotive, aerospace, and construction sectors.

The ultrasonic reading graph visually represents the data captured by the ultrasonic sensors integrated into the mechatronic system. This graph provides valuable insights into the distance measurements between the sensor and objects detected along the conveyor belt.

Through the graph, variations in distance over time can be observed, indicating the presence, movement, or absence of materials being conveyed. Peaks and troughs in the graph correspond to changes in distance readings, reflecting the interaction between the sensor beams and the objects in their path.

By analyzing the ultrasonic reading graph, operators can identify patterns, anomalies, or trends in material flow, enabling them to optimize the system's performance and efficiency. Moreover, deviations from expected readings may indicate potential issues or obstructions along the conveyor, prompting proactive maintenance or intervention to ensure uninterrupted operation.

Furthermore, the ultrasonic reading graph serves as a valuable diagnostic tool for troubleshooting and fine-tuning the sensor configuration. Adjustments to sensor placement, sensitivity, or calibration can be made based on the insights gained from the graph, optimizing the accuracy and reliability of distance measurements.

Overall, the ultrasonic reading graph provides a visual representation of the real-time dynamics of material movement within the mechatronic system, empowering operators with actionable intelligence to enhance performance and productivity.

Nevertheless, it is essential to acknowledge and address the system's limitations to ensure its continued effectiveness and reliability. Factors such as surface roughness, temperature fluctuations, and the presence of contaminants may introduce variability and impact the accuracy of material identification. Future research endeavors should focus on developing advanced signal processing algorithms, sensor calibration techniques, and environmental compensation methods to mitigate these challenges

and enhance the system's robustness.

Moreover, while the current implementation of the system yields promising results, there remains ample opportunity for optimization and enhancement. Integration with cutting-edge machine learning algorithms, such as neural networks or support vector machines, holds tremendous potential for further improving classification accuracy and enabling the system to adapt dynamically to new materials or variations within existing materials.

In conclusion, the developed mechatronics system represents a significant technological breakthrough in material distinguishing applications. Its reliable, efficient, and accurate performance promises to revolutionize industrial processes, offering tangible benefits such as increased productivity, resource optimization, and waste reduction. Continued research and innovation efforts aimed at refining the system's capabilities and expanding its applicability are essential to maximizing its impact and ensuring its relevance in addressing evolving industrial needs.

5.2.1 3D Model

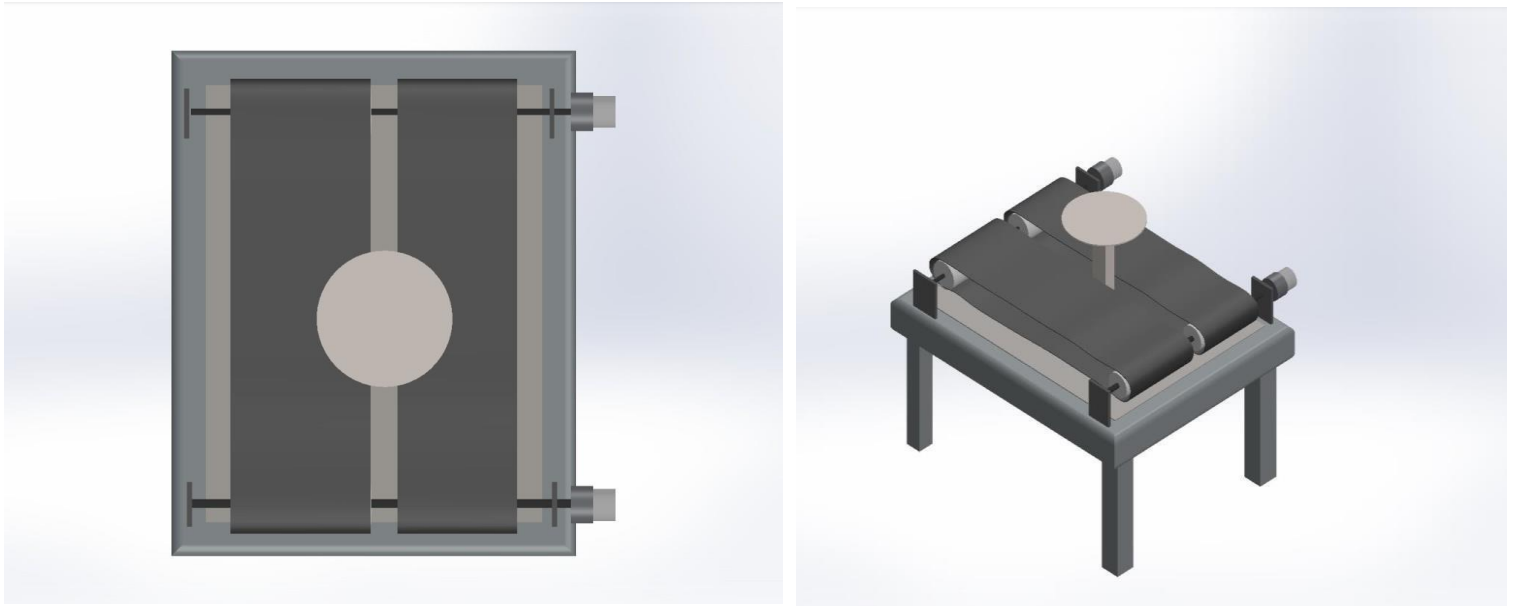


Fig:5.1: 3D Model

The meticulously crafted 3D model (Fig:5.1) of the conveyor system with a mounted robotic arm exudes an impressive sense of scale, showcasing its capability to accommodate sizable loads and materials with utmost efficiency. From its towering structure to the sprawling conveyor belts, every component of the design speaks to its capacity to seamlessly integrate into large-scale industrial operations. The expansive layout hints at its adaptability to diverse manufacturing environments, promising unparalleled versatility in material handling tasks. Moreover, the robust construction and meticulous attention to detail underscore its resilience and durability, ensuring uninterrupted performance even in the most demanding production settings. In essence, your 3D model represents a remarkable fusion of cutting-edge mechatronic engineering and innovative design, poised to revolutionize material distinguishing processes in industrial applications.

5.2.2 Conveyor base fabrication



Fig:5.2: Fabrication of Base

Conveyor base fabrication (Fig:5.2) is a critical aspect of developing a robust material handling system, requiring meticulous attention to detail and expertise in engineering and fabrication techniques. At its core, this process involves the careful selection of materials, often high-quality metals like steel or aluminum, chosen for their durability, strength, and resistance to corrosion.

Precision welding techniques are employed to join these materials together, creating a sturdy framework that serves as the foundation for the entire conveyor system. Engineers work closely with fabricators to design the base, considering factors such as load capacity, operational environment, and compatibility with other system components.

During fabrication, advanced manufacturing processes such as laser cutting and CNC machining may be utilized to ensure accuracy and consistency in component production. Additionally, surface treatments such as painting or powder coating may be applied to enhance the base's resistance to wear and tear.

By prioritizing precision, durability, and quality, conveyor base fabrication sets the stage for a reliable and efficient material handling system. It lays the groundwork for smooth conveyor operation, enabling seamless movement of materials within industries.

5.2.3 Robot arm mount 3D model



Fig:5.3: 3D mount for arm

Utilizing 3D printing (Fig:5.3) for the fabrication of the mount to place a robotic arm on the conveyor offers several advantages that enhance the efficiency and effectiveness of the overall system.

Firstly, 3D printing enables the creation of complex geometries and intricate designs that may be challenging or impossible to achieve with traditional manufacturing methods. This flexibility in design allows engineers to optimize the mount's structure and functionality, ensuring optimal performance within the constraints of the conveyor system.

Moreover, the additive manufacturing process allows for the use of lightweight yet durable materials, such as thermoplastics or composite filaments. This not only reduces the weight of the mount itself but also minimizes material waste, making it a more environmentally friendly option compared to traditional machining processes.

Overall, 3D printing revolutionizes the fabrication process for mounting a robotic arm on a conveyor, offering unparalleled flexibility, customization, and efficiency. By harnessing the benefits of additive manufacturing, engineers can create mounts that are perfectly tailored to the specific requirements of the application, ultimately enhancing the performance and functionality of the mechatronic system.

5.2.4 Robotic Arm



Fig:5.4: Robotic Arm

In this project, the robotic arm (Fig:5.4) plays a pivotal role as a dynamic and adaptable component within the mechatronic system. Designed with versatility and precision in mind, the robotic arm serves as a multifunctional tool for handling a variety of materials with finesse and efficiency along the conveyor.

Its articulated joints and grippers enable a wide range of movements, allowing for precise picking, placing, and manipulation of items as they move along the conveyor belt. Whether it's sorting, stacking, or assembling components, the robotic arm offers unparalleled flexibility and control, enhancing the overall throughput and productivity of the system.

Equipped with advanced sensors and feedback mechanisms, the robotic arm operates with remarkable accuracy and reliability. These sensors provide real-time data on position, orientation, and environmental conditions, allowing the arm to adapt swiftly to changes in the workflow and ensure consistent performance.

In essence, the robotic arm in this project represents a cornerstone of modern material handling and distinguishing processes, and efficiency in the realm of mechatronics.

5.2.5 Program

```
#include <SoftwareSerial.h>

SoftwareSerial mySerial(9, 10); // RX, TX

unsigned char Send_Date[6] = {0XAA,0XAA,0XFE,0X01,0X00,0X53};

unsigned char buffer_RTT[100] = {};

uint8_t checksum = 0;

void setup() {

  Serial.begin(9600);

  mySerial.begin(115200);

  mySerial.write(Send_Date,6);

}

void loop() {

  while (mySerial.available() > 0)

  { if(mySerial.read() == 0XAA)

    { buffer_RTT[0]=0XAA;

      for(int i=1;i<8;i++)

        { buffer_RTT[i]=mySerial.read(); }

      checksum

      =(buffer_RTT[0]+buffer_RTT[1]+buffer_RTT[2]+buffer_RTT[3]+buffer_RTT[4]+buffer_RTT[5]+bu

      ffer_RTT[6])&0X00FF;

      if(buffer_RTT[7]== checksum)

        { Serial.println(buffer_RTT[4]);          //read data bit status}

    } } delay(5);}
```

Programming and coding are integral components of this project, providing the intelligence and control necessary to orchestrate the seamless operation of the mechatronic system.

Through programming, the behavior of the robotic arm, as well as the coordination of its movements with the conveyor system, can be finely tuned to optimize efficiency and accuracy in material handling tasks. This involves writing algorithms to control the arm's actuators, such as motors or pneumatic cylinders, ensuring precise positioning and manipulation of objects.

Additionally, coding is utilized to integrate sensors and feedback mechanisms into the system, enabling real-time monitoring of environmental conditions and object detection. By interpreting sensor data and implementing decision-making logic, the program can autonomously adjust the arm's movements in response to changing conditions, enhancing reliability and adaptability.

Furthermore, software development plays a crucial role in the interface between the mechatronic system and human operators or supervisory control systems. User interfaces, visualization tools, and communication protocols are developed to facilitate interaction and monitoring of the system's performance.

Moreover, advancements in programming languages and development frameworks enable the implementation of advanced functionalities, such as machine learning algorithms for object recognition or predictive maintenance capabilities. These technologies further enhance the intelligence and autonomy of the mechatronic system, paving the way for increased efficiency and productivity in industrial applications.

Overall, programming and coding are fundamental to the success of the project, enabling the realization of the mechatronic system's capabilities and ensuring its seamless integration into industrial workflows.

5.2.6 Frequency Graph

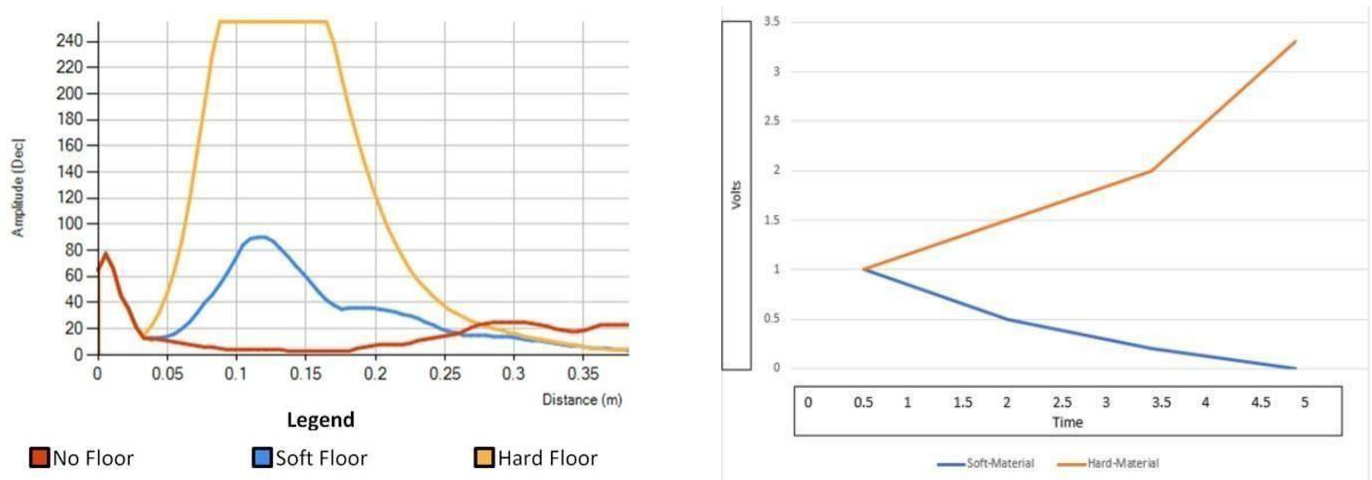


Fig:5.5: Frequency Graph

The frequency graph generated by the material-detecting ultrasonic sensor (Fig:5.5) provides valuable insights into the acoustic properties of detected materials. This graph visually represents the unique frequency signatures produced by different materials as they interact with the ultrasonic sensor.

By analyzing the frequency graph, operators can distinguish between various materials based on their acoustic characteristics. Hard surfaces typically exhibit sharper, more defined frequency peaks, while softer materials may produce smoother, more attenuated responses. These distinctive frequency patterns enable precise material identification and classification in real-time.

Moreover, changes in the frequency graph over time can indicate variations in material composition, density, or surface texture. This information is essential for quality control, sorting, or process optimization purposes, allowing for efficient and accurate material handling operations.

Additionally, the frequency graph serves as a valuable diagnostic tool for troubleshooting and system optimization. Anomalies or deviations from expected frequency patterns may indicate issues such as material contamination, environmental factors affecting sensor performance.

Overall, the frequency graph generated by the material-detecting ultrasonic sensor enhances the intelligence and functionality of the mechatronic system, enabling precise and reliable material detection and classification in industrial applications.

5.2.7 Project Working

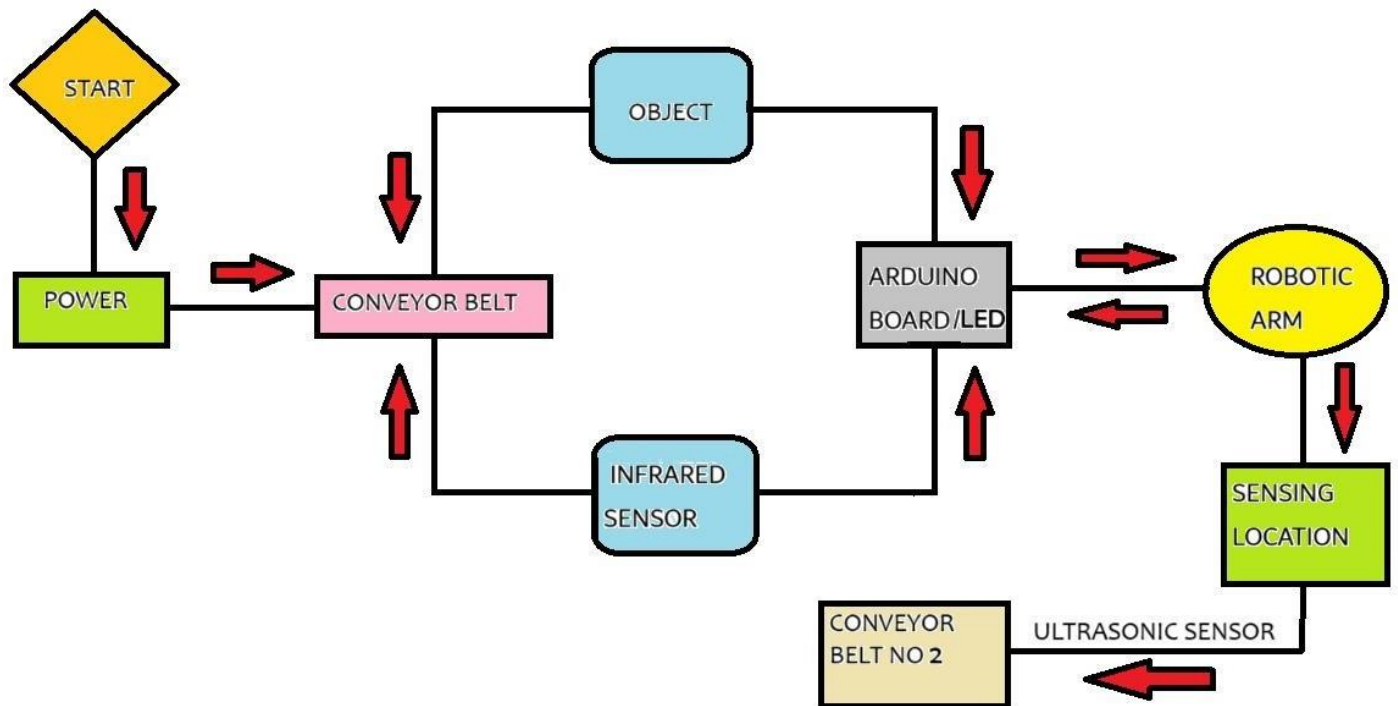


Fig:5.6: Project Working

The working methodology (Fig:5.6) of this project follows a structured approach, involving planning, design, fabrication, integration, testing, deployment, and maintenance. Each phase is crucial for ensuring the successful operation of the conveyor system with the robotic arm and ultrasonic sensors. It begins with planning and design to outline system requirements and layout, followed by fabrication of mechanical components and integration of electrical systems. Software development then enables control and coordination of system functions. Testing and validation ensure functionality and performance, leading to deployment and implementation. Continuous monitoring and maintenance sustain long-term reliability and efficiency.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

A mechatronics material handling system is designed with integrated sensors and an Arduino Uno for automated object sorting. An ultrasonic sensor is employed to distinguish between hard and soft surfaces based on distance. Further object classification is carried out using a load cell to determine the weight. Depending on the combined input from the ultrasonic sensor and load cell, the Arduino Uno controls the robot's actions. Objects are then sorted and placed onto different locations on a conveyor belt. This system offers an efficient and automated solution for sorting objects based on their material characteristics and weight.

6.2 CONCLUSION

In this project, we have successfully designed mechatronics material handling system integrated with advanced sensors and an Arduino Uno for the purpose of automated object sorting. The utilization of an ultrasonic sensor allows for the discrimination between hard and soft surfaces based on distance, while a load cell is employed for accurate weight determination. The Arduino Uno acts as the control unit, processing data from both sensors and directing the robot's actions accordingly. The end result is an automated system that efficiently sorts objects and deposits them into various locations on a conveyor belt. This system represents a highly effective and automated solution for object sorting, taking into account both material characteristics and weight. By combining the capabilities of these sensors and the Arduino microcontroller, we have achieved a versatile and precise sorting mechanism that has the potential to significantly enhance the efficiency of material handling processes in various industrial settings.

REFERENCES

- [1]. Shridevi A Mali; G Sravanthi; Siva Subba Rao P; Raja S; Sushma S J; A R Reddy(2018). "Detection Range of Ultrasonic Sensor for Different Colors", ISSN: 2278-0181 ,DOI : 10.17577/IJERTCONV5IS21022.
- [2]. Damir Markucic (2000). "Possibilities of Material Classification by Means of Ultrasound"
- [3]. Bo Zhu; Tao Geng; Gedong Jiang; Zheng Guan; Yang Li; Xialun Yun(2023). "Surrounding Object Material Detection and Identification Method for Robots Based on Ultrasonic Echo Signals",ISSN: 1998-218, DOI: 10.1155/2023/1998218.
- [4]. Ivan Muller; Renato Machado de Brito; Carlos Eduardo Pereira; Valner Brusamarello (2010). "Load cells in force sensing analysis -- theory and a novel application", ISSN: 1114-8035 DOI: 10.1109/MIM.2010.5399212.
- [5]. Vijay A. Kamble; Vasudev D. Shinde; Jayant K. Kittur (2020). "Overview of Load Cells", ISSN: 2581-3722.
- [6]. Dharmannagari Vinay Kumar Reddy (2014). "Sorting Of Objects Based On Colour By Pick And Place Robotic Arm And With Conveyor Belt Arrangement", ISSN 2278 – 0149.
- [7]. Harish K; Megha D; Shuklambari M; Amit K; Chaitanya K Jambotkar (2017). "Pick and Place Robotic Arm Using Arduino", ISSN: 2278 -7798.
- [8]. Ranjeet Kumar; Sandeep Chhabra; Ajay Singh Verma; Anurag Gupta (2018), "Analysis of load cell", ISSN 0973-4562.
- [9]. Omar Sabah Al-Dahiree; Mohammad Osman Tokhi; Nabil Hassan Hadi; Nassar Rasheid Hmoad; Raja Ariffin Raja Ghazilla; Hwa Jen Yap; Emad Abdullah Albaadani (2022), "Design and Shape Optimization of Strain Gauge Load Cell for Axial Force Measurement for Test Benches" , DOI:10.3390/s22197508.
- [10]. Fredy Raptopoulos; Maria Koskinopoulou; Michail Maniadakis (2020). "Robotic Pick-and-TossFacilitates Urban Waste Sorting", IEEE 16th International Conference on Automation Science and Engineering (CASE), ISBN:978-1-7281-6905-7, DOI: 10.1109/CASE48305.2020.9216746

[11]. Dal-Ho Kim; Sang-Ryong Lee; Choon-Young Lee (2006). "Material Classification Using Reflected Signal of Ultrasonic Sensor" DOI:[10.5302/J.ICROS.2006.12.6.580](https://doi.org/10.5302/J.ICROS.2006.12.6.580).