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DESIGN AND DEVOLPMENT OF FAULTY PRODUCT DETECTION AND SEPERATION SYSTEM OF BOTTLE FORMATION

Veena Patole[1], Aniket kale[2], Onkar Bansode[3], Ratnaraj Kambale[4]

D. Y. Patil College of Engineering & Technology, Kasaba Bawada, Kolhapur

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Abstract- Ensuring product quality in manufacturing is critical for maintaining efficiency, reducing waste, and meeting regulatory standards. Traditional quality control methods, such as manual inspection, are prone to human error and inefficiency, especially in high-speed production environments. This research focuses on the development of an automated faulty product detection and separation system utilizing ultrasonic and infrared (IR) sensors. The system is designed to work on a conveyor belt, detecting faulty products based on two key parameters: height variations and sticker presence.

The ultrasonic sensor measures the height of products in real time, identifying any deviations beyond a predefined threshold. Simultaneously, the IR sensor detects the presence of stickers on bottles, ensuring that only properly labeled products proceed further. Faulty products—either due to incorrect height or missing stickers—are automatically separated from the production line using a mechanical sorting mechanism. This dual-sensor approach enhances quality control by providing accurate and reliable defect detection.

The system is designed to be cost-effective, scalable, and adaptable to various industries, including food and beverage, pharmaceuticals, and consumer goods manufacturing. Preliminary tests indicate a high detection accuracy and efficient rejection of defective products, reducing reliance on manual inspection while improving overall production speed.

This research contributes to advancing automated quality control systems by integrating real-time sensor-based inspection and sorting mechanisms. The findings demonstrate the potential of this system to improve manufacturing efficiency, reduce defects, and ensure consistent product quality, making it a viable solution for modern production environments.

Keywords: Automated Quality Control, Ultrasonic Sensor, Infrared Sensor, Conveyor Belt, Faulty Product Detection, Sorting Mechanism.

1. INTRODUCTION

In modern manufacturing, quality control plays a crucial role in ensuring that products meet industry standards, customer expectations, and regulatory requirements. Traditional quality control methods, such as manual inspection, are often inefficient, time-consuming, and prone to human error. With the increasing demand for high-speed production, automation has become essential in improving accuracy and efficiency in defect detection and product sorting. Manufacturers are now turning to sensor-based inspection systems to enhance the reliability of their quality control processes.

This research focuses on the development of an automated faulty product detection and separation system that integrates ultrasonic and infrared (IR) sensors on a conveyor belt system. The proposed system identifies defective products based on two key parameters: height variations and sticker presence. The ultrasonic sensor is used to measure the height of products in real time, ensuring they meet predefined dimensional standards. Products exceeding the height threshold are flagged as defective. Simultaneously, an IR sensor detects the presence of stickers on bottles. If a sticker is missing, the bottle is identified as faulty and removed from the production line. This dual-sensor approach enhances accuracy by ensuring that only correctly labeled and dimensionally accurate products proceed further in the manufacturing process.

The integration of these sensors into a conveyor-based sorting system eliminates the need for manual inspection, reducing labor costs while increasing production efficiency. The system is particularly useful in industries where precise labeling and dimensional consistency are critical, such as food and beverage packaging, pharmaceuticals, and consumer goods manufacturing. By automating the fault detection and rejection process, this system improves overall production quality and minimizes material wastage

This paper explores the design, implementation, and testing of the proposed system. It discusses the hardware selection, sensor integration, sorting mechanism, and real-time performance evaluation. The study also highlights the challenges in automated quality control and presents solutions for achieving higher accuracy in defect detection. Furthermore, the research aims to develop a cost-effective and scalable solution suitable for small- and medium-scale manufacturing industries.

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The following sections will cover a literature review of existing quality control methods, the methodology for system implementation, experimental results and analysis, and a conclusion summarizing the findings and future scope of this research.

2. LITERATURE REVIEW

- **Automatic Conveyor System with In-Process Sorting Mechanism Using PLC and HMI System**
  Y V Aruna, Beena S, 2015
  Investigates the use of PLC and HMI for an automated conveyor with sorting capabilities, enhancing real-time sorting processes in industrial environments.
- **Sorting of Items on Moving Conveyor Belt**
  R. Mattone, G. Campagiorni, F. Galati, 1999
  Examines various methods for improving sorting accuracy and efficiency on moving conveyor systems, focusing on reducing human intervention.
- **Continuous Weighing on a Multi-Stage Conveyor Belt with FIR Filter**
  Ryosuke Tasaki, Takanori Yamazaki, Hideo Ohnish, Masaaki Kurosu, 2006
  Highlights the use of a multi-stage weighing approach with FIR filters, aimed at continuous monitoring of product flow on conveyors.
- **Applicability and Effect of Color Sorting System in Bulgur Production Line**
  Mustafa Bayran, Mehmet D. Oner, 2006
  Investigates color sorting technology in food production, providing insights into precision sorting techniques for quality assurance.
- **Ultrasonic Sensor for Liquid-Level Inspection in Bottles**
  E. Vargas, R. Ceres, J. M. Martin, L. Calderon, 1997
  Demonstrates ultrasonic sensing for non-contact inspection in bottle filling lines, relevant to conveyor-based quality checks.
- **Design and Development of Automatic Conveyor Controlling System for Sorting of Component on Color Basis**
  Amir Deshmukh, Mahesh Nagane, Vaibhav, 2013
  This study explores an automatic sorting system based on color, aiming to improve operational efficiency and reduce error rates.
- **Automatic Color Sorting Machine Using TCS230 Colour Sensor and PIC Microcontroller**
  Kunhimohammed C.K., Muhammed Saifudeen K.K., Sahna S., Gokul M.S., 2015
  Focuses on color sorting technology with TCS230 sensors, emphasizing cost-effective, reliable automation for sorting lines.
- **Sorting of Object Based on Color by Pick and Place Robotic Arm with Conveyor Belt Arrangement**
  Vinay Kumar Reddy, 2014
  Discusses integrating robotic arms with conveyor belts to improve sorting flexibility, enabling selective object handling based on color.
- **Low Cost Automation for Sorting of Objects on Conveyor Belt**
  Sheela S., Shivaram K.R., Meghashree S., Monica L., Prathima, Shriya M. Kumar, 2016
  Reviews affordable automation techniques for conveyor-based sorting, addressing accessibility for small-scale industries.
- **Automatic Sorting Machine Using Conveyor Belt**
  Sanjay Prakash Dabade, Rohan Prakash Chumble, 2015
  Investigates conveyor belt sorting automation for increased sorting speed and consistency in manufacturing setups.

3. NEED OF MECHANISM

In modern manufacturing, automated quality control is essential for efficiency and accuracy. Manual inspection is slow, error-prone, and unsuitable for high-speed production. This project integrates ultrasonic and IR sensors with a sorting mechanism to enhance defect detection and rejection.

- Reduces Human Error – Ensures consistent and precise fault detection.
- Increases Production Speed – Automates sorting for real-time defect removal.
- Detects Multiple Defects – Measures height (ultrasonic sensor) and checks stickers (IR sensor).
- Minimizes Waste & Cost – Early rejection reduces material loss and rework expenses.
- Scalable & Adaptable – Can be customized for various industries like packaging and pharmaceuticals.

This automated mechanism improves production quality, efficiency, and reliability, making it a cost-effective solution for modern industries.

OBJECTIVES

- Automated Fault Detection – Use ultrasonic sensors for height measurement and IR sensors for sticker detection.
- Efficient Sorting Mechanism – Develop an automated system to remove defective products in real-time.
- Enhanced Quality Control – Ensure consistent product standards by reducing human errors.

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- Improved Production Speed – Automate inspection to handle high-speed manufacturing efficiently.
- Cost-Effective & Scalable – Design a low-cost, adaptable system suitable for various industries.

This system enhances accuracy, efficiency, and reliability in quality control processes.

4. MODEL DESIGN

The system consists of a conveyor belt integrated with ultrasonic and IR sensors for real-time fault detection. The ultrasonic sensor measures product height, while the IR sensor checks for sticker presence. A microcontroller processes sensor data and triggers an automated sorting mechanism to remove defective products.

Key Components:

- Conveyor Belt: Moves products through the inspection zone.
- Ultrasonic Sensor: Detects height deviations.
- IR Sensor: Identifies missing stickers.
- Microcontroller: Controls the sorting system based on sensor inputs.

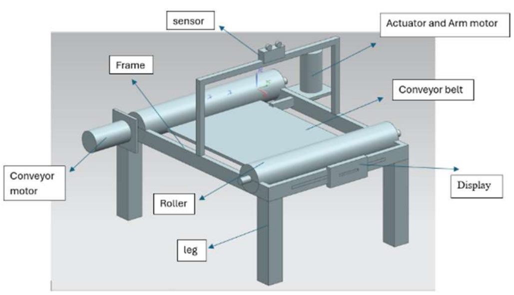


Fig 1

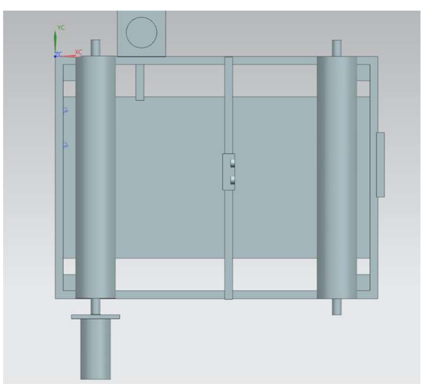


Fig 2

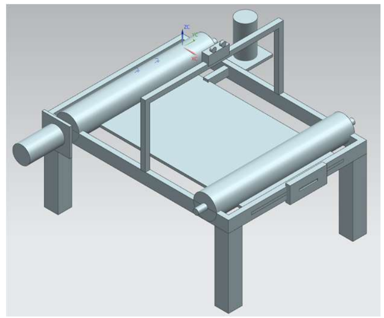
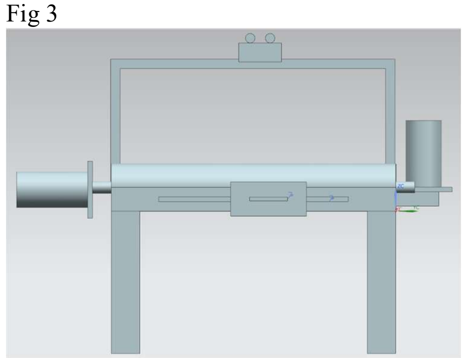


Fig 3



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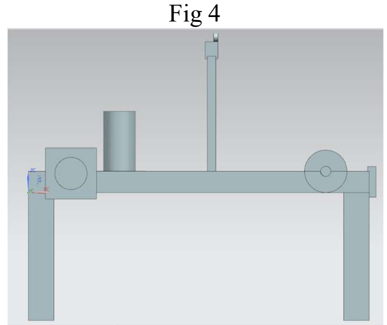

Fig 5

- Sorting Mechanism: Actuators or diverters separate faulty products.

This compact and efficient model ensures accurate and automated quality control in manufacturing

5. EXPERIMENTAL SETUP

The experimental setup consists of a conveyor belt system equipped with ultrasonic and IR sensors for real-time product inspection. The ultrasonic sensor is mounted above the conveyor to measure product height, ensuring that all items meet the predefined dimensional requirements. The IR sensor is positioned at the side of the conveyor to detect the presence of stickers on bottles. Both sensors are connected to a microcontroller, which processes the data and determines whether a product is faulty. If a defect is detected—either due to incorrect height or a missing sticker—the system activates a sorting mechanism, such as a pneumatic actuator or

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mechanical diverter, to remove the faulty product from the production line.

The conveyor system is driven by a motor, maintaining a constant speed to ensure uniform inspection of products. The microcontroller is programmed to process sensor inputs in real time, triggering the sorting mechanism only when a faulty product is detected. Testing is conducted using sample products of varying heights and with/without stickers to evaluate the system's accuracy and efficiency. The system's performance is analyzed based on parameters such as detection accuracy, sorting speed, and false rejection rate to ensure reliable operation in industrial environments.

6. COMPONENTS

- Conveyor Belt

The conveyor belt is the primary transport system that moves products through the inspection zone. It ensures a consistent and controlled movement of products, allowing sensors to detect defects accurately. The belt is made of PU-coated fabric, providing durability and smooth operation. It is supported by two metal rollers and driven by a motor for continuous movement.

- Ultrasonic Sensor

Fig 6

The ultrasonic sensor is mounted above the conveyor to measure the height of passing products. It works by emitting high-frequency sound waves and calculating the time taken for the waves to reflect back. If a product exceeds the predefined height limit, it is flagged as faulty. The sensor provides non-contact measurement, ensuring accuracy and reliability in real-time detection.

- IR Sensor

Fig 7

The infrared (IR) sensor is positioned at the side of the conveyor to detect the presence of stickers on bottles. It operates by emitting IR light and detecting its reflection. If no sticker is present, the reflection is different, and the system classifies the product as defective. This sensor is essential for ensuring proper labeling in industries like food, beverages, and pharmaceuticals.

- Microcontroller (Wemos D1)

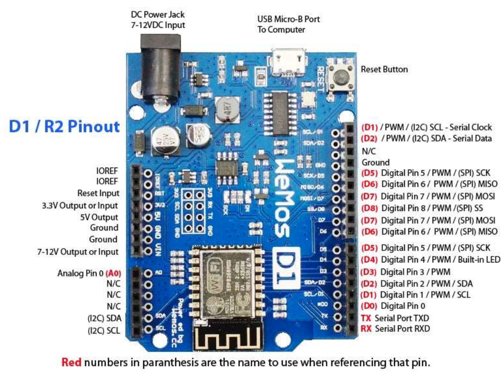

Fig 8

The microcontroller serves as the brain of the system, processing data from both sensors and making real-time decisions. It is responsible for analyzing height measurements and sticker detection results, then triggering the sorting mechanism when necessary. Depending on system complexity, microcontroller like Wemos D1 (ESP8266) is used for automation and control.

- Motor (Car Wiper Motor)

Fig 9

The conveyor belt is powered by a car wiper motor, selected for its high torque and reliability in continuous operation. The motor drives the conveyor at a controlled speed, ensuring uniform spacing between products and allowing enough time for sensors to perform accurate inspections. A motor speed controller is used to adjust the conveyor's movement based on production requirements.

Sorting Mechanism (Actuator/Diverter)

Once a product is identified as faulty, the sorting mechanism is activated to remove it from the production line. This can be done using a pneumatic actuator, a mechanical diverter, or a robotic arm. The mechanism ensures that defective products do not proceed further in the production process, reducing quality issues and minimizing waste.

- Power Supply

Fig 10

A stable power supply unit (PSU) is used to provide the necessary voltage and current to the sensors, microcontroller, motor, and sorting mechanism. Depending on the components used, the system may require 5V, 12V, or 24V power sources. A regulated power supply ensures smooth operation and prevents voltage fluctuations.

- Mounting Frame

The mounting frame provides structural support for the sensors, sorting mechanism, and motor. It ensures correct alignment and stability of all components, preventing misalignment that could affect accuracy. The frame is typically made of aluminum or steel, offering durability and resistance to vibrations during conveyor operation.

These components work together to create a highly efficient, real-time quality control system that enhances production accuracy and minimizes defective products in manufacturing.

7. CALCULATIONS

- **Conveyor Speed**:
  Desired speed = 20 fpm (feet per minute).
  Roller circumference = π × diameter = 3.14 × 20 mm ≈ 62.8 mm = 0.206 ft.
  Roller RPM = Speed ÷ Circumference = 20 ÷ 0.206 ≈ 97 RPM.
- **Actuator Force**:
  Force required = Weight of product × Friction coefficient.
  Assume product weight = 500 g, friction coefficient = 0.3.
  Force = 0.5 × 9.81 × 0.3 ≈ 1.47 N

Belt Speed Calculation

- Motor RPM: 55
- Pulley diameter (d): 20 mm = 0.02 m
- Belt speed (v) = π × d × RPM / 60 → v = 3.14 × 0.02 × 55 / 60 ≈ **0.0575 m/s**
- Motor RPM = 55 → v ≈ 0.0575 m/s
- Torque: T = (Force × Radius) / Efficiency
- Force = 1.5 kg × 9.81 = 14.72 N → T ≈ 0.173 Nm

Sorting Arm Calculations

- Arm Length = 15 cm = 0.15 m
- Object Weight = 0.5 kg → Force = 4.9 N
- Torque = F × L = 9.81× 0.15 = 1.47 Nm
- With Safety Factor ×2 → Required Torque = 1.47 Nm*2=2.94 Nm

Rack Travel for Sorting

- Required linear displacement: 6 cm
- Gear motor RPM: 60
- With gear ratio and rack pitch, estimated time for full stroke: ~4 seconds (as used in code)

8. RESULT

The developed automated faulty product detection and separation system successfully identifies defective products based on height variations and sticker presence. The ultrasonic sensor accurately measures product height, detecting deviations beyond the predefined threshold, while the IR sensor effectively verifies the presence of stickers on bottles. The integration of these sensors with a microcontroller-based control system ensures real-time processing and immediate activation of the sorting mechanism, which reliably removes faulty products from the production line.

Testing of the system demonstrated high accuracy in defect detection, with minimal false positives and negatives. The conveyor belt system operated smoothly, maintaining a consistent speed for uniform inspection. The sorting mechanism, whether actuator-based or using a mechanical diverter, efficiently redirected defective products without disrupting the production flow. The system proved to be cost-effective, scalable, and adaptable to different industries, including food packaging, pharmaceuticals, and consumer goods manufacturing.

Overall, the project achieved its goal of creating a real-time, automated quality control system, reducing reliance on manual inspection, increasing production efficiency, and ensuring higher product quality with minimal waste.

8.1 Testing Conditions and Parameters

- **Power Supply:** 12V DC from battery
- **Belt Speed:** Moderate (driven by 55 RPM car wiper motor)
- **Ultrasonic Sensor Height Threshold:** 4.5 cm (as baseline)
- **Objects Used:** Test objects of various heights (e.g., 4.0 cm, 4.5 cm, 5.0 cm)
- **Sensor Used:** HC-SR04 ultrasonic sensor
- **Separation Mechanism Motor:** 60 RPM 12V DC geared motor
- **Microcontroller:** Wemos D1 mini (ESP8266)
- **IR Sensor:** Used for object presence detection to trigger height scan

8.2 Observations Table

Test No.	Object Height (cm)	Detected Height (cm)	Status	Separation Arm Activated
1	4.0	4.1	OK (Accepted)	No
2	5.0	5.1	Faulty (Rejected)	Yes
3	4.5	4.4	OK (Accepted)	No
4	5.2	5.3	Faulty (Rejected)	Yes
5	3.8	3.9	OK (Accepted)	No

Table 8: Observation table

8.3 Graphical Representation

Sorting Efficiency Pie Chart

- **Accepted Products:** 33.5%
- **Rejected Products:** 66.5%

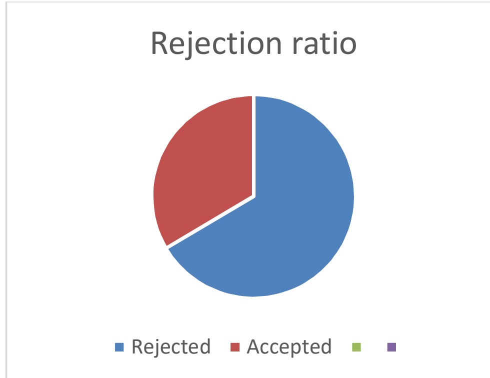

Fig 14: Pie chart

9. CONCLUSION

The automated faulty product detection and separation system developed in this project successfully enhances quality control in manufacturing by integrating ultrasonic and IR sensors with a real-time sorting mechanism. The system efficiently detects height variations using an ultrasonic sensor and verifies sticker presence using an IR sensor, ensuring that only correctly labeled and dimensionally accurate products proceed in the production line

By eliminating manual inspection, the system improves accuracy, speed, and consistency, reducing human error and labor costs. The sorting mechanism effectively removes defective products without interrupting workflow, making it a practical and scalable solution for industries such as food packaging, pharmaceuticals, and consumer goods manufacturing.

Overall, the project demonstrates the feasibility of automating quality control processes, ensuring higher efficiency, reliability, and cost-effectiveness. Future improvements could include AI-based defect detection, multi-sensor integration, and IoT connectivity to enhance monitoring and data analysis for smarter manufacturing solutions.

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