Simulation and Analysis of In Pipe Wall Pressed Robot for Inspection and Cleaning Operations

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Abstract: The aim of the project is to design a pipe cleaning and inspection robot for industrialapplications. This is going to use very simple mechanism for cleaning the internal area of thepipe with changing diameters. The design is focusing on developing a bevel gear mechanismwhich can able to clean and translate the robot body into the pipeeffectively. Here we are goingto use only single DC motor for both cleaning and locomotion in the pipe. The inspection ofthe pipe is by using the ultrasonic sensor. The ultrasonic sensor is going to give the distancebetween the obstacle and the robot. According to the distance measured we are going to knowabout the bends and joints. The ultrasonic sensor is also going to give information regardingthe waste materials accumulated in the pipe.

1 INTRODUCTION

Pipes are one of the most important components that are being used for the transportation of the raw materials in many industries. They are the integral part of oil and gas industries. Pipelines are used to carry materials like water, crude oil, gases, petroleum and industrial waste. Due to over usage the pipes will damage very less time. So we have to monitor the pipes continuously and clean the pipes on a regular basis. But inspection and cleaning the pipes is not an easy task it requires a lot of effort and time.

In olden days, large size pipes like drainages are cleaned manually by labors. Because of the size of the pipes and shapes involved with them wecan't use men for all occasions. Especially the industrial pipes vary in size from millimeters to meters and contain many types of harmful substances inside the pipe. The shapes are also very complicated, and branches like T-shape, Y-shape, increaser, decreaser and elbow are making the locomotion even more difficult. Because of the harmful substances it is necessary to use devices that can do the inspection and cleaning operations in thepipe.

Because of the above reasons the only option we left with is the robots. The robots can come handy for pipeline inspection and cleaning. Now a day's many researchers are working on the development of in-pipe robots. There are many robots designed for inspection and cleaning some of them are given below

1. Wheeledtype
Caterpillartype
2. Wall-pressedtype
3. Walkingtype
4. Inchwormtype
5. Pig type (Pipe InspectionGauges)

Fig.1 Welding problem in prototype and prototype testing

2. OBJECTIVE

1. The objective of the project is to design a pipe cleaning and inspection robot for industrial applications.
2. To develop an in-pipe robot for pipes with changingdiameters.
3. To develop a single mechanism for both locomotion andcleaning.
4. To implement low-cost inspection system with goodaccuracy.
5. To develop better cleaningdevice.

3. CONCEPT 1-PRIMARYMODEL

Many concepts have been developed but the first idea is to design an in-piperobot which can perform cleaning with help of three dc motors and locomotion by using a two high torque dc motors. For automatic adjusting to pipe size we planned to use a piston cylinder mechanism. To inspect the in-pipeenvironment we planned to use a camera at the front portion of the in-pipe cleaning robot.

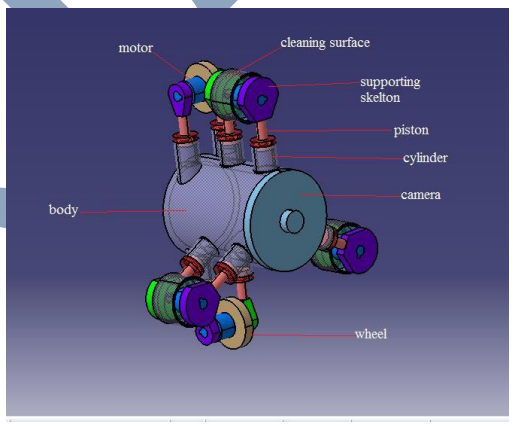

Fig 2 In-pipe cleaning robot

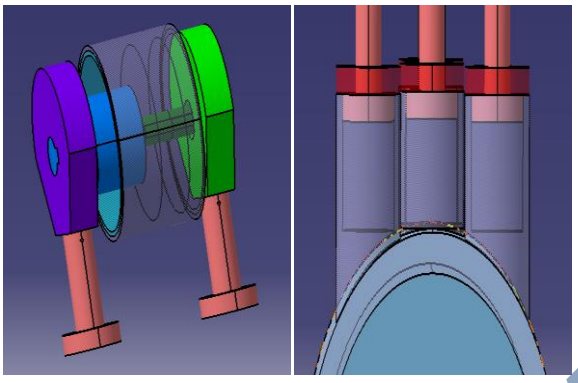

Fig.3 Cleaning portion and piston-cylinder mechanism

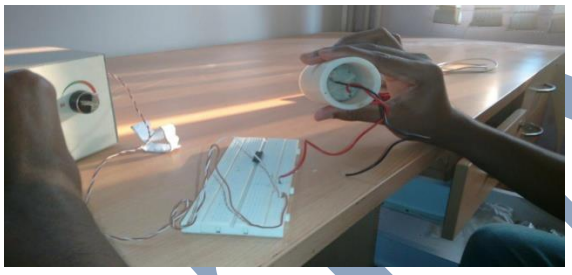

Fig 4Testing the prototype-1

Fig.5 3D printer & fabricated model

The above figure1 showing prototype testing. It is also giving information about the defects in the design which are mention in the following points.

The designed model has many drawbacks like

1. Complexdesign
2. Singlemodule

3. Too many electronicdevices
4. Piston cylindermechanism
5. Drag due to cleaningportion
6. Directionchanges

Complex design

The above model is very complex in structure. Due to the complex structure the motors may not provide sufficient torque to the body to move forward and backward.

Single module

There are no separate modules for cleaning and locomotion. This is one of the major drawbacks in the model. Because of the single module while the cleaning is being performed there are chances in the power cables to get detached from the robot. Since my design is a wired one.

Many electronic devices

Many electronic devices are there in the robot. They are control circuit, DC motors and camera. As we know there are many types of corrosive substances in the pipe that is going to damage theelectronic components.

Piston and cylinder mechanism

The piston and cylinder mechanism used for automatic adjustment to pipe size. The mechanism may not work properly because of the compressed gas used in it. The structure is also can't provideenough strength.

Fig. 6 Interfacing of ultrasonic sensor with Arduino controller

Drag caused by cleaning portion

Since the cleaning wheels are in the same axis to the pipe diameter, while cleaning they can do better cleaning. Coming to the locomotion of the robot in the pipe the cleaning wheels are goingto cause lot of drag to the robot. Because of it the robot may require high amount of torque to move in and out.

Direction change

There are many types of joints like T-joint, Y-joint, etc. and shapes likeelbows in a pipe structure. Because we used a single module there is no such mechanism for direction changing which is very crucial in the pipe.

The above figure is showing the interfacing of ultrasonic sensor with arduino. The ultrasonic sensor used here is HC-SR04. There are four pins in the ultrasonic sensor, they are

1. Trigger
2. Echo

3. Vcc
4. Ground

4.OVERVIEW

Development of in pipe robot has been divided into several parts, they are

1. Computer aideddesign
2. Analyzing thedesign
3. Fabrication ofprototype
4. Testing theprototype

Here we are going to discuss the prototype development. How it is made and controlled using the latest controllers are going to be discussed in this chapter.

a. *Fabrication ofPrototype*

After the CATIA model is ready, the CATIA file is exported to the 3D printer. The printer is going to generate the 3D model of the design.

Control Circuit of In-PipeRobot

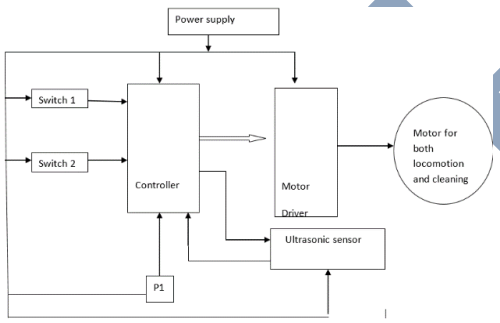

Fig 7Pipeline cleaning robot control circuit

Figure 8 is showing the control circuit used for the in-pipe robot. The control is very simple and easy to operate. Even person with little knowledge in electronics can easily control the in-pipe robot. The control circuit has various components like

1. Controller
2. Ultrasonicsensor
3. DCmotor
4. Motordriver

5. Potentiometer
6. Powersupply
7. Switches

Controller

Controller is the major component in any control circuit. It is like brain of the body. The main concern in design is to provide a very simple controller. There are many types of controllers in the market but according to our need it should be compatible to all the components. When we are going to write the code for controlling the robot, it supposed to beeasy. Hence we decided to use the arduino mega 2560 controller for the in-pipe robot.

The control is very is to handle. There are predefined slots for power supply, PWM, etc. so it will be very easy for us to make connection with the remaining components. The size of the controller is also very small and it can easily accommodate large number of devices. Coming to the coding part, it is open source to everyone. One can go through the site and can get the code. What we have to do is to make modification in the code according to ourneeds.

Ultrasonic sensor

The ultrasonic sensor is a simple device that is generally used for distance measurement. The working principle of the ultrasonic sensor is just like a bat. There are two portions in an ultrasonic sensor 1 trigger 2 echo. The trigger portion will emit the ultrasonic waves. When the ultrasonic waves hit some object in front of it, it will be reflected back tosensor.

Theecho portion is going to receive the reflected ultrasonic waves. The time gap between the trigger signal and received signal is calculated and according that the distance between the sensor and obstacle is measured. The same principle has been used here to detect the obstacles in the pipe.

The main reason behind using the ultrasonic sensor in this in-pipe robot is the cost of the device is very less. The sensor is also very accurate compared to other devices.

DC motor

The motor is one of the major components in the control circuit. It is used to provide both transmission and cleaning. For performing thetasks it has to provide high amount torque. Since we require very high torque there is need to use a geared motor with low RPM. For this we areusing a 300 RPM geared motor. The motor is tested and is giving very good amount of torque. It can able provide cleaning and transmission.

Motor driver

Motor driver play a prominent role in controlling the DC motor. The motor driver helps in changing the direction of rotation of the DC motor. The driver is going to receive the signals from controller. According to

control signal the driver is going to change direction of rotation. There will be H-Bridge in the motor driver which is making the taskpossible.

The working principle of the H-bridge is very simple. The construction is showed below. The direction of rotation of the motor depends on the flow of current in the motor. The motor driver is the main component that changes the flow of current according to the controlsignal.

5. IN-PIPE ROBOT FOR CLEANING ANDINSPECTION

1. The robot is designed for pipe with diameters ranging from 70mm to 80mm.The designed model is going to perform the cleaning and inspection tasks in the pipes with diameter in that range only. We the design is very flexible that we can able to perform tasks with minimum of 70mm to a large size pipes. By increasing the spring slot and the cleaning wiper length we can able clean the large pipes. To increasethe wheel length the same procedure has to befollowed.

2. Inspection by using ultrasonic sensor is giving accurate distance between robot and the obstacles. The ultrasonic sensor is able calculate the distance between the bends and joints in the pipe. It is also able to detect the flaws in the pipe. The ultrasonic sensor is able detect the flaws up to 2.3 meters only in the pipeenvironment. The minimum operating flaw diameter is 10mm.

3. The bevel gear mechanisms is working for both transmission and cleaning when compared with sun gear mechanism. The gear mechanism designed here is able lock the tooth better. The speed of wheel is 122 RPM for maximum input of 360RPM.

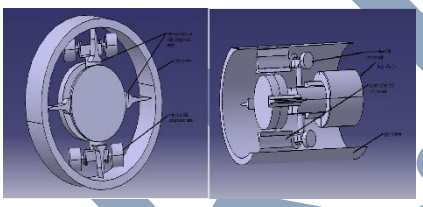

Fig 7Fullyexpanded robot in pipe

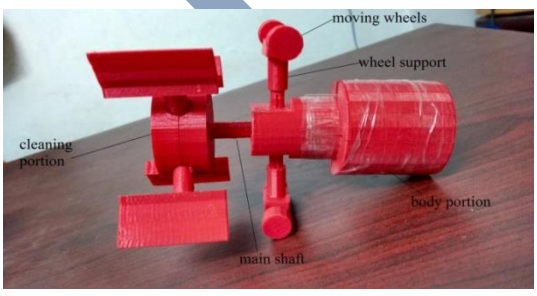

Fig 8Showing the body cover of the robot.

4. Simulation is performed in CATIAworkbench.

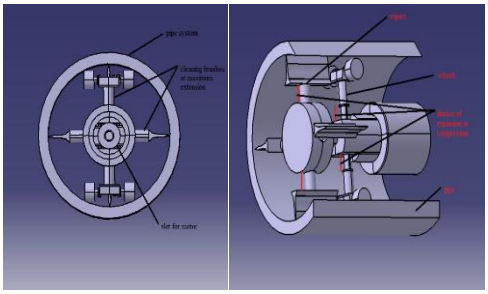

Fig 9Fully compressed robot in pipe

5. The cleaning mechanism is working properly showed in the figures 64 & 65. It is able to adjust and clean the pipe with changingdiameters.

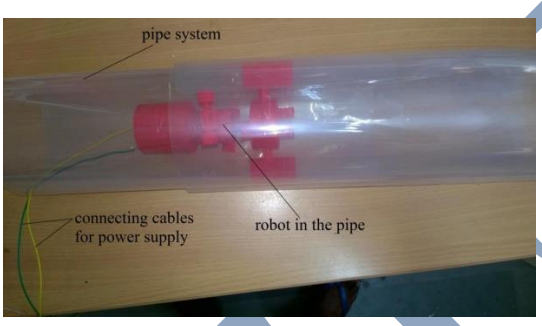

Fig 10: Robot inside a pipe

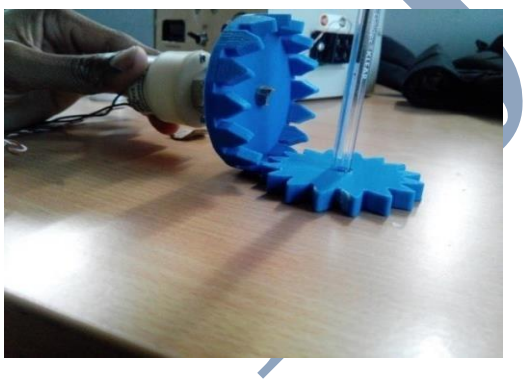

Fig 11Testing of bevel gear mechanism

5. DISCUSSION

The use of ultrasonic sensor of inspection is providing better results compared to the other sensors. The sensor used is also very cheap. We can able replace the sensor easily when got damaged. It was very good at detecting the cracks in the pipes.

The designed prototype is one of the best models for all types of pipes. It can able to clean the pipes with diameters ranging from few millimeters to several meters. The only thing we have to do is just scale the design according to the need.

The suspension mechanism used in the cleaning portion is very simple mechanism. It contains simple springs for compression and extension. But coming to the suspension system used in the wheel portion is a very genius design. The system was able move and make adjustment to the change in the pipe sizes simultaneously.

The cleaning wipers used are able provide very less drag while moving. They are so designed that it can able clean a large portion in very less time. The bevel gear mechanism is the best suitable mechanism used for this robot. The mechanism is very accurate in providing cleaning andmoving.

6. CONCLUSION

The work performed in this project is to develop a wall-pressed in-pipe robot for cleaning and inspection. In developing the wall-pressed in-pipe robot we require various mechanisms for cleaning, moving, actuation and inspection. For cleaning there are four cleaning wipers mounted on the cleaning portion. The wipers are self-adjustable according to the size of the pipe. The cleaning portion contains springs for automatic adjustment. There are two wheels in the system for moving the robot in and out of the pipe. The wheels are mounted on the wheel support. The wheel support is placed on the body. The suspension spindle in the drive shaft makes the wheels to self-adjust according to the pipe diameter.

The actuation part of the robot has two actuators. One is anelectronic actuator that is a DC motor. The second one is a mechanical actuator that is a bevel gear. The motor is connected to the bevel gear. The bevel gear is actuating both the wheels and the cleaning device of the robot. For theinspection there is an ultrasonic sensor included in the robot. The main reason behind using the ultrasonic sensor is its accuracy in detecting the flaws in the pipe. The device is also very small so we can easily use the ultrasonic sensor for small sizepipes.

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