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DESIGN, FABRICATION AND PERFORMANCE ANALYSIS OF PIPE LINE INSPECTION ROBOT

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Abstract - The robot is a multifunctional manipulator designed to reduce the human power. A pipe inspection robot is a device that is inserted into pipes to check for obstruction or damage. The objective of this project is to inspect the internal structure of the pipelines defects, using a robot. The robot detects the major defects like cracks, dents, corrosion, cup dent, saucer dent, welding defects etc. The performance of robot was improved by redesigning the electronics control systems by utilizing the existing mechanical platform. The electronic sensors especially ultrasonic sensor detects the internal defects of pipe with more accuracy by producing ultrasonic waves towards the internal surface of the pipes. The infrared cameras fixed with the robot gives online video about the defects. The benefit of this inspection robot is that can be travel in dark and wet environments in pipelines. Then it provides a human wears with a digital video feed of the internal status of the pipes.
Keywords: Drive Shaft, Journal bearing, fuel consumption, mass, weight.

I. INTRODUCTION

Pipeline systems deteriorate progressively over time. Corrosion accelerates progressively and long term deterioration increases the probability of failure (fatigue cracking). Limiting regular inspecting activities to the "scrap" part of the pipelines only, results ultimately into 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. This project provides information on the "robotic inspection technology".Pipelines are proven to be the safest way to transport and distribute Gases and Liquids. Regular inspection is required to maintain that reputation. The larger part of the pipelines system is accessible by In-Line Inspection Tools but this access is limited to the section in between the launching and receiving traps only. Unfortunately, corrosion does not have this limitation.

The industry looks for means of inspecting these in-accessible pressure holding piping systems, preferably, without interrupting the operations. It is a fact that sufficiently reliable and accurate inspection results can only be obtained by direct pipe wall contact/access. If that is not feasible from the outside, we have to go inside. Since modifying pipeline systems for In-Line Inspection is mainly not practical, PIPE INSPECTION ROBOT pursues development of ROBOTIC inspection services for presently in-accessible pipeline systems.

II. DESIGN AND FABRICATION OF PIPE LINE INSPECTION

2.1 SELECTION OF MATERIALS

The materials used for this machine are light and rigid. Different materials can be used for different parts of the robot. For optimum use of power the materials used should be light and strong. Wood is light but it is subjected to wear if used for this machine. Metals are the ideal materials for the robot as most if the plastics cannot be as strong as metals. Material should be ductile, less brittleness,

malleable, and high magnetic susceptibility. Among the metals, aluminum is the material chosen for the linkages and the common rod, which is made as hollow for reduction in weight. However, other materials are chosen for the motor.

The materials chosen for the motor should have high magnetic susceptibility and should be good conductor of electricity. The materials are copper and so on. But aluminum is chosen as the materials for the linkages and central body because of its much-desired Properties. Aluminum has lightweight and strength; it can be used in a variety of applications. Aluminum alloys with a wide range of properties are used in engineering structures .The strength and durability of aluminum alloys vary widely, not only because of the Components of the specific alloy, but also because of heat treatments and manufacturing Processes. Another important property of aluminum alloys is their sensitivity to heat.

Work shop procedures involving heating are complicated by the fact that aluminum, unlike steel, will melt without first glowing red. Aluminum alloys, like all structural alloys, are also subject to internal stresses following heating operations such as welding and casting. The problem with aluminum alloys in this regard is their low melting point, which make them more susceptible to distortions from thermally induced stress relief.

- The toughness, as measured by crack propagation energy, decreases as yield stress increases.
- At the same yield stress, the under aged structure has greater toughness than the over aged structure.

2.2 EFFECT OF TEMPERATURE

Another important property of acrylic is their sensitivity to heat. Work shop procedures involving heating are complicated by the fact that aluminum, unlike steel, will melt without first glowing red. It like all structural alloys, are also subject to internal stresses following heating operations such as welding and casting. The problem with acrilic in this regard is their low melting point, which make them more susceptible to distortions from thermally induced stress relief.

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2.3 MECHANISM

The mechanism involved here is a four bar mechanism consisting of three revolute joints and one prismatic joint is shown in the figure 2.1.

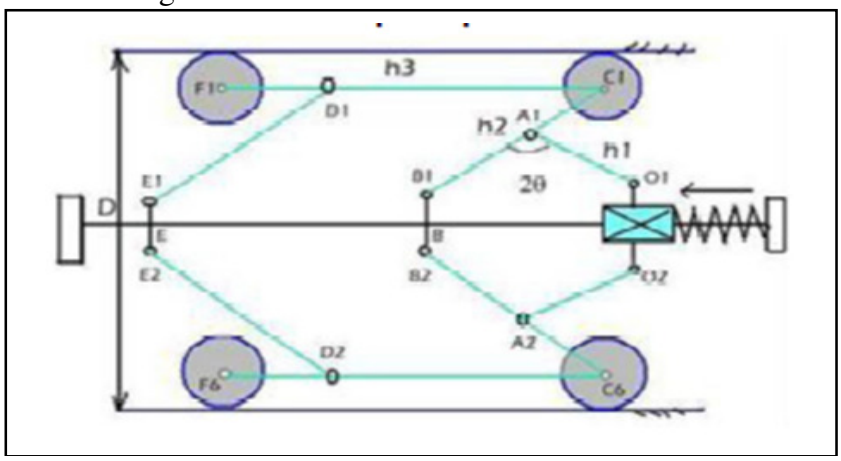


Figure 2.1 Mechanism of PIR

2.4 KINEMATICS OF MECHANISM

The linkage structure can be represented as in figure depicted. This is a four-bar mechanism Consisting of three revolute joins and one prismatic as depicted. Thus, the motion of all revolute joints can be described in terms of the displacement db.

2.5 STATIC ANALYSIS

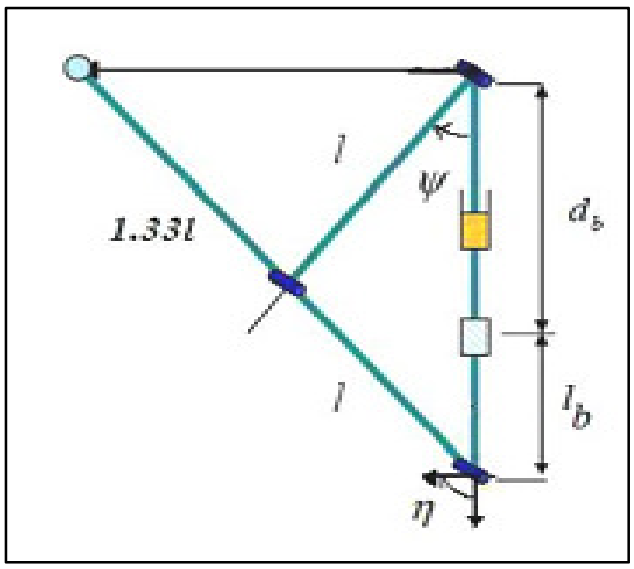
In order to decide the actuator size, it is necessary to perform the static analysis. Assume that in Fcx and Fcz denote the reaction force and the traction force exerted on the four-bar by the driving wheel, respectively. The linkage mechanism is shown below in figure 2.2 and 2.3.Now applying the virtual work principle to the free-body diagram gives.

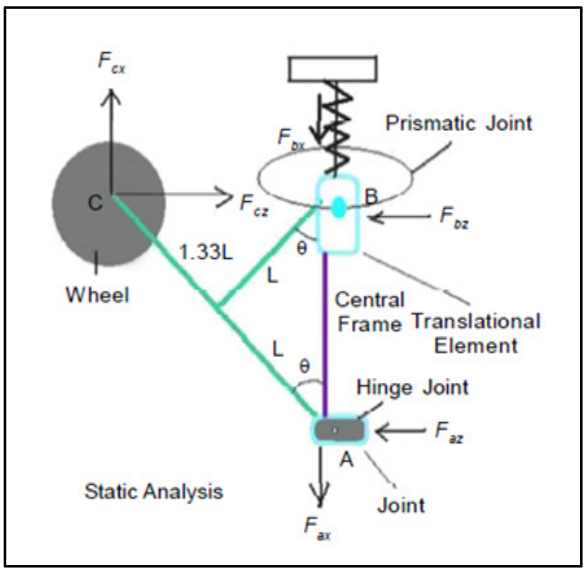
Figure 2.2 Linkages of PIRFigure 2.3 Static Analysis

2.6 FABRICATION

A pipe inspection robot consist of central element having 12.7 mm diameter 3 mm thickness and 176 mm in length, one translational element having 15mm dia. 3mm thick & 20mm in length.There are 12 links out of which 3 links are 105mm (A1, A2, A3),6 links of 85mm(B1,B2,B3,B4,B5,B6) & another 3 links of 30mm(C1,C2,C3).The spring is 90mm in length.

The central elements are joined to the 6 links the length of 28mm.The element links are attached to fulcrum with pin joint on the periphery with 120̊ lateral spacing at the points 1,2,3 is shown in figure 2.4Also 3 links are B4,B5,B6 are attach to another point 4,5,6 which are 50mm from point 1,2,3 as shown in fig. in the same way as in previous point. The one end of the three links which are 30mm in dia.(C1,C2,C3) are attach to the translation element in outer side to fulcrum with pin joint which are 120̊ in lateral spacing & the another end is attach to the links B4,B5,B6 at point with pin joint is shown in figure.2.1.The another link with length (A1,A2,A3) is attach to the end of the links (B1,B2,B3,B4,B5,B6) at the distance .The motor & wheels are mounted on the links (A1, A2, and A3). The front end of the structure is attached with the swiveling & turning head consist of camera & fitted with BO motor.





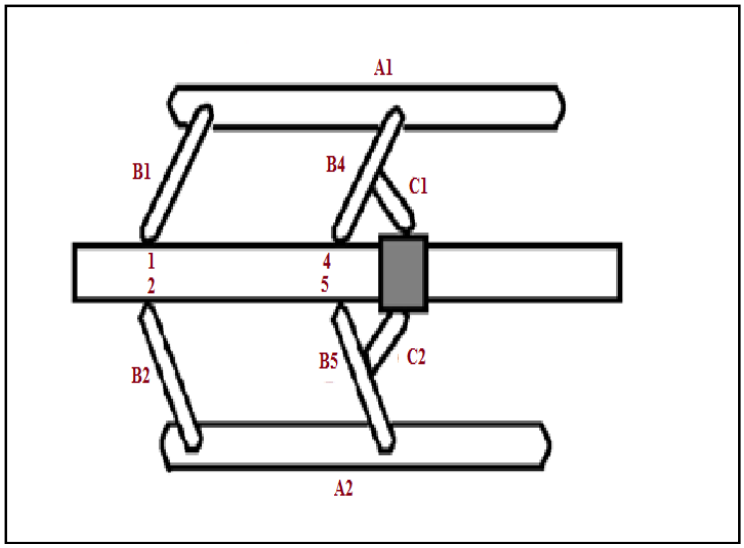


Figure 2.4 Construction of links

The camera & lights are mounted in a swiveling head are attached to the cylindrical body. The swiveling head are integrated to the lighting device a typically used in LED. The LED is used to illuminate inside the pipe line. The camera is pan & tilt by remotely.The motor wiring as shown in fig. are supply with 12v dc power supply through adaptor. The 3v dc power is supplied to the BO motor of camera. Operate the motor wheel the robot remote is connected.The camera is connected to the display equipment.There are 6 wheels the dia. Of wheel 72mm.There are 6 D.C motor having 10rpm & 12v.There are 2 BO motor having 60rpm & 3-9v.The BO motor is used for actuate the camera & light and it is fixed to the front side of the robot. The spring is attached to the end of the robot and it provide expand & compression motion to the links with the help of translational element. The total construction of the robot is shown in the annexure.

III. PERFORMANCE OF THE PIPE INSPECTION ROBOT

As Pipe Inspection Robot is designed mainly for circular bore pipes, it have ability to move inside any bore diameter pipes ranging from 8 inch to 10 inch(203mm to 254mm). Suitable mechanisms are provided so that it gains ability to move inside the bends and tapered pipes.The PIR have ability to see inside the dark pipes where no human eyes can see. This made possible by mounting the surveillance camera and LEDs on head of the PIACR. The output is send to outside screen where the digital hi-quality image can be received is shown in the figure 3.1.

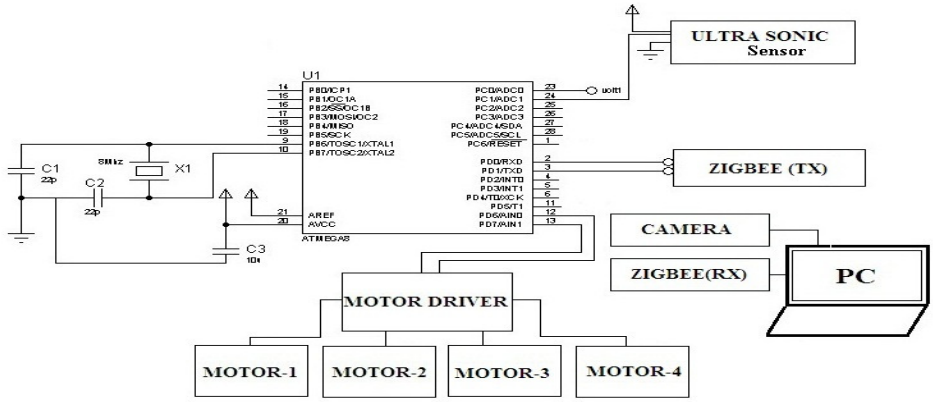


Figure 3.1 Block diagram showing working principal of pipe inspection robot

The perfect fitness between the pipe and robot is first conformed after inserting the robot in the pipe. Then the supply of DC 12Vdc current from is on for working of robot and the camera is also started. With the help robot control having three buttons, working of robot can be easily control the motions which is forward and reverse by one button and by other two buttons the motion which is swiveling and tilting of the camera head fitted in front of the robot can be control so that we can see the pictures and videos inside the pipe.Working of PIR is starts from its insertion in pipe. The front three arms is compressed by hand and then inserted in the pipe and then back three arms is inserted by pushing the PIR. The motors driven are the first six arms mentioned here, they pull whole setup. PIR is about 175 cm in length and to move it freely inside the bend pipes, a 2 degree of freedom joining is provided at the middle so that it can turn easily. As switch is on and current is flowing through wires, wheels starts moving and forces PIR to propel forward. Using the friction between wheels and pipe, the motion of wheels become possible.PIR could have more than three arms for better judgment and perfection but it would increase the weight and cost of manufacturing and hence we need to do tradeoff between money involvement and perfection. PIR wheel motion is provided with 10 rpm, 12V DC motors hence its speed can be maintained between -10 to 10 rpm. The power provided to motors is from single 12V dc adapter hence load on each motor will be minimum that expected.

As we mentioned earlier that PIR will be able to move inside any diameter ranging between 203mm to 254mm, we had to provide auto adjusting mechanism that can expand and contact as PIR moves inside the pipe. Spring of suitable stiffness is mounted on base rod. 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. We took good care of stiffness of spring such that it can move against the pipe and do not put too high pressure of tires which can jam it and restrict the motion. 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 main idea behind providing small shock-ups is not meant to absorb shocks but to make good individual expansion of arms in case of bends and turns. When a vehicle turns, two vehicles cannot have same angular velocity. Hence the outer arm must expand and shorter arm must compress. But as if we have used simple links then this wouldn't be possible. The mini suspension arms (previously mentioned shock-ups) provide individual expansion provision to arms and hence all arms are sticked to the pipe while turning.

The robot is run inside pipe by forward and reverse motion of the wheel which has the speed of 10 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 tilted by another button provided camera head motion on the remote control. The swiveling of camera can be achieved for 180 degree in addition 180 degrees for tilting and thus in combination the envelope of 180 degree can be easily seen through the camera. The output image from camera is send to Computer screen which may be laptop, monitor, TV or any such device which gives the visual picture. The camera sends this picture to the output screen with help of extension cable is shown in fig. 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. The length which it can capable to inspect is depends upon the length of the extension cable provided to robot. To insure the tractive force required pulling the long extension cable and 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.

IV. RESULTS AND DISCUSSION

The objective of the paper is achieved by improving the electronic control system and design modification. The ultrasonic sensors combined with microcontroller for better output graph results.

Using infrared cameras instead of normal low vision cameras are the advantage of this inspection robot. The kinematics of the modified for better movement in different diameter pipelines. The metals can be eliminated by using acrylic material for reducing the overall weight of the robot. The drive motor revolution speed can be increased for better movement in horizontal direction inside the pipelines. The video inspection images and output graph from the ultrasonic sensor is shown in the figure below 4.1.

The payload of the inspection robot can be reduced to the weight of 2 kg according to the end effector weight and part weight. The accuracy of the robot can be increased by improving the microcontroller sensor circuits. And the speed range of the robot drives can be improved to 160 cm/s. The ultrasonic transducer wavelength can be increased to 50 MHz. Compared with non-destructive testing efficiency can be increased up to 78%.The amplitude distance of the robot can be increased to 10 meters.

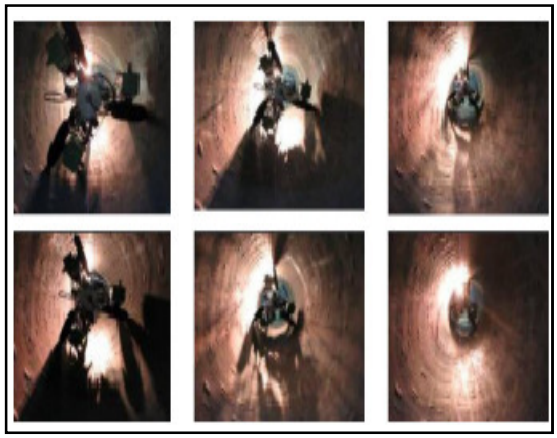


Figure 4.1 Inspection operations by the robot inside the pipeline

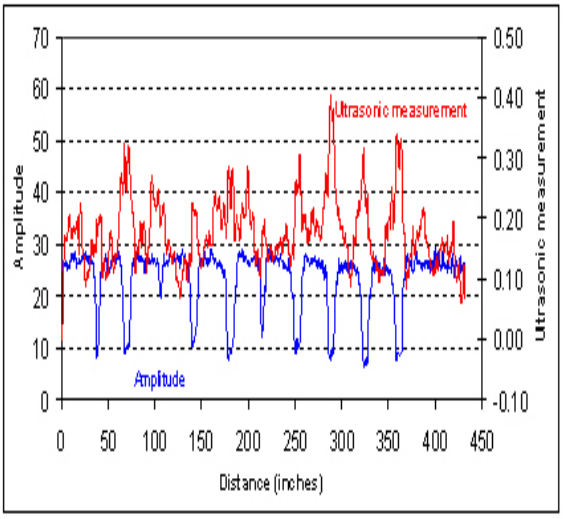


Figure 4.2 output graph results of ultrasonic testing

V. CONCLUSION

Robots play an important role in inside pipe-network maintenance and their repairing. Some of them were designed to perform the specific tasks for pipes with constant diameters and other may adapt the structure function of the variation of the inspected pipe.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 sensors) The major advantage is that it could be used in case of pipe overall diameter variation with the simple mechanism. We developed a pipe inspection robot that can be applied to 203mm- 254mm pipeline.

The inspection operation of this robot is different from others. A 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 linkage actuation and increasing the flexibility of the mechanism. The robot is designed to be able to travel in horizontal pipelines with more gripping capacity. Several design of the Pipe inspection robot has been completely fulfilled.

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