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Control of Pipe Inspection Robot using Android Application

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ABSTRACT

The existence of liquids (for example chemicals, milk products, beverages, petroleum products, water, oil etc.) and gas industries existence is mainly dependent on the working of pipelines. In the long run of the usage the damage may be caused in the pipelines and the flow of content may be effected. This research paper describes an in-pipe inspection robot. In the present work the robot is designed, modeled using solid works and the same is fabricated. The robot is made to operate using an Android application and inspection of the defects is done. This research paper describes an in-pipe inspection robot.

Keywords: Kinematic Links, Solid Work software, Micro controller 8051, Static Analysis

I. INTRODUCTION

Robots, reduces the human effort and also makes comfortable for the user along with convenience with increased efficiency. Wide variety of works in industries is done by the use of robots. An in-pipe inspection robot is also one of the important robot which is used for the inspection of pipes where human reach is not possible. The various constructional elements of the robot are fore leg system, a rear leg system and a Central body. The fore and rear leg systems are constructed by using kinematic links that are arranged at an angle of 120 degree with respect to each other to operate inside a pipe of different diameters. Firstly solid works 2016 software is used for the modeling of robot is then, all dimension of model is used for the prototype. The central element of the robot is attached with spring body to operate in pipes of 560mm to 680mm diameter range. After that robot is used for the inspection and all photos are taken. All parameter are based on the base size of pipe diameter is 60cm.

Several years of usage makes the pipe lines become old and get damaged due to deterioration like , steel pipe carrying water or gas, concrete pipes, plastic pipes and ceramic pipes. For the inspection of these pipelines during maintenance an automatic inspection robot is needed as human reach is not possible. In earlier research, many researchers have worked on pipe inspection robot, they have taken the different criteria or different pipe diameter for the inspection of the pipelines. E Navin [1] ,has taken the smaller pipe diameter of 160mm to 180mm and defects were found by wireless camera . D. Lee et al [2] ,used a two specific mechanisms in the robot are important for successful locomotion: the Adaptable Quad Arm Mechanism (AQAM) and the Swivel Hand Mechanism (SHM). Y-S Kwon et al [3] has designed robot using only two wheel chains and inspection pipe is 80mm to 100mm. Atushi K, et al [4], used screw drive chain and inspection of curved pipe. In the other cases [5-8] the pipe diameter taken was small and many of them used manual method, none of them have used the Bluetooth android application software, a wireless communication system for life time maintenance was developed in order to control the inspection robot and transmit the collected data to the terminal, which is located at the pipe inlet, and its performance was analyzed. The advantage of present research work is that it uses detects the defects in the pipe of diameter 56 cm to 68 cm and robot is fully controlled by smart phone hence there is no use of any remote and long wire for operate the robot.

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II. MECHANISM OF PIR

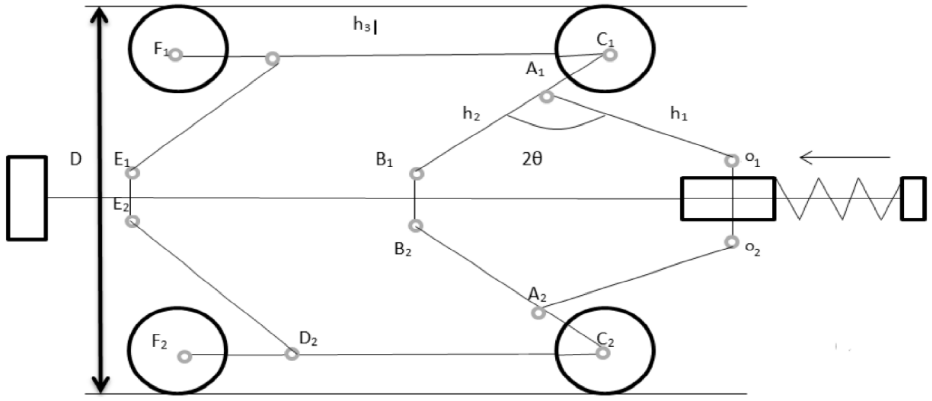

Figure 1: Mechanism of PIR [1]

Figure 1 shows the mechanism of PIR(pipe inspection robot). This robot consist of a fore leg system, a rear leg system and a Central body. The fore and rear leg systems are constructed by using kinematics links that are arranged at an angle of 120 degree with respect to each other to operate inside a pipe of different diameters. The head of the robot is fitted with camera and LED, whereas the sensor is on the central body and smart phone is available for the forward and backward movement of robot. In mechanism motors are attached on all the six wheels. Camera is connected to the receiver and receiver gives all photos and videos on monitor.

Variable used in mechanism are:-

D= Pipe diameter

h_1= First link

h_2= Second link

h_3= Third link

E_1E_2 & B_1B_2= fixed hinges on central frame.

O_1O_2= Hinges on prismatic joint.

Table 1
Parameter of all parts

S.No.	*Description*	*Symbols*	*Size*
1.	No. of Links for Robot		04
2.	No. of wheel for Robot		06
3.	No. of DC Motors		06
4.	Length of link first	h_1	09.50cm
5.	Length of link second	h_2	18.50cm
6.	Length of link third	h_3	34.50cm
7.	Length of Robot		75cm
8.	Diameter of Pipe		60cm
9.	Length of Spring		13cm
10.	Pitch of Spring		13mm
11.	Central frame Inner Diameter		4.5cm
12.	Central frame Outer Diameter	D	4.9cm
13.	Hinge Length	O_1O_2	08cm
14.	Radius of wheel	R	4.75cm
15.	Bush Inner Diameter		.08cm
16.	Bush Outer Diameter		.10cm
17.	Slider Length		17cm
18.	Slider Inner Diameter		.50cm
19.	Slider Outer Diameter		.54cm

Table 1 shows the finalized dimensioned of the robot based on available pipe size used for the transportation of fluid.

To calculate the Inspection pipe diameter formula used

$$D = 2r+2d+2h_2\cos\theta \quad (1)$$

Where, r= radius of robot wheel

d= distance between E_1 & E_2

h2= length of the link h; θ= angle between h2 & h1.

$$D= 2\times4.75+2\times12.45+2\times18.2\times\cos45 \quad (2)$$

$$D=9.5+24.9+25.73=60.13=60\text{cm}$$

III. STATIC ANALYSIS OF PIR

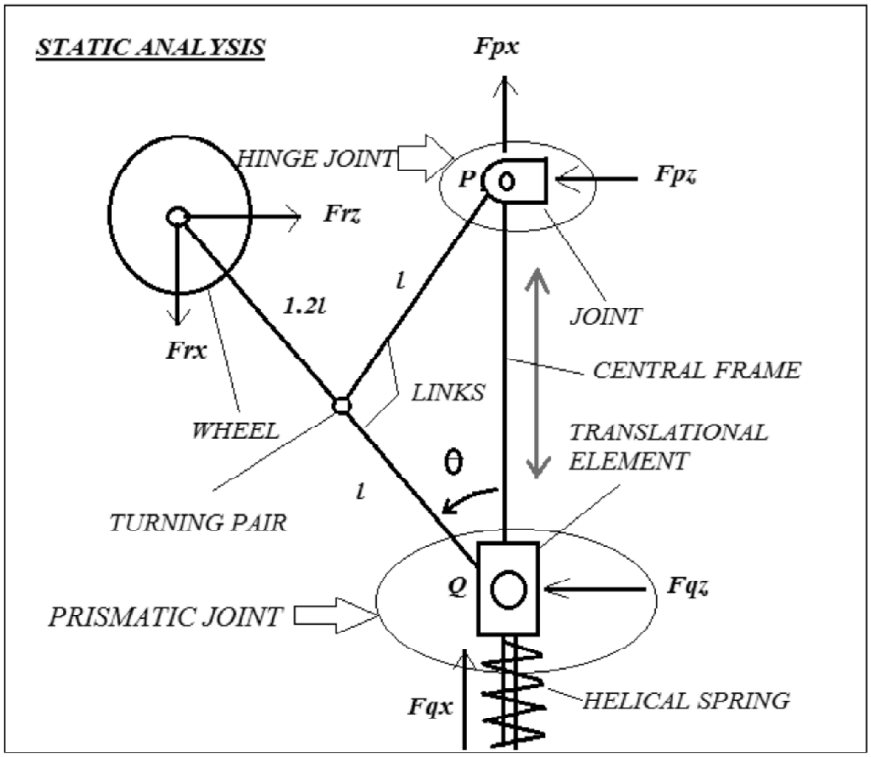

Figure 2: Static analysis of PIR [1]

Figure 2 for the design calculation [9] static analysis is done so has to verify the correctness of the dimension calculated for the PIR.

Using the famous virtual work principle and applying it to the free-body diagram gives

$$dW= F_{rz}\, dz- F_{qx}\, dx= 0 \quad (3)$$

Where, F_{qx} is a Spring force.

F_{rz} is pipe wall force.

This is because only F_{rz} and F_{qx} conduct work.

The corresponding coordinates of these forces relative to the coordinates located at the P hinge are expressed as:

$$Z = 2.2l\sin\theta,\ x= 2.2l\cos\theta \quad (4)$$

$$dW = F_{rz}\, d(2.2l\sin\theta) - F_{qx}\, d(2.2l\cos\theta)$$

$$= F_{rz} \times 2.2l\cos\theta d\theta - F_{qx} \times 2.2l\sin\theta d\theta = 0 \quad (5)$$

Rearranging gives

$$F_{qx} = F_{rz} \times \cos\theta/\sin\theta$$

Thus, the spring force at the prismatic joint Q is related to the normal force F_{rz} by

$$F_{qx} = F_{rz} \times (\tan\theta)^{-1} \quad (6)$$

The total weight W of the robot is the sum of the six traction forces exerted on the wheel. Thus, each traction force F_{rz} is one six of the whole weight of the robot structure.

Thus, the size of the actuator enclosed in the wheel is calculated by

$$T = F_{rx} \times r = Wr/6 \text{ at } \theta = 45^{\circ} \quad (7)$$

Where, r is the radius of the wheel.

IV. DESIGN CALCULATION

Various steps of design calculation are-

5.1. Torque required for robot to move

The total weight W of the robot is the sum of the six traction forces on the wheel. Thus, each traction force F_s is one six of the whole weight of the robot structure. Thus, the size of the robot enclosed in wheel is calculated by;

$$T = F_s \times r/6 \quad (8)$$

Where, F_s is the spring force in N

r is the radius of the wheel

T is the torque required for robot

W= 7.60kg,

Traction force on each wheel= 7.60/6=1.26kg

Normal reaction on one wheel (R) = m×g=1.26×9.81=12.41 N

$$Fs = \mu R \quad (9)$$

Where, μ= coefficient of friction.

Fs =0.1×12.41=1.241 N

T=1.241×0.0475=0.04944 N-m

5.2. Actual weight of the robot with the available motor

The supply required for the 6 individual motors will be 12V and 1.2 AH. This 280:1 gear motor spins at 60RPM at 12V.

Force= Torque/Radius=1.26kg

From the calculation, an individual motor will drive the robot having 1.30 to 1.5 kg. Perhaps 6 motors could be used for the crawling, so that total weight of the robot should be restricted to 7.60 kg or below.

5.3. Current required for robot.

The supply required for an actuator is 12V and 500mA at max. Supply current for Robot is 320mA. Six actuators will be used for the robot to creep inside a pipe. Since the voltage required is 12V, it is needed to

ensure that the connection should be in parallel where the voltage remains the same and the current will be sum of all the current values in each individual.

12V,is the required voltage (Parallel connection) 'I' being the required current in ampere.

$$I = I_1+I_2+I_3+I_4+I_5+I_6 \quad (10)$$

$$I = 320+320+320+320+320+320$$

$$= 1920mA = 1.92A$$

5.4. Required Power: calculation

In the present work electrical power and mechanical power both are required.

$$\text{Electrical power } P=VI \quad (11)$$

$$=12\times1.92=23.04Watt$$

$$\text{Mechanical power } P=T\times\omega \quad (12)$$

$$\omega = (2\times\Pi\times N)/60 = (2\times3.14\times60)/60=6.28$$

$$=0.04944\times6.28=.3104Watt$$

For practically used electrical power is always greater than mechanical power because electrical power is converted in mechanical power.

Mechanical power<electrical power.

5.5. Speed of robot

$$V= (\Pi\times D\times N)/60 \quad (13)$$

$$= (3.14\times.095\times60)/60$$

$$= 0.298m/s$$

V. MODEL OF PIR AND ITS COMPONENTS

The modelled(using solid works 2016) components are shown in the Figs. 3,4.

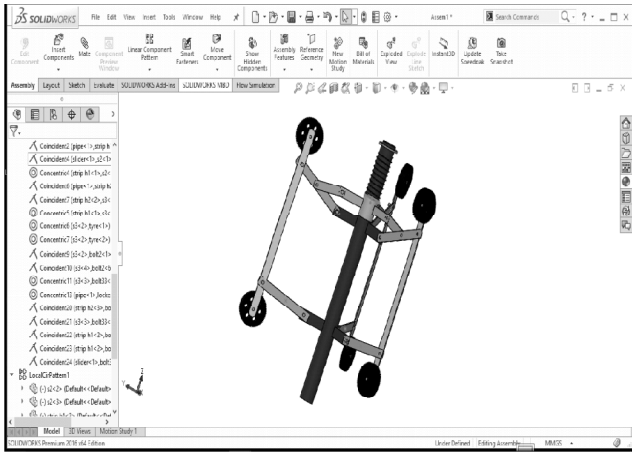

Figure 3: Model of PIR

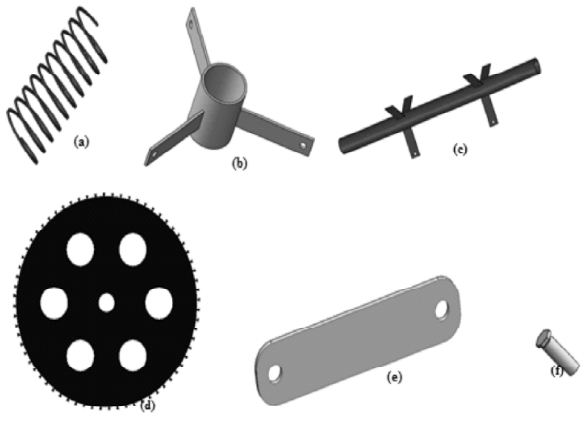

Figure 4: Parts of PIR

VI. PROTOTYPE OF PIR

The fabricated working model of PIR is shown in Fig. 5.

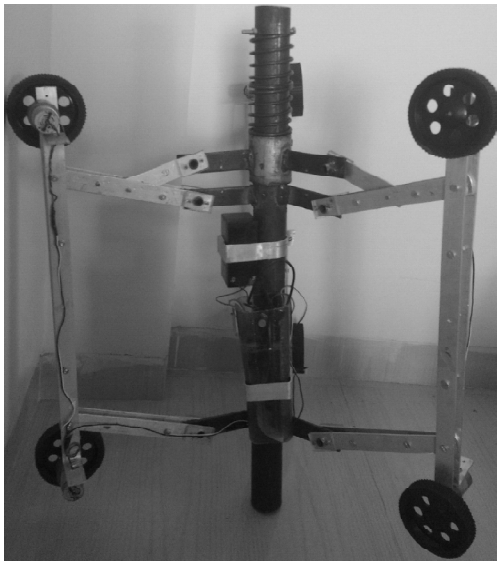

Figure 5: Prototype of PIR

VII. CONTROLLING PROCESS OF ROBOT USING SMART PHONE

Now a day technology is reach high level. In latest technology smart phone mobile is plays important role. To control the robot latest technology is used. Micro controller 8051 is used as a processor. Micro controller is connected to the Bluetooth software and all forward and backward motion of the robot is control by smart phone. Bluetooth software is connected with the smart phone Bluetooth. For operation of robot smart phone apps is used. Name of apps is "Arduino" Bluetooth app.

Micro controller is connected to the relays and relays are connected to the blue tooth software. In these robot 8 relays are used. 6 relay is for the motion of robot and one is for the camera and last one is for the LED light. Six relay is used for the forward and backward motion of robot. One relay is connected with 2 motor and all functions are operated by smart phone.

VIII. RESULTS AND INSPECTION PHOTOS

The Fig 6 shows images of inspection for the pipe: of size 60 cm, water line and ceramic material underground.

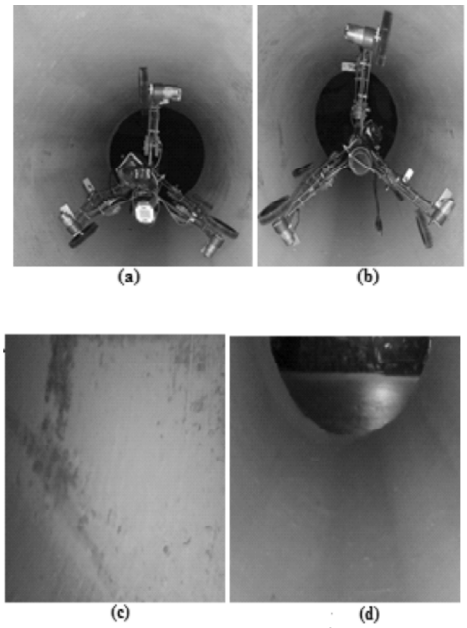

Figure 6: All are inspection photos

IX. CONCLUSION

In this research paper designing of pipe inspection robot has been done. Many types of pipe inspection robots are available in the market, but our focus is on the importance of six wheel robot This robot consist of four link mechanism having degree of freedom one, which means it is a working machine. The maximum diameter of pipe which can be inspected by the robot is 68cm and can inspect in a tolerance of -10 to -12cm. So the robot can be used for the inspection of 56cm to 68cm diameter pipes. The design calculations of pipe inspection robot has been done and all the calculation of load and other are taken to base size of the pipe diameter is 60cm.The use of Bluetooth app makes the robot user friendly with ease in operation and higher efficiency.

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