

DESIGN AND IMPLEMENTATION OF ROBOT FOR PIPE INSPECTION

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Abstract – Pipes are subject to corrosion and fractures or cracks from inside over time due to rigors usage .Hence Pipes need to be inspected from time to time. This task comes with many challenges such as pipes can span over great lengths and also pipes come in different diameters. Thus the idea of using robot to move inside the pipe for inspecting for cracks and corrosion is proposed in this paper. The robot which is designed is cable of moving inside the pipes of diameters 10 cm – 14cm and has successfully produced footage of the pipe channel from inside.

Key Words: Pipes, Robots, Cracks, Fractures, Inspection

1. INTRODUCTION

As the world is advancing, everyone are looking to automate the work and lessen human efforts. People are taking the help of robots in complex situations and hostile environments where humans cannot reach out. Robots are being used in Nuclear reactors, under water explorations, air surveillance etc.

Robots help to reduce the burden on humans and increase the productivity by completing the tasks effectively. Robots are being used in many fields where mere human reach is challenging. By the use of robots one may solve many challenges.

As the industrial sector is growing rapidly there are quite a few challenges that are being faced by the industries which effects the production of the industries. Pipes or rather pipelines are used for transporting water, petroleum products, and different chemicals since ancient times. From household water supply and LPG supply to industrial uses, pipelines are used.

There are different types of pipes such as PVC, metal etc. Some of the common challenges faced by these pipes are cracks, corrosion, airgaps, rust or any junk present in the pipes which blocks the flow. These problems are discussed in detail in the following paragraphs.

As we are well aware that pipes may decay over time via numerous means. It may occur due to external pressure or due to long run of the object. Mainly cracks occur outside as well as inside the pipes over time. One can identify the cracks outside but it is challenging to identify the cracks inside of the pipes.

Pipes can come in different sizes, some pipes may also be unreachable like underground pipes and ones which are

underwater. Hence, in order to maintain the pipe one needs to check the condition of the pipe periodically. Pipes are to be checked from the inside also, thus to do that as explained above it is challenging for humans to do this work manually. There are certain areas which are inaccessible to humans and also the pipe diameter may be very small and as a result one cannot reach inside.



Fig -1: Cracks in Pipes

Figure -1 depicts the effects of cracks in a pipe when left undetected and unfixed. Thus, it is very important to inspect the pipe for any cracks or fractures from inside during the maintenance period. Even after manufacturing phase, pipes are to be inspected.



Fig -2: Corrosion in Pipes

Figure -2 shows the effect of corrosion inside metal pipes if left undetected and untreated. Hence, inspection of the pipe from inside is needed periodically.

One more challenge is the length of the pipes may be very long and hence one may not identify the blockage etc. Pipes need to be maintained so as to get the functionality

right. Hence we have to check for the presence of cracks or fractures.

2. LITERATURE REVIEW

The main objective of this paper is to design & develop a robot such that it is able to traverse into different pipes and of different sizes to check for any obstruction and damages which are usually cracks and corrosion internally. That is to help to inspect the pipe under maintenance process and testing.

The robot should be able to send visual feed of the channel of the pipe inside via a cable which is connected to the laptop. It should be also able to fit into sizes of range 10 cm to 14 cm diameter pipelines. Also it should be able to move in vertical pipelines also.

To design a robot which is sleek and is able to both in horizontal and in vertical Pipes and to able to fit in different diameter pipelines, to traverse inside a pipeline channel in forward and backward directions and capture the condition inside the pipe by producing real time footage to the display unit which is generally a computer.

A prototype has been made by [1], their main goal is to inspect the pipe by the means of translational element fitted on central rod for small accommodation in pipe diameters. They have used three relay switches to control the entire robot with a camera mounted on top of it. Compared to the above model our prototype has better design and it can adjust to dimensions in the ranges from 10cm to 14cm. Our robot can expand and compress according to the diameter of the pipe.

In a prototype made by [2], their objective is to clear the blocking part by the means of milling operation. Their proposed model is a wall press type robot. Compared to this model our model does not clear the obstruction rather it sends the footage of pipe channel inside to the user about the blockage by the means of continuous data transmission by the camera module. Their model cannot detect cracks and breaks whereas our robot will send the whole footage thus enabling the user to identify any obstruction, cracks or corrosion. Hence, the user would be able to do something above it.

In this prototype [3], to tackle the challenge they have proposed a screw driver type wall press adaptable robot. It has rotor, stator, and control unit. This model does not have any camera installed, their main goal is only to fit the robot inside the pipes and it only works for ranges 127mm to 152mm.

Our model has many advantages, it can fit inside for different sizes by expanding and contracting the arms, it can send continuous footage of the pipe inside, it can turn in bends.

3. PROPOSED DESIGN METHODOLOGY

3.1 Design Architecture

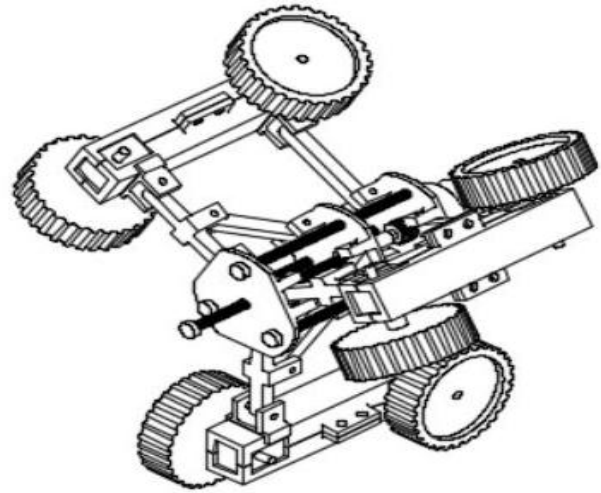


Fig - 3: Design Architecture

The design consists of a central body which is a long bolt which is attached via nuts using three discs, this bolt screws and unscrews by rotating in clockwise and counter clockwise direction. There are three additional bolts which are fixed these are used to hold the discs together. The disc which is on the top is a fixed one that is it does not move, the disc which is present at the middle which is a movable one and the disc which is present at the bottom is a center shaft motor disc. There are three arms present which contain two wheels that are attached to the arms via motor lids. The discs are connected to the arms via links which help move the arms. Figure-3 is a CAD sketch of the robot model taken from Fusion 360 software tool.

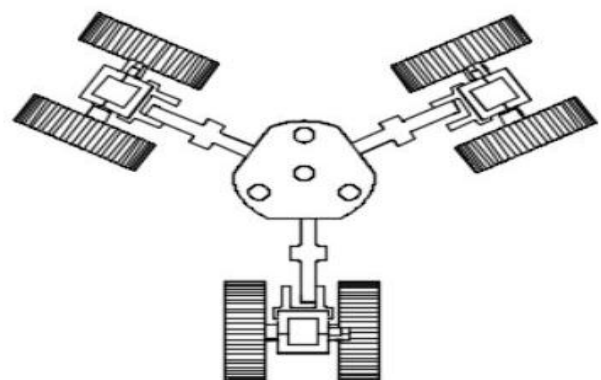


Fig - 4: CAD Sketch of the robot top view

Figure - 4 shows the top view of the model .It is a CAD sketch taken from Fusion 360 tool.

The design is developed in two phases, firstly design of different parts of the model in done using Fusion 360. Then 3D printed and assembly of the parts.

The design consists of the following parts:

- Center shaft motor disc:

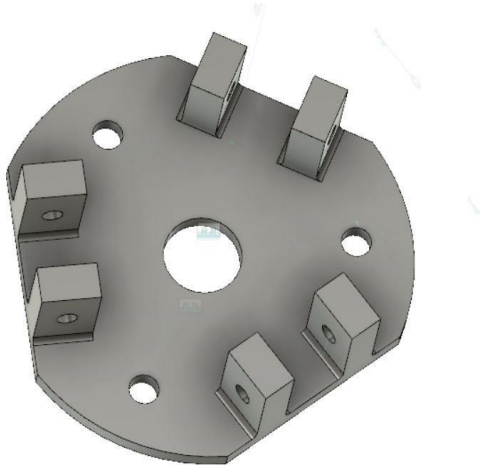


Fig - 5: Centre shaft motor disc CAD model

This disc houses the center shaft motor in the middle hence there is large hole to hold the motor at the center. The disc has three additional circular hole where the three additional bolts are through. The disc is a fixed disc. The disc is connected to the arms via links which are attached at the three edges. This disc is placed at the bottom of the body.

- Movable disc:

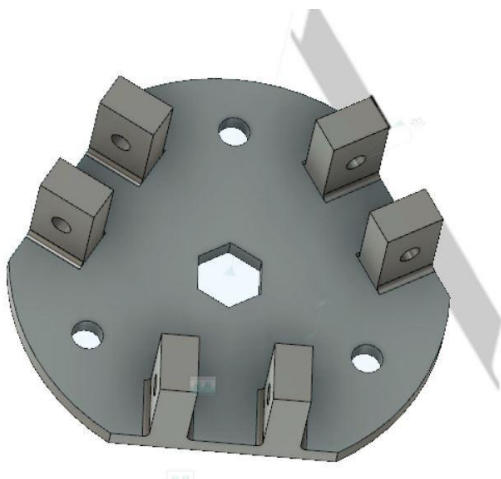


Fig - 6: Movable disc CAD model

This disc holds central bolt with the nut in the middle and the other three additional bolts are through in the other three small hole. It is movable disc. It is placed at the center, the three arms are attached to this disc via links

which attach at an angle of 51 degrees. This disc slides along the main bolt.

- Fixed disc:

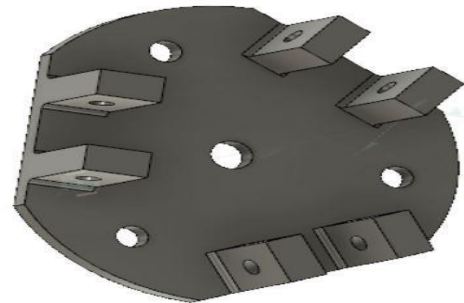


Fig - 7: Fixed disc CAD model

This is disc is fixed disc that is it's not movable. It is fixed at the top with the central bolt at the center and the additional three bolts at the three holes present at the edges. It is also connected to the three arms via links which attach to the disc.

- Motor casings:



Fig - 8: Motor casing CAD model

The casings are used to house the BO motors which are used in the arms. There are two casings used one upper and one lower where the motors are placed. This frame together with the wheels act as arms of the robot.

- Motor support:

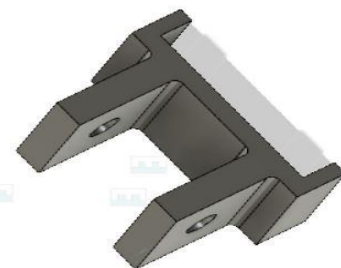


Fig - 9: Motor support CAD model

The motors are held by these support part which are fixed with the motor casings.

- Links:



Fig - 10: Link part CAD model

These parts are used to attach or connect the motor casings with the discs.

- Joints:



Fig - 11: Joint CAD model

These are joints which connect the center shaft disc which is present at the bottom of the body to the bottom of the casings of the three arms.

- Wheels:



Fig - 12: Wheel

The wheel is 3D printed is fixed with the motors. There are total of six wheels present, two for each arm for easy movement of the robot.

- Full CAD Model:

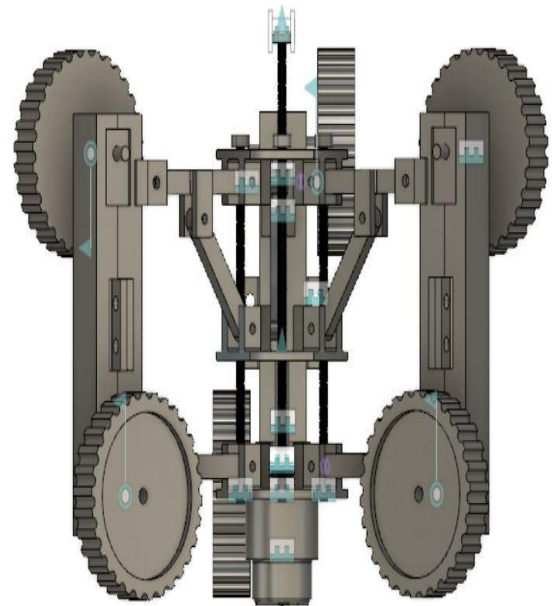


Fig - 13: Full CAD model

The above figure depicts the complete fully assembled CAD robot model simulated in fusion 360 CAD software tool.

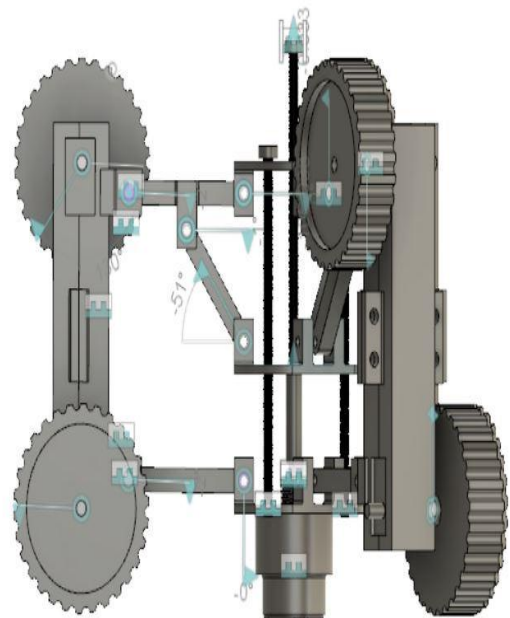


Fig - 14: Full CAD model Side view

Figure -14 gives the side view of the fully assembled CAD model of the robot.

3.2 Hardware Architecture

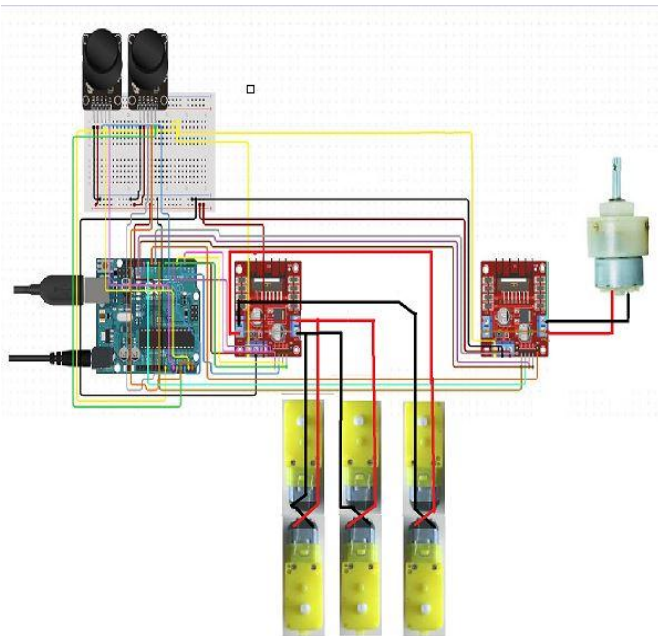


Fig - 15: Circuit diagram

The above figure shows the circuit connections. We have selected the Arduino Uno microcontroller to run the robot. The battery operated DC motors are used to rotate the wheels. The battery operated DC motors are connected to motor driver and the motor driver is in turn connected to the Arduino UNO board. The center shaft motor is connected to the board and is used to rotate the central bolt. Joystick modules are connected to the board and are interfaced with the motor driver. The joystick modules are used to control the robot's motion. A camera is mounted on top of the robot and is connected to the display unit in this it is a laptop.

Table -1: Hardware & Software components

S.NO	Components Description
1	Arduino Uno microcontroller - 1no.
2	Motor driver L298N - 2no.
3	Centre shaft motor (12v, 60 R.P.M) -1no.
4	Battery Operated DC motors (6v, 100 R.P.M) - 6 no.
5	Joystick module - 2no.
6	Camera
7	Jumper wires
8	3D Printed Parts
9	Power bank
10	Breadboard

11	Arduino IDE
12	Fusion 360 CAD tool
13	Cura Ultimaker
14	Laptop(Computer)

3.3 Working

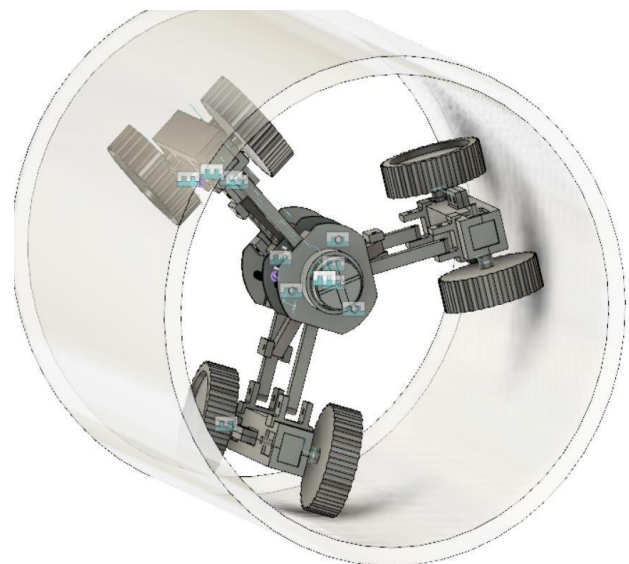


Fig - 16: CAD simulation front view

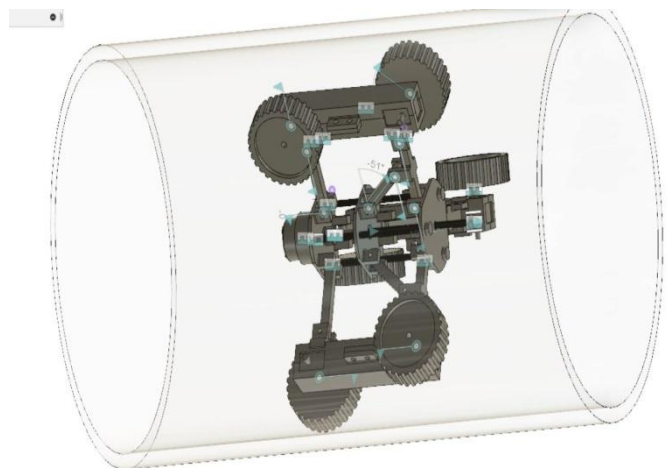


Fig - 17: CAD simulation side view

Figure -18 shows front view & Figure -19 shows the side view of the working simulation of the robot inside the pipe which is obtained using Fusion 360 tool. As the center shaft motor starts rotating which is controlled by the joystick module, it also rotates the bolt since the bolt is coupled with the center shaft motor. Then the movable disc which is attached to the bolt via a nut moves while the bolt unscrews, this movable disc and the fixed disc are connected to the arms via a links and joints at certain angle (0 - 51 degrees) at which contracts or expands accordingly, which is adjusted till it touches the walls of the pipe. Another joystick module is used to control the BO

motors of the arms which run the wheels on and make them rotate forward or backward. The bot then moves inside the pipe and starts capturing the channel inside using the web camera installed on top of it. It continuously sends the feed to the display unit (laptop) where one can see the pipe channel and look for any cracks or damages and corrosion.

4. RESULTS & DISCUSSIONS

4.1 Construction of the robot

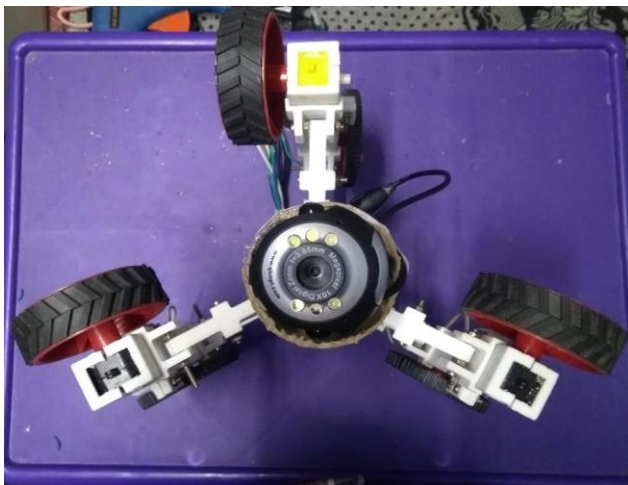


Fig -18: Top view of 3D printed robot

The above figure shows the side view of the 3D printed and assembled robot.

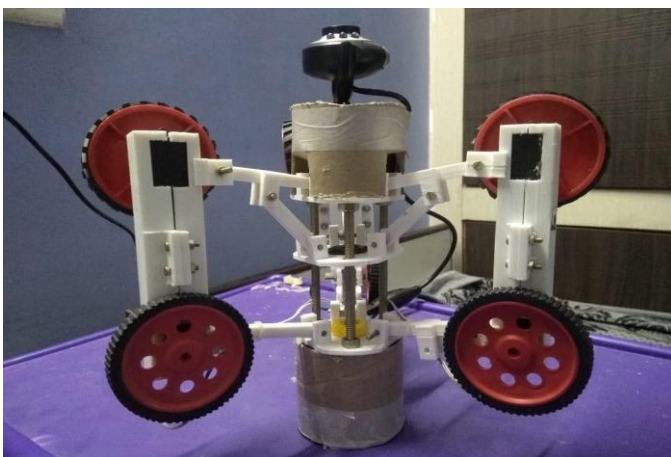


Fig -19: Side view of 3D printed robot

The above figure is the picture of the robot taken from the top.

4.2 Circuit setup

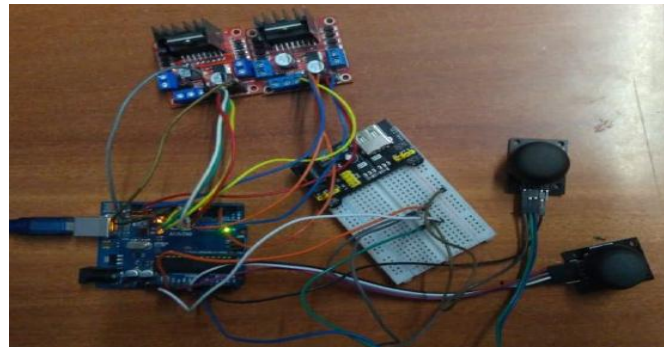


Fig -20: Circuit setup

The electronic circuit setup of the pipe inspection robot is shown in the above figure.

4.3 Experimental setup



Fig -21: Pipe setup

In order to conduct the test firstly the pipe is setup, the above figure represents the same.



Fig -22: Inserting the robot inside the pipe

Insertion of the robot inside the pipe for testing is depicted in the above figure.

4.4 Experimental results



Fig -23: Robot moving inside the pipe

After inserting the robot inside the pipe, using the joystick module the arms are made to touch the walls of the pipe. Then, using another joystick it is made to move forward. The above figure depicts the robot successfully able to adjust to the pipe diameters and is able to traverse forward inside the pipe smoothly.



Fig -25: Robot returning back

After sending the footage the robot is made to return back using the joystick module this is done by reversing the rotation of the motors which in turn makes the wheels rotate in the opposite direction. The above figure shows the successful returning of the robot.

5. CONCLUSION & FUTURESCOPE

The robot used to inspect the pipeline for cracks and corrosion or any blockages, is completed and has been tested with results verified. This bot has the ability to traverse inside the pipe of diameters ranging from 10cm to 14 cm. The whole model has been designed in Fusion 360 CAD tool and henceforth 3D printed. It has a camera attached and a temperature and humidity sensor interfaced. The bot runs smoothly inside the pipes and gives the expected visuals and results.

This project has been developed for small-scale applications but we plan to extend this design for large scale applications with added features such as attaching cleaning mechanism for pipe cleaning, etc. We also plan to automate the bot so that it can make simple decisions by itself using machine learning. We also tend to case the body for better sustainability. The bot can also be housed with different sensors like the Infra-red etc. for more clear inspection.

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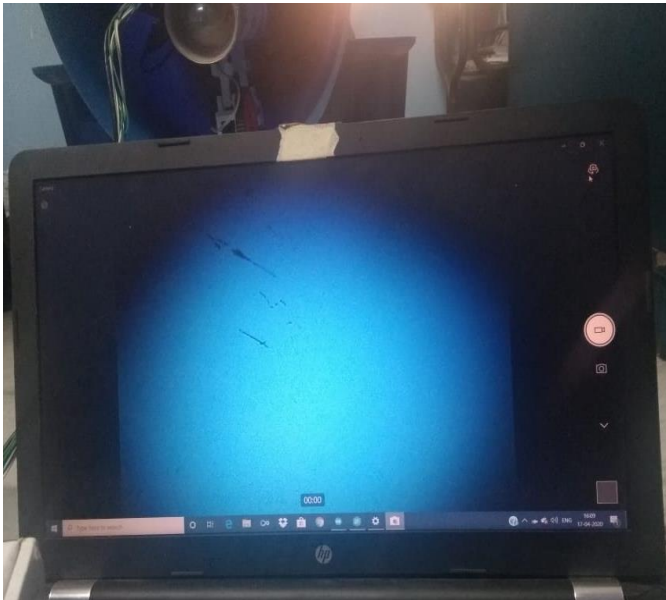


Fig -24: Footage of inside pipe channel sent by robot

The robot has successfully sent the live footage captured by the camera. The footage is being shown by laptop. From the visuals we can make out that there are some marks or cracks present inside the pipe which is being shown.

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