A Review of Design and Development of Pipe Inspection Robot

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Abstract:-A engineer is always focused towards challenges of bringing ideas and concepts to life. Therefore, sophisticated machines and modern techniques have to be constantly developed and implemented for economical manufacturing of products. At the same time, we should take care that there has been no compromise made with quality and accuracy. In the age of automation machine become an integral part of human being. By the use of automation machine prove itself that it gives high production rate than manual production rate. In competition market everyone wants to increase their production & make their machine multipurpose.

The engineer is constantly conformed to the challenges of bringing ideas and design into reality. New machines and techniques are being developed continuously to manufacture various products at cheaper rates and high quality An in-pipe robot with active pipe-diameter adaptability and automatic tractive force adjusting is developed for long-distance inspection of industrial pipelines with different diameter series. Its physical design employs the scheme that 3 wheels of a linkage mechanism are circumferentially spaced out 120° apart symmetrically. And for *detection* cracks, corrosion led , Bluetooth camera makes it more user friendly .

Keywords: In-pipe inspection robot, Detection, Inspection.

1. Introduction

There are a wide variety of pipelines such as urban gas, sewage, chemical plant, nuclear power plant etc., which are indispensable in our life. Also, pipelines are the major tools for transportation of oils and gases and a number of countries employ pipelines as the main facilities for transportation. In our country, the urban gas pipelines currently go up to 13,000 Km long but since most of them have been constructed in 1980's, there happen a lot of troubles focused by aging, corrosion, cracks, and mechanical damages from third parties. Continuous activities for *inspection*, maintenance and repair should be performed from now on. However, those activities need enormous budgets that may not be easily handled by gas companies as they are mostly small and medium in size.Efficient equipmentfor *inspection* and in targeted maintenance program are required in gas industries An*in-pipe inspection* robot for the *inspection* of pipe with pipe diameter adaptability is introduced here. There were various models developed for the pipe *inspection* however this robot excludes various disadvantages associated with them.Robotics is one of the fastest growing engineering fields, presently they are used for wide variety of works specially in manufacturing industries e.g. spot welding, loading and unloading of tool and work piece, painting etc. Primarily robots are designed in such way that they reduce humanintervention from labour intensive and hazardous work environment; ;sometimes it is also used to discover inaccessible work place which is generally impossible to access by humans The complex internal geometry and hazard content constraints of pipes require robots for *inspection* purpose . With these constraints, *inspection* of pipe becomes so more necessary that, tolerating it may lead to some serious industrial accidents which contaminate environment and loss of human lives also. For *inspection* of such pipes, robot requirement is must especially in order to check corrosion level of pipe, recovery of usable parts from pipe interior, for sampling of sludge and scale formation on pipe internal surface etc. Designing of a new*in-pipe inspection robot* is carried out in this research work.

2. Review

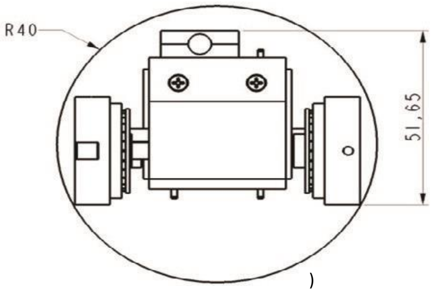
H.R. Choi, S.M. RyewfRobotic system with active steering capability for internal *inspection* of urban gas pipelines [2002] [6] explained as Mechanism of active adaptation to pipe diameter:

The pipe diameter adaptive mechanism is the actuator of active adaptation to pipe diameter and adjustment of tractive force. It is composed of three sets of parallelogram wheeled legs circumferentially spaced out 120° apart symmetrically. Each parallelogram wheeled leg has a front driving wheel and a rear driving wheel. Illustrates the one of three sets. The operation of the pipe diameter adaptive mechanism is driven by a step motor with convenience to be controlled. This motor is called the adjusting motor. Under the control of motor driver, the adjusting motor drives rotation of the ball screw pair which can push three sets of parallelogram wheeled legs to make driving wheels contact to inner wall of pipe, or adjust the pressure between driving wheels and pipe wall. This structural design makes it possible to realize the adaptability to pipe diameter and tractive force adjusting together, and the pipe diameter adaptive mechanism with this structure can realize adjustment in a wide range. The nut of ball screw, pressure sensor and axial sliding bush are connected together by screw bolts. The pressure sensor, which may test the sum of pressures between all the driving wheels and pipe wall indirectly, is useful for the control of pressing the driving wheels against the pipe wall with a stable pressure to obtain sufficient and stable tractive force, and on the other hand, can provide overload protection to prevent the mechanism overloading.

Mechanism of tractive force adjusting:

A pipeline *inspection* robot must obtain sufficient tractive force to pull its tether cable and other equipments while traveling inside a gas pipeline to complete *inspection*, maintenance, and repair tasks. When the motion motor of a wheeled robot can produce an enough driving force, its tractive force is determined by the adhesion force which depends on the normal pressure and adhesion coefficient between driving wheels and pipe wall. Thus, a wheeled robot with the pipe diameter adaptive mechanism, which can produce an additional normal pressure to change the adhesion force between driving wheels and pipe wall, is capable of adjusting its tractive force in a certain range.Along with the increase of *inspection* distance in pipeline, more tractive force of the robot is demanded to overcome increasing friction resistance of the tether cable, or an additional kinetic resistance caused by pipe slope. However, when the motion motor of the robot produces more driving force, the adhesion force only contributed by robot weight may be insufficient, and its driving wheels may slip on the surface of pipe wall. Therefore, an additional pressure enhancing adhesion force should be produced by the pipe diameter adaptive mechanism to improve the tractive capacity of the robot. This is realized as the way that the action of the adjusting motor drives rotation of the ball screw pair with the output torque T and produces the thrust force F which drives parallel linkage ABCD to press the driving wheels against inner wall of the pipe with an additional pressure.

Md RaziqAsyraf Md Zin Development of a Low Cost Small Sized In-Pipe Robot Procedia Engineering 41 [2012][2]In this, problem is developed when the robot has limited coverage area of the pipe. Current Solutions are largely sized and not appropriate for small sized pipes. A prototype of final designSuccessfully demonstrated a robot travelling upside and downside on ferromagnetic surfaces for small diameters from 80 to 180 mm The main objective of project is to tackle varying pipe geometry such as pipe brunch, pipe diameters and pipe elbows for small diameter pipes magnetic wheels gives vertical motion within the pipe ensuring maximum *inspection* coverage area . considering small size requirements driver of robot to be small as possible. The required motor for robot is decided by torque required and that can be calculated by maximum value of force required to drive the robot multiplied with the radius of wheel . by calculating that servo motor is used and its name is HS-225 MG which is reasonably small sized magnetic wheels are used for vertical motion. The magnet disc used for *inspection* robot wheel rim is neodymium magnet type a type of rare earth magnet widely used for modern equipment as hard disk drives and motors . this type of magnet presents only solution for magnet wheel application due to its high strength and size ratio. But its limitation is it is used in only ferromagnetic substance pipelines.



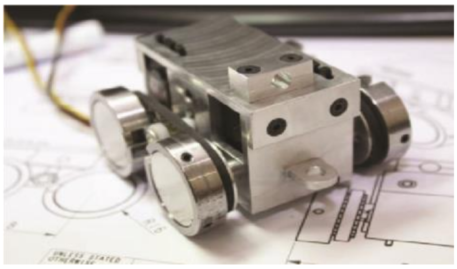


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Fig 3.1 completed prototype [2]

Venkatasainathbondada. *Detection* and quantitative assessment of corrosion on pipelines through image analysisProcedia Computer Sciencevolume 133, [2018] [3] he had done *detection* and quantification of corrosion on pipe using digital image processing technique for that he followed methodology like identification of scene constraints, Image acquisition, image filtering, HIS colour space conversion, corrosion *detection*, morphological operations and corrosion quantification. He detected corrosion through image and quantification by measuring corrosion area, location of centres of corroded region and damaged surface.

Fig 3.2 image of corrosion captured through camera [3]

Quantification : Corroded surface [3]

$$\% \text{ of corrosion} = \frac{\text{Number of corroded pixels}}{\text{Total number of pixels used to represent the pipe}}$$

Ahamed khan Development of a Laboratory-scale Pipeline *Inspection* Robot Procedia Computer Sciencevolume 76, [2015] [4] explained as Development of laboratory scale pipeline *inspection* robotThe wheeled type robot is chosen as the drive mechanism for this PIR in order to improve the ideal speed and diameter adaptability of pipes. Direct assessment is dangerous so that he used this colour sensing technique to detect different type of cracks. Colour sensor is selected to be attached to robot for crack *detection* where transverse crack, longitudinal crack, slant crack are represented by red yellow and blue colour from the experiment the PIR proven to be able to detect crack at high accuracy of 90%.

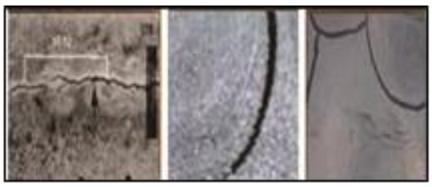


fig3.3Types of Cracks [4]fig3.4Transverse, Longitudinal and Slant Cracks[4]

S.K. Pradhan Design of a New *In-Pipe Inspection Robot*Procedia Engineeringvolume 97, [2014] [5]studied existing types of *in-pipe inspection robot* like wheel type robot, caterpillar type robot, without wheel type robot and there advantages disadvantages. He concluded that screw type *in-pipe inspection robot* has many advantages and he designed robot for pipe diameter ranging from 127mm-152mm. He analyse kinematic and dynamics for the design of screw type *inspection* robot.

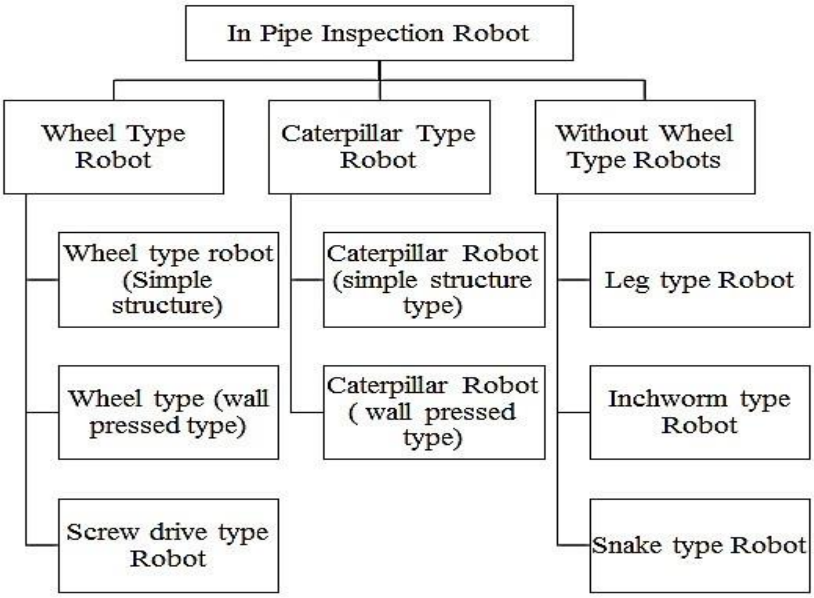


Fig3.5 Classification of IPIR [5]

Performance indicator	Wheel type robot			Caterpillar type robot		Without Wheel Type Robot		
	Wheel type robot (Simple structure)	Wheel type (wall pressed type)	Screw drive type robot	Caterpillar Robot (simple structure type)	Caterpillar Robot (wall pressed type)	Leg type robot	Inchworm type robot	Snake type robot
Vertical Mobility	Poor	Very Good	Very Good	Fair	Very Good	Very Good	Fair	Fair
Steerablity	Very Good	Fair	Fair	Fair	Fair	Very Good	Fair	Fair
Size and shape adaptability	Poor	Very Good	Fair	Poor	Very Good	Very Good	Fair	Very Good
Flexibility of body	Rigid	Rigid	Less flexible	Rigid	Rigid	Rigid	Flexible	Flexible
Stability of robot	Poor	Very Good	Very Good	Fair	Fair	Fair	Fair	Fair
Moztion efficiency	Fair	Fair	Very Good	Fair	Very Good	Very Good	Very Good	Fair
Number of actuators	Fair	Fair	Less	Less	Less	More	More	More
Wireless control	Fair	Very Good	Fair	Fair	Fair	Poor	Poor	Poor

Fig 3.6Comparison of IPIR'S [5]

Nicholas S Flann, Kevin L Moore, Lili Ma small mobile robot for security and *inspection* operations Original Research Article Control Engineering Practice, Volume 10, Issue 11, November[2013] [1] explained as Description of the *inspection* robot system *Inspection* In consideration of safety, concrete structures are inspected for cracks, leakage, spall and other attributes; however, cracks are of particular concern, for they most significantly affect the state of the concrete. Cracks in concrete structures arise from poor repair, contractions due to rapid temperature decreases, fluctuations between contractions and expansions from temperature changes, and extra loads from partial ground expansion. Cracks can be classified as vertical, horizontal, shearing or complex. About 40% of cracks are vertical, 11% are horizontal and 30% About 40% of cracks are vertical, 11% are horizontal and 30% are shearing, see fig.

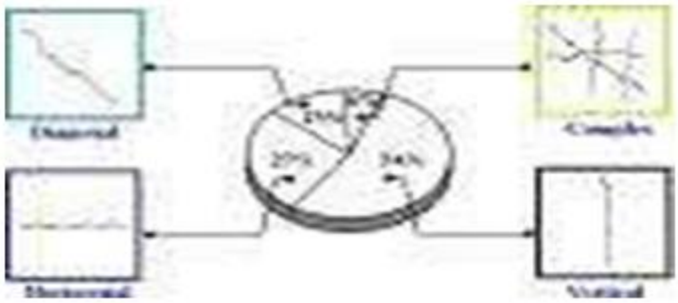
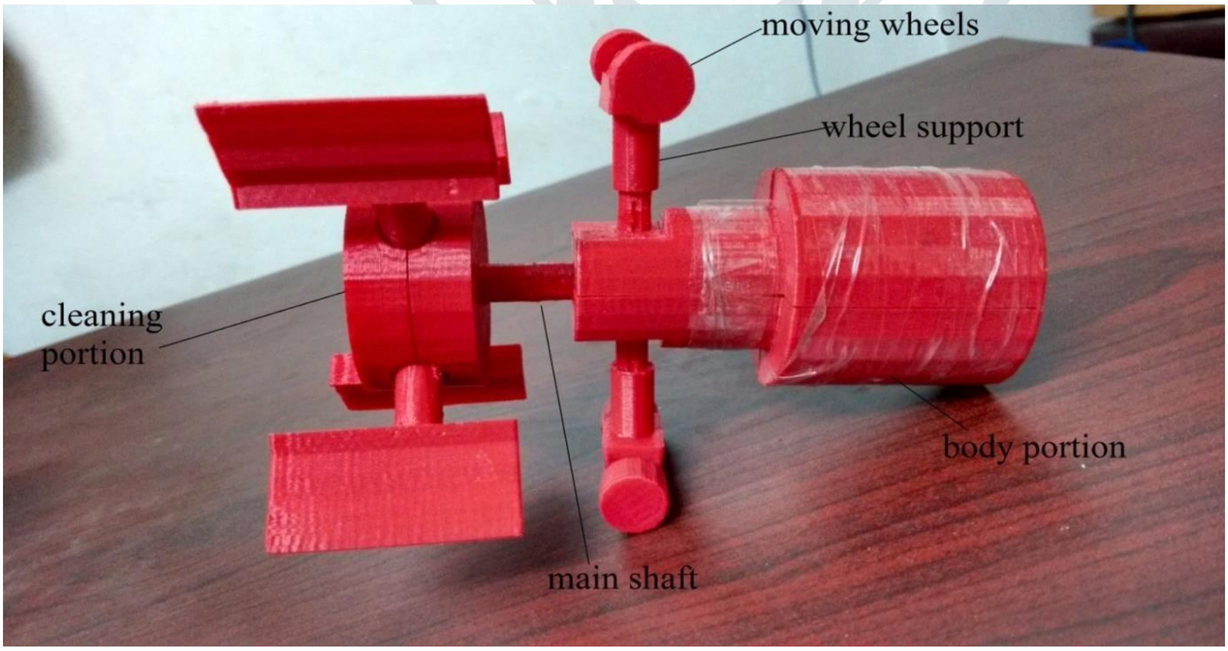


Fig 3.7 Proportions of cracks. [1]

The mobile robot system consisted of optical, mechanical, and data storage devices. These devices stored images of the surface of the concrete structure, maximized the contrast distribution of crack and non-crack areas, and minimized the noise while the system automatically moves parallel to the structure.The crack detecting system was software that extracts and computes the numerical crack information from the image data. The software extracted the length, width and orientation of cracks. The crack detecting system provided information that helps determine if additional precision *inspection* of a structure is needed.The mobile robot system consisted of a CCD line camera, frame grabber, controlling apparatus for an auto-focus device, vibration-reducing device, illuminator and encoders to measure the velocity and position of the unit; To compute the distance of the robot from the structure, velocity and position were used, this allowed the camera to be focused and controlled without an inspector.

Saenz, J., Elkmann, N., Stuerze, T., Kutzner, S., &Althoff, H. provided discussion on the results obtained. The design model can easily pipes from 70mm to 80 mm in diameter. There are various mechanisms used but the final suitable mechanism for actuation is the bevel gear mechanism. The ultrasonic sensor is very accurate in detecting the flaws in the pipe. It can easily give information of inner surface of with up to distance of 3.6 meters. The 300RPM DC motor used in this robot is good enough to provide high torque. The body cover is providing excellent insulation to the motor. It makes the robot to sustain for long time. The wall-pressed in-pipe robot can provide better anchoring robot to keep in position.



Atwood, C. C., Juchniewicz, R. P., Kratzer, E., Slifko, A., & Johns, P. J. studied on types of different types of inspection robots and sensor used in them., in-pipe robots configured into the following six types:

i. Wheeledtype
ii. Caterpillartype
iii. Wall-pressedtype
iv. Walkingtype
v. Inchwormtype
vi. PIG type(Pipe InspectionGauges)

Sensors used by robots for performing inspection operation

SI. No	Type of sensor used	Application
1.	Ultrasonic sensor	Detecting flaws in the pipe.
2.	Magnetic sensor	Tracing and locating the robot in the underground pipes.
3.	Infrared sensor	Inspection of pipe environment.
4.	Vision sensor	Visual inspection of the pipe.
5.	Touch /capacitive sensor	To detect paint thickness and flaws the pipe
6.	LASER	For the purpose of detecting flaws

3. Conclusion

Robots can be effectively used as tools to carry out work in labour intensive, hazardous and unreachable work environments.Wheel type robotis use for better autonomy and achieve vertical motion.Use of tilted and guide wheels for traversing curves and bends in pipes. Infrared/Ultrasonic inspection for better detection of defects these are long range sensors for better defect detection. In-Pipe inspection robot[1] concrete structures are inspected for cracks, leakage, spall and other attributes and show a considerable improvement in the accuracy and precision of the inspection.

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