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Design and Fabrication of an In-Pipe Inspection Robot

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Abstract: **Leak detection in gas pipelines has always been a great challenge for engineers, which prompts us to develop much better ways to inspect pipelines efficiently. Saving time and money at the same time are priorities of the pipeline inspection. There have been numerous models around the world but performance varies on a wider range. Most of the inspection systems have limited applicability, are neither reliable nor robust, while others depend on the user experience. This project work consists of developing an 'In Pipe Inspection Robot' that move inside a pipeline and find the position of leakage. The need of a leak detecting system, types of leak detecting system are discussed in brief. Leak detection is done using the principle of pressure gradient around the leakage area and The robot chassis is incorporated with the electronic components for the movement of robot inside the pipeline.**

Keywords: **FSR, Pressure Gradient, Ultrasonic sensor.**

I. INTRODUCTION

The transport and distribution network of natural gas is a complex and continuously expanding task According to various studies, pipelines as a means of transport, are the safest, but this does not mean that they are risk-free. Main risk in this field is the leakage in the pipelines. Recent studies reveal that damages occurred due to in gas pipeline industries are most commonly due to the leakages in the pipelines [3].

The techniques for inspection are as follows :

- In-pipe inspection
- Out-of-pipe inspection

In-pipe inspection means using the unit for detection inside the pipeline. This consists of moving and non-moving methods for detection. This methods rely mainly on the usage of special sensing devices in the detection of gas leaks. Depending on the type of sensors and equipment used for detection, hardware methods can be further classified as: acoustic, optical, cable sensor, soil monitoring, ultrasonic flow meters and vapour sampling. In-pipe monitoring has a difficulty that correct position of leak can't be found out. Also a human cannot go inside the pipeline and check the position.

Pressure difference in the area of leakage. The system is used for detecting leaks in pipes with 10 inch inner diameter. The design can be suitably changed according to the diameter of the pipeline under study. Slight variation inside the pipe will be automatically adjusted by the robot. The design can be used in any kinds of pipelines, let it be plastic, metal or any other kind as there will be pressure difference in all kind of pressurised pipelines.

II. MECHANICAL DESIGN

The shape and size of the robot are the most critical factors in determining maneuverability, which depend on the pipeline configuration[1]. The urban gas pipelines basically consists of straight pipelines running horizontally and vertically. There are also elbows, branches, reducer, valves with unexpected mechanical damages such as dents, gouges, removed Past experience has shown that in-pipe inspection is more accurate, less sensitive to external noise, and also more robust [2].

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Most researches are done in designing simple and accurate In-pipe leak detection system. This gave us the idea of designing such a leak detection unit. Using a gas sensor may result in faulty positioning of the leakage inside the pipeline and it will be not suitable for every kind of gases. This difficulty was overcome by the principle of negative pressure difference in the area of leakage. The system is used for detecting leaks in pipes with 10 inch inner diameter. The design can be suitably changed according to the diameter of the pipeline under study. Slight variation inside the pipe will be automatically adjusted by the robot. The design can be used in any kinds of pipelines, let it be plastic, metal or any other kind as there will be pressure difference in all kind of pressurised pipelines.

The urban gas pipelines basically consists of straight pipelines running horizontally and vertically. There are also elbows, branches, reducer, valves with unexpected mechanical damages such as dents, gouges, removed metals caused by third-parties, which are not reflected in the layout drawing and demands highly flexible design of robots. The presented robot is for the in pipe inspection of the urban gas pipelines with the diameter of 250mm which is the most popular size in our country.

Based on the considerations of the pipeline configuration, the requirements of design can be derived as follows:

(1) Steering capability in branches,

(2) Driving through pipelines with a diameter of 240-260 mm (nominally 10 in. +-20%),

(3) Sufficient traction forces. The mobile robot should have sufficient weight carrying capacity (approx. 1.7 kg).

The configuration of pipelines restricts the whole size of the robot and the current technology determines the possibility of implementation because actuator, drive electronics, embedded controller, power supply, sensor, and communication tools would have to be placed in an extremely small space. One reasonable solution to this problem is the use of articulated structure such as snake-like or multi-joint robots though the control of the robot gets more difficult. The detector module is attached onto the mobile robot.

A 2 wheel drive mobile robot was designed with an Omni-directional wheel at the front for easy turn ability. 1 inch thick wheels (six in nos) are attached to the motors. The mobile robot motor is selected by calculating the torque the robot has to carry.

2.1 SENSING UNIT:

When designing the sensing unit the main problem faced was obtaining a design which can detect leaks at any angle around the circumference of the pipe. A 360 degree observability in a long pipeline. The module should also comply with the diametrical change in the pipeline due to damages, bends etc. The detection concept and the detector design are discussed in the forthcoming part. Detection is based on identifying the existence of a localized pressure gradient ($\partial p/\partial r$, where r stands for the radial coordinate of the pipe).

This pressure gradient appears always in pressurized pipes in the vicinity of leaks and is independent of the pipe size and/or pipe material. Moreover, the pressure gradient exists in different media inside pipes, which makes the detection method widely applicable (gas, oil, water pipes, etc.). This can be shown by considering a straight pressurised pipe. Due to the difference in pressures ($\Delta p = phigh - plow$) the gas leak through the opening. All size of leaks can be detected using the pressure difference, but we concentrate only on smaller diameter leaks, as larger diameter leaks can be found out by other means.

The proposed detection concept is based on the fact that any leakage in a pipeline changes the pressure and flow field of the working medium [4]. The main conclusion is that the region near the leak that is affected is small. However, this region is characterized by a rapid change in the static pressure, dropping from pHigh inside the pipeline, to plow the surrounding medium resting outside (see Fig. 3). The latter phenomenon is essentially a radial pressure gradient.

There is a local drop in the pressure around the leakage region. A suction pressure will be developed due to the pressure drop between the high pressure inner side and atmospheric pressure outside. Numerical studies showed that the radial pressure gradient close to the leak is large in the magnitude and drops quickly as the distance increases. Identifying leaks based on radial pressure gradient will be reliable and effective.

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In previous designs using the pressure gradient concept a number of sensors will be placed across the diameter of the pipe. Directly measuring the pressure at each point in order to calculate the gradient is not efficient and should be avoided. However, as a leak can happen at any angle φ around the circumference, full observability would require a series of pressure sensors installed around the perimeter of the pipe. To avoid the complexity of such an attempt, we use a more simple and efficient mechanism for detection. To achieve full observability around the circumference of the pipe, a circular membrane is utilized. The membrane is kept such that it always moves close to the pipe walls at all times complying with diameter changes and other defects on the walls and the material should be such that it should get attracted to the small suction pressure caused due to the leakage.

Now discussing about the carrier, the carrier assures the locomotion of the system inside the pipe. The wheels are clamped onto the carriers. The outer radius of the wheels touches the inner diameter of the pipe. The wheels was made with a material such that the traction between the pipe and wheels were reduced to the maximum extent. The force sensitive resistor was used for obtaining the analog data of the movement of the drum, onto which the diaphragm is attached. Either FSR or Flex sensor can be used for determining the force. The sensor was placed on a platform placed behind the front plate, or the sensor chassis.

Main functions the robot should carry out are:

- Autonomously move inside the pipe. Change its course of direction when it identifies an obstacle (turns in the pipes).
- In the course of its motion find the leaks with the help of force sensor and ultrasonic sensor.
- Give and take information with the Bluetooth interface

V. ELECTRONIC COMPONENTS

- One Force Sensitive Resistor (FSR) with an actuation force of 0.1 N are used for the detection of the movement change of the drum. The sensitivity range is about 0.1-102.
- One ultrasonic sensor to detect obstacles.
- 12V DC 200 rpm motors 6 in numbers are used for the actuation of the mobile robot.
- One Arduino Uno board is used for the controlling the movement, Detecting the FSR reading of the module.
- Power supply given by capacitor of 47 k-ohm.
- I.C. driver -LM378
- Regulator 7508

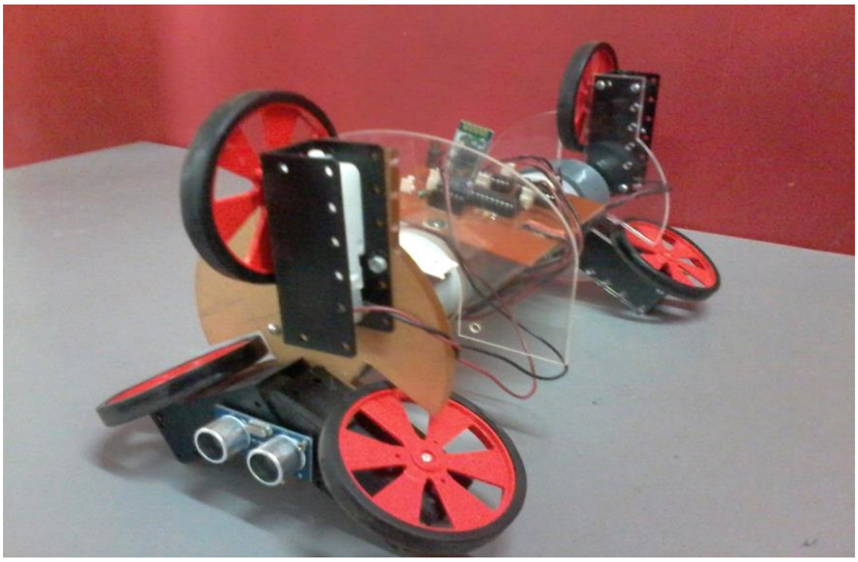

Fig 1 Robot Body

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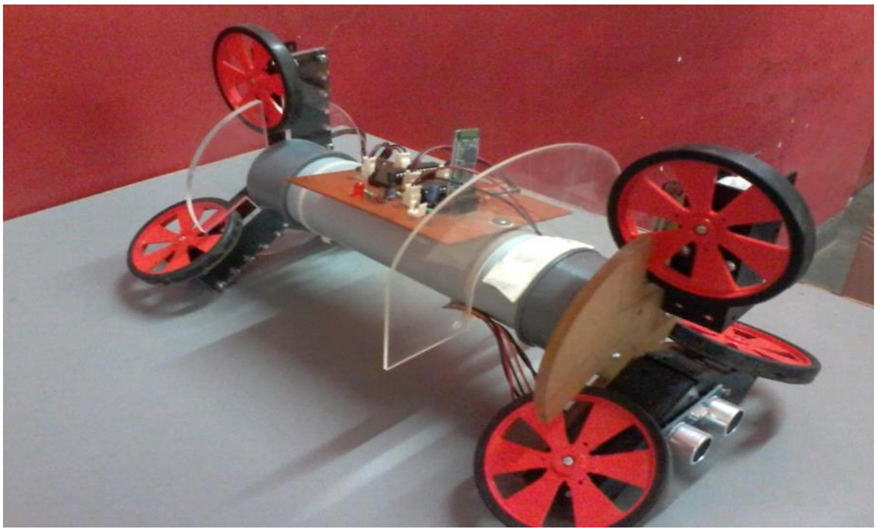

Fig 2 Front view

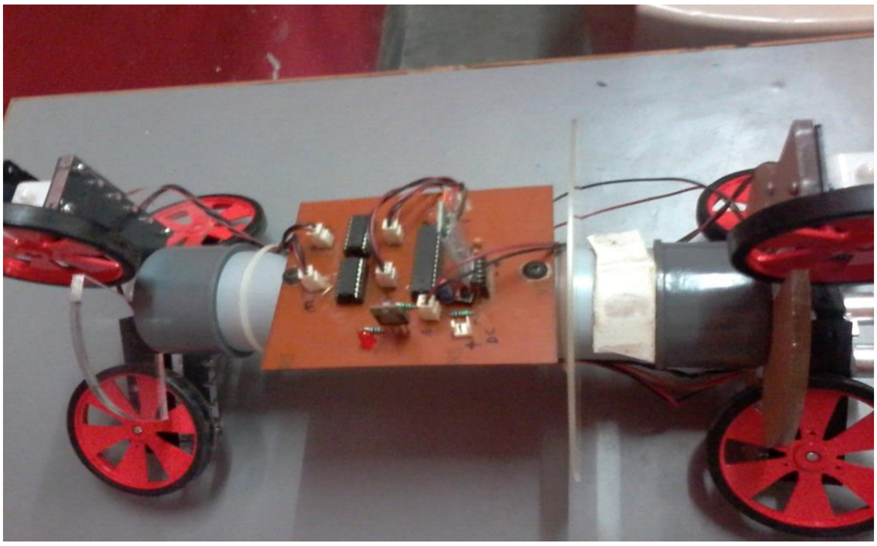

Fig 3 Top View

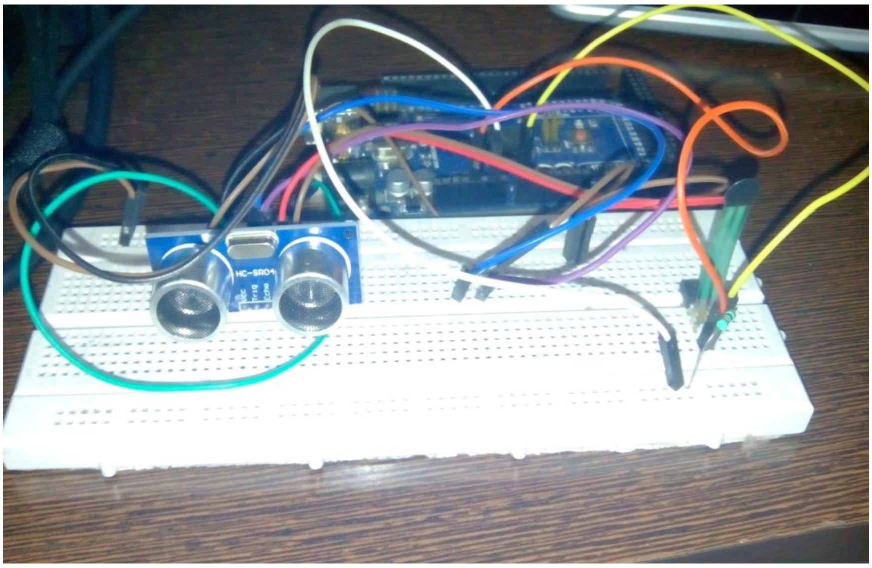

Fig 4 Bread Board with capacitance circuit

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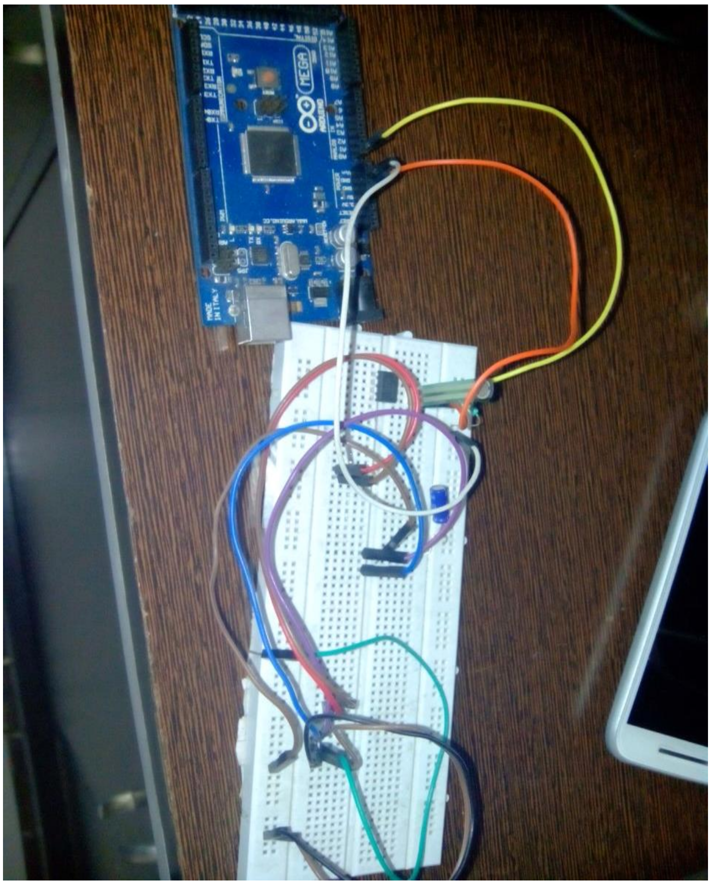

Fig. 5 Arduino Microcontroller

VI. CALCULATIONS

Given:

Length 250mm

Diameter (max) 250mm, diameter (min) 200mm

Mass 1.7 kg

Voltage supply 24 V

Speed= 0.35m /s

- Power required to run single motor is,

  P = W × v

  = m*g*v

  =1.7*9.81* 0.35

  = 5.8369 watt

- Hence, Power required to run DC motors to drive the robot is,

  P(required) = 2*5.8369 =11.67 watt

Position of Defect

Speed Taken = 0.35 m/s

Travel Time of robot = 200 sec (assume)

Therefore, Distance Covered will be = 0.35*200 = 70m

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