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Measuring Pipe Thickness with Ultrasonic Thickness Gauging Machine Using Robotic Arm

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Abstract-Measuring pipe thickness is crucial for industrial maintenance and safety. This Project presents a robotic system that uses UTG (ultrasonic thickness gauging) machine to measure pipe thickness. This system consists of a robotic arm mounted on a Remote-controlled car which is manually controlled to the required position. The UTG (ultrasonic thickness gauging) machine emits high frequency sound waves and the time delay is calculated as thickness and a camera is fixed and it tilts to see and note the values and also to observe the way. The data can be analysed to detect the corrosion, erosion (gradual degradation), or any defects in pipelines. This project minimizes human interaction in intricate areas, improves accuracy and offers a cost-effective approach to industrial pipeline inspection.

Keywords - Ultrasonic Thickness Gauging, Robotic System, Pipe Thickness Measurement, Industrial Maintenance, Corrosion, Erosion Detection Pipeline Defect Analysis, Intricate Area Accessibility**.**

1.INTRODUCTION

Pipelines are an essential part of various industries, including oil & gas, manufacturing, and water distribution. Over time, factors such as corrosion, erosion, high-pressure flow, and environmental conditions degrade the pipe walls, leading to a reduction in thickness. If not monitored effectively, thinning pipes can result in leaks, structural failures, costly downtime, and environmental hazards.

Conventional pipeline inspection methods involve manual ultrasonic thickness gauging (UTG), where technicians use handheld devices to measure pipe thickness at selected locations. However, these methods are time-consuming, labour-intensive, and pose safety risks, especially in hazardous environments like chemical plants, underground tunnels, and confined spaces.

To address these challenges, this project proposes a robotic system equipped with ultrasonic sensors, a robotic arm. The system will efficiently navigate complex and low-clearance areas to measure pipe thickness remotely, reducing human intervention and improving accuracy in pipeline inspections.

2. BODY OF PAPER

The prototype developed for this project is a wireless, camera-equipped robotic car integrated with a 2-DOF robotic arm and an Ultrasonic Thickness Gauging (UTG) machine. It is designed to remotely measure pipe thickness in complex environments like culverts and low-clearance industrial areas.

Fig-1

2.1. MANUFACTURING

The robotic arm was first modelled using CAD software, and the parts were fabricated using 3D printing with PLA material. All electronic components, including the microcontroller, motor drivers, servos, and sensors, were tested individually before being integrated onto the baseboard. The components were securely mounted and interconnected using jumper wires and soldering to ensure stable operation. Once assembled, the system was programmed and calibrated for synchronized motion of the robotic arm and accurate functioning of the ultrasonic thickness gauge. Additionally, the camera feed from the ESP32-CAM and Bluetooth-based control system were tested and successfully validated to ensure smooth remote operation.

MECHANICAL STRUCTURE:

- **Base Platform**: A flat wooden or MDF board used as the chassis to mount all electronic and mechanical components.
- **Wheels & Motors**: Four wheels powered by BO (Battery Operated) motors, providing mobility on flat and semi-rough surfaces.
- **Robotic Arm**: Made using PLA plastic, 3D printed, providing two degrees of freedom (X and Y axes). Controlled via servo motors (SG90 and MG995).

- **UTG Mount**: The Ultrasonic Thickness Gauge sensor is securely mounted on the robotic arm for stable contact with the pipe surface during measurements

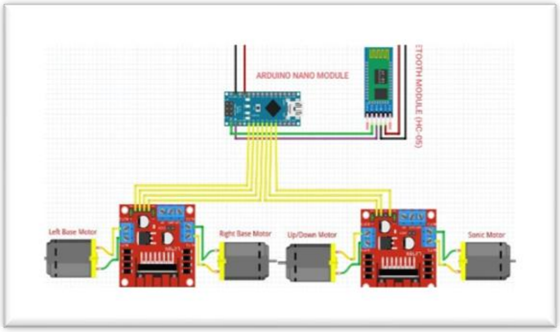

Fig 2

ELECTRONIC COMPONENTS

A) HC-05 BLUETOOTH MODULE

- Enables wireless communication between the robot and a mobile device or PC.
- Used for manual remote control of the robot.

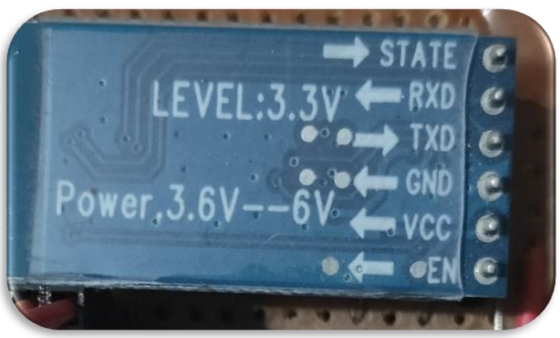

Fig.3 Hc-05 Bluetooth module

B) ARDUINO NANO MODULE

- Acts as the main microcontroller unit.
- Controls motors, servos, and reads sensor data
- Compact and ideal for embedded systems.

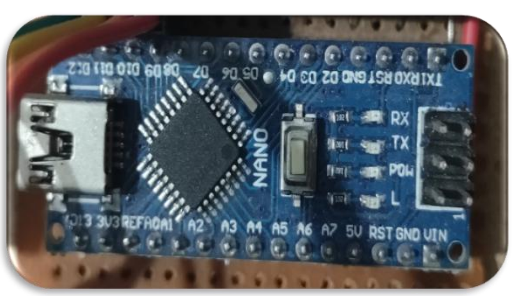

Fig.4 Arduino nano module

C) L298N MOTOR DRIVER MODULE

- Drives the BO motors using external power supply.
- Supports forward and reverse motion.
- Controlled via digital pins from the Arduino.

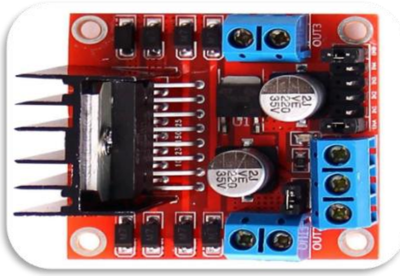

Fig.5 L298n motor driver module

D) LI-ION BATTERY

- Provides portable power to the entire system.
- Rechargeable and lightweight.
- Powers both logic and motor circuits.

Fig.6 Li-ion battery

E) JUMPER WIRES

- Connect various modules and components to each other.
- Enable easy prototyping without soldering.
- Used for both power and data lines.

Fig.7 Jumper wires

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F) LM2596 DC STEP-DOWN BUCK CONVERTER

- Regulates voltage from the Li-ion battery to 5V.
- Prevents damage to sensitive components.
- Ensures stable operation of microcontroller and peripherals.

Fig.8 Lm2596 dc step-down buck converter

G) ESP-32 CAMERA MODULE

- Provides real-time video streaming.
- Helps in navigation and remote monitoring.
- Has onboard Wi-Fi for wireless communication.

Fig.9 Esp-32 camera module

H) BO MOTORS WITH BO WHEELS

- Provides mobility to the robotic platform.
- Lightweight and low-power motors ideal for prototypes.
- Allows forward, reverse, and turning movements.

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Fig.10 Bo motors with boo wheels

I) SERVO MOTOR (SG90)

- Controls lightweight parts of the robotic arm.
- Provides precise angular movement (0° to 180°).
- Operates on 5V with low current draw.

Fig.11 Servo motor (sg90)

J) SERVO MOTOR (MG995)

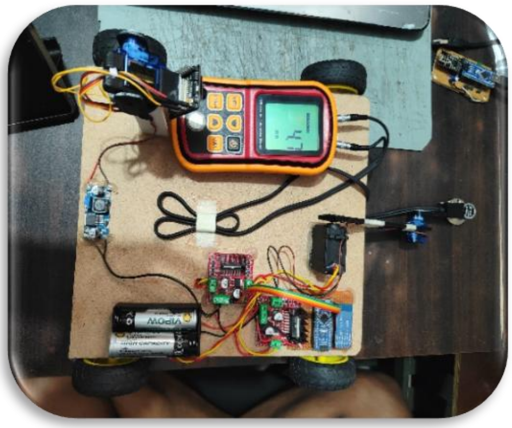
- Handles heavier movements in the robotic arm.
- Higher torque compared to SG90.
- Suitable for lifting the UTG sensor securely.

Fig.12 Servo motor (mg995)

CONCLUSION

The developed system effectively inspects and measures pipe thickness in confined and hazardous environments. By combining mechanical design (robotic arm), electronics (UTG, wireless control), and software (camera interface, remote operation), the prototype proves to be a cost-effective, portable, and modular solution for industrial pipe inspection.

The 3D-printed arm using PLA material maintained structural integrity during testing and showed the viability of low-cost manufacturing methods.



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