Design and Fabrication of In-Pipe Inspection Robot for Gasline Application

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Abstract— We have selected this UDP project "In-pipe Inspection Robot for Gas line Application" to provide more safety to the workers or the employees working in the industries/refineries. The main objective of this project is to provide a safer way for the workers to inspect the pipes in the industries. By the use of this robot, the workers/employees will be able to inspect the pipe with greater accuracy, also the inspection time will be greatly reduced. And as the robot will do the inspection, the mistakes will likewise be disposed of with many degrees. Our robot will be controlled by the operator away from the inspection site. So, there will be safety given to the operator as well as the inspection will be done in no time. Our robot has a four-bar mechanism which enables our robot to go in variable size pipes. This robot will be equipped with sensors so that it helps the operator for further work and so better results will be obtained. Thus, scheduled inspection will help keep an eye on pipes health. Therefore, it gives a better inspection.

Keywords: Robot, Pipe Defects, In-Pipe Inspection, PIR, Mobile Robot, Gas Line Inspection

I. INTRODUCTION

Robotics is one in every of the quickest growing engineering fields of nowadays. Robots are designed to form human effortless and be useful in many ways. As in most dangerous situation, humans cannot work so to work in dangerous and inaccessible situations, robots are designed to help humans to complete the work and not putting human life in danger. In earlier times, as the robots were not designed or because of limitations of technology and knowledge, the robots were not used in the industries and the humans themselves by putting their lives in danger did the work in the inaccessible situations. But now as there has been an improvement in the technology and also in the knowledge, robots are far advanced than before. These days the use of robots is more common than before. Not only for big machinery assembly but also small assembly robots are used. As robots remove the human factor so there is no objection of error.

The inspection of pipelines may be relevant in improving the efficiency of the plant. Thus, an inspection of pipelines is a tedious job if done manually an also costly. The inspection of the pipeline should be regularly done and it takes a lot of time if done manually. These specific operations of inspection, maintenance, cleaning, etc. are expensive, thus is it necessary to use robots for pipe inspection.

Pipeline system deteriorates progressively over time. As the internal geometry of the pipe is complex and so robots are the best possible solutions for this task. Pipelines have internal scale formation. Corrosion, cracks, bends or rupture of pipe. And not everything can be seen by labors or worker inspecting the pipe. For this purpose, an in-pipe inspection robot is designed so that this robot can give the internal view of the pipe have cracks, weld cracks, dents, out of roundness of pipe, scale formation, etc. The complex internal geometry of pipe and hazardous content in the pipe makes it necessary to use a robot for inspection purpose. Inspection of the pipe becomes necessary because if tolerated if may lead to a serious accident in the industry which may propose danger to the environment as well as human lives.

As the industry looks for inspecting the in-accessible parts of a pipeline, preferably without interrupting the operations. It is a fact that sufficiently reliable and accurate inspection results only be obtained by direct contact with the pipe surface. If that is not possible than inspection needs to be done internally and also modifying the pipeline system is not an option and also not practical. Therefore, robots are necessary and also the best solutions for this purpose.

II. PROBLEM STATEMENT

Pipes are widely used in chemical industries and gulf countries for carrying petrol, diesel, oil etc. But after some years these pipes get damaged and defects are occurring in the pipe. Also, operator safety is a major concern while inspection. And, with the inspection of the pipeline, it is necessary to know the composition of the air inside the pipe which is under inspection.

The main problem arises where the robot cannot move in some cross-section of pipe such as t-bent. The robot should be flexible enough to move in pipe. Also, it should be lightweight. The material selected for the robot should withstand the temperature of the environment in which it is used. Also, by using different sensors on the robot the operator is not exposed to the inspection area physically and only the robot will be physically present inside the pipeline. The robot should give a clear view of pipe from inside and the robot should give an accurate and feasible solution with the help of sensors.

III. OBJECTIVES

- To make it lightweight.
- To make the robot flexible which can adapt according to pipe parameters.
- To make the inspection process safer for the worker to inspect.

IV. LITERATURE REVIEW

A. Defect Identification in Pipelines using pipe inspection robot (2012):

In this paper, the mechanism used is a four-bar mechanism which helps the robot to go in variable size diameter pipes. The four-bar link mechanism consists of three revolute joints and one prismatic joint.

Also, the materials used are lightweight and rigid. Different parts can be used for different components of the robot. For optimum use materials selected should be lightweight and strong.

And so, the robot as able to go in 140-180mm diameter pipes.

Design and development of pipe inspection robot (2015):

The robot mechanism is developed in such a manner that it should contract and expand between the desired limits. The parallelogram type design is made which helps the robot to go in 200-260mm diameters pipes and it helps the robot to move uniformly.

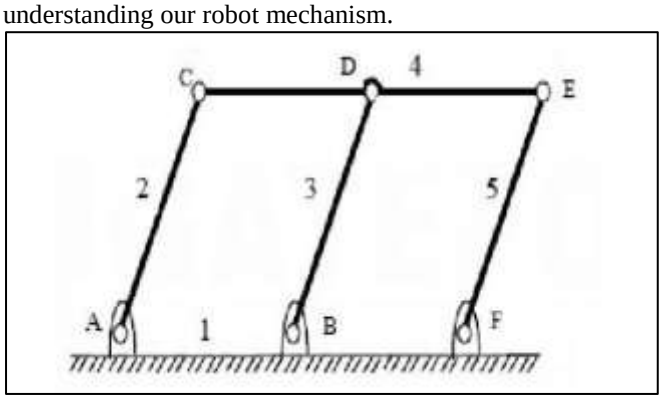
Link dimensions must be equal for uniform motion. The angular position must not exceed more than 90^0 and must not be less than 45^0. Therefore, the robot was able to go in 200-260mm diameter pipes.

B. Design, Fabrication and performance Analysis Of pipe inspection robot (2016):

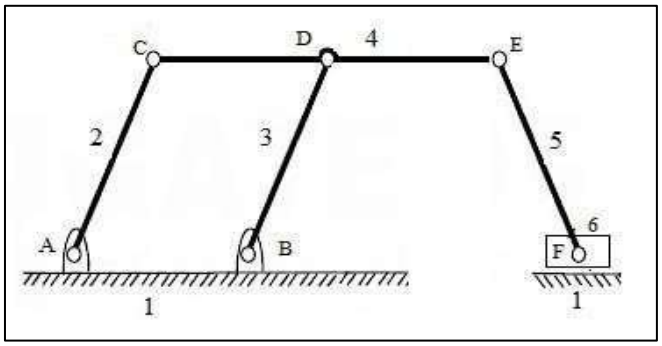
The ultrasonic sensor was used for better inspection. The robot was able to go in 203-254mm diameter pipes. Using infrared cameras instead of normal vision cameras is the advantage of this inspection.

V. METHODOLOGY

The robot mechanism should be such that it can smoothly contract and expand in the pipe between the chosen limits. The mechanism causes the whole robot to work as a complete system as one links helps another link connected to it which again moves other link, which helps the robot to move and adjust in the pipe. A simple mechanism helps in understanding our robot mechanism.

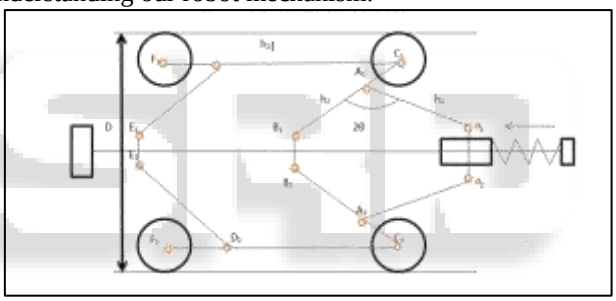


But the required mechanism does not make the robot adaptable for different diameters of pipe. The joint F is made into a screw pair. The orientation of link 5 is changed so that when e, link 5 moves in the opposite direction pushing the screw pair direction forward the input, link 2 moves in the clockwise and vice versa. This combination of linkages makes the mechanism contract in the clockwise direction and expands in counter clockwise direction.



Link dimensions are to be equal for execution of uniform motion. Angular position of link at the maximum diameter must not exceed 90 and not go below 45 for proper functioning.

Now, the entire system consists of front legs, rear legs, and a central element on which everything is mounted. The front legs as well as the rear legs are constructed by kinematic links. Both the front and the rear. The robot mechanism should be such that it can smoothly contract and expand in the pipe between the chosen limits. The mechanism causes the whole robot to work as a complete system as one links helps another link connected to it which again moves other link, which helps the robot to move and adjust in the pipe. A simple mechanism helps in understanding our robot mechanism.



The head of the robot is fitted with camera and the sensor and remote is available for the forward and backward movement of robot. In mechanism actuator are attached on all the six wheels. Camera is connected to the receiver and receiver gives the inside view on the monitor i.e. the mobile screen.

A. Degree of Freedom

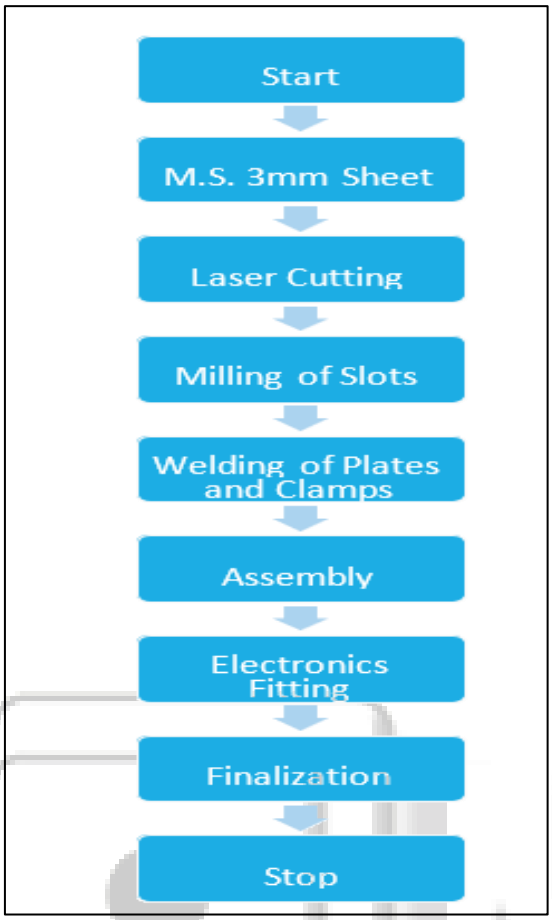
"Minimum number of independent variables required to define the position or motion of system is known as degree of freedom of system". The mechanism has got 3 revolute pairs and a prismatic pair, so the mechanism involved here is a four-link mechanism.

Number of links, n=4
Number of joints, j=4
Number of higher pair, h=0
The Kutzback's equation for the degrees of freedom is:
F=3(n-1)-2j-h
Therefore, F=3(4-1)-2*4-0
F=3*3-2*4
F=9-8=1

If F = 1, degree of freedom is one. The mechanism has fully constrained motion and this represents a working mechanism which has practical utility. All the working mechanisms have single degree of freedom.

VI. WORKING OF ROBOT

A. Fabrication Process Flowchart:

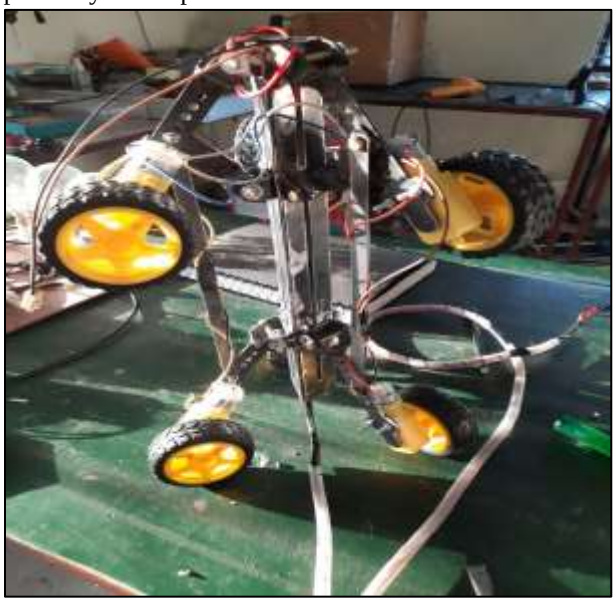


B. Working of the robot:

Working of PIR starts from its insertion in the pipe. The pipe in which the robot has to go is measured in terms of its diameter and the links of the robot are adjusted to the required position so that the robot can move in the pipe. Also, the clamps mounted on the central element can be adjusted in the slots so that it can move up and down giving the robot variable sizes for inspection. The motors drive the wheels with the help of batteries. As the wheels move, they move the whole robot and so the camera moves forward. Using the friction between the wall and the wheels the robot can move. Hence the robot can be controlled by the operator and the operator gets the visual inspection of the robot.

The Sensors used are smoke sensor and proximity sensor. The smoke sensor starts it works as soon as it detects the smoke and it depends on the density of smoke. The more the density more will be the sensitivity of the sensor to detect the smoke. As the sensors are mounted on the robot and the robot will go inside the pipe, in case if there is smoke the smoke will not have anywhere to go so it will spread along the pipe and as the robot will go more towards the place of fire the smoke will reach the smoke sensor and as the density of smoke will be more the smoke sensor will detect the smoke and will make a "Beep" sound so that the operator will know the place of fire.

Another sensor is a proximity sensor. If some object becomes an obstruction for the robot to move or reverse it will detect and show a light that shows that there is some obstruction in the way of the robot to move. And so, the operator will get to know about the type of object/Obstruction and the place where the object is the pipeline by the help of the camera.

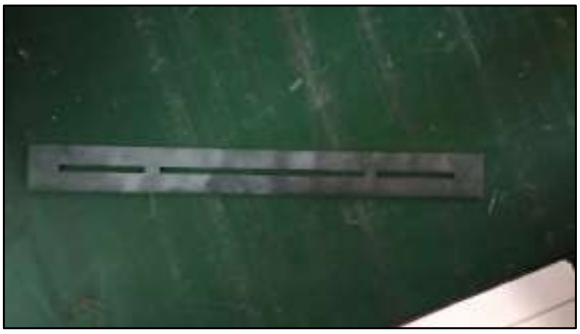


Now, the central element is taken as MS plate of 3mm thickness each with 3 slots on each of the plate for more flexibity to the robot as the clamps can move up and down along the central element and can be fixed on a desired position. Also using a rod of MS would not be feasible as it puts on more weight to the robot. So, plates were the best option to as a central element for our robot.

We used slot system for more flexibility. As the slots are there on the central element, we made slots on the links as well so that the robot gets more flexibility. First the links are connected as per desired slot and still flexibility is needed then clamps can move up and down as per desired position.

VII. COMPONENTS

A. Central Element



Length-300mm
Breath-30mm
Thickness-3mm
Slot- 1. Two small slots of
length-54.17mm and breath-4mm
2. One big slot of
length-135.44mm and breath-4mm

B. Link 2

Length-200mm
Breath-10mm
Thickness-3mm
Hole diameter 3mm

C. Link 3

Length-100mm
Breath-15mm
Thickness-3mm
Hole diameter 3mm

D. Link 3

Length-40mm
Breath-15mm
Thickness-3mm
Hole diameter 4mm

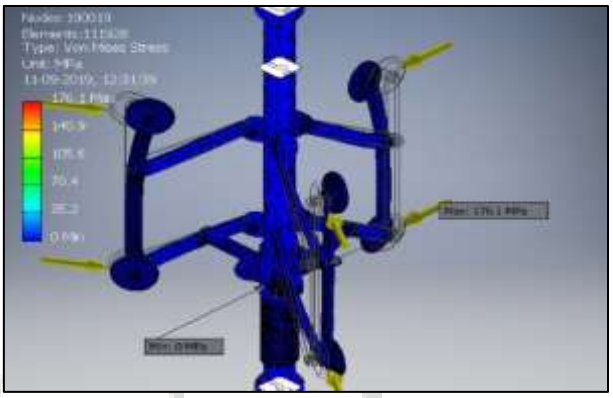
E. Motor

Single shaft Straight B.O. motor
Revolution - 150rpm
Power - 3-9v

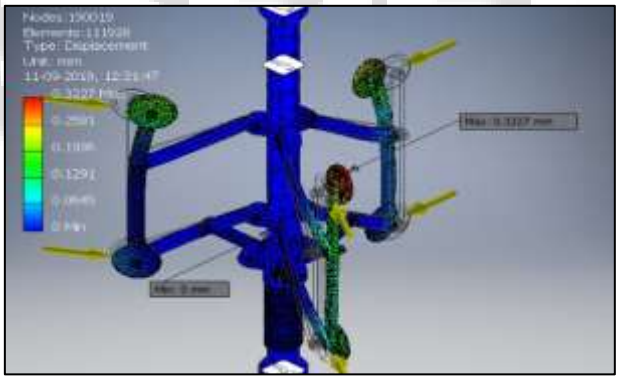
F. Camera

VIII. STRESS-STRAIN ANALYSIS

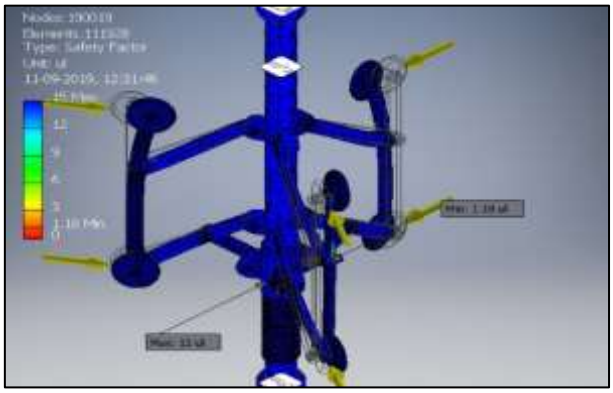
A. Von Mises Stress



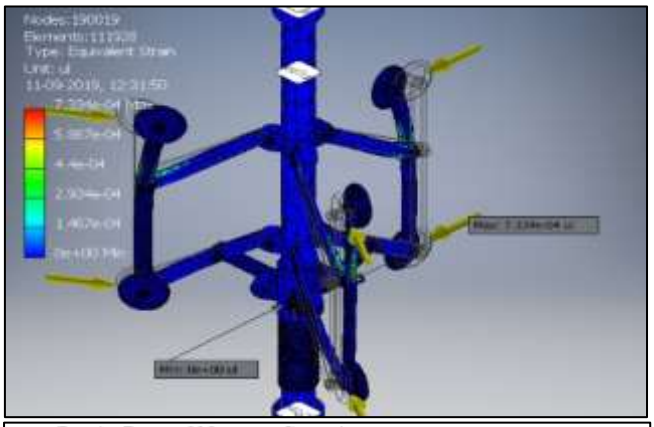
B. Displacement



C. Safety Factor



D. Equivalent strain



Reaction Force and Moment on Constraints

Constraint Name	Reaction Force		Reaction Moment	
	Magnitude	Component (X, Y, Z)	Magnitude	Component (X, Y, Z)
Fixed Constraint:1	5.66 N	0 N	1.67679 N m	-0.160907 N m
		-5.66 N		0 N m
		0 N		1.66905 N m

Table 15

Result Summary

Name	Minimum	Maximum
Volume	151114 mm^3	
Mass	0.580855 kg	
Von Mises Stress	0 MPa	176.073 MPa
1st Principal Stress	-35.826 MPa	184.908 MPa
3rd Principal Stress	-210.337 MPa	23.3859 MPa
Displacement	0 mm	0.322687 mm
Safety Factor	1.17565 ul	15 ul
Stress XX	-139.218 MPa	152.03 MPa
Stress XY	-90.4161 MPa	62.2374 MPa
Stress XZ	-61.4066 MPa	75.2076 MPa
Stress YY	-173.626 MPa	172.318 MPa
Stress YZ	-67.9662 MPa	67.2723 MPa
Stress ZZ	-134.07 MPa	140.817 MPa
X Displacement	-0.148281 mm	0.214237 mm
Y Displacement	-0.239379 mm	0.312581 mm
Z Displacement	-0.0926263 mm	0.0110994 mm
Equivalent Strain	0 ul	0.000733389 ul
1st Principal Strain	-0.0000035877 ul	0.000752878 ul
3rd Principal Strain	-0.000863795 ul	0.0000062014 ul
Strain XX	-0.000545711 ul	0.000606298 ul
Strain XY	-0.000524003 ul	0.000360694 ul
Strain XZ	-0.000355879 ul	0.000435862 ul
Strain YY	-0.000732396 ul	0.000679911 ul
Strain YZ	-0.000393895 ul	0.000389873 ul
Strain ZZ	-0.00061587 ul	0.000527057 ul
Contact Pressure	0 MPa	134.261 MPa
Contact Pressure X	-104.125 MPa	94.5903 MPa
Contact Pressure Y	-127.708 MPa	106.668 MPa
Contact Pressure Z	-95.1295 MPa	102.189 MPa

IX. ROBOT SPECIFICATION

Main Application	Inspection
Mass	2-2.5kg
Material	MS and Aluminium
Type	Cater-pillar
Sensors	Smoke sensor and proximity sensor
Circuit	Arduino
Motor	B.O. Motor
Camera	FPV camera with Wi-Fi module

X. ADVANTAGES

Following are the advantages of using In-pipe inspection robot:

1) Gives more safety to workers.
2) Accurate and safe inspection.
3) Gives better understanding of the problem.
4) Time saving and efficient.
5) Probability of making error reduces.
6) Can be used by less-skilled worker as well for geometrical error in pipes.
7) Worker does not need to be at the exact site of inspection as the robot can be controlled from a distance.
8) More reliable than a human for inspection as error are reduced.
9) Easy to operate.
10) Operating cost of other equipment will eventually be reduced as regular inspection will be done.

XI. APPLICATION

Following are the application for In-pipe inspection robot:

1) Can be used in all industries/refineries.
2) Can be used in gas line pipes.
3) Can be used where environment is not suitable for humans.
4) Can be in a hazardous environment where temperature is high.
5) Can be used to detect smoke or leakage in a pipe with the help of smoke sensor.
6) Can be used to detect any kind of obstruction in pipe flow with the help of IR proximity sensor.
7) Detects various defects/problems in pipe line.

XII. CONCLUSION

From all the above theory and research work we can say that in-pipe inspection is better for providing safety to the workers and also provides better inspection. Over all this robot will provide the information about the damages in the pipe and along with that it will also provide the information about the environment inside the pipes i.e. hazardous gases present at the defective spot with help of smoke sensor and will also detect any kind of obstruction in the pipe line with help of IR proximity sensor. Hence, we can say that use of in-pipe inspection robot for gas line is a better option for workers as both safety and inspection is taken into account.

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