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PIPELINE INSPECTION CRAWLER FOR FAULT DETECTION

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Abstract:

Pipelines, a cost-effective method for fluid delivery, degrade over time due to factors like corrosion, leading to leaks and environmental contamination. Regular inspections are crucial for maintaining optimal operation. In-pipe inspection robots (IPIRs) offer a superior alternative to manual inspection, utilizing visual and non-destructive testing methods. Various IPIR designs include wheel-driven, track-driven, wall-press, and pipe inspection gauge (PIG) robots. Manual inspection requires significant time and effort, while robotic inspection allows for fast, accurate, and low-cost examinations. The unique 6W chassis design and camera-equipped robot enhance pipeline inspection efficiency, reducing the need for costly replacements.

Keywords **—** Pipe inspection robot, Design aspects, Pipelines, Leak Detection, Pipe Leakage

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I. INTRODUCTION

water distribution systems worldwide often face significant losses during transit from treatment plants to consumers. according to the international water supply association (iwsa) in 1991, "unaccounted for water" (ufw) typically ranges from 20-30% of production. in older systems, this percentage can be as high as 50%. leaks in pipelines, whether for water, oil, or gas, are common problems in infrastructure globally. many leaks remain undetected for years because their sources are not visible.

one of the most viable solutions for inspecting pipelines is the use of robots. various types of pipes are used to construct essential lifelines such as water and gas supplies in modern society. robotics, one of the fastest-expanding technical sectors, offers significant advantages in this context.

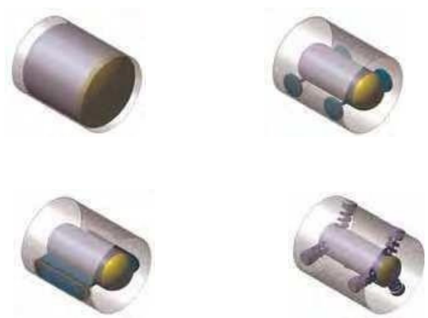
robots are now utilized for a wide range of tasks, particularly in the manufacturing industry, including spot welding, tool and workpiece loading and unloading, painting, and more.

robots are primarily designed to eliminate human intervention in labor-intensive and dangerous work environments. however, they also play a crucial role in accessing and uncovering areas that are typically difficult for humans to reach. in the context of pipeline inspection, robots can travel through pipes, identifying leaks and structural weaknesses that would be

impossible to detect manually without significant effort, time, and cost.

the adoption of robotic technology in pipeline inspection not only enhances the efficiency and accuracy of inspections but also significantly reduces the costs associated with manual inspections and the

REPLACEMENT OF DEFECTIVE PIPELINES. ROBOTIC INSPECTIONS ALLOW FOR FAST, ACCURATE ASSESSMENTS AT A LOWER COST, MITIGATING THE RISK OF ENVIRONMENTAL CONTAMINATION AND RESOURCE WASTAGE.



II.Types of Pipe-Inspection Robot:

(a) Pig type, (b) Wheeltype, (c) Caterpillar type, (d) Wall press type, (e) Walker type, (f)Inchworm type, (g)Lead screw type.

Pipe-inspection robots are essential for maintaining pipeline integrity in various industries. There are several types of inspection robots, including pig type, wheel type, caterpillar type, wall press type, walker type, inchworm type, and lead screw type. These robots are designed with considerations for maneuverability, stability, and adaptability to different pipeline diameters. Unlike Wi-Fi networks, ZigBee's mesh networking protocol helps in establishing self-healing architectures, making it suitable for remote monitoring in set-top boxes, satellite transceivers, and home gateways.

Chemical industry pipelines are prone to corrosion, cracking, and leaking due to the variety of chemicals they transport, which can lead to efficiency reduction and potential hazards.

Traditional inspection methods are time-consuming, exhausting, and costly. Robots, however, can perform these tasks more efficiently and safely.

They reduce human intervention in labor-intensive and hazardous environments and can access areas that are typically impossible for humans to reach. Robots are crucial for inspecting complex internal geometries and hazardous contents within pipes, preventing serious industrial accidents and environmental contamination. Research on pipeline inspection robots has explored various criteria and pipeline diameters for effective inspection. Key mechanisms in these robots include the Adaptable Quad Arm Mechanism (AQAM) and the Swivel Hand Mechanism (SHM). Another design involves using two-wheel chains for inspecting pipes with diameters of 80 to 100mm. Screw drive chains are used for curved pipes, and worm gear mechanisms are employed for inspecting pipes with diameters of 180 to 200mm. These advancements in robotic inspection technology enhance safety, efficiency, and reliability in pipeline maintenance.

III. OBJECTIVE

The main objectives are as fallow

- To fabricate Pipe inspection robot.
- To design CAD modules using design software.
- To simulate the assembly CAD module using proassembly.
- To determine the amount of voltage and current required for the motor to traverse a robot insidea pipe with forward and backward motion and should also do vertical climbing in pipe.
- It should be able to move in various diameters of pipe.
- To design a robot that can move horizontally
- In the pipe.
- To construct a robot that can minimize the mud and scale inside the pipe.

IV.MATHAMATICAL MODELING

1) Design of Pipe Inspection Robot

The materials selected for the pipeline inspection robot are chosen for their lightness and rigidity to ensure optimal power use and durability. Metals are preferred over plastics due to their superior strength. Aluminum is particularly favored for the linkages and central body because of its lightweight, strength, and versatility. It's used in various applications due to its desirable properties such as malleability, ductility, and high magnetic susceptibility. The aluminum components are designed to be hollow, reducing the overall weight of the robot.

For the motor, materials with high magnetic susceptibility and good electrical conductivity are required, with copper being a common choice. However, aluminum is also used in motor linkages and the central body due to its advantageous properties. Aluminum alloys are employed in engineering structures because they offer a wide range of properties influenced by specific alloy compositions, heat treatments, and manufacturing processes. These alloys are known for their sensitivity to heat, which complicates workshop procedures involving heating, such as welding and casting, as aluminum melts without glowing red likesteel.

The toughness of aluminum alloys, measured by crack propagation energy, tends to decrease as yield stress increases. An under-aged aluminum structure generally has greater toughness than an over-aged one. Despite these complexities, aluminum remains a preferred material due to its balance of strength, lightness, and malleability, making it suitable for various structural

V.Mechanism

THE MECHANISM INVOLVED HERE IS A FOUR-BAR MECHANISM CONSISTING OFTHREE REVOLUTE JOINTS AND ONEPRISMATIC JOINT AS DEPICTED.

Mechanism of PIR:

$H = 2r + 2d + 2h2\times\cos\theta$,Where,

h1 = 30 mm, h2 = 85 mm, h3 = 105 mm (h1 =OA, h2 = BC = D, h3 = CF)

$H=2\times36+2\times28+2\times85\times\cos45$ $H=248.20$mm

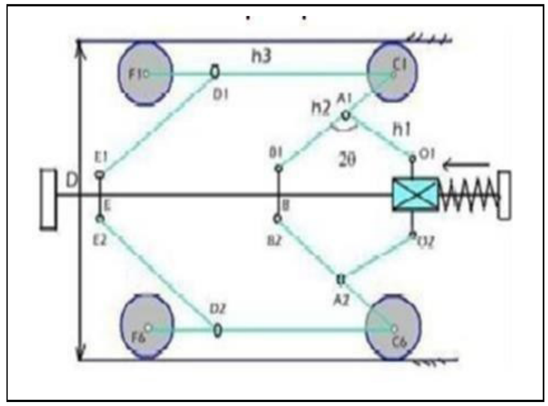
Where D - Diameter of the pipe in mm, d - Distance between EE' in mm.h1, h2, h3 arethe length of the linksin mm. r-Radius of the wheel, H=Height of robot outside the pipe.

For uniform Diameter, Assume

$D=2r+2d+2h2\cos\theta$ $D=2\times36+2\times28+2\times85\times\cos50=$**D= 237.27mm**

Kinematics of Mechanism:

The linkage structure can be represented as in figure depicted. This is a four-bar mechanism Consisting of three revolute joins and one prismatic as depicted.Thus, the motion of all revolute joints can be described in terms of the displacement db.



Static Analysis: In order to decide the actuator size, it is necessary to perform the static analysis. Assume that in Fig., Fcx and Fcz denote the reaction force and the traction force exerted on the four-bar by the driving wheel, respectively. Now applyingthe virtual work principle to the free-body diagram gives:

Static Analysis

$\delta W = Fcz\ \delta z - Fbx\ \delta x = 0$

Where, Fbx is spring force. This is because only Fcz and Fbx conduct work. The corresponding coordinates of these forces relative to the coordinate locatedat the A hinge are expressed as:

$z = 2.33/\sin\theta$, $x = 2.33/\cos\theta$

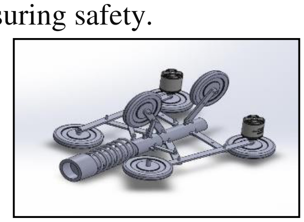
$\delta W = Fcz\delta\ (2.33l\sin\theta) - Fbx\delta\ (-2.33l\cos\theta)$

$= Fcz*2.333/\cos\theta - Fbx*2.33/\sin\theta\ \delta\theta.=$

0Rearranging gives:

$Fbx = Fcz*\cos\theta/\sin\theta$

The spring force at joint B is related to normal force Fcz by $Fbx = Fcz*\tan\theta$. Total weight W of the robot is divided into six traction forces, each Fcx being one-sixth of W. Actuator size is calculated by $\tau = WR/6$. Spring stiffness is 0.9 N/mm, requiring a minimum 3 kg torque actuator. Three actuators with 1.5 kg torque each are used for a total of 4.5 kg torque, ensuring safety.



VI.Result

1. We use pipeline inspection crawler in different diameter of pipes because of spring mechanism used and it capture the shape of pipe diameter.
2. We visualize the internal defects in the pipeline when the maintenance of pipeline occurs.
3. Defects like corrosion, dents, abnormalities and cracks can be visualize by using crawler by whichcamera is mounted at a front side.
4. Camera captures the pictures of defects and transfer the Realtime data through ESP 32 WIFI Module to the device for analyse of data.

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