International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 4, April - 2013

Design and Fabrication Of Pipe Robot That Can Insepect In Various Pipe Types

Harish J[1], Sivanathan.K[2]

1 Research scholar, Robotics, SRM University, Tamilnadu, India
2 Assistant professor, Mechtronics, SRM University, Tamilnadu, India

Abstract

In this project, a new design for a pipe robot can travel through various pipe configurations including vertical, elbow, and branch pipes. One specific mechanism of the robot are important for namely the Adaptable Quad Arm Mechanism (AQAM) and. The AQAM allows the robot to travel in reduced branch pipes and branch pipes with zero-radius of curvature, which are both common in real life but which pose a challenge to the previously developed in-pipe robots. The microcontroller enables the robot to change its orientation, and in particular, allows it to bypass bumps. The prototype was able to through elbow and vertical pipes with a diameter of 305 mm and zero-radius of curvature reduced branch pipes of at least 305 mm×259 mm to 305 mm×290 mm or smaller. Using the microcontroller the robot will moves in various pipes.

Index Terms: *AQAM, Catia, Pipe robot…*

---***---

1. INTRODUCTION

Pipelines are used to transport fluids such as water, oil, and gas, which are crucial to everyday life. However, repairing pipes has always been problematic due to geographical difficulties. In-pipe robots have thus received special attention as an effective solution to resolve this issue. In-pipe robots may be classified in several different ways. They may be categorized into wheel track inch worm walking and pig types depending on their travelling mechanisms. They may also be categorized according to their structures: single-plane type with arms 180° apart, or 3- plane and 4-plane types which have arms separated by 120° and 90°, respectively. While the 3-plane and the 4-plane types have a large traction force and exhibit stable performance in pipes, the single-plane type enjoys the advantages associated with its simple architecture. Another criterion for categorizing in pipe robots is their method of adapting to a pipe's inner surface, passive or active adaptation. Many passively an adaptable in-pipe robot adapt to a pipe's inner surface with springs only, no additional actuators are used. In-pipe robots that adapt to pipes actively, however, can travel more effectively than the robots with passive adaptation because the normal force between the robot and the pipe is controlled with additional actuators. Many of the developed in-pipe robots can traverse simple pipe configurations, such as straight pipes or pipes with no variation in diameter. Although some robots can travel through branched and elbow pipes, travelling in branched pipes is still regarded as a challenge in the field of in-pipe robotics. Even these robots that are designed to travel through branched pipes have difficulty in managing certain types of branched pipes, namely

- Reduced branches, or branch pipes that have different hole diameters
- Branches with zero radius of curvature

Moreover, these robots require difficult and complicated locomotion or control strategies to traverse these types of pipes. Differential wheel drive type robots are considered to be the most successful at travelling through branches. However, the following problems can occur when these types of robots inspect branch pipes with the two aforementioned conditions. The robot can get stuck in a zero-radius of curvature branch due to a lack of space for turning in the worst-case scenario the robot can crash into the edge of the branch, which may damage the robot. The problems mentioned in problem 1 might be exacerbated in a reduced branch pipe. In-pipe robots designed for larger pipes are usually larger and thus heavier. Because differential wheel drive type robots experience some impact during turning in a branch, an increase in weight can substantially reduce the robot's endurance. Introduce a new design for a simply structured in-pipe robot with simple yet effective locomotion strategies for travelling through reduced branch pipes and branches with zero radius of curvature as well as vertical and elbow pipes. This newly developed robot's motion through branches is not associated with crashes; therefore, this robot has the ability to travel through larger pipes Conducted simulation studies to predict the robot's abilities and to build a prototype also conducted experiments with various pipe configurations to characterize a prototype of our proposed in-pipe robot.

2. DESIGN

To enable the proposed robot to travel in both reduced branch and zero-radius of curvature branch pipes safely without requiring a complicated locomotion strategy, designed the wheels to follow the inner configuration of branch pipes by using the normal force between the wheel and the inner wall of pipe as illustrated .To this mechanism as the Adaptable Quad Arm Mechanism (AQAM). Using this mechanism, a robot can travel through various branch pipe shapes simply by changing the direction of rotation of each wheel. For a robot to travel into a branched hole, however, it needs to have a specific orientation with respect to the pipe. The robot needs to have a specific y-directional orientation to enter into the branched hole. Steering mechanisms for locomotion in branches have been studied previously the robot propose is designed to change its orientation in a pipe by employing steerable hands This mechanism the Swivel Hand Mechanism (SHM), which makes the robot's hands rotate with respect to the arm. The structure of the proposed robot equipped with the AQAM and SHM. The AQAM consists of the body, the arms, and the springs that connect the components.

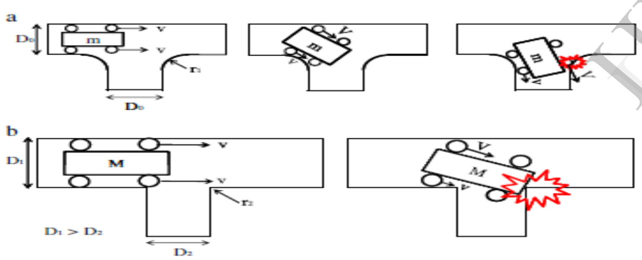


Figure 2.1 Differential wheel drive type

When the wheel contacts to the inner wall of pipe, the arm will be rotated with respect to the body by the contacting force which is generated by the moment due to the length difference spring 1 and spring 2.The hand is positioned at the end of the arm consisting of the wheel and the U-frame and it can be rotated with respect to the arm. degree of freedom (DOF) configuration is the relevant part of the robot. Because the proposed robot is a single-plane type, it has a large non-contact area in the pipes. The hands can be rotated with respect to the arms by the SHM, which enables the robot to change its orientation with respect to the pipe. Due to this characteristic, the robot can avoid bumps in pipes, to summarize, the main features of the proposed robot design are

- The robot is a wheeled, single-plane, and passively adaptable type robot.
- The robot can rotate along with its moving direction by rotating wheels about the arm

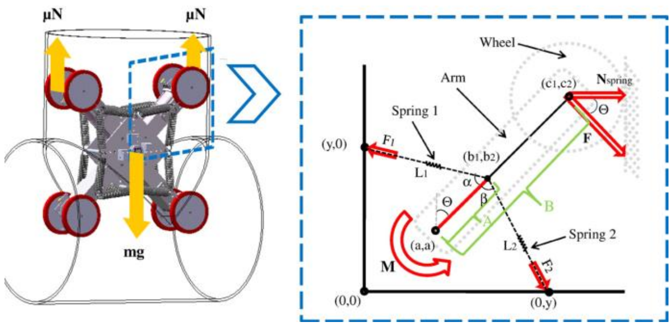
2.2 Adaptable quad arm mechanism (AQAM)

The proposed robot is programmed to travel in pipelines; it should exert sufficient normal force between the wheel and the inner surface of the pipe. The AQAM enables the robot to do so. This mechanism is important for travelling in branches in particular

Two issues need to be considered to design an AQAM that will allow the robot to travel in branches of the desired sizes.

- The first issue is overcoming the gravitational force experienced by the robot during travel in vertically positioned branches
- The second issue is overcoming spring moment with the torque generated by motors in the arms to turn in a branch

Analysis of the first issue allowed us to determine the maximum possible diameter of the branched hole for travelling, while that of the second issue allowed us to determine the minimum size of the branched holes of reduced branch pipes. To address the first issue, we need to determine the frictional force that the AQAM can generate when the robot is travelling in a vertically positioned branch, the robot will create a greater frictional force than in any other motion in branch pipes because it has to use only two arms to overcome gravity. In the diagram, (y, 0), (0, y), (b1, b2), (c1, c2), (a, a), and (0, 0) denote the locations of spring 1 and spring 2 fixed on the body, the location of both springs fixed on the arm, the location of the axis of the wheel, the location of the hinge connecting the arm and body, and the location of the center of the body, respectively, in two-dimensional Cartesian coordinates. Also, θ is the angle between the axis of the vertical pipe and the axis of the arm, k is the spring constant, α is the angle between spring 1 and the arm, β is the angle between spring 2 and the arm, A is the distance between (a, a) and (b1, b2), B is the distance between (a, a) and(c1, c2), L1 and L2 are the lengths of extended spring 1 and spring 2, respectively, F1 and F2 are the forces exerted by spring 1 and spring 2, respectively, is the moment on the hinge (a, a), and N spring is the normal force between the wheel and the pipe surface.



2.2 The first AQAM issue: Overcoming gravity with two arms.

The minimum normal force required for the robot to overcome gravity is

$$N_{min}=mg/2\mu$$

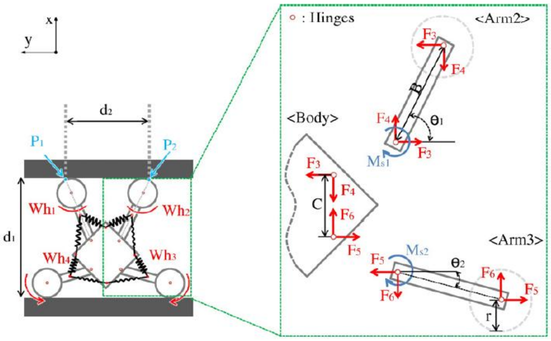
μ and g are the coefficient of friction and the acceleration of gravity, respectively. To confirm the AQAM with the parameters set to those could exert a force larger than the minimum normal force needed, derived an equation for the normal force exerted by the two springs (N spring). The free body diagram.

$$X_{d1} = L_1\text{-}X_{1}\text{----------- }1$$
$$X_{d2} = L_2\text{-}X_{2}\text{-----------}2$$
$$b_1 = a+ A \sin \Theta\text{------}3$$
$$b_2 = a+ A \cos \Theta\text{------}4$$
$$L_1 = \sqrt{b_1}+(y-b_2)^{2\text{-------}}5$$
$$L_2 = \sqrt{(y-b_2)^2+b_2}^{2\text{-------}}6$$
$$\alpha = \cos^{-1}\{A^2+L_1^2-(y-a)^2-a^2/2L_1A\}\text{--------}7$$
$$\beta = \cos^{-1}\{A^2+L_1^2-(y-a)^2-a^2/2L_2A\}\text{--------}8$$

xd1, xd2, and xi denote the elongated lengths of spring 1 and spring 2 and the initial length of the spring. If xd1 or xd2 becomes shorter than zero, the value should be set to zero, because the springs exert no force on the arm in these cases. The equations for the moment on the hinge (a, a) exerted by two springs and the normal force generated by the springs.

$$M = kA\ (X_{d2}\sin\beta\text{-}\ X_{d1}\sin\alpha)\ \text{-------}10$$
$$N\ spring = F\cos\theta = M/B\cos\theta\text{-----}11$$

The second issue associated with the AQAM, considered the situation described here, wheels 1–4. The robot makes the distance between wheels 1 and 2 as small as possible by rotating wheels 2 and 3 clockwise and wheels 1 and 4 counter-clockwise in a straight pipe. Denote the distance between P1 and P2, the points where the two axes of the arms meet the endpoints of their wheels, as d2. Even though the situation does not coincide perfectly with the real conditions a robot encounters when travelling in a branch, analyzing this situation and considering d2 as the minimum possible traverse diameter of the branch makes subsequent calculations easier and also yields reasonable results.d1 and d2 are the diameters of the branch, Ms1 and Ms2 are the moments on the hinges which connect arms 2 and 3 and the body, F3 and F5 are the forces on the axes of the wheels for arms 2 and 3 exerted by the DC motors F4 and F6 are the normal forces between wheels 2 and 3 and the pipe's surface θ_1 and θ_2 are the angles.

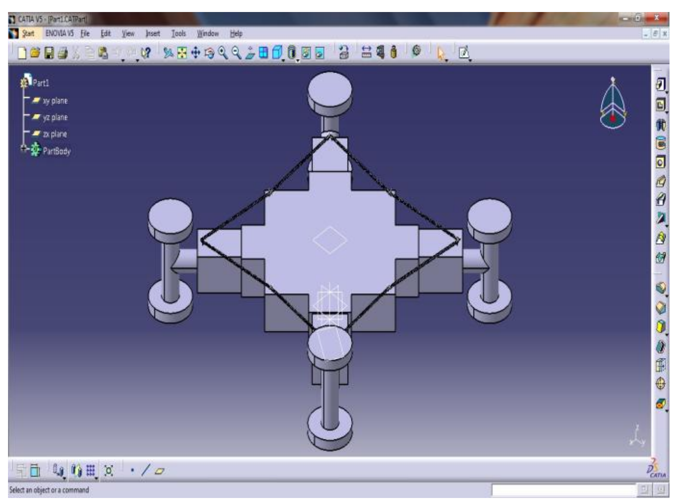


2.3 The second AQAM issue: Overcoming the moment generated by the springs with the torque generated by DC motors in the arm

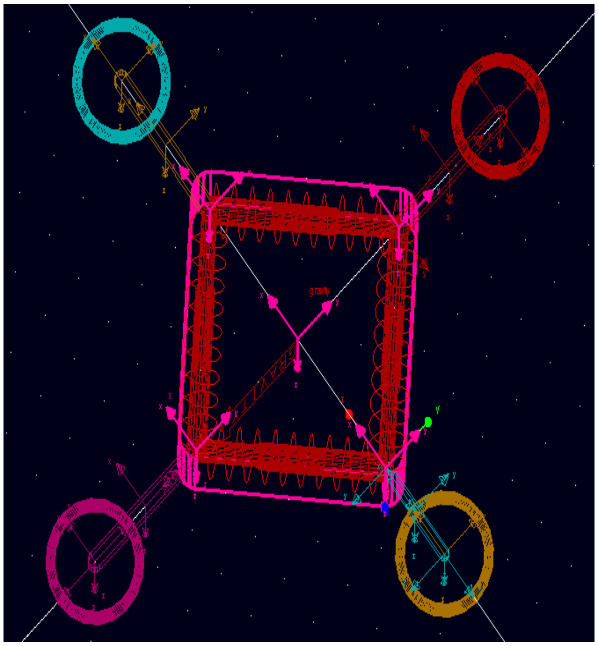
When T is the allowable torque of the motor in each arm, the equilibrium of force and moment gives

$$F_4= F_6$$
$$F_3= F_5 = T/r$$

A larger spring constant increases the performance of the robot with regard to the first AQAM issue while a smaller spring constant enables the robot to traverse a larger range of branch sizes (second issue). This means that simply by modulating the spring constant, the performance range of the robot in branched pipes can be modified.



2.4 MODEL IN CATIA

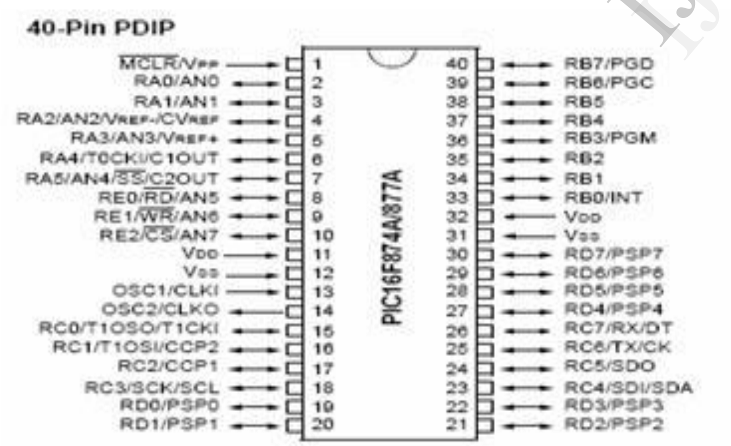


2.5 AUTOMATED DYNAMIC ANALYSIS OF MECHANICAL SYSTEM OF THE ROBOT

3. MICRO CONTROLLER

3.1 Pin description

Pin description of the PIC16F877A



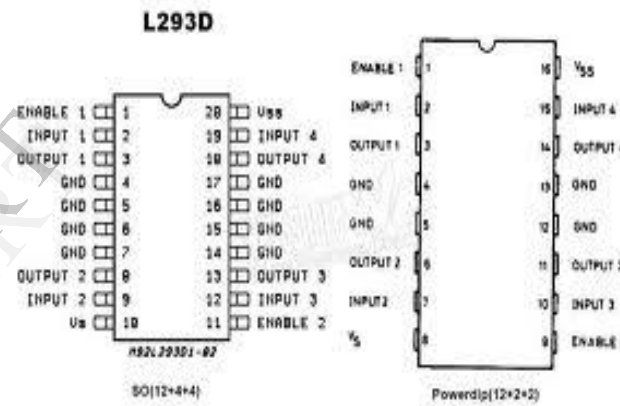
3.1 PIC16F877A

PIC16F877A is a high performance RISC CPU with only 35 single word instructions to learn and also all instructions are single-cycle instructions except for program branches, which are a two-cycle. The operating speed is 20MHz. it has three memories RAM, ROM and Flash memory as mentioned in the table below. It also has three timers, two 8 bit and one 16 bit timer. The main motive of selecting this particular controller is that of its limited instruction set, which will consume less time to understand and program the controller and also while compared to other controllers with the same features this is the less cost controller. The table shown below is some of the details of PIC 16 bit family.

Device	Program Memory		Data SRAM (Bytes)	EEPROM (Bytes)	I/O	10-bit A/D (ch)	CCP (PWM)	MSSP		USART	Timers 8/16-bit	Comparators
	Bytes	# Single Word Instructions						SPI	Master I^2C			
PIC16F873A	7.2K	4096	192	128	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F874A	7.2K	4096	192	128	33	8	2	Yes	Yes	Yes	2/1	2
PIC16F876A	14.3K	8192	368	256	22	5	2	Yes	Yes	Yes	2/1	2
PIC16F877A	14.3K	8192	368	256	33	8	2	Yes	Yes	Yes	2/1	2

4.2 Motor Driver

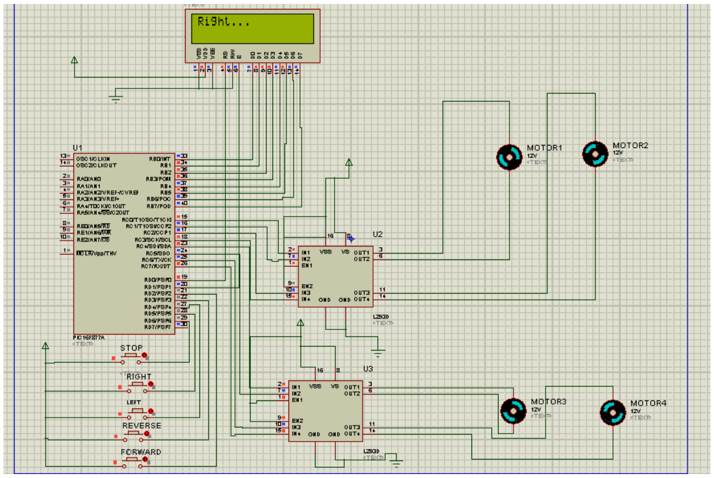
Interfacing the driver circuit to the micro controller in the robot that controls the motors



4.2 DRIVER CIRCUIT

LM293D is a motor driver IC. The use of the driver circuits is that the controller runs with input voltage VCC=5v. Even though it gets input as 5v internally the voltage levels will be at 3.4v only and at that voltage the current will also be less, which won't be sufficient for a motor to run. So, through the driver circuits we do the interfacing and use the driver as a medium to boost the current and fire the motor to run. The connection of the driver circuit to the controller is given here below: Port B is connected to the driver circuit (L293D) in port B 15th is connected to the input IN1 to the driver circuit. The 16th pin is connected to the input IN2, 17th pin is connected to the IN3 and 18th pin is connected to the IN4.

Port B is connected to the driver circuit (L293D) in port B 23rd is connected to the input IN1 to the driver circuit. The 24th pin is connected to the input IN2, 25th pin is connected to the IN3 and 26th pin is connected to the IN4. Port c is connected to the switches which controls the robot.21st is pin connected to switch 1 named (stop).pin 22nd is connected to the switch 2(right),pin 27th connected to switch 3(left),pin 28th connected to the switch 4(reverse),pin 29th is connected to the switch 5(forward).



4.3 CONTROLLING THE ROBOT USING MICRO-CONTROLLER

5. LOCOMOTION CHARACTERISTICS AND CONTROL STRATEGY

One of the strong points of our proposed robot is its ability to travel through various pipe shapes without using a complicated locomotion or control strategies. To make the robot turn into a branched hole, the operator should first orient the robot's body appropriately using the SHM, then rotate wheels 1 and 2 clockwise, and wheels 3 and 4 counterclockwise until wheels 1 and 2 approach the edges of the branch. Next, if the operator rotates wheels 2 and 3 clockwise and wheels 1 and 4 counterclockwise, the robot will turn into the branch, adapting to it's configure. In the case of straight motion in a branch, one can simply continuously operate the wheels of the robot as depicted in, regardless of its orientation. The robot can also successfully navigate elbows by applying different velocities to the wheels. the wheels that are in contact with the larger radius of curvature (ρ1) part of the elbow pipe should rotate faster and the wheels in contact with the smaller radius of curvature (ρ2) of the elbow pipe should rotate slower. In addition, the structure of the AQAM makes it possible for the robot to navigate bumpy pipes as well as straight pipes of various diameters. As mentioned previously, the simple architecture of the robot and uncomplicated locomotion strategies allow the proposed robot to navigate a variety of pipe types that have been challenging for previously developed robots. Previously reported robots use auxiliary parts or connect modules in serial to move successfully in a branch. Our proposed robot was designed to maneuver in elbow and a branch using its own mechanical configuration

The strategy for changing orientation

Many pipe inspection robots cannot rotate about their moving direction because they move with wheels or tracks that have large friction and that can side-slip. Our proposed robot can steer its wheels, thereby changing its orientation. In this section, we estimate the wheel rotation needed to achieve the desired orientation (roll) of the robot by analyzing the geometry of some components of the robot and the pipe. From the geometric relationship depicted in, it is possible to determine α, the angle of travel of the wheels with respect to the x-z plane (plane A). Here, Point A is where the wheel and the inner surface of the pipe meet, plane A is the tangent plane to the inner surface of the pipe at Point A, and Plane B is the extended surface of the wheel. As it is possible

to determine the orientation of Plane B by transforming the orientation of x-y plane by the angle μ with respect to the z-axis and angle −γ with respect to the transformed y-axis (y′), z″ →, which is the normal vector of Plane B.

$$\vec{Z''} = R_Z(\mu) R_y(-\gamma) \vec{Z} = \begin{bmatrix} \cos(\mu) & -\sin(\mu) & 0 \\ \sin(\mu) & \cos(\mu) & 0 \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} \cos(-\gamma) & 0 & \sin(-\gamma) \\ 0 & 1 & 0 \\ -\sin(-\gamma) & 0 & \cos(-\gamma) \end{bmatrix} * \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

CONCLUSION

In this paper, we described simple mechanisms and locomotion strategies for an in-pipe robot. Our proposed robot employs an adaptable quad arm mechanism (AQAM) the combination of this mechanism enables the robot to traverse various types of pipe configurations, including branches, elbows, and vertical pipes. We verified the strategy that we developed to change the orientation of the robot to avoid obstacles and maneuver through pipes of various shapes. We performed experiments using a prototype of our robot to evaluate its performance, and we demonstrated that the robot can successfully traverse various pipe shapes. In particular, the prototype was able to travel in branches with zero radius of curvature and branches of different diameters, both of which occur commonly in real-world applications but are a challenge for the in-pipe robots developed previously. A comparison of the characteristics of our proposed robot and previously developed robots is provided. For the autonomous locomotion in various pipe configurations and the real application to industries, the robot needs to be equipped with a sensing mechanism to detect the location of the branched holes and bumps. The next version of this robot would be equipped with this mechanism and have some structural modification to solve problems discussed with these improvements we expect that the next generation of this robot will have high possibility of application to practical pipe inspection fields.

.

REFERENCES:

[1]. T. Okada, T. Sanemori, MOGRER: a vehicle study and realization for in-pipe inspection tasks, IEEE Journal of Robotics and Automation 3 (1987) 573–582.

[2]. T. Oya, T. Okada, Development of a steerable, wheel-type, in-pipe robot and its path planning, Advanced Robotics 19 (6) (2005) 635–650.

[3]. S.G. Roh, H.R. Choi, Differential-drive in-pipe robot for moving inside urban gas pipelines, IEEE Transactions on Robotics 21 (1) (2005) 1–17.

[4]. K. Suzumori, T. Miyagawa, M. Kimura, Y. Hasegawa, Micro inspection robot for 1-in pipes, IEEE/ASME Transactions on Mechatronics 4 (3) (1999) 286–292.

[5]. M. Horodinca, I. Dorftei, E. Mignon, A. Preumont, A simple architecture for in-pipe inspection robots, Proc. International Colloquium on Mobile and Autonomous Systems, 2002, pp. 61–64.

[6]. S.M. Ryew, S.H. Baik, S.W. Ryu, K.M. Jung, S.G. Roh, H.R. Choi, Inpipe inspection robot system with active steering mechanism, Proc. IEEE/RSJ International Conference on intelligent Robots and Systems, 3, 2000, pp. 1652–1657.

[7]. H. Schempf, E. Mutschler, V. Goltsberg, G. Skoptsov, A. Gavaert, G. Vradis, Explorer: untethered real-time gas main assessment robot system, Proc. 1st International Workshop on Advances in Service Robotics,(ASER'03), Bardolino, Italy, Mar. 2003.

[8]. Y. Zhang, G. Yan, In-pipe inspection robot with active pipe-diameter adaptability and automatic tractive force adjusting, Mechanism and Machine Theory 42 (2007) 1618–1631.

[9]. T. Miyagawa, N. Iwatsuki, Characteristics of in-pipe mobile robot with wheel drive mechanism using planetary gears, Proc. International Conference on Mechatronics and Automation, 2007, pp. 3646–3651.

[10]. P. Li, S. Ma, B. Li, Y. Wang, Development of an adaptive mobile robot for in-Pipe inspection task, International Conference on Mechatronics and Automation, 2007, pp. 3622–3627.

[11]. S. Hirose, H. Ohno, T. Mitsui, K. Suyama, Design of in-pipe inspection vehicles for φ 25, φ 50, φ 150 pipes, Proc. IEEE International Conference on Robotics and Automation, 1999, pp. 2309–2314.

[12]. Y. Kawaguchi, I. Yoshida, H. Kurumatani, T. Kikuta, Y. Yamada, Internal pipe inspection robot, Proc. IEEE International Conference on Robotics and Automation, 1995, pp. 857–862.

[13]. J. Park, D. Hyun, W. Cho, T. Kim, H. Yang, Normal-force control for an in-pipe robot according to the inclination of pipelines, IEEE Transactions on Industrial Electronics 58 (2001) 5304–5310
.

BIOGRAPHIES:

	JAMPANI HARISH RESEARCH SCHOLAR ROBOTICS SRM UNIVERSITY TAMILNADU INDIA
	K.SIVANATHAN ASSISTANT PROFESSOR MECHATRONICS SRM UNIVERSITY TAMILNADU INDIA