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Mathematical modelling, design and fabrication of pipe inspection robot

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Abstract

Robotics has many applications in today's era. Pipes were used to keep the fluid transmitter safe. However, these pipes are affected by fatigue, cracking, leakage, sediment, breaking down, humid environment, and chemical reaction, which causes rust and fatigue. All of these issues are related to the installation and maintenance of pipes in various applications. In the latest technology inspections of pipes done by using the robot controller reduce the inspection time and preventive repairs activity. But due to certain circumstances, there may be a chance of unfit pipes conditions. In this experiment has been study method of operations, robot movement, mechanisms, and benefits. Then, by using CATIA software important parameter has to be considered like designing and drafting This construction has a well-designed mechanism. To validate the software results, a series of experiments was conducted with visual report, camera and GUI toolbox. The use of a mini-cam for visualising in-pipe inspections or other devices required for detecting failures that appear in the inner part of pipes using measuring systems with lasers, sensors, and so on. In this research inside pipe modular robotic system is proposed inside of the pipes. Testing has been done for different movement and different slopes. The important thing is the amount of force between robot tracked units and pipe wall.

Keywords — Robot for pipe inspection, Flexible mechanism, Image processing, Designing and fabricating pipe inspection robot.

1. INTRODUCTION

Pipeline systems deteriorate progressively over time. Corrosion accelerates progressively and long term deterioration increases the probability of failure (fatigue cracking). Limiting regular inspections to the "scrap" section of pipelines results in a pipeline system with questionable integrity.. The confidence level in integrity will drop below acceptance levels. Inspection of presently uninspected sections of the pipeline system becomes a must.

Pipelines have really been known to be the safest method of transporting and supplying gases and liquids. To keep that reputation, regular inspections are required. In-Line Inspection Tools have access to the majority of the pipeline system, but only to the section between the launching and accepting traps. Corrosion, on the other hand, does not have this restriction. The industry is looking for ways to inspect these inaccessible pressure holding piping systems without disrupting operations. Direct pipe wall contact/access will be the only way to obtain sufficiently reliable and accurate inspection results. If we can't do it from the outside, then we'll have to go inside. Because modifying pipeline systems for In-Line Inspection is generally impractical, PIPE INSPECTION ROBOT pursues development of ROBOTIC inspection services for presently in-accessible pipeline systems.

Robotics is one of today's fastest growing engineering fields. Robots are supposed to replace humans in capital-intensive or dangerous processes, as well as to operate in inaccessible conditions. Robots are being used more more often than ever before, and they are no longer limited to the heavy manufacturing industries.. The inspection of pipes may be relevant for improving security and efficiency in industrial plants. Because these specific operations, such as inspection, maintenance, and cleaning, are costly, the use of robots appears to be one of the most appealing solutions. Pipelines, which are tools used to transport oils, gases, and other fluids such as chemicals, have long been used as major utilities in a number of countries. Many problems have recently occurred in pipelines, with the majority of them being caused by corrosion, cracks, and mechanical damage while dealing with third parties.. So, continuous activities for inspection, maintenance and repair are strongly demanded.

Robots with a flex (adaptable) structure may boast environmental adaptability, especially to pipe diameter, as well as enhanced dexterity, controllability, and the ability to operate in adverse circumstances. Wheeled robots are the most basic, use the least amount of energy, and have the excellent potential for long-distance travel. Loading the wheels with springs, robots also provide some advantages in controllability by being able to adapt to in-pipe unevenness, relocate straight down in pipes, and stay stable without sliding back in pipes.. Such robots also have the advantage of being more easily miniaturised. The main challenge in their design and implementation is combining the ability to move with that of self-sustaining, as well as the properties of light weight and dimension. The adaptability of the in-pipe robots to the inner diameters of the pipes represents a critical design goal. Robot applications for pipeline utility maintenance are currently regarded as one of the most appealing solutions available in industry.

2. LITERATURE REVIEW

Literature review includes the previous work or research work done on pipe inspection robot concept. It gives an idea about how pipe inspection robot works and performs various function. Also how the concept actually comes into existence. Also provides the brief about why there is the need of the robot, why not only humans. Robots have wide history of being in use ever since industrialization. There has been an ever growing development in the field which is noted in the several records.

Ankit Nayak and S. K. Pradhan (2014): Their research focuses on the investigation of design issues related to the development of in-pipe inspection robots. Different design related issues of in pipe inspection robots are investigated in this paper. Further, robots are classified on the basis of structure and method of locomotion. Ability and special advantages of each type of structure and locomotion system are presented followed by some example of already developed in-pipe inspection robot by several researchers in previous years. Their observations can be utilized as a guideline while designing IPIR for a particular application.

Atul Gargade et-al(2013): They did the analysis and modeling of the pipe inspection robots in their work. This robot is made up of three components: a foreleg system, a back leg system, as well as a body. The fore and rear leg systems are built with three worm gear systems arranged at a 120-degree angle to each other to operate inside a pipe of varying diametersThe springs are connected to each leg and the robot body to allow it to operate in pipes with diameters ranging from 140mm to 200mm.

E Navin Prasad(2012): They proposed a six wheeled model for the inspection of pipelines. A very important design goal of their robotic systems is the adaptability to the inner diameters of the pipes. The main advantage is that it can be used in the event of pipe diameter variation using a simple mechanism. Their model is applicable to 140-180mm pipeline. This robot's mechanism kinematics and actuator sizing have been investigated. To test the feasibility of this robot for inspection of in-house pipelines, a real prototype was created. The researcher employed a PCB board capable of driving a DC motor.. The propulsion of the robot has been successfully conducted using only three motors. Their robot is designed to be able to traverse horizontal and vertical pipes successfully.

Matthieu Jones et-al(2012): They proposed a high speed in pipe inspection robot model.
The following are the findings from their work.

1) The maximum speed of the pipe inspection robot should be 80 mm/sec.
2) The robot should be able to detect leaks.
3) The erosion inside the pipeline, directly affects the speed of robot
4) The important limitation of the robot is that the large volume of raw data which needs to be processed.
5) The resolution can be sacrificed to a certain extent; however, it is preferable to keep it as high as possible while still maximizing the speed.

Mihaita Horodinca et-al: They designed a simplified structure for an in-pipe inspection robot. The robot is made up of two parts that are articulated with a universal joint. A set of wheels moving parallel to the pipe's axis guides one part along the pipe, while tilted wheels rotating about the pipe's axis forces the other part to follow a helical motion. To generate motion, a single motor is placed between the two bodies. To accommodate changing tube diameters and pipe curves, all of the wheels are suspended. The robot is self-contained, with its own batteries and radio link. They built four different prototypes for pipe diameters of 170, 70, and 40 mm. For smaller diameters, the batteries and radio receiver can be mounted on a separate body that is attached to the others. The proposed architecture is very straightforward, and the rotary motion can be used to perform scrubbing or inspection tasks.

Majid M. Moghadam et-al: Researchers did work on an in-pipe inspection crawler that can be adjusted to fit the inside diameter of the pipelines. One of the most important requirements for pipeline repair and maintenance is the ability to monitor and evaluate the pipe's interior. The mechanism makes use of three independent rubber track units that are symmetrically spaced out 120 degrees circumferentially. The device operates in an active mode to accommodate a wide range of pipeline diameters ranging from 250 mm to 350 mm. Such a range, however, can be easily expanded by increasing the length of the robot's linkages. It can also travel through vertical, horizontal, and curved pipes. With the help of the springed arms' special design, it can also passively pass over small obstacles on the interior surface of the pipes and navigate through various elbow joints in the piping system. Furthermore, a novel autonomous adjusting algorithm is presented to help the operator better regulate the contact force without the use of a force sensor. The robot also has a pan and tilt camera..

3. MAJOR COMPONENTS OF PIR

3.1CHASSIS:-

The chassis is built in the body style. The robot's chassis is made of galvanized steel sheet that is reinforced along its girth with aluminum strips. Motors have been used in mechanical transmissions. Independent drive allows for smooth movement inside the pipe, and the four rear wheels are easy to run, resulting in chassis stability and minimal wheel wear during operation.

A chassis is a built-in framework that allows for the construction and use of a metal matrix composite. The circular, usually steel frame that supports an automobile's body and motor and is attached to the axles. The framework to which components of radio, television, or other electronic equipment are attached. A framework that aids in the construction and use of a manufactured. The circular, usually steel frame that supports the body and motor of an automobile and is attached to the axles. The framework to which radio, television, or other electronic equipment components are attached.

3.2 DC GEAR MOTOR:-

Synthetic compound gear motors are relatively light, small in size, and simple to install. The motors are available in a variety of RPMs (revolutions per minute). For this robot, we can purchase a motor with a speed range of 40 to 100 RPM. The greater the torque, the lower the RPM (which doesn't matter much for this robot).

Features

- One DC motor and wheel, with integrated gearbox.
- 40 rpm output shaft gearbox means powerful enough to tackle inclines and carpet at around 3 meters/min.
- 12V DC motor, 7.2A so that it can be run

Photograph 3.2 DC Gear motor

3.3 RUNNER WHEEL:-

Wheels that can be used with synthetic compound gear motors. These wheels will come with two screws. These two screws are used to connect the wheels to the plastic gear motors.

Photograph 3.3 Wheels of PIR

3.4 FOCUS LIGHT:-

A semiconductor is a light-emitting diode (LED). LEDs are used as indicator lights in many devices and are becoming more popular for general lighting. Early LEDs, which first appeared as practical electronic components in 1962, emitted low-intensity red light, but modern versions are available in visible, ultraviolet, and infrared wavelengths, with very high brightness..

When a light-emitting diode (LED) is turned on, electrons within the device change their configuration, releasing energy in the form of photons. This is known as electroluminescence, and the colour of the light (corresponding to the energy of the photon) is determined by the semiconductor's energy band gap. Because an LED's area is often small (less than 1 mm2), integrated optical components can be used to shape its radiation pattern. LEDs outperform incandescent light sources in numerous ways, including lower energy consumption, longer lifetime, increased physical robustness, smaller size, and faster switching. LEDs with enough power for room lighting, on the other hand, are more expensive and require more precise current and heat management than compact fluorescent lamp sources with comparable output.

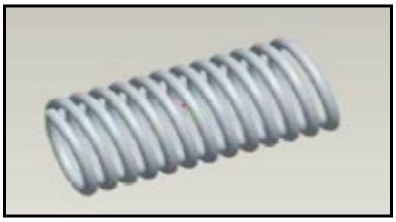
Photograph 3.4 Light emitting diode

3.5 COMPRESSION SPRING:-

A spring, in its most basic form, is a mechanical device used to store and then release energy due to resilience, to absorb shock, or to maintain a force between contacting surfaces. They are made of an elastic material that has been shaped into a helix shape and returns to its natural length when unloaded.

The spring used in this case is made of hardened steel. Compression springs are primarily used to apply tension.The purpose of spring is as follows:

- An open standard spring generates the force exerted by the portable robot mechanism on the pipe walls.
- In the event that the pipe diameters change, the helical spring located on the central axis ensures that the structure is repositioned.



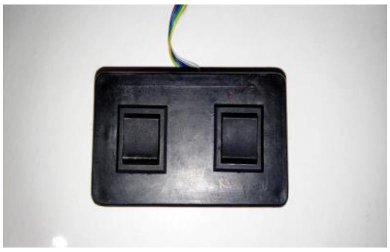
Photograph 3.5 Compression Spring

3.6 WIRELESS CAMERA:-

The transmission of data over a long distance without the use of electrical conductors or wires is referred to as wireless technology. Bluetooth cameras, like all other devices, have a channel. Before you can see the picture, you must first tune in to the recipient's channels. The wireless camera image is sent by the transmitter to the receiver, which collects it and sends it to our TV or desktop via a TV tuner card. The camera is attached to one end of the frame, and the robot is designed to inspect inside a pipe, which is viewable on a desktop computer. To view the inside of the pipe, the camera sends a signal to the receiver, which receives it and connects to the monitor.

Photograph 3.6 Wireless camera & Receiver

3.7 CONTROL REMOTE:-

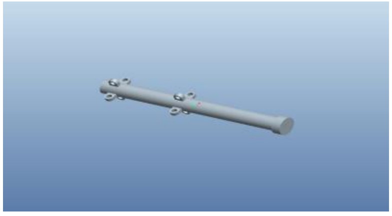


Photograph 3.7 Remote Control

The control panel has only been built for the wire version. The control panel in the wireless control version will be a laptop's screen and keyboard. Many switches on the control panel activate specific motors (of the drive, the arm, the grab, the vertical supporting wheel, and the camera platform) and lighting. Special controls (located inside the control panel's casing) were used to control the modelling servos as well as the stepper motor.

3.8 CENTRAL FRAME

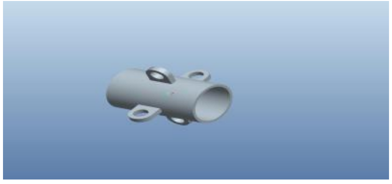
The frame of the robot is its central body. It supports all other components and houses the batteries in the body's centre. The four joints are brazed at 90 degrees on the central frame. At one end of the frame, a wireless camera is fixed.



Photograph 3.8:- Central Frame

3.9 TRANSLATIONAL ELEMENT

Translational motion elements are the movable parts of the robot that slide along the central body for repositioning in the event of pipe diameter variation. This element has a central hole drilled through it to allow for translation along the central body. This constrains the links to certain extreme angles beyond which they cannot be translated. The joints of the translational motion elements are brazed at 90 degrees so that the links can be attached to them.



Photograph 3.9 Translational Element

3.10 LINKS

Kinematic link or element refers to each resistant body in a machine that moves relative to another resistant body. A resistant body is one that does not deform while transmitting force. The key element of the robot that translates motion is the link. A linkage is formed by connecting links. The mechanism at work here is a four-bar mechanism with three revolute pairs and one single prismatic pair, as shown. Links houses the camera's receiver, switch, and 9v battery.

Photograph 3.10: Links

3.11 Batteries

Batteries power a motor and a wireless camera. The motor and radio frequency are powered by a 6v supply from the central body, while the wireless camera is powered by a 9v battery. And three-volt batteries for the transmitter, which has two toggle switches. The first is for motor forward and reverse control, while the second is for glowing LEDs. A 12v battery is also required to power the DC motor that drives the robot's four wheels.

Photograph 3.11 Batteries (12V & 9V)

3.11 Transmitter

A set of equipment used to generate and transmit electromagnetic waves carrying messages or signals, to which is attached a camera with an output device that transmits video and pictures

4. DESIGN OF PIR

4.1 Selection of materials:

This machine's materials are light and rigid. Different materials can be used to construct various parts of the robot. The materials used should be light and strong in order to make the best use of power. Wood is light, but it will wear if used for this machine. Metals are the best materials for the robot because most plastics are not as strong as metals. The material should be ductile, brittle, malleable, and magnetically susceptible. Among the metals, aluminium was chosen for the linkages and the common rod, which is hollow for weight reduction. The motor, on the other hand, is made of different materials.

The materials used in the motor should have a high magnetic susceptibility and be good electrical conductors. Copper and other metals are used. However, aluminium was chosen as the material for the linkages and central body due to its desirable properties. Aluminum is lightweight and strong, making it suitable for a wide range of

applications. In engineering structures, aluminium alloys with a wide range of properties are used. The strength and durability of aluminium alloys vary greatly, not only due to the alloy's components, but also due to heat treatments and manufacturing processes. Another important characteristic of aluminium alloys is their heat sensitivity.
Workplace heating procedures are complicated by the fact that, unlike steel, aluminium will melt without first glowing red. Internal stresses occur in aluminium alloys, as they do in all structural alloys, as a result of heating operations such as welding and casting. Because aluminium alloys have a low melting point, they are more prone to distortions caused by thermally induced reducing stress.

- Robustness decreases as yield stress increases, as measured by crack propagation energy.
- The underaged structure has greater toughness than the overaged structure at the same yield stress.

4.3 Mechanism:
As shown, the mechanism is a four-bar mechanism with four revolute joints and one slider joint.

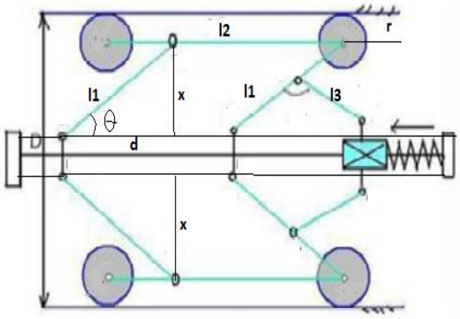


Fig 4.1: Mechanism of PIR

D = Inner diameter of the pipe.
d = Outer diameter of the pipe.
r = Radius of the wheels.
x = Distance from the O.D. of central frame and centre line of wheels.
From the above fig.
Sin Θ = x/l1
Therefore, x = l1 Sin Θ
Now,

$$D = 2.r + 2.x + d$$

Hence,

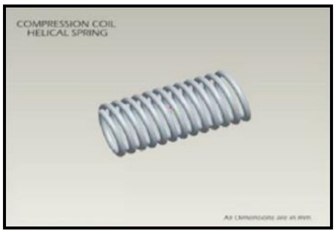
$$D = 2.r + 2.L_1 \text{ Sin } \Theta + 2\ d$$

This is the required relation, to get the inner diameter of the pipe.

4.4 Design of various elements of PIR

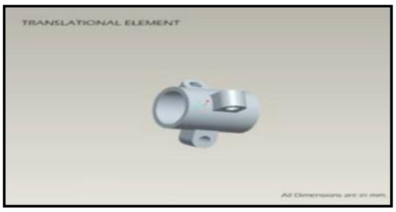
4.4.1 Helical spring

Inner diameter – 18 mm
Outer dia – 20 mm
Pitch – 5 mm
Free length of the spring – 290 mm
Solid length of the spring-- 102.5mm
Material – Oil tempered Stainless steel



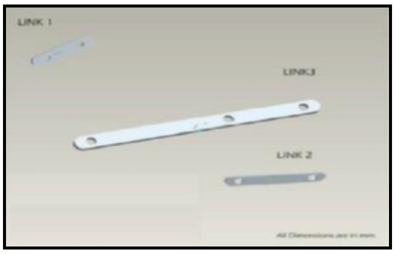
Photograph 4.4.1: Helical Spring

4.4.2 Translational Element
Inner diameter – 22 mm
Outer diameter – 27 mm
Length of the element – 50 mm
Material – Mild steel



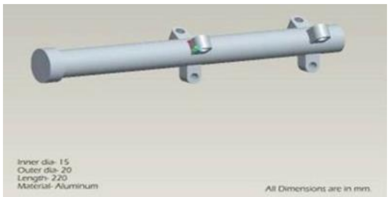
Photograph 4.4.2: Translational Element

4.4.3Wheel
Wheel Diameter – 72 mm
4.4.4 Distance between the Extreme links
Link 1 – 130 mm
Link2 – 230 mm
Link3 – 60 mm
Thickness – 3 mm
Drilled holes – 5 and 3 mm
Material – Aluminium



Photograph 4.4.3: Links

4.4.5 Central Element
Hollow
Inner dia – 12 mm
Outer dia – 16 mm
Length – 630 mm
Material – Mild steel



Photograph 4.4.5 Central Frame

5. DESIGN CALCULATIONS

According to all the original dimensions of robot,

r= 40mm ; l1=130mm ; d=16mm ; ϴ=62.3

According to mechanism :-

$D = 2r + 2.l_1 \sin \Theta + 2d$

For maximum pipe diameter

D = (2*40) + (2*130*sin(62.3)) + (2*16)

= 341.99mm ≈ 34.2cm

For minimum pipe diameter

D = (2*40) + (2*130*sin(43)) + (2*16)

= 289.31 mm ≈2 9cm

Hence, range of pipe diameter for inspection, by PIR is approximately 29 cm to 34 cm.

6. CONSTRUCTION OF PIR

A pipe inspection robot is made up of a central element with a diameter of 12 mm, a thickness of 4 mm, and a length of 63 cm, and one translational element with a diameter of 22 mm, a thickness of 5 mm, and a length of 50 mm. There are 16 links, four of which are 230mm (A1, A2, A3, A4), eight of which are 150mm (B1, B2, B3, B4, B5, B6, B7, B8), and four of which are 75mm (C1, C2, C3, C4). The length of the spring is 290mm.

The central element is connected to eight 150 mm long links. Links on the central element are attached to the fulcrum with pin joints on the periphery with 90 lateral spacing at points 1, 2, 3, 4, as shown in figure..

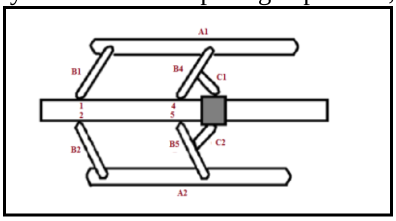


Fig 6.1 Construction of PIR

In addition, four links, B4, B5, B6, B7, are attached to another point, 4, 5, 6, 7, which is 230mm from point 1, 2, 3, 4, as shown in the figure in the same manner as the previous point. The one end of the four links (C1, C2, C3) is attached to the translational element in the outer side to the fulcrum with a pin joint that is 90 degrees in lateral spacing, and the other end is attached to the links B4,B5,B6,B7 at a point with a pin joint, as shown in the figure.

Another link of the same length (A1, A2, A3, A4) is attached to the end of the links (B1, B2, B3, B4, B5, B6) at the distance shown in the figure. The motor and wheels are attached to the links (A1, A2, A3, A4), as shown in the figure. The structure's front end is attached with a swivelling and turning head comprised of a camera and fitted with a BO motor.

A long cable wound around a winch connects the camera to the display equipment (output). There are six wheels, each with a diameter of 72mm. There are six D.C motors with 10rpm and 12v. There are two BO motors with 60rpm and 3-9v. The BO motor, which is attached to the front of the robot, is used to activate the camera and light. The spring is attached to the robot's end and provides expand and compression motion to the links via a translational element.

Photograph 6.1 Top view of PIR

Photograph 6.2 Complete PIR Model

Photograph 6.3 PIR locating defects

7. WORKING PRINCIPLE

Working principle used in this robot is Inversion of Four bar mechanism or GRASHOFF'S LAW.

CONDITION FOR FOUR BAR KINEMATIC CHAIN OR GRASHOFF'S LAW: -*"It states that the sum of the shortest and longest link in the kinematic chain must be less than the sum of other two remaining links."*

INVERSION OF MECHANISM:

A mechanism is a kinematic chain with one link fixed. The fixed is called as frame. Different mechanisms are obtained by fixing different link in a kinematic chain. The process of choosing different link in a kinematic chain for the frame is known as invasion.

INVERSION OF FOUR BAR MECHANISM:

Various types of inversions are:-

- COUPLED WHEELS OF A LOCOMOTIVE (Double crank mechanism)
- PANTOGRAPH (Double Lever mechanism)

For inserting the robot in the pipe we have to pull the translation element backward there by compressing the spring as shown in the fig A. due to the arrangement of links according to four bar mechanism the outer most link move inward. After introducing robot in pipe we have to leave the translation element, then spring expand and due to the fore of the spring and arrangement of link again the outmost link move outward and robot get hold in the pipe.

WORKING OF PIR

WORKING

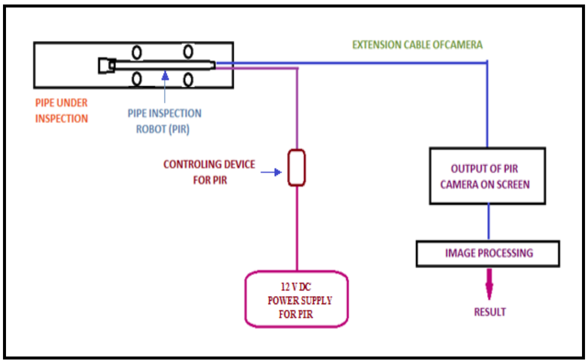


Fig 7.1:- Flow-chart showing working of pipe inspection robot

Working of the Pipe Inspection Robot

The PIR has a proclivity to see inside dark pipes where human eyes cannot. This was made possible by mounting a surveillance camera and LEDs on the PIR's head. The output is routed to an external screen, where the digital high-quality image can be viewed..

After inserting the robot into the pipe, the perfect fitness between the pipe and robot is first conformed. Then the supply of DC 12V dc current from is turned on for the robot's operation, and the camera is turned on as well. With the help of a robot control with three buttons, the working of the robot can be easily controlled the motions of forward and reverse by one button and swivelling and tilting of the camera head fitted in front of the robot by the other two buttons so that we can see the pictures and videos inside the pipe.

The operation of a PIR begins with its insertion into a pipe. The front arms are compressed by hand and inserted into the pipe, followed by the rear arms, which are inserted by pushing the PIR. When the switch is turned on and current flows through the wires, the wheels begin to move, causing the PIR to propel forward. The motion of wheels is made possible by the friction between the wheels and the pipe.

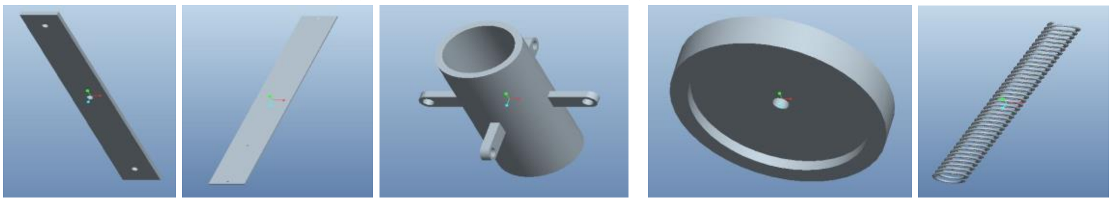
PIR wheel movement is provided with low rpm, 12 V DC motors, allowing for consistent speed. Because the power to the motors is supplied by a single 12V DC adapter, the load on each motor will be lower than expected.

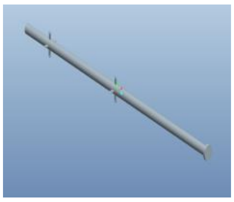
An auto adjusting mechanism that can expand and contact as PIR moves inside the pipe is provided. Spring of suitable stiffness is mounted on base rod, as seen in figure, so that as arms gets contracted due to load of compression against pipe, spring get compressed and tend to expand outward trying to push arms back to their normal position but as pipe restrict them, they cannot move. Even if the pipe interior is smooth, using pressure between compressed tire and pipe, PIR can move easily. This is another application of spring.

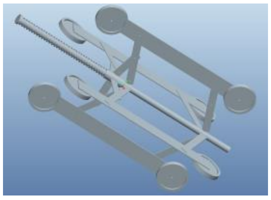
The robot is run inside pipe by forward and reverse motion of the wheel which has the speed of very less rpm. This constant slow speed is to insure better inspection because of the high speed there may be possibility to miss the any defect. The camera is controlled by another button provided on the remote control. The output image from camera is sent to Computer screen which may be laptop, monitor, TV or any such device which gives the visual picture.

Operator can control the robot and see the picture of the inside pipe on the output screen and thus if there is any defect such as such as internal material loss , big crack, weld defects dents corrosion erosion or blockage in the pipe can be detected . To ensure the tractive force required for pulling the other accessories, robot train can be used which can be made by joining the two or more robots through the universal joints at the end. The inspection can be done on the basis of video and pictures inside the pipe provided by camera. The result can be obtained directly on the basis of these pictures or with the help image processing.

COMPONENTS AND PROTOTYPE IN CREO







INSPECTION METHODS

8.1 Video Inspection:

Robots deployed for the video inspection of pipe systems possess a maneuverable head that can be turned 360° and tilted 90°. This means that even video pictures can be shot right below the pipe wall. Separate video recording of on-line video data at the control point allows the operator to monitor, achieve and add comments to the footage. Using highly specialized, closed-circuit cameras, we can perform visual inspection of all pipe systems, from as small as 6 millimeters - or 1/4 inch - in diameter up to any size.

8.2 Visual Inspection:

Due to the cost of advanced inspection techniques, less expensive forms of Nondestructive evaluation is often desired. Visual inspection is currently one of the most commonly used nondestructive evaluation techniques because it is relatively inexpensive as it requires minimal, if any, use of instruments or equipment, and it can be accomplished without data processing. As mentioned previously, visual inspection can only detect surface defects. However, a large number of structural deficiencies have surface indicators (e.g. corrosion, concrete deterioration). Aside from a limited range of detection, visual inspection does have further drawbacks. It is extremely subjective as it depends on the inspector's training, visual acuity, and state-of-mind. Also external factors such as light intensity, structure complexity, and structure accessibility play a role in determining the effectiveness of visual inspection.

8.3 Ultrasonic inspection

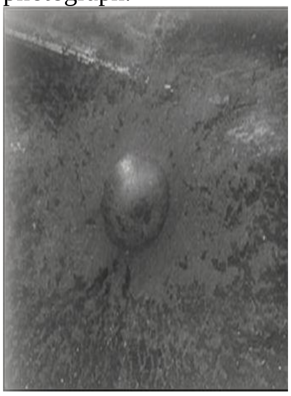
Common non-destructive in-line inspection technologies such as magnetic flux leakage (MFL), ultrasonic testing (UT) and eddy current systems cannot detect stress corrosion cracking (SCC), especially in gas pipelines. Based on an electro-magnetic acoustic transducer (EMAT), a new type of ultrasonic sensor uses physical effects such as the Lorentz force and magneto striction. It therefore works independently of a coupling medium between the sensors and the pipeline to be inspected, thus providing the ideal crack inspection solution for both liquid and gas pipelines. The ultrasonic waves only travel a short distance between the EMAT sender and the receiver. As a result, data evaluation is relatively simple and false alarms can be avoided. The EMAT sender generates a tailored shear horizontal wave characterized by distinct frequencies which make it especially sensitive to near-surface defects.

Provided that no cracks are present, the generated wave propagates in one direction from the EMAT sender to the EMAT receiver which records it as a transmission signal. If, however, there is a crack-like defect between the EMAT sender and the EMAT receiver, one part of the signal is reflected back to the EMAT sender where it is recorded as an echo signal by the second EMAT receiver.

9. PERFORMANCE AND TESTING

Following the design and modeling of the proposed mechanism a prototype unit was built. The prototype was built for a robot with the weight of 1.8 kg. The body of the robot was fabricated mostly from aluminum. The Robot was driven by 4 dc motors. PIC robot tested successfully for movement in horizontal and inclined pipes. The robot has a good mobility and ability to pass over small obstacles.

The important thing is the amount of force between robot tracked units and pipe wall. Even in horizontal moving, attachment of the up tracked unit in addition to bottom ones, improve the movement of robot. Because in this state 4 motors participate in robot move although friction is more. In addition to this, the robot is more stable and distribution of load on different actuators is more similar. Monitoring the pipe inside was suitable and the control of different actuators was effectively possible. The model of PIR is drawn with the help of mechanical engineering software tool Pro ENGINEER and PIR while inspection of various defects are shown in photograph.




Photograph 9: a) Dent in pipeline b) Joint in pipeline

10. CONCLUSIONS

Robots play an important role in inside pipe-network maintenance and their repairing. Some of them were designed to realize specific tasks for pipes with constant diameters, and other may adapt the structure function of the variation of the inspected pipe.

In this research inside pipe modular robotic system is proposed. An important design goal of these robotic systems is the adaptability to the inner diameters of the pipes. The given prototype permits the usage of a mini-cam for visualization of the in-pipe inspection or other devices needed for failure detection that appear in the inner part of pipes (measuring systems with laser, sensors etc).

The major advantage is that it could be used in case of pipe diameter variation with the simple mechanism. We developed a pipe inspection robot that can be applied to 290 mm- 340 mm pipeline. A real prototype was developed to test the feasibility of this robot for in section of in-house pipelines.

The types of inspection tasks are very different. A modular design was considered for easily adapted to new environments with small changes. Presence of obstacles within the pipelines is a difficult issue. In the proposed mechanism the problem is solved by a spring actuation and increasing the flexibility of the mechanism. The robot is designed to be able to traverse horizontal and vertical pipes. Several types of modules for pipe inspection mini-robot have been presented. Many of the design goals of the Pipe inspection robot have been completely fulfilled.

11. FUTURE SCOPE

- Detection of minor cracks using ultrasonic sensor.
- Distance meter, to identify the actual location of defects.
- Painting of pipelines from inside.
- Cleaning of pipelines by using water jet.
- To design the robot with track & wheel mechanism.

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