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Design and Fabrication of an Inline Pipe Inspection Robot

Akshay Ashok Sonawane, Sultan Shahajahan, Azhar Rehaman

Abstract**: already there are various designs available in the case of an inline-pipe inspection robot. This research paper aims at preparing a new design along with its fabrication process. For a start we studied the readily available deigns and there advantages as well as limitations. We have used CATIA V5R19 to design our robot. The key factors we have considered while in the process of design are mobility, safety in operation, steer ability, and the most important one is size and shape adaptability. Our model is a wireless flexible pipe inspection robot which is capable to pass through a pipe with diameter in range of 6-9 inches. We can detect various defects such as cracks, corrosion, buckles, etc.**

Index Terms**: inline pipe-inspection, mobility, shape adaptability, wireless.**

I. INTRODUCTION

The basic concept behind the development of an inline-pipe inspection robot is to reduce cost of labour and increase safety in inspection. The gas, liquids distribution pipelines as well as heavy industrial plants require routine inspection. We have designed and fabricated our robot considering the complexity in pipes used in various power plants. Our robot can adapt itself according to the varying pipe diameter ranging from 6-9 inches. Instead of using a single locomotive system we have used dual locomotive system so that our robot can pass through elbows and T-sections also. Universal coupling is used for making the robot propel in curve shape instead of using a flexible coupling due to the robustness of universal coupling. The microcontroller is used to make the robot fully autonomous. Wireless camera is attached at the top of the assembly which can cover area under 180°. The output of camera is given through the receiver connected to LED screen. The range of camera receiver is approximately 30m while that of the remote is 10m.

II. LITERATURE REVIEW

From the research paper of Atul Gargade [8], robots are used to remove human being from laborious and dangerous work. This project describes an in- pipe inspection robot. This robot consist of a fore leg system, a rear leg system and a body. The fore and rear leg systems are constructed by using three worm gear system that are arranged at an angle of 120 degree with respect to each other to operate inside a pipe of different diameters. The springs are attached to each leg and the robot body to operate in pipes of 140mm to 200mm diameter range. Here, all major components of robot are designed. Modeling and assembly of robot components is done in Solidworks 11. Stress analysis of all major components is done in Solidworks 11 and Static stress analysis of proposed in-pipe inspection robot assembly is carried out in Ansys 13. This robot is used for offline visual inspection of gas pipelines, water pipelines and drain pipes etc. This robot also has wide applications in chemical industries as well as in gulf countries for inspection of oil and gas pipelines.

From the research paper of E. Navin Prasad [9], Inspection robots are used in many fields of industry. One application is monitoring the inside of the pipes and channels, recognizing and solving problems through the interior of pipes or channels. Automated inspection of the inner surface of a pipe can be achieved by a mobile robot. Because pipelines are typically buried underground, they are in contact with the soil and subject to corrosion, where the steel pipe wall oxidizes, and effectively reducing wall thickness. Although it's less common, corrosion also can occur on the inside surface of the pipe and reduces the strength of the pipe. If crack goes undetected and becomes severe, the pipe can leak and, in rare cases, fail catastrophically. Extensive efforts are made to mitigate corrosion. Pipe inspection is necessary to locate defects due to corrosion and wear while the pipe is transporting fluids. This ability is necessary especially when one should inspect an underground pipe. In this work, Pipe Inspection Robot (PIR) with ability to move inside horizontal and vertical pipes has been designed and fabricated. The robot consists of a motor for driving and camera for monitoring. The research paper of Ankit Nayak [1], proposes screw type inspection robot. He has given advantages of his model. He has also performed kinematic and dynamic analysis on it and finally concluded that it's behavior is good. The research paper of Lee Vuen Nee[2], proposes wheeled type robot. His model gives 90% accuracy in crack detection and can tilt in range of -30° to +20°. The research of Kentarou.Nishijima [3], in pipe inspection robot which analyses image data and he has tested his robot in various pipe materials to calculate the loses in microwave signals. The research paper of Nur Shahida Roslin [4], proposes a hybrid locomotion system for inspection. The research paper of Xin Li [5], proposes guarding algorithm along with optimal guarding algorithm.

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III. MECHANISM

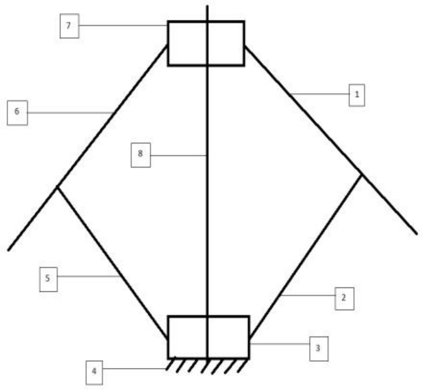

Fig.1-Mechanism

Fig.2-Actuator

A. Degrees of Freedom

$F = 3(n-1)-2f_1-f_2$
n = no. of links of mechanism with fixed links.
f_1 = no. of pin joints or revolute pairs or pairs that permits one degree of freedom.
f_2 = no. of roll-slide pairs.
$F = 3*(8-1)-2(9)-0$
$F = 3$
We are using a universal coupling so our robot has 6-degrees of freedom.

IV. DESIGN

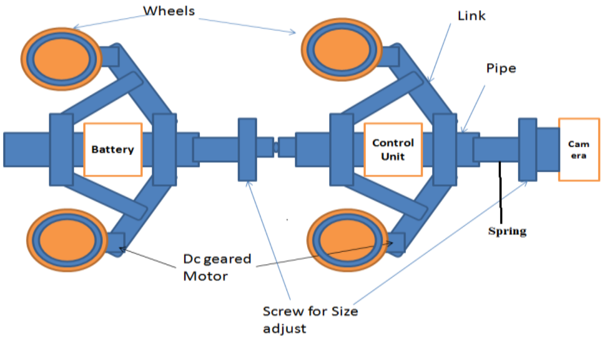

Fig.1-Design

B. Motor

Total load on robot = 20N
Power required to robot to carry weight of 20N with 0.1m/s speed is,
$P = W \times v$
$= 20 \times 0.1$
P = 2watts.
In worst case if only one motor is working then it has to give total power. Power required to 6-DC motors to drive the robot is,
$P_{required} = 6 \times 2$
$P_{required}$ = 12watts
If a motor of 8v & 2amp current is selected then power provided by 6 motors is,
$P_{provided}$ = 16watts
Here, $P_{provided} > P_{required}$ …….. Hence ok.
So, select 6-DC motors of 6v, 1amp current & 35rpm each.

C. Material Selection & Calculation of Spring Stiffness

Material: stainless steel wire for normal corrosion resistance
Type: Ground end Maximum elongation of spring is given as,
δL = L2 L = 98.7368 75.4718 δL = 23.265 mm

Spring force calculation:
In vertical case, total load acting on robot is additional sum of weight of robot and frictional force i.e. 30N ∴ we have to design a spring which will hold the load of 30N
∴Design the spring for 30N force; Calculation of spring stiffness (K):
Spring stiffness = spring force / maximum elongation of spring
K = 30/23.265
K = 1.29N/mm

Fig.3-Compression Spring

D. Spring Proportions

Calculation of spring wire diameter (d):
average service Design stress is,
τ = 48.5 kgf/mm2 τ = 485 N/mm2
but, shear stress in spring is given by formulae,
$\tau = (8*F*C)/(\pi*d*d)$
$485 = (8*30*6)/(\pi*d*d)$
d = 0.97mm

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V.FABRICATION

A.Links

The links are made of galvanized iron. We have performed the following operations on links: Drilling, cutting, grinding, and hammering.

Fig.4-Links

B.Bushes

The bushes are made up of nylon material due to its low weight, low wastage of material while cutting; withstand higher temperature, good friction co-efficient and low cost. Operations performed on bush are cutting and drilling.

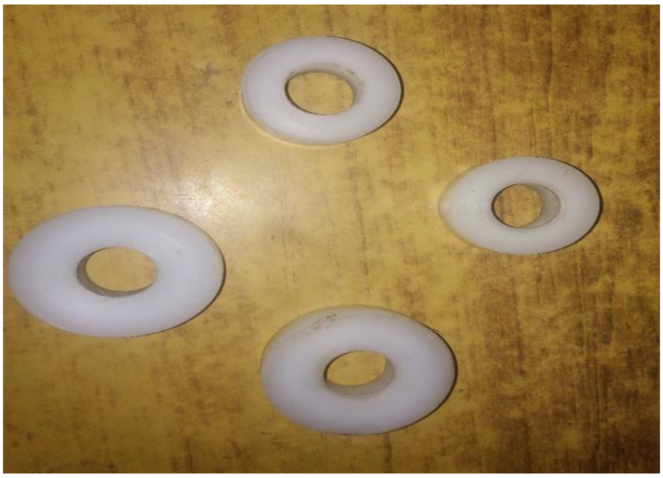

Fig.5-Bushes

C.Aluminium pipe

We have performed cutting operation on pipe with 1mm thickness and 18mm diameter.

Fig.6-Aluminium Pipe

VI. DESIGN ON CATIA V5R19

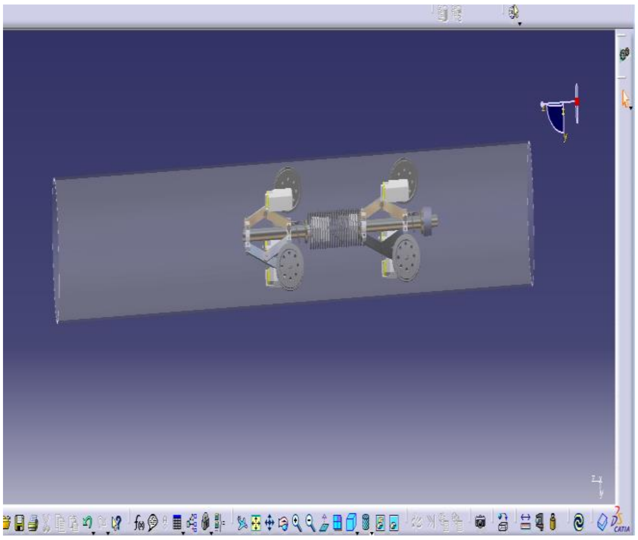

Fig.7-PIR inside Pipe

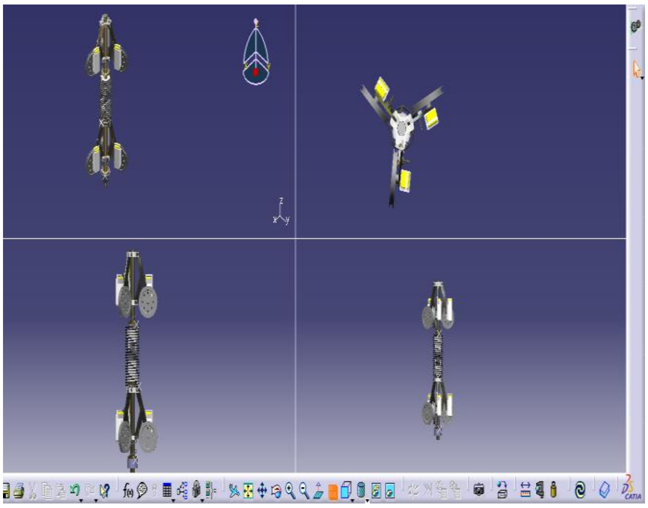

Fig.8-Different Views of PIR

VII.ACTUAL MODEL

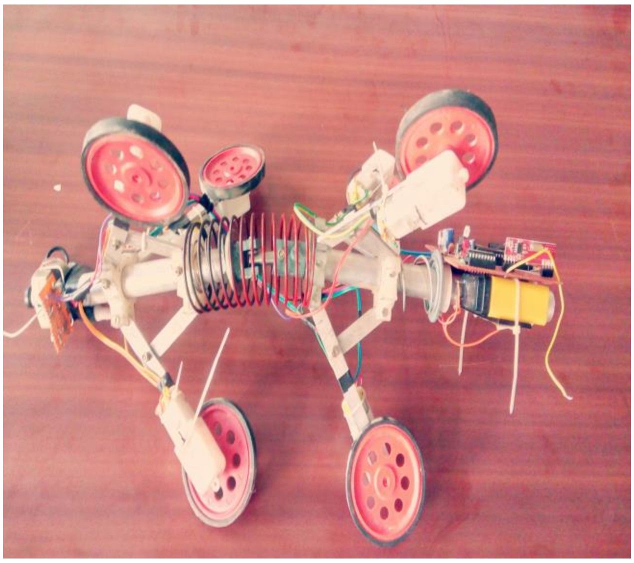

Fig.9-Actual Model of PIR

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Fig.10-Practical Application of PIR

VIII. CONCLUSION

The flexible autonomous [10] inline pipe inspection robot is designed and fabricated. The design is prepared in CATIA V5R19 to simulate the model. Our robot is finally in working condition and able to inspect in practical situations. It has ability to travel in vertical as well as horizontal directions and turn in elbows. It is employed with dual locomotion system to achieve this goal. The universal couplings used to connect the upper and lower sections of robot.

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