Design and Development of Pipe-inspection robot with vision 360°

Karthik CH¹, Pramod Sreedharan¹
¹Department of Mechanical Engineering, Amrita Vishwa Vidyapeetham, Amritapuri, India
E-mail: nanikarthik06@gmail.com, pramods@am.amrita.edu

Abstract. A pipe is a most commonly used product in the daily operations of industrial plants. Boiler pipes and inner ribs reduce pollution, allowing industrial plants to be both environmentally friendly and economically efficient. However, if these pipes are damaged, it will cause a huge problem for humans and ecological imbalances. Therefore, an inside inspection of a pipe is most necessary, regular duty being conducted by a surveyor of the plant. Pipe inspection includes checking for cracks, defects, leaks, corrosion and blockages in a region. However, an individual cannot do this inspection due to life-risk impact, and there is a necessity for human intelligence. This proposed robot design helps inspect a portion of the building in less time than the entire vision. In addition, the view can be recorded and easily the damaged or blocked portions of the pipe.

1. Introduction
Without proper pipeline inspection, dangerous activities occur worldwide, including the Belgium gas pipeline, Ijegun, Kaohsuing, Mexico Tlahuelilpan, Qingdao Oil, and San Bruno natural gas explosions, which resulted in the world’s highest loss-making incidents. As a result, many researchers have proposed Figure 1 as an ideal solution to overcome this specific scenario.

In this mechanical territory, Pipeline shape is one of the essential and effective strategies of liquid and vaporous cloth moving interplay. During the development and preservation of pipeline systems, one of the problems regarded within the cutting-edge situation is the research of inner lines in which human beings cannot truly attain them. The complicated inward calculation and dangerous material imperatives of lines require robots for research functions. With these obstacles, research into the line seems so fundamental that enduring it would prompt some real mechanical mishaps that sully the weather and the
loss of living souls. Architects and professionals are trying to meditate to cope with this problem with mechanical technology and mechanization.

Progress mechanics is one of the quickest planning fields and can be used for many applications, particularly in gathering ventures. Spot welding, stacking, and unloading of the device and workpiece, painting and then a few. Essentially, robots are intended to reduce human mediation from working in true and unstable painting environments; on occasion. They are also used in an inaccessible space that is extremely difficult to gain access to for individuals. In addition, the complicated internal calculations and volatile substance restrictions of the lines require robots for audit reasons. With those constraints, evaluation of the line ends up being essential to such a quantity that struggling with it may provoke some certifiable cutting-edge injuries that smash the environment and mishaps of living souls.

![Figure 1. Fishbone pipeline inspection [13]](image_url)

For examination of such lines, robots need to specifically look at the utilization degree of the road, healing of usable components from the pipe interior, looking at the ooze and scale direction of action on the inner line floor, and so on. Planning for another in-pipe appraisal robot is finished in this investigation. It consists of a kinematic and dynamic examination of a screw power type robot.

Kinematic tests are performed to determine the path of the rotor development and to further differentiate the robot's development within the immediate and pipeline. Furthermore, the impact of frictional force, drag pressure, and robot mass are researched by the robots from the glorious kingdom of robots to locate the necessary motor electricity for shifting to stages, skewed, and vertical pipelines.

The proposed research focuses on designing and developing pipeline inspection robots that can be deployed in the pipeline structure from 300 mm to 600 mm, which can be enhanced to fit into the desired pipe dimensions. The 360-vision camera with a real-time image integrated into the head-mounted display will efficiently detect the crack. It will be an added advantage in the proposed design. Furthermore, the images can be post-processed through an automation process. The initial stage design and development with simulation analysis will be carried out with various outputs.
2. Related Work

The Pipeline Inspection Robot (PIR) is planned for gaseous petrol pipelines. Capability to traverse both horizontal and vertical pipelines. However, due to the low contact, [1] it is unsuitable for water traces and oil pipes. Restricted scope of line breadth (going from 25 to 50 cm).

The boundary of the plan of the robot is the distance across the line. The picked (two hundred mm and 260 mm) pipes individually for our robot because of the decrease in most cut-off factors. Then, the robot switched to a motion in a 250 mm PVC pipe. It was discovered to move smoothly in both a horizontal and vertical direction.

Kenki Matsui proposed using an Omni-directional vision sensor capable of taking 360-degree snapshots directly into the pipe. A pipeline review robot uses an independent portable robot with ultrasound sensors and is associated with the pipeline via GSM and GPS. Furthermore, the IP digital camera has been used for visible evaluation, capacity coordination for simple statistics surveys, and snapshots [5].

In light of innovation, another 360-degree imaginative and prescient framework for transportable robot direction uses a static monocular camera. It is feasible to display the overall environmental factors of the robot with a solitary sensor on the screen. The digicam Furthermore, it can recognize the location and path of an object and prepare using photographs.

PIR is supposed to be painted on the pipe's 300mm to 500mm width. As a result, exhibitions of the planned robots and the proposed PID regulator have taken place [11]. Reproductions and tests have been carried out to validate demonstrations of deliberate robotic equipment to chip away at stages, instantly, and at elbow pipelines.

The mechanical re-enactment of the following flexible robotic for pipe exam employs MATLAB and V-REP programming and is used to change the posture of the song force modules to regulate various line dimensions and shapes. The layout of the robot is portrayed as centred around pedipulators, used to change the posture of the music pressure modules to regulate numerous line styles and sizes. The pedipulators are demonstrated with the help of a MATLAB computer. The models are checked using V-REP and MATLAB co-recreations. In the long run, the goal of the model is regarded as inspecting the rig. The robot uses common area guidelines, processed using the numerical models of the pedipulators [12].

A self-governing robot is utilized for in-pipe assessment. The device has a focal pole where a translational thing is geared up, connected to the three edges of the connections and the wheels. DC engines are joined to the wheels to accomplish the force required. A digital circuit comprising three switch switches is utilized to control the entire hardware of the DC engines, camera and translational component. The digital camera is positioned at the best point for gathering, which can be pivoted along these lines to provide a wide field of view within the line. The robot considers the identification of breaks, erosion's, pitting and several others [2].

Helical springs are commonly used in machine suspension arrangements. However, this entire applied spring was made with the assistance of metal, which eventually increased the heaviness of the entire running device, which became an impediment to expanding its capability [8]. As a result, our venture demonstrates the feasibility of incorporating composite materials in designing a helical loop suspension framework. Furthermore, this proposing approach will result in more noteworthy firmness with a diminished load of the spring, which can benefit this undertaking greatly.

3. Methodology
Pipeline structures are among the most important and efficient means of carrying out fluid and gaseous material transfer processes. One of the current challenges in pipeline structure construction and maintenance is inspecting a pipe where humans can physically reach it. Engineers and researchers are trying to intervene to address this problem with robotics and automation. The proposed research focuses on designing and developing pipeline inspection robots that can be deployed in the pipeline structure from 300 mm to 600 mm, which can be enhanced to fit into the desired pipe dimensions. The 360 degree vision camera with a real-time image that is integrated into the head-mounted display will give an efficient way of detecting the crack [7]. It would be an added advantage to the proposed design. The images can be post-processed through an automation process. The initial stage of design and development with simulation analysis will be carried out. This disadvantage will lead to hardware construction and testing in real scenarios.

![Figure 2. Design of the robot for pipeline inspection](image)

3.1. Design analysis

In this design, the wheel drive type mechanism of the robot uses robot parameters from more than five actuators. The payload is up to 18 kg. It only has three degrees of freedom. The motor generates the robot's mobility, the tilted wheels, and the supporting springs on each unit. All the wheels are in contact with the inner surface of the pipe. During the robot’s motion, the angle of the wheel tilt remains constant. The robot can move in a variety of directions, including vertically and horizontally. However, the robot's design allows it to move only in dry state pipeline areas. In a screw-drive type robot mechanism, the mobility parameters, steer-ability and size and shape adaptability are all fair. The robot's stability is excellent [3].
3.2. Model analysis

- To learn about geometry’s natural frequencies (resonating frequencies).
- To know the vibration characteristics (mode shapes) of geometry.
- Find connection errors in the geometry.

4. Results

This method approaches pipeline inspection by comparing measurements. First, the robot measures the actual inner diameter of the pipeline and compares it to a set value. The set value can be altered to inspect different pipes with diameters ranging from 300 mm-600mm. They proposed a new robot design based on a literature review and followed the pipe inspection robot’s figure 4 step-by-step process. Figure 5 shows the layout of the Length, height, and width, and all parameters will be perfect for the diameter of the pipe, and dimensions with requirements were tabulated and shown in Table 1.

4.1. Design analysis
Table 1. Requirements of the Robot Design.

| S.no | Name of the item                  | Dimension    |
|------|----------------------------------|--------------|
| 1    | Total Length of the robot        | 427mm        |
| 2    | Width of the robot               | 292.39mm     |
| 3    | Height of the robot              | 292.39mm     |
| 4    | Weight of the Robot              | up to 18kg   |
| 5    | Actuators and dc motors          | 8            |
| 6    | Total Wheels                     | 12           |

Figure 5. Measurement of Robot Design

- The robot has an accelerometer that can be used to measure changes in motion or orientation. Along three axes (X, Y, Z). Rotation on the x-axis is called the roll, rotation on the y-axis is called pitch, and Rotation on the z-axis is called yaw. Along the z-axis is yaw, as shown in figure 6.

- The position of all three axes, with the right-hand rule for describing the angle of their rotations.
4.2. *Static Analysis of the Structure*

Based on the design of the robot, we have to analyse each specification of the robot. In the analysis part, we have to do a static structural analysis of each part. One end of the analysis part is a fixed part, and the other is a force applied to the spring. When we add the various forces to the spring, we can analyse its position. The figure 7 depicts various colour notations. For example, the spring is overloaded in red (yellow and green are safe loads), and forces are acting on the spring [14].

The main challenge in the project is controlling and navigating the pipe inspection robot inside the pipe, detecting damage or cracks, and providing a real-time image via a head-mounted display. The challenges in this simulation section are primarily in designing the robot with solid working software. First, import the robot design to ROS (Robot Operating System) software and simulate with all other sensors. Then
we must simulate the robot in our environment to locate the robot moving in various structured pipes. Here we are using the design of the robot for pipe inspection in the ROS simulation in Table 1. As a result, the design model is a 3D CAD model converted into a URDF (Unified Robot Description Format) file [15]. For the simulation in ROS, a URDF model of the robot must be developed. The URDF file will need to contain all the links and joints of our model, its inertia values, plugins etc. The following step is to launch the gazebo file and run a robot inside the pipe in a gazebo simulation of the robot, then detect the crack using Rviz, a camera, and sensors.

![Figure 9. ROS](image)

5. Conclusion
Design and analysis have been carried out as shown in the previous chapter. Currently working on simulation inspection can run different inspection shapes by using ROS simulation. The stress and distortion analysis of the robot's large components is completed independently in ANSYS 14.5. Stress research effects are coordinated with the logical outcome, and the two traits are not exactly satisfactory. It also implies that development methods are effectively applied to the unique challenges of robots. The inspection industry's future scope is very broad. Although we have only made the first stepping stone into the first fit of the robot's pipe diameter and more work related to the second has begun, the inspection will find any cracks or damage that may develop on top of this simulated result. Much more work can be done in this field by utilizing image processing as well as computer vision. Automated inspection of industrial areas is the one area where automation is yet to establish its presence significantly, and this research could be the start of something innovative. Because it was designed for a helical pipe system, the robot can operate on both horizontal and vertical pipe systems.

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