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Design and Fabrication of in-Pipe Inspection Robot for Crack Analysis and Detection

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Abstract:- Our project involves designing and constructing a robot that can inspect pipes. The structure of the robot is composed of three outside frames connected by links spaced 120 degrees apart to a center translator. A camera is mounted on the main frame in the center, which enables it to view the interiorof the pipe. The linkages are equipped with wheels and DC motors to enable the robot to go throughsmall pipes. These motors are controlled by a bidirectional switch, which permits them to travel either forward or backward. This robot was designed specifically to find issues in pipes, such as fractures or buckling.

Keywords:- *In-Pipe Inspection Robot , Crack Detection , Crack Analysis , Robotic Inspection , Robot Design Fabrication Process.*

I. INTRODUCTION

The primary goal of developing an inline-pipe inspection robot is to lower labor costs while improving inspection safety. Regular inspection is necessary for both big industrial operations and the pipelines used for the distribution of liquids. We took into account the intricacy of the pipelines utilized in different power plants when designing and building our robot. It has been shown that the safest way to transfer and distribute liquids is through pipelines. Maintaining that reputation requires routine inspection

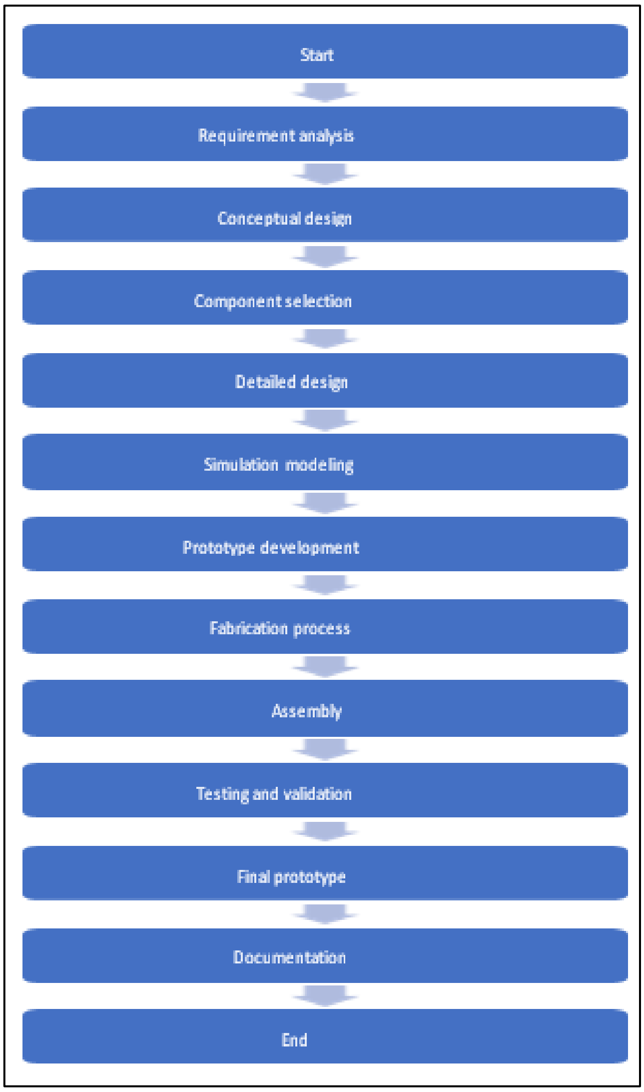
The majority of the pipeline equipment is accessible through the use of in-line inspection tools. Pipeinspection is the methodical study of pipelines to find any problems like leaks, dents, corrosion, andcracks. Conventional inspection techniques, such visual inspection by hand or excavating pipeline segments, are frequently expensive, time-consuming, and unfeasible, particularly for pipelines situated in dangerous or distant areas.

The robot is completely self-sufficient thanks to the microcontroller. A wireless camera that can cover an area under 180 degrees is mounted to the top of the assembly. The receiver that is attached to the LED screen receives the camera's output. The remote has a 10 m range, and the camera receiver hasabout a 30 m rang

One of the industries with the quickest rate of growth is robotics, which is employed in a wide rangeof manufacturing tasks. Their primary purpose is to lessen the need for human involvement in demanding and dangerous work settings. In this research project, a semi-autonomous wall press typerobot is dynamically analyzed in order to design a new in-pipe inspection robot. Robots are requiredfor monitoring purposes inside pipes of varying sizes in both nuclear power plants and companies with gas pipelines. For the purpose of inspecting internal pipe corrosion, sludge formation, and cracks, a pipeline exploration robot is required. Given that the dimensions of industrial pipes may vary, we require the robot's capacity to modify its shape, which is why we have implemented Chuck-jaw device to enable the robot to adjust to varying pipe diameters.

When compared to conventional inspection techniques, pipe crawlers provide a number of advantages. First of all, they have access to parts of the pipeline that are inaccessible to humans, likesubterranean pipelines, vast stretches, and vertical sections. Second, pipe crawlers minimize operational disturbance and delay by conducting inspections without the requirement for excavation or pipeline shutdown. Furthermore, pipe crawlers can offer more thorough and precise inspection data, facilitating proactive maintenance to avert expensive failures and environmental harm

➢ *Design Methodology:*



II. SELECTION OF MATERIALS

The materials used to build this machine are robust and light. The robot can be constructed from a variety of materials in different parts. To maximize the use of electricity, lightweight and durable materials should be selected. Despite being lightweight, wood will deteriorate if used for this machine. Since most polymers aren't quite as strong as metals, metals are the ideal materials for the robot. The substance should be pliable, ductile, less brittle, and have a high magnetic sensitivity. Aluminum was utilized to make the links and the common rod, which is hollow to reduce weight. Different materials are chosen for the engine. The motor's materials should be excellent electrical conductors and extremely magnetically sensitive.thin Materials consist of several items like copper.However, aluminum was selected as the material for the core body and connectors due to its highly desirable qualities. Aluminum has many applications since it is lightweight and robust. A wide rangeof aluminum alloys are used in engineering buildings. The strength and durability of aluminum alloys can differ greatly based on the alloy's components, heat treatments, and manufacturing procedures. Another important property of aluminum alloys is their sensitivity to heat. The fact that aluminum melts without initially burning red, in contrast to steel, affects work shop procedures involving heat. Aluminum alloys are susceptible to internal stresses during heating procedures like welding and casting, just as other structural alloys. Aluminum alloys present a challenge because of their low melting temperature because of this increased susceptibility to distortions brought on by thermally induced stress release.

A. Mechanism:

As can be seen in the image, the mechanism in question is a four-bar mechanism with three revolutejoints and one prismatic junction. 2r, 2d, and 2h2cosθ are equivalent to H. In this case, h1 = 176 mm, h2 = 215 mm, and h3 = 265 mm (h1 = OA, h2 = BC = D, h3 = CF). H = 2×36 + 2×28 + 2×215× H = 558 mm

Where d is the distance between EE' in millimeters and D is the pipe's diameter in millimeters. The connection lengths, denoted as h1, h2, and h3, are provided in millimeters. H is the robot's height outside the pipe, and r is the radius of the wheel. 18 for a constant diameter

Let D = 237.27 mm and assume that D = 2r + 2d + 2h2. Mechanism's Kinematics:

The diagram illustrates the connection structure. Four bars make up this device, which as depicted consists of three revolute joints and one prismatic junction. Consequently, all revolute joints can have their motion described by the displacement db.

B. ESP 32 Camere Aeduino Code

```
#include "esp_camera.h"#include <WiFi.h>
#define CAMERA_MODEL_AI_THINKER // Define the camera model#include "camera_pins.h" // Include camera pin definitions
const char* ssid = "your_SSID";

const char* password = "your_PASSWORD"; void startCameraServer();
void setup() { Serial.begin(115200);
// Initialize the cameracamera_config_t cnf;
cnf.ledc_channel = LEDC_CHANNEL; cnf.ledc_timer = LEDC_TIMER; cnf.pin_d0 = 16;
cnf.pin_d1 = 17;

cnf.pin_d2 = 18;

cnf.pin_d3 = 19;

cnf.pin_d4 = 21;

cnf.pin_d5 = 36;

cnf.pin_d6 = 39;

cnf.pin_d7 = 34;

cnf.pin_xclk = 0;
```

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```
cnf.pin_pclk = 22;

cnf.pin_vsync = 25;

cnf.pin_href = 23;

cnf.pin_sscb_sda = 26;

cnf.pin_sscb_scl = 27;

cnf.pin_reset = -1;
cnf.xclk_freq_hz = 20000000; cnf.pixel_format = PIXFORMAT_JPEG;
// Init the camera

esp_err_t err = esp_camera_init(&config);if (err != ESP_OK)
{
Serial.printf("Camera init failed with error 0x%x", err);return;
}

// Connect to Wi-Fi WiFi.begin(ssid, password);
while (WiFi.status() != WL_CONNECTED) {
Serial.println(WiFi.localIP());

// Start the camera server bystartCameraServer();
}
```

The ESP32-CAM is an internal pipe inspection robot that can be used to convey images and monitorthe conditions inside pipes. Through this scenario, a key component antenna, the right functions, andthe implementation framework usage are shared.

C. Overview

The ESP32-CAM can take the visual system of a robot as the main system, letting the robot's wheeledcameras display live video and sense images of the pipe interior. Such a procedure allows in findingblockages, corrosion, plus other issues, which are usually very laborious to manually check.

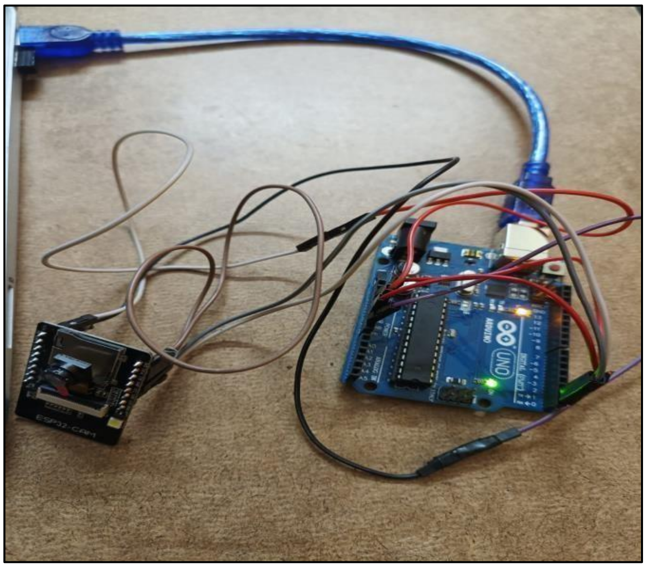

Fig 1: Esp 32 cam & Aurdino uno

III. DESIGN SPECIFICATIONS

A pipe inspection robot's central component measures 450 mm in length, 3 mm in thickness, and 12.7 mm in diameter. The diameter of one translational element is 15 mm. 20 mm in length and 3 mm in width. There are a total of 12 links: 6 are 215 mm (B1, B2, B3, B4, B5, B6), 3 are 176 mm (C1, C2, C3), and 3 are 265 mm (A1, A2, A3). The spring has a 90mm length.

The six links are connected to the core component; each link is 215 mm long. As shown in fig. linkson the central element are connected to the fulcrum in a manner similar to the previous point by useof pin joints at positions 1, 2, and 3, respectively. The other end is connected to links B4, B5, and B6 at a point, and the three links, each with a 176mm diameter, are fastened to the translationelement's fulcrum on the outside using pin joints with a 120° lateral spacing. A second link of length (A1,A2,A3) is linked to the ends of the links (B1,B2,B3,B4,B5,B6) at the distance shown in fig. The motor and wheels are mounted on links A1, A2, and A3. The front of the building is equipped with a rotating head that can be turned and swiveled, which houses a BO motor and a camera.

The cylindrical body is fitted with lights and a camera on a swiveling head. The type of LED lightingthat is commonly used has a rotating head built in. The LED lights up the inside of the pipe line. The camera has remote tilt and pan capabilities. A 12 volt DC adaptor powers the motor wire as shown in Fig. Three volts of DC electricity are supplied to the camera's BO motor. Turn the motor wheel byusing the robot remote. The output device, or display equipment, has a long wire that is wound arounda winch to connect the camera. Each of the six wheels has a diameter of 4.5 by 1.2 cm. There are six12 volt D.C. motors running at 10 rpm. Two BO motors, each capable of 3–9 volts and 60 rpm. TheBO motor, which is fixed to the robot's front side, controls the light and camera. The robot's end- connected spring applies a translational element to provide the links with an expand and compression motion.

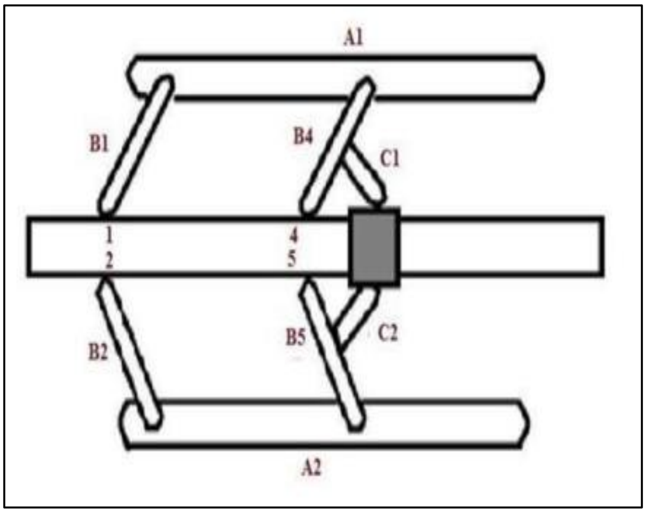

Fig 2: Layout

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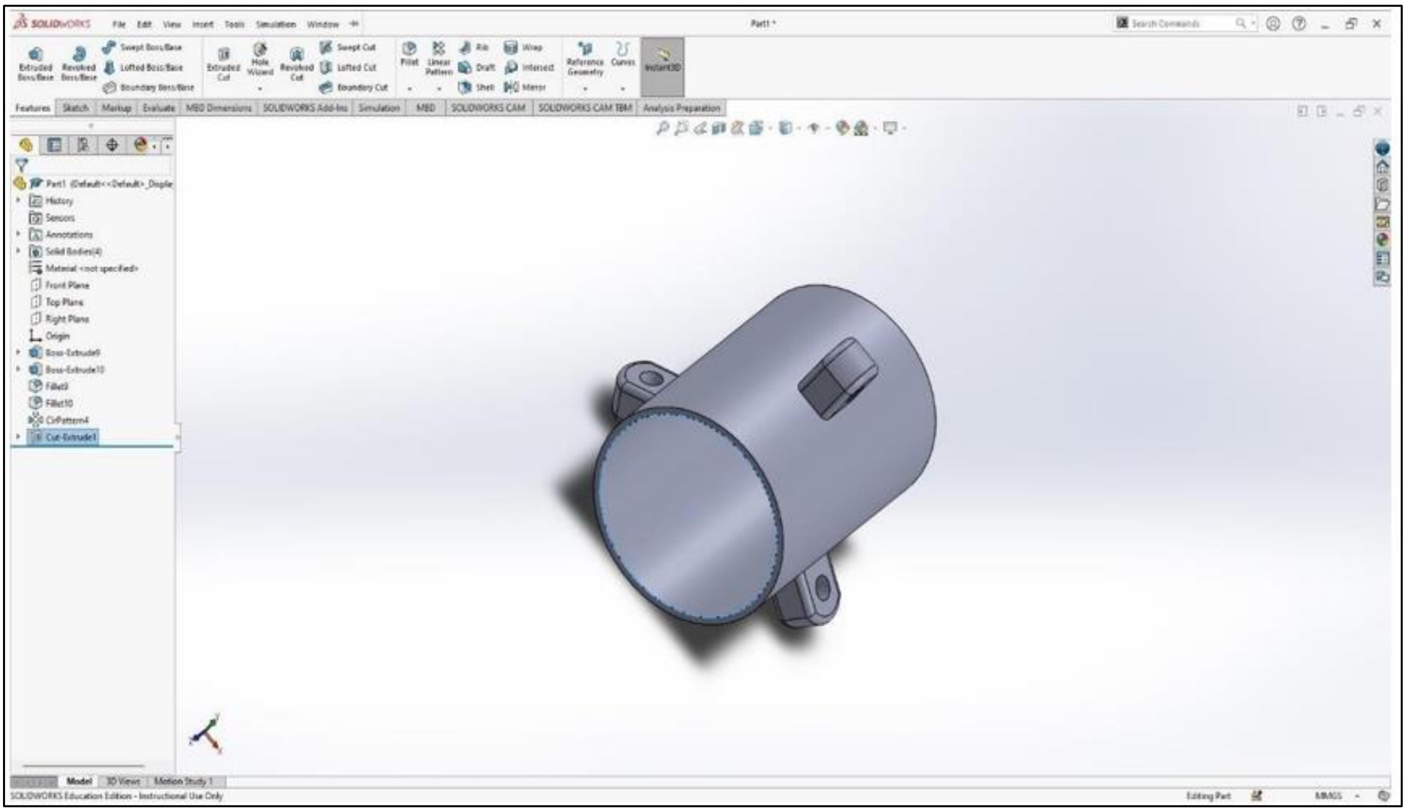

Fig 3: Transition Element

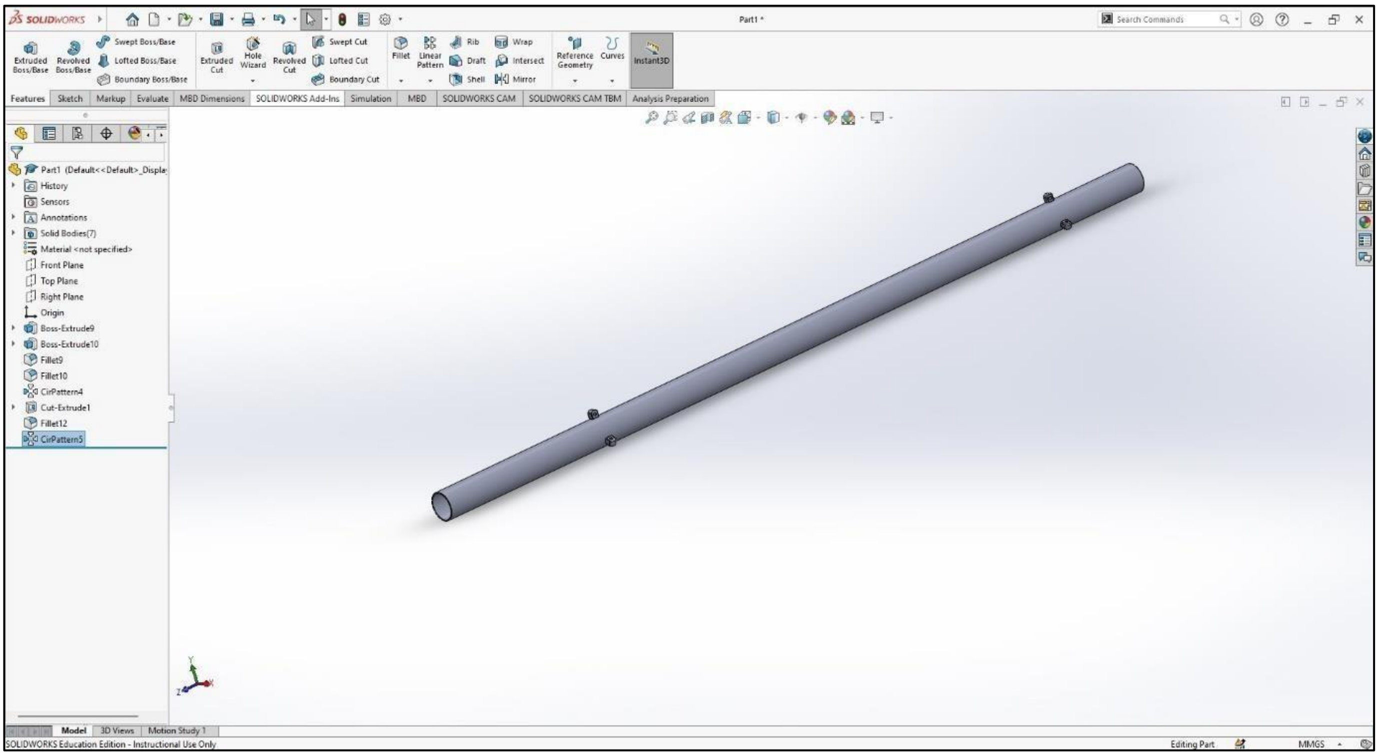

Fig 4: Central Frame

IV. DRILLING OPERATIONS

In order to guarantee accuracy and alignment over the range of rod sizes, drilling operations on flat rods measuring 26.5 cm, 21.5 cm, and 17.6 cm necessitate meticulous planning and precision. Choos ing an appropriate drill bit size based on the intended hole diameter is the first step in the procedure After that, each rod is measured, and the design specifications are followed while marking the hol e locations. To keep the drill bit from slipping when drilling, guide points are madeon each designa ted area using a centre punch. To prevent movement, the rods are then clamped into position on a w orkstation or drill press. Cutting fluid is used to lower heat and wear on the drill bit when drilling is done at the

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proper speed and feed rate. Following drilling, To ensure smoothness, the hole is debur red to eliminate sharp edges. Lastly, quality checks are performed to make sure the rods are prepare d for additional assembly or use by verifying that the hole diametersand placements match specific ations.

Fig 5: Drilling operations

V. WELDING OPERATIONS

When assembling in-pipe inspection robots, gas welding is occasionally utilized, especially when working with particular metal components that need clean, strong joints. Steel and other materials that can be utilized in the robot's frame or linkage arms can be welded using this technique, which usually uses an oxy-acetylene flame. Gas welding can be used in in-pipe inspection robots to create seamless, continuous welds that preserve the robot's stability and structural integrity while it maneuvers through difficult pipe environments.

Fig 6: Welding Operations

The pipe inspection robot can traverse through pipes with any hole diameter between 500 mm and 550 mm as it is primarily made for circular pipes. It was able to move in arcs and narrow the pipes because the right mechanisms were employed. PIRs can see down dark pipelines that are invisible tothe human eye. The addition of LEDs and a security camera to the PIACR's head allowed for this. An external display receives the output and displays a high-quality digital image. Only when the robot is inserted into the pipe can the ideal fit between the two be determined. Next, the 12V DC power is switched on. To activate the robot and turn on the camera With one button for forward andbackward motion and two more for moving and tilting the camera head installed in front of the robot, the three-button robot controller makes controlling the movement of the robot simple. Designed to allow you to take pictures and videos within the tube. The moment the PIR is inserted into the tube,it starts to function. The rear three arms are inserted by pushing the PIR after the front three arms have been manually pushed in and placed into the tube.The first six arms described here are the drivemotors, which pull the entire system. The PIR is approximately 450 mm long, and it has two degreesof freedom to move freely inside the arc tubes. internal connection, allowing for easier rotation. Thewheels will begin to move when the switch is activated and current passes through the cables, compelling the PIR to advance. Wheel movement is made possible by friction between the wheels and the tube.

Fig 7: Assembly of Robot

VI. RESULTS

Table 1: For Horizontal Pipe

No	Distance (cm)	Time	Speed(cm/sec)	Mean (cm/sec)
1	250	120.25	2.08	2
2	250	130.32	1.92	2

Table 2: For Vertical Pipe

NO	Distance (cm)	Time	Speed(cm/sec)	Mean (cm/sec)
1	250	165.65	1.51	1.5
2	250	168.50	1.49	1.5

VII. CONCLUSION

Internal pipeline networks are maintained in large part by robots. Some can adjust the design functionto the variation of the pipe being tested, while others are made to carry out specific functions on a set diameter (240mm) pipe. A tube-based modular robotic system is the end product of this project.These robotic systems are designed to find tubes that can be modified. The demonstrated prototype enables the employment of a small camera to view pipe inspections or other instruments (such as laser and sensor-based measurement systems) to find damage inside pipes. With only small adjustments, the modular design has shown to be easily adaptable to new settings. Blockages in pipelines are a challenging problem. By pushing the spring and enhancing the system's flexibility, the mechanism resolves the issue. The Robot is made to climb both vertical and horizontal pipelines. A range of module options were showcased for the little pipe inspection robot. Numerous projects involving pipeline inspection robots have been completed.

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