Thickness Measurement Inspection Robot

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Problem Statement

The Oil and gas and Water industries encounter a pressing challenge in optimizing thickness measurement methods for tanks, pipes, and vessels, seeking to minimize time, cost, human involvement, and enhance measurement accuracy and quality.

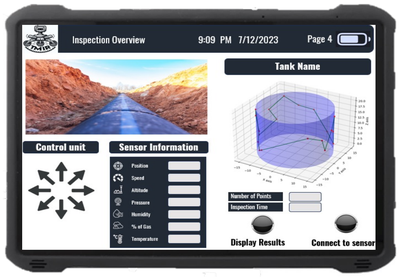
Constraints

Constraint	Value
Battery Lifetime	<2hrs
Connection Range	>50 meters
Weight	<15 Kg
Operating Temperature	<80°C

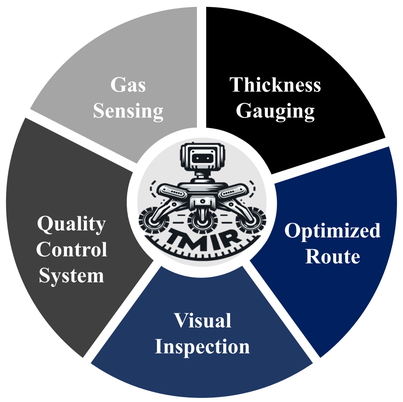
Specifications

Specification	Target Value
Reading time	5 seconds
Movement angle	All directions
Adhesive Force	500 N
Speed of movement	10 m/min
Battery lifetime	2 hours
Number of tasks w/o human intervention	3
Range of connection	50 meters
Inspect both flat and curved surfaces (tanks and pipes)	At least 8 inch

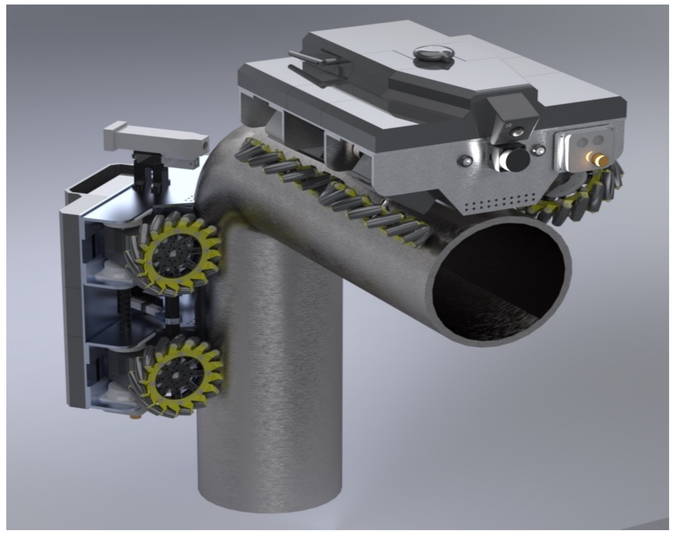
User Interface



Main Features

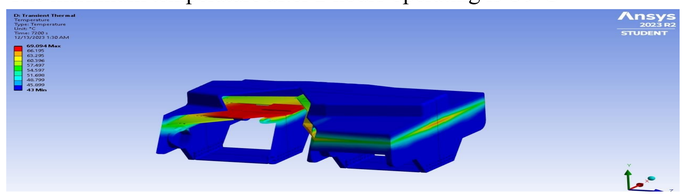


3D Model

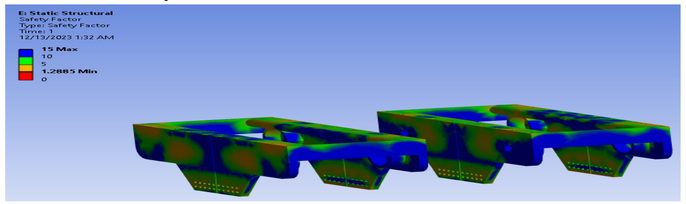


Finite Element Analysis

The maximum temperature after 2 hours operating **is 69°C**



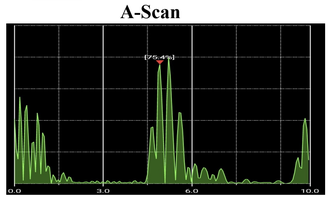
The factor of safety is **1.28** which is the desired



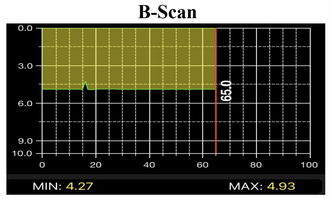
Ultrasonic Testing

Specification	Value
Measurement Range	0.8 to 50 mm
Measurment Accuracy	<± (0.005X + 0.1) mm
Weight	50 g
Operating Temperature Range	from -30 to +50 °C
Battery	built-in LiPol rechargeable

A-Scan



B-Scan



Robot Route Optimization

Purpose

Our purpose in optimizing the robot route on large tanks is to solve the navigation problem frequently encountered in the industry to reduce the total inspection time

Parameters

v = Robot velocity equal to 9 m/min
RT = Reading time equal to 5 seconds
N = Number of inspected points
R = Tank radius
H = Tank height

Decision Variables

$$x_{ij} = \begin{cases} 1, if\ point\ j\ is\ reached\ by\ point\ i \\ 0, \quad Otherwise \end{cases}$$

Objective Function

$$\text{Min } \frac{1}{v}\left(\sum_{i=1}^{n}\sum_{j=1}^{n} D_{ij}x_{ij}\right) + RT * N$$

Auxiliary Variables

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}$$

Constraints

$$\sum_{\substack{i=1 \\ i\neq j}}^{n} x_{ij} = 1 \qquad \forall j = 1, \dots, n$$

$$\sum_{\substack{j=1 \\ j\neq i}}^{n} x_{ij} = 1 \qquad \forall i = 1, \dots, n$$

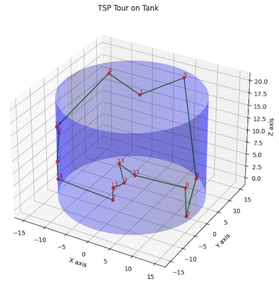
$$u_i + 1 \leq u_j + M(1 - x_{ij}) \quad \forall i, j = 2, \dots, n, \quad i \neq j$$

$$x_{ii} = 0 \qquad \forall i = 1, \dots, n$$

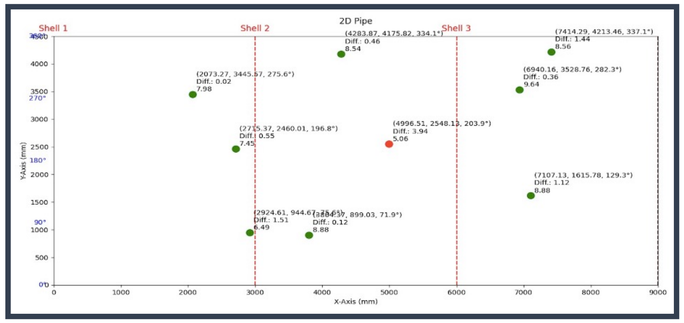
$$x_{ij} \in \{0,1\}\ \forall i = 1, \dots, n, \quad \forall j = 1, \dots, n \quad i \neq j$$

$$u_i \geq 0 \qquad \forall i = 2, \dots, n$$

Optimal Tour



Quality Control Procedure



No Action Required **Monitor** **Action Required**

(x, y, degree)
Diff : (Old reading – New reading)
Thickness Reading

Status of the Reading:
Diff > Allowance factor, **Light Red**
Diff < Allowance factor, **Light Green**
Diff = Allowance factor, **Light Yellow**

Quality Thickness Measurement Report

Equipment Overview:

1. **WASTE WATER**
2. **API 620 Pipe**
   - Construction Standard: API 620 ELEVENTH EDITION, ADDENDUM
   - Operation Parameters:
     - Internal Pressure: 0.38 Barg.
     - Temperature: 45 °C.
     - Service: WASTE WATER.
   - Design Parameters:
     - Internal Pressure: 0.7 Bar.
     - Temperature: 82 °C.
   - Post Weld Heat Treatment (PWHT)
3. **Shell Material of Construction**
   - A516-70 with a thickness of 8 mm.
   - Internal Coating: INTERLINE 984

Analysis for Shell1 8mm:

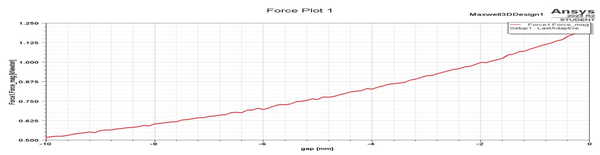
- Reading (X, Y, Degree, Thickness): Action Required
- Reading (X, Y, Degree, Thickness): No Action Required
- [More items follow...]

References:

- API 653
- API 650
- NBIC (Part 3)
- ASME BPVC Sec (II, V)
- ASME PCC-2 Article 2.11

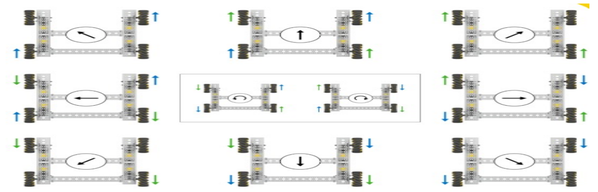
Validation

TMIR can provide up to 500N of pulling force using rare earth permanent magnets



TMIR can operate up to 2 hours by using LIPO Battery that has the capacity of (30Ah)

TMIR manoeuvres in 10 directions by using Mecanum wheels type and inspect on surfaces until 8" curvature by implementing Linear Actuators



The raspberry pi has 4 USB inputs, through this we can include a USB Dongle (USB Wi-Fi antenna) to exceed the range of 50 meters

By fixing the optimized total distance of visiting all points, optimizing the robot's velocity will lead to a reduction in inspection time

Velocity (m/min)	6	7	8	9*	10	11	12
Distance (m)	157	157	157	157	157	157	157
Time (min)	28	24	21	19	17	16	14
Reduction (%) in Time	46%	26%	11%	0%	-9%	-16%	-23%

Conclusion

Using TMIR, substantial improvements have been made to existing industry technology. By optimizing the velocity and route of the robot used for inspections and simplifying quality control procedures, a remarkable time reduction of over 16% compared to competitors has been achieved. Additionally, TMIR offers the flexibility of utilizing multiple sensors based on specific requirements, making the inspection process more adaptable and efficient. These enhancements make TMIR a game-changer in the industry, significantly improving inspection procedures.

Future Work

1. Surface crack detection using AI techniques
2. Fully automated inspection activities
3. Optimize robot route using AI techniques
4. Increase robot operating time