iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** IV **Month of publication:** April 2018

DOI: http://doi.org/10.22214/ijraset.2018.4727

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue IV, April 2018- Available at www.ijraset.com

Wall Climbing Device for Inspection of Large Metallic Surfaces

Naeem N Bate [1], Rajat R Gadhave [2], Vibhav V Pradhan [3], Viraj M Chawan [4]
[1, 2, 3, 4] *Mechanical Engineering Department, Pillai College Of Engineering, Mumbai University.*

Abstract: ***This paper presents a simple, economical yet effective tool for carrying out inspection task. There is a shear requirement of the inspection to be carried out in industries in order to prevent or cure the problems. The aim is to design and develop a wired wall climbing device. The device will use magnets mounted on wheels which will hold it on the metallic surface due to magnetic attraction and the drive will be provided by DC Geared motors. The device can be used for inspection of large metallic surfaces for the detection of cracks, corrosion and other problems on the exterior and interior of large metallic tanks. Our team is responsible for design and fabrication of the device. Designing of the RC controller will depend on types of sensors mounted and application of the device.***

There are a various methods used for inspecting problem areas on metallic tanks. Prevalent method of inspection is to construct scaffolding structure and to manually inspect the required area by sending up an operator. This method is time consuming and also dangerous for the operator. Our team intends to design a device that uses DC power supply to power all aspects of the device including motors, controller, and sensors. A tether cable will allow communication with the device and motion control will be achieved by wired RC controller. This allows the operator to control the device and receive real time data from device.

Live streaming of video from camera will be sent to the operator console to guide the device, analyze and to record the data. The camera is mounted on Pan Tilt mechanism which allows camera to be swivelled to left-right and up-down allowing it to have a wide area of coverage. The motion of Pan Tilt will be controlled from operator console. The device is also incorporated with slider mechanism to have continues inspection and cover more area of inspection. This slider could be used to mount sensors which will be used for inspection. The data available from device can be stored and analyzed to predict catastrophic failures that might lead to capital, human, environmental loss. Thus it will result in cost effective and reliable inspection device.

Keywords*: *Inspection, Device, Large Metallic Surfaces, Magnets, RC Control, Drive Wheels, Live Streaming, Recording.

I. INTRODUCTION

Storage tanks require inspection at regular intervals to ensure deterioration is detected at an early stage. Effective inspection identifies the repairs required before the point where leakage or other failures occur, avoiding environmental contamination, product loss, or even catastrophic failure *[11]*.

The material and the weld are inspected for manufacturing defects when constructed but must also be periodically inspected throughout their service life for signs of damage. The carbon steel is prone to attack by corrosion and in some circumstances cracks can form over time *[12]*. NDT personnel use visual, X-ray, ultrasonic and other inspection methods to search for flaws and service-induced damage as shown in fig. 1.

Fig. 1 Evidence of Shell Corrosion *[13]*

A. Applications

A climbing robot shall climb; it shall move upwards on metallic surfaces and performs different jobs. The surfaces could be large metallic surfaces. On principle, all kinds of jobs which are necessary on the metallic surface of a structures, on a wall and, on a ceiling of structures like tanks are possible fields for using the device *[10]*.

This device can be used to:

1) Inspect storage tanks and associated containment areas in industrial plants, tank terminals and other locations
2) Measure the shell of tanks and extent of metal loss
3) Detect corrosion and delamination
4) Remove the need for costly scaffolding or rope access
5) Provide quick data collection in real time analysis *[11]*.

This device can be used in Oil and Gas, Chemical, Food, and Marine industries. This could also be used on large metallic structures such as Windmill, Bridge, AC ducts etc. for inspection purpose.

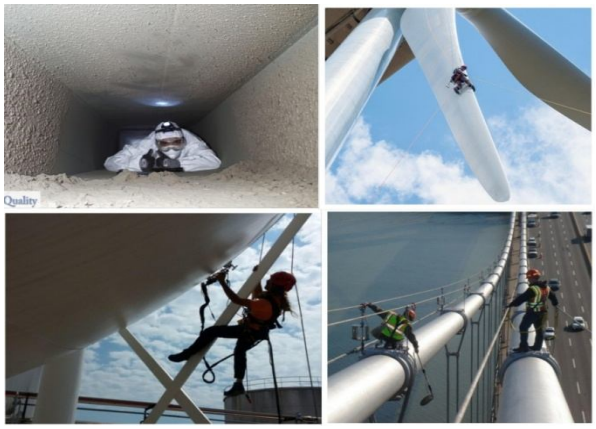


Fig. 2 Application's [14] [15] [16] [17]

II. LITERATURE REVIEW

This literature review investigates state-of-the-art research work on wall-climbing robots *[1]*. The rapid growth of technology has made inspection an essential part of the industrial practice. Many advanced and traditional techniques are available for inspection today. But still the cost of inspection practice is considerably high. There is surely a need to reduce the cost of inspection and make the process economical yet advanced and performance oriented.Inspections of the tank walls is done manually with the inspector in a man lift, on scaffolding or hanging down from the top as shown in fig. 3.

Fig. 3 Conventional Inspection Procedure *[18]*

A much safer way to make an inspection is to use a wall climbing device. It mainly involves the advances of various adhesion and locomotion mechanisms for wall-climbing robots, and also discusses various wall-climbing robots mobility *[1]*. The two main criteria to distinguish these types are the adhesion mechanism and the locomotion principle. According to, the most common adhesion mechanisms are magnetism, vacuum suction, specific attachment devices such as rails or pegs and grippers/clamps. The locomotion can be based either on wheels, tracks, legs or arms *[1]*.

After studying above adhesion mechanisms we found that:

1) Vacuum adhesion has good adaptability to various types of surfaces (including non-ferromagnetic surface) but it cannot be used on rough or corroded surface. It also requires a vacuum pump to produce continuous vacuum pressure hence it is not portable.
2) Dry adhesion can be used on any surface but due to complexity in this technique, it cannot be used in this application.
3) Electro static adhesion requires large electrostatic adhesive pads to produce required holding force. It is also not reliable and requires more power.
4) Magnetic adhesion gives higher holding force, higher reliability if permanent magnets used, also it does not require external power to produce holding force. Compared to other adhesion mechanisms it gives same holding force in small size. Also it can be easily used on rough and corroded surface.

Hence considering above factors magnetic adhesion with wheeled locomotion is best suited for this application.

A. Objectives

The objective of this work is as follows:

1) To study the status of traditional inspection in industry and the technologies involved in it.
2) To study scope of automation in inspection.
3) To reduce human intervention and improve safety in inspection.
4) To design &develop cost effective and reliable inspection system.
5) To design & develop versatile inspection tool.

III.PROBLEM STATEMENT

The storage of dangerous goods in tanks must be executed in a safe way. In order to reduce the economic as well as the environmental risks, a thorough knowledge of the tank condition, and in particular the tank bottom and shells, is of outmost importance *[19]*.It is necessary to design a device that can carry, control the NDT inspection tool or probes for the purpose of NDT operation on exterior as well as interior of large metallic tanks. Suitable tool or probe is needed to be found out which can be used for purpose of inspection of metallic tanks. It should reduce danger for technician by eliminating direct human interference in testing as shown in fig. below. Finally, it should save inspection time and cost without compromising on the quality levels.

The aim is to design cost effective inspection on Ferro-Magnetic structures without the need for costly scaffolding or rope access *[19]*. The crawler system can be automatically or manually operated and transverses the tank shell either at equal distant points or 100% around the tank circumference *[19] [20]*.

IV.DESIGN

A. Design of Components

1) *Frame and Base Plate:* Frame is required to have a sturdy structure & should provide maximum space for mounting of motors and other components. Thus Frame can be made of steel C-sections as shown in fig.4. C-section would provide good strength and is easy to work on. The frame is rectangular style design with length: 30 cm, width: 20 cm and height: 4.5 cm. The frame designed for device needs a base plate for supporting motors, circuits and other components as shown in fig.4. It should also have a slot for slider mechanism. For that 5mm thick plywood can be used.

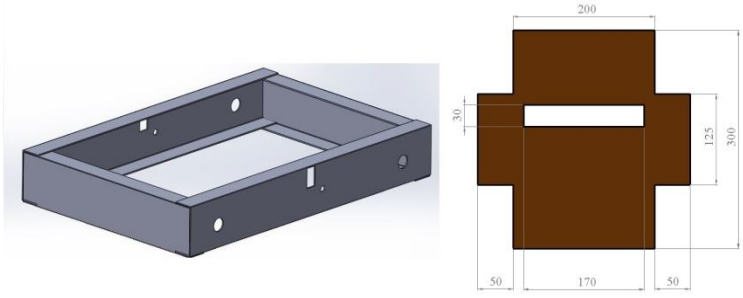


Fig. 4 Frame and Base Plate

2) *Wheel Design*

The wheels are required to carry magnets on its periphery which would give holding force to the device. The dimension of wheel should be such that it should provide enough ground clearance and carry 8 to 10 magnets. Wheel of 7cm diameter can be used as it a

standard size and easily available. To incorporate magnets easily on periphery of wheel a rim is designed. The rim will have slots on its periphery for magnets.

Laser cutting method can be used to manufacture rims, by cutting required shape of rim as shown in fig.5 in sheet of required material and thickness as it is more accurate, has high strength, is cost effective and also will require less time to manufacture. This will provide optimum design which will save time and cost and would serve the purpose. Then the rims can fitted on wheels with suitable means to the wheel.

The magnets can be fitted in slots provided in rim by suitable means as shown in fig. 5.

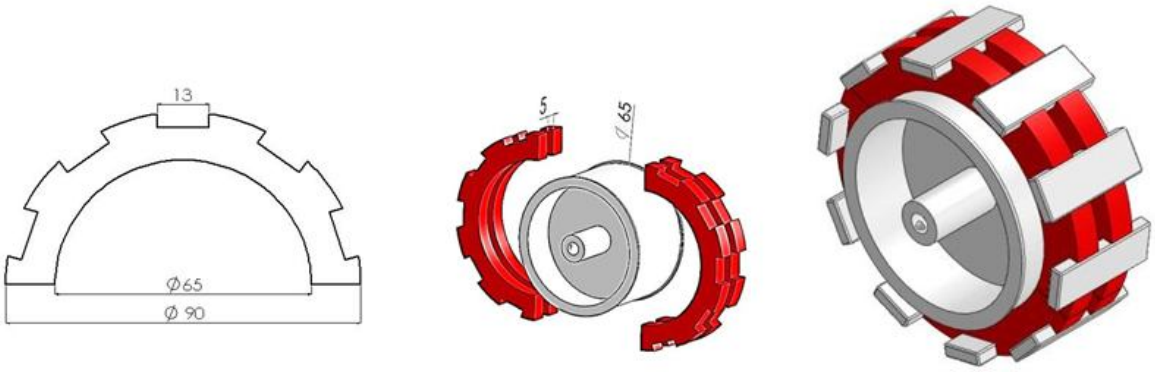


Fig. 5 Rim Design

3) *Magnet Selection:* The magnets needs to provide the cohesive force needed to keep the device on a vertical surface. The magnet will also provide the normal force required to create the friction needed for mobility. Rectangular magnets are best suited for the application as they would provide proper contact with metallic surface and will be easy to be fitted on the wheel. Rare earth Neodymium magnets are best suited for this application. Neodymium magnets are available in varies grades ranging from N30 to N52 based on magnetic flux density.

As per availability in market, design requirement and magnetic flux N35 grade is selected. According to wheel size and availability of magnet size35*13*4 mm is selected. This magnet will provide 50N force.

4) *CAD Model of Assembly*

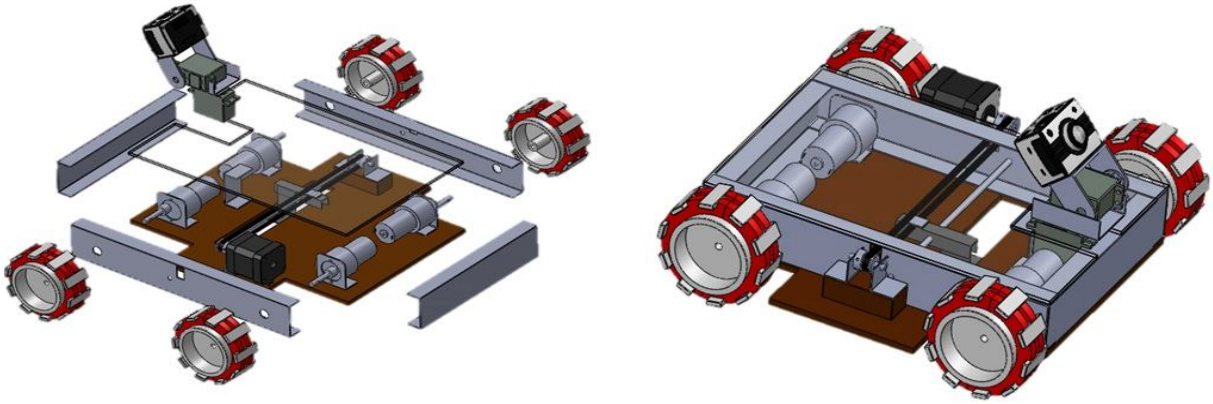


Fig. 6 CAD Assembly

V. CONSTRUCTION

A. Fabrication

1) *Drive Wheel:* Design is modified and laser cutting method of manufacturing is chosen. New design has the rim in two halves. Each wheel will have 4 halves. The rim is manufactured by cutting required shape in acrylic sheet of 8mm thickness. This rim is fitted on the wheel by using a strong epoxy adhesive (bond tight). Each wheel will carry 10 magnets in slots provided in rims. Magnets are fitted with the help of same epoxy adhesive as shown in fig. 7.

Fig. 7 Laser Cut Rim Wheel with Rims

2) *Remote controller:* SPMS is used to power drive motor and stepper motor. It requires wired connection. The drive motors are control by DPDT switches. The remote-controller used is a Switch Box made up of Polypropylene plastic. Two DPDT switches for drive control and two potentiometer for Pan/Tilt control of camera are fitted in switch box. It also consists of a slider switch to turn ON/OFF the DC power supply to the device as shown in Fig. 8.

Fig. 8 Remote Controller

3)Complete Assembly

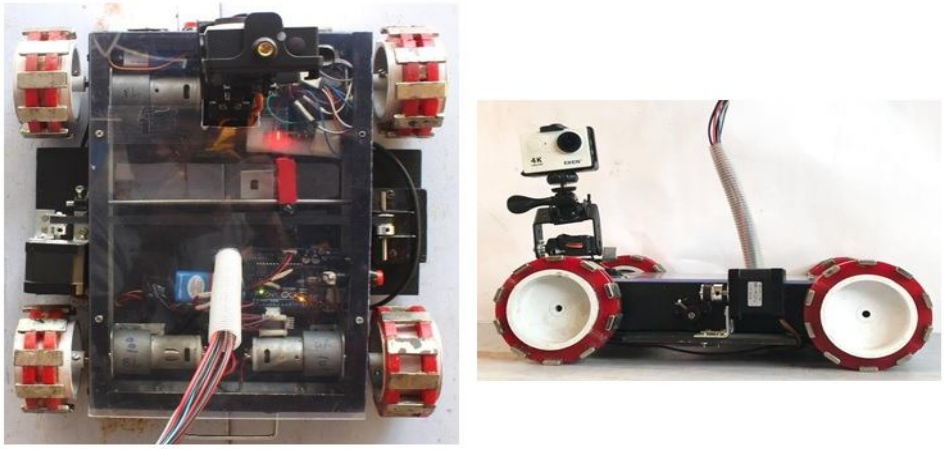


Fig. 9 Complete Assembly

VI.INSPECTION

Tank requires various inspections for detection of wall thickness, corrosion, wear and tear, cracks, blow holes, weld deterioration, leakages, etc. To serve the purpose of inspection the device is provided with following mechanisms.

A. Pan/Tilt Mechanism

Pan/Tilt mechanism with a camera is used for Visual inspection of welds, plates, and appurtenances. Pan/Tilt mechanism is shown in fig.10. This mechanism allows operator to pan and tilt the camera through RC controller. This will increase the viewing angle of camera and serve its purpose for surveillance.

Fig. 10 Pan/Tilt Mechanism and Servo Bracket

It consist of two servo motors one for pan and later for tilt. These motors are mounted using clamps and couplers. The camera is mounted on oblique U shape aluminum servo bracket. The Pan and tilt motion is controlled by potentiometers fitted in RC controller.

B. Slider Mechanism

For inspection purpose the sensor is required to move along the direction perpendicular to the motion of device with certain velocity and length of stroke. This will scan area of metallic surface while moving. The area scanned will have width equal to stroke of slider and length equal to distance travelled by device as shown in Fig. 11.

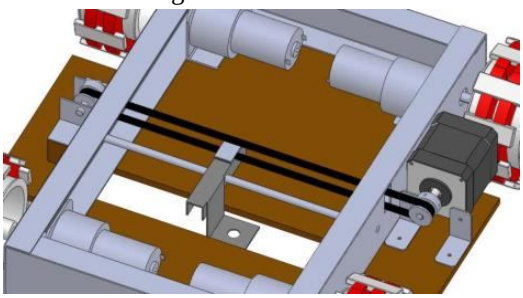


Fig. 11 Slider Mechanism

To get required reciprocating motion timing belt and pulley mechanism as shown in fig. is used. The pulley is driven by stepper motor. The slider mechanism consists of an aluminium slider which has provision to mount various sensors, which is guided by a steel rod fitted to frame. The slider is attached to belt and moves along with it. The belt gets controlled motion by stepper motor through pulley. The motor is rotated to certain rotations to required stroke of slider. For this Arduino is programmed to control stepper motor through motor driver (A4988).

C. Schematic of Working Setup

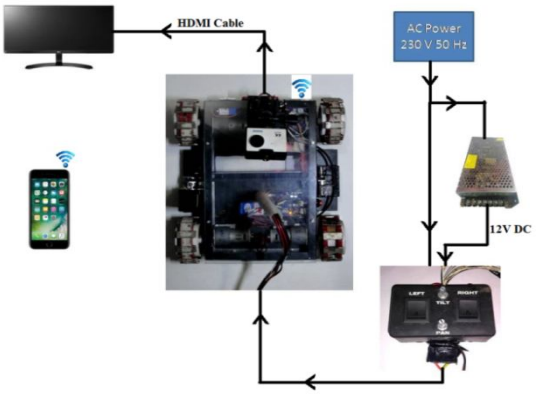


Fig. 12 Schematic of Working Setup

D. Actual Working Setup

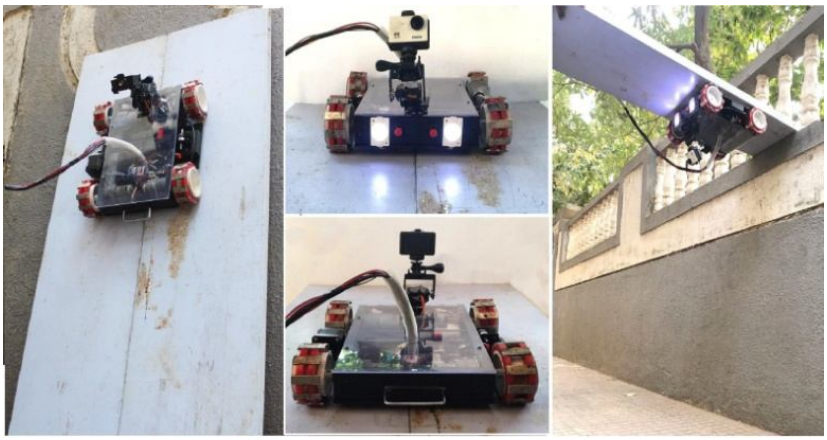


Fig. 13 Actual Working Setup

VII. RESULT

The development of adhesion and locomotion mechanisms, which include magnetic adhesion and wheeled locomotion are comprehensively investigated in this paper. The advantages of this adhesion/locomotion mechanism are discussed in terms of its reliability, flexibility, and complexity. This is successfully equipped in the device and tested on metallic plate. Device is tested for inter-plane transition and inspection of overhead surfaces. The inspection tools used on device, Pan Tilt and Slider Mechanism successfully tested during inspection on metallic plate.

A. Overall dimensions of device are as shown below:

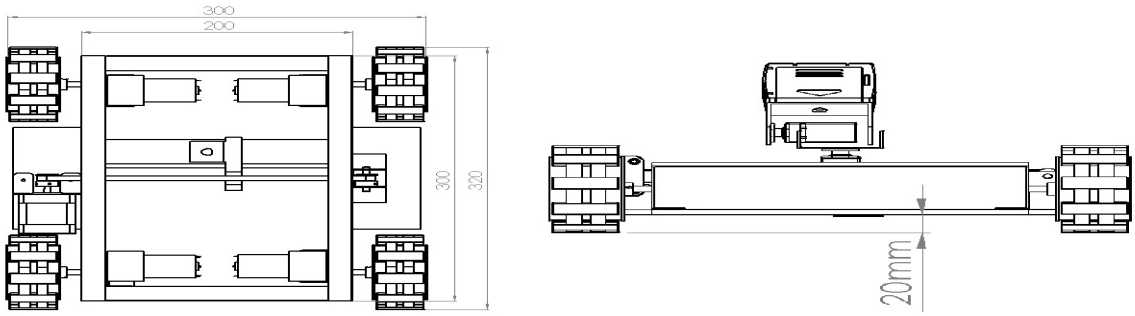


Fig. 14 Overall dimensions of device

B. Key Specifications

TABLE I
Key Specifications

1. Dimensions	0.3x0.32m	2. Interface	Wired
3. Weight	3.5kg	4. Pay load	4.5kg
5. Adhesion	Neodymium Magnet wheels	6. Camera	4k action camera
7. Drive	DC geared motor	8. Max. tether length	2 m
9. Drive wheels	Outer diameter 0.09m	10. Wi-Fi range	20m
11. Speed	0.3 m/sec	12. Ground Clearance	0.02m
13. Power supply	12 Volt DC	14. Pan/tilt	180 degree

VIII. CONCLUSION

This paper investigated the design and development of a wall-climbing inspection device to inspect large metallic surfaces. The device is applicable for various inspection tasks, such as detection of cracks, corrosion, thickness measurement on large metallic surfaces like tanks, ducts, pressure vessels, bridges, and so on.

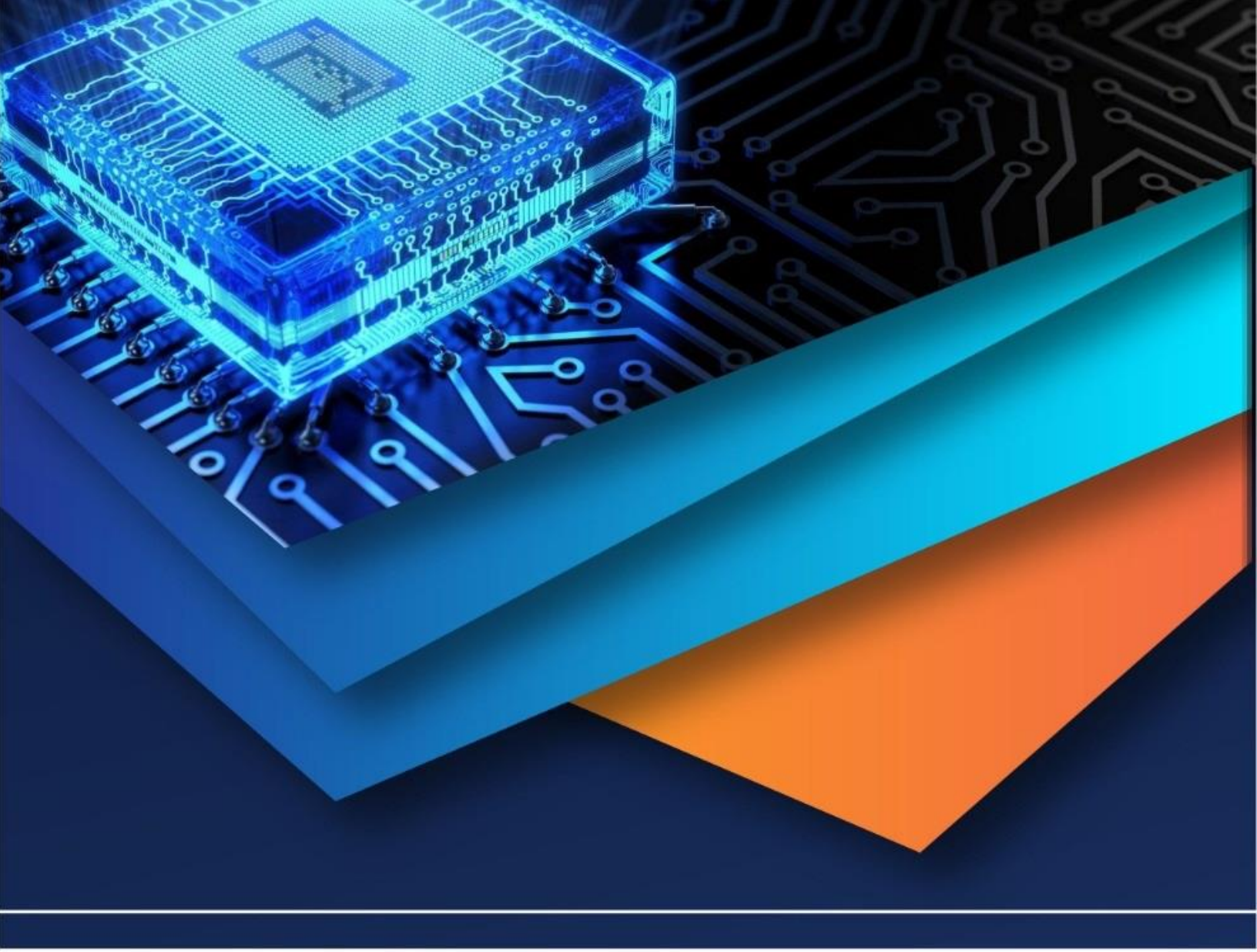
This simpler, compact and lightweight device provides a safe and effective means to deal with hazardous inspection operations. The device is built to be used for inspection on smooth as well as rough surfaces (corroded surface). Various inspections instruments or tools can be mounted on it to carry up on wall.

Due to optimizations in structure and components, its mass is 3.5 kg; the size is 300x320x200mm³ – small enough to fit well in the almost all environments. This magnetic wheeled climbing device has the capability to work in all inclination. The payload of device is around 4.5kg.

This device provides safety by reducing direct human intervention in the process of inspection. Economy is provided along with ease of operation, reducing demand of highly skilled labour. Thus it is an alternative for most primitive method to erect scaffolding and perform inspection task.

REFERENCES

[1] Shanghai, China, Yuan Chang, Xiao-Qi Chen,Chang Y., Chen "Design of A Scalable Wall Climbing Robot for Inter-Plane Traversing", The 4th International Conference on Robotic Welding, Intelligence and Automation (RWIA"2014), , Oct. 25-27, 2014.
[2] Fischer, Wolfgang; Tâche, Fabien; Siegwart, Roland,"Magnetic Wall Climbing Robot for Thin Surfaces with specificobstacles", 2008.
[3] C. Rui, "A Gecko-Inspired Electroadhesive Wall-Climbing Robot," Potentials, IEEE, vol. 34, pp. 15-19,2015.
[4] A. Faina, et al., "Development of a climbing robot for grit blasting operations in shipyards," in Robotics and Automation, 2009. ICRA '09. IEEE International Conference on, 2009, pp. 200-205.
[5] WeiminShen and Jason GuYanjunShen,"Permanent Magnetic System Design for the Wall-Climbing Robot", Conference Paper in Applied Bionics and Biomechanics, January 2006.
[6] Hwang Kim, Dongmok Kim, Hojoon Yang, Kyouhee Lee, KunchanSeo, Doyoung Chang and JongwonKim,"Development Of A Wall-Climbing Robot Using A Tracked Wheel Mechanism", School of Mechanical and Aerospace Engineering, Seoul National University, Seoul, Korea, April 16, 2008,
[7] B.Vishanth, S.Kathiravan, S.Giri Prasad, R.Raju, D.James Deepak "Analysis Of Wall ClimbingRobot", 2014.
[8] Ayyagari D P PrudviRaj ,DeviduttaNayak "Design And Development Of Wall Climbing Robot", National Institute of technology, Rourkela, 2014.
[9] ShunsukeNansai and Rajesh Elara Mohan "A Survey of Wall Climbing Robots: Recent Advances and Challenges", 1 July 2016.
[10] Hans J. Yberle, "Application of climbimg robot RoSy II in the business of building conservation", Robotersysteme Yberel GmbH, Neumarkt, Germany.
[11] Introduction. Available online: https://www.silverwingndt.com/applications/storage-tanks-integrity/
[12] Introduction. Available online: https://www.nde-ed.org/AboutNDT/SelectedApplications/ TankInspection/ TankInspection.htm
[13] Chris Brooks, "API 653 Tank Inspection, Tank Maintenance, And Causes Of Tank Failure", Storage-Tanks-Inspection-Maintenance and Failure
[14] Duct Inspection. Available online:http://www.sdairquality.com/commercial-air-duct-cleaning-san-diego/
[15] Windmill Inspection. Available online: https://www.sulzer-schmid-labs.ch/
[16] Spherical Tank Inspection. Available online: http://www.integrityndt.com.tr/rafineri-muayene-yonetimi/
[17] Bridge Inspection. Available online: http://www.srsrailuk.co.uk/access-vehicles/bridge-inspection
[18] Conventional Inspection Procedure Using Scaffolding Available online: http://www. coatingspromag.com/articles/steel-coatings/2014/12/some-like-it-geothermal-power-plant-recoat
[19] Problem Statement. Available online: https://www.sgs.com//media/global/documents/ brochures/ sgs-ind-storage-tank-a4-en-14.pdf
[20] Problem Statement. Available online: http://arllabservices.com.au/wp-content/uploads/2014/05/STORAGE-TANKS.pdf
[21] Problem statement. Available online: http://www.tankrob.eu/introduction/
[22] Oblique U-shaped Servo Bracket. Available online : https://www.amazon.com/BangBang-Oblique-U-shaped-Bracket-Manipulator/dp/B072J8PKL5
[23] Available online: http://mechanical.final-year-projects.in/a/77-wall-climbing-robot.html



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY