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ANALYSIS AND CONTROL OF MOBILE ROBOT FOR PIPE LINE INSPECTION

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ABSTRACT

Analysis and control of Mobile Robot for pipeline inspection requires design of a robot equipped with the required sensors. In this work the velocity and acceleration analysis of four bar mechanism used to operate the robot has been investigated. The robot is controlled with micro control 8051 which has two part the transmitter section and receiver section. The transmitter section consist of four switch to give four order and receiver section connected with global system mobile to operated mobile robot after receive order to starting work and sending message if mobile robot detected any obstacle. The receiver section also contains infra sensor IR it work beside (GSM) global system mobile to detected obstacle. The use of GSM helped in building interactive capabilities thereby decrease the time taken for addressing the problem.

Keyword: Mobile Robot, Obstacle, Micro Control 8051, GSM, Acceleration Analysis, Receiver Section, Transmitter Section.

INTRODUCTION

Robotics is one of the fastest growing engineering fields of today. Robots are designed to remove the human factor from labor intensive or dangerous work and also to act in inaccessible environment. The use of robots is more common today than ever before and it is no longer exclusively used by the heavy production industries. Autonomous robots can act on their own, independent of any controller. Autonomous pipe inspection method should be introduced to improve the inspection efficiency by reducing the time and manpower in the inspection process. The inspection of pipes may be relevant for improving security and efficiency in industrial plants. These specific operations as inspection, maintenance, cleaning etc. are expensive, thus the application of the robots appears to be one of the most attractive solutions cleaning etc. are expensive,. The pipe-lines are the major tools for the transportation of drinkable water, effluent water, fuel oils and gas.

MECHANISM BLOCK DIAGRAM

This is major components for mobile robot most of it fabricated from of aluminum materials. They are different types of aluminum clamps at different in size and shape at different positions, Six rectangular aluminum clamps are used to support the bases of the micro motor. Aluminum part it consist of three aluminum rods, six aluminum nuts it used for fixing 4 bar link mechanism, Two circular clamps are used, One is for front and other one is back for fixing the and also used for big motor which is used for expanding and compressing for the purpose of the movement of connecting screw from forward to backward. There are three belts it used for moving the robot that is for rolling. there are six links, four links for four bar link mechanism that means they are connected in cross section like 'X' and two for supporting links. Here this mechanism used for expanding and compressing the size of the robot. As shown in figure 1 and figure 2.

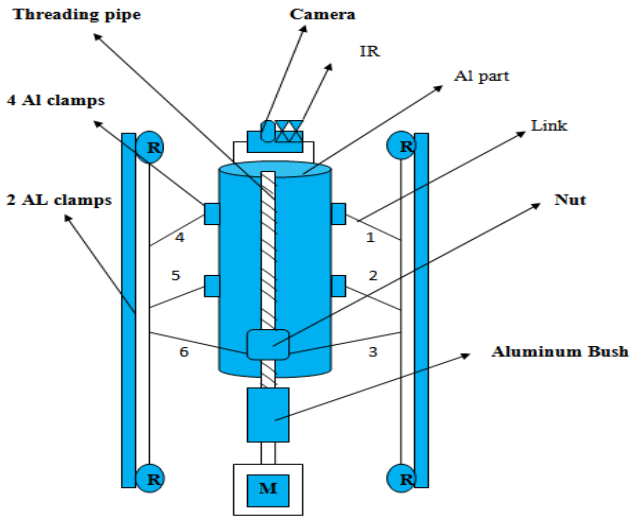

Fig 1: Block Diagram Of pipeline robot

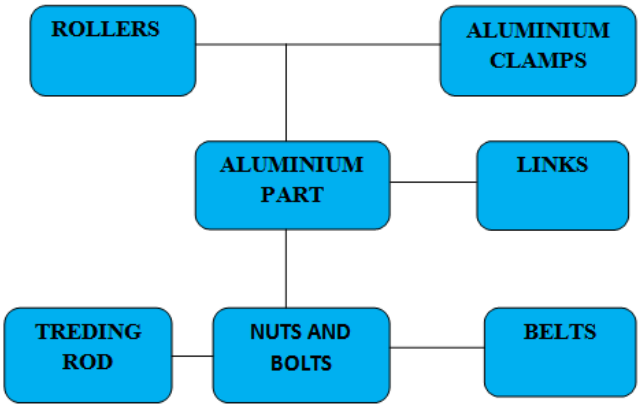

Fig 2: Mechanism Block Diagram

COMPONENT REQUIREMENT FOR THE SENSING SYSTEM, OBSTACLE SENSOR (INFRARED SENSOR)

This is an infrared based sensor which can be used for obstacle sensing detection between basic contrasting sensing, encoder sensor, IR remote signal sensing, etc and also for wireless infrared communication. The sensor provides high immunity from ambient light and can be used in all light conditions quite effectively. It used to detected object, there is one pair it consist of {Tx (transmitter) & Rx(receiver). The IR receiver always receives the signal coming from the IR transmitter continuously and whenever any obstacle comes then IR receiver generates low voltage signal and that low voltage signal is fed to controller and it sends message by using GSM

BLOCK DIAGRAM OF RECEIVER SECTION RX

The receiving part a robot gets the power through the battery and it is lightened up with the help of LED lights and the signals coming from the transmitter through RF module and they are decoded into digital format which is known language to microcontroller and by using that controlled signals robot will move and here four motors are connected to robot to make a move front, back, right, left and one motor is used to control the robot arm for opening and closing and here the driver circuits that is L293D IC's are used to drive the motors and IR transmitter and IR receiver are connected to mobile robot. Robot is fitted with camera for viewing the obstacle and internal flaws of pipe. As shown in fig 3

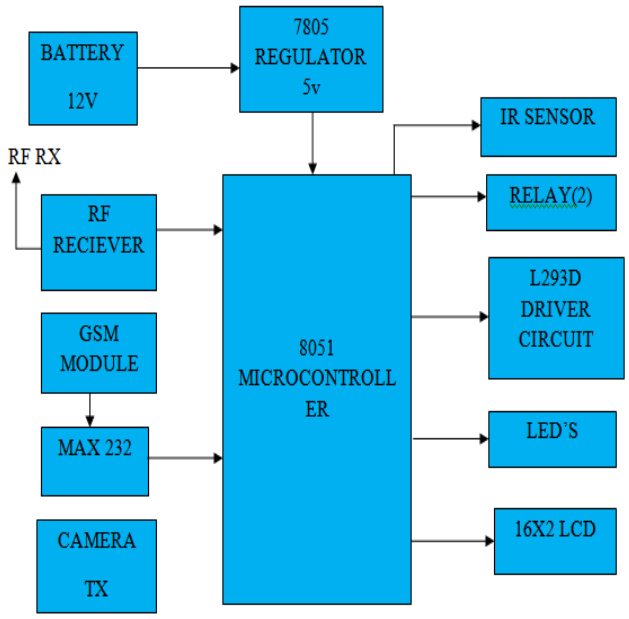

Fig 3: Block Diagram Of reciver section Rx

BLOCK DIAGRAM OFTRANSMITTER SECTIONTX

In transmitting section, it consist of power supply, 8051 microcontroller, switch control, RF transmitter, camera receiver, PC and mobile. this transmitting section gets the power from the power supply section which is +5v and whenever it is pressed any switch like S1, S2, S3, S4 , from switch control for respective forward, backward, clockwise, anticlockwise, left, right movements then

microcontroller receives the signal and send to receiver through the RF module i.e., transmitter and we also have camera receiver to capture the visuals of our robot by using camera which is fitted to robot and by using our mobile we can communicate with the GSM as shown as in fig 4

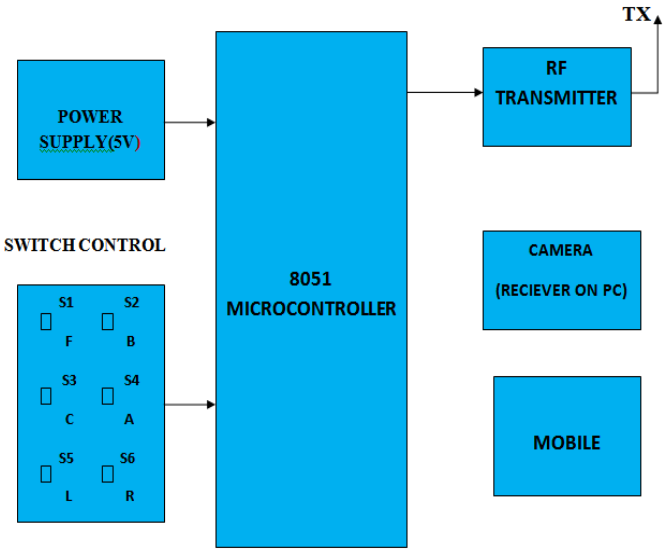

Fig 4: Block Diagram of Transmitter section TX

VELOCITY ANALYSIS

The basic mechanism involved here is a four bar mechanism consisting of three revolute joints and one prismatic joint as depicted in fig 5

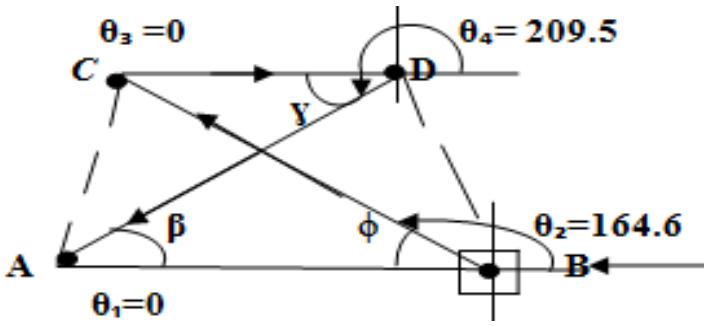

Fig 5: Velocity analysis

Where:
AB= r_1 = 60 mm , θ_1 =0
BC is Input Link = r_2 = 60 mm, $\theta_2 = 180 - \phi$
Φ is angular position for input link
$\Phi = \sin^{-1}$ (hg / BC)
$\phi = \sin^{-1}$ **(16 60)** = 15.4
$\theta_2 = 180 - \phi = 164.6$
CD =r_3 = 33 mm , $\theta_3 = 0$
DA, output link =r_4= 60 mm, $\theta_4 = 180 + \gamma$, as shown as in table 1

Table 1: 4 Bar Links Mechanism

Φ	Θ_2= 180- φ	Θ_3	γ	Θ_4= 180+γ	AB mm	BC mm	DA mm	CD mm
15.4˚	164.6˚	0	29.5˚	209.5˚	60	60	60	33
22.2˚	157.8˚	0	32.2˚	212.2˚	52	60	60	33
28.6˚	151.4˚	0	35.6˚	215.6˚	44	60	60	33
35.7˚	144.3˚	0	39.7˚	219.7˚	34	60	60	33
40.2˚	139.8˚	0	42.7˚	222.7˚	25	60	60	33
48.8˚	131.3˚	0	49 ˚	229˚	18	60	60	33

Velocity for link 1 (V_1) = 0 fixed link
$\bar{r}_2$ =$\bar{BC}$ = 60 cos 164.6 i+ 60 sin 164.6 j
$\bar{BC}$ = -57.8 i+ 15.9 j
Velocity for link 2 (V_2), W_2 = 10.5 rad /sec
$\bar{V}_2$ = $\bar{BC}$ * W_2
$\bar{V}_2$ = - 106.9 i- 607.67 j = 617 mm/sec
Velocity for link 3 (V_3)
CD =r_3 = 33 mm, θ_3 = 0
= 33 cos 0 i+33 sin 0 j
$\bar{r}_3$ = 33 i
$\bar{V}_3$ = $\bar{r}_3$ * W_3
$\bar{V}_3$ = 33 W_3 j
$\bar{DA}$ = r_4 = 60 mm, θ_4 = 180˚+ γ
$\bar{DA}$ = r_4 = - 52.2 i – 29.5 j
Velocity for link 4 (V_4),V_4 = $\bar{r}_4$ * W_4
V_4 = 29.5 W_4 i- 52.2 W_4 j
V_4 = V_2 + V_3
Compare i component and j component
29.5 W_4 + 0 W_3 = - 106.9
- 52.2 W_4 - 33 W_3 = - 607.67
Solve equation 1 &2
W_4= - 3.6 rad /sec, W_3 = 24.1 rad/ sec
V_2 = 617 mm/sec velocity for second link
V_3 = 795.3 mm/sec velocity for third Link
V_4 = 215.8 mm/sec velocity for fourth link
as shown as in table 2 & fig 6

Table 2: Velocity for Links 2, 3, 4

Φ	v_2 mm/sec	v_3 mm/sec	v_4 mm/sec
15.4°	617	795.3	215.8
22.2°	629.97	960.3	443.1
28.6°	629.9	973.5	515.1
35.7°	629.7	993.3	569.3
40.2°	629.8	920.7	598.6
48.8°	629.4	825	622.8

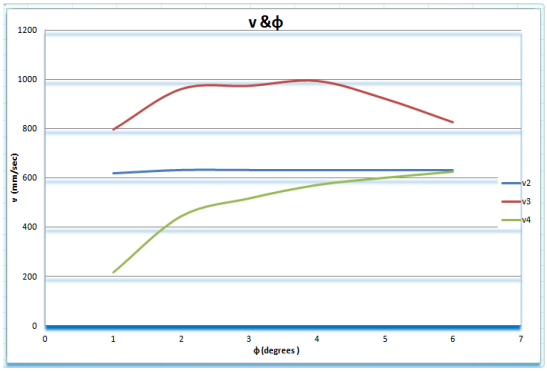

Fig 6: Velocity for links 2,3,4

ACCELERATION ANALYSIS

Acceleration analysis four bar mechanism which consisting of three revolute joints and one prismatic joint as shown in fig 7

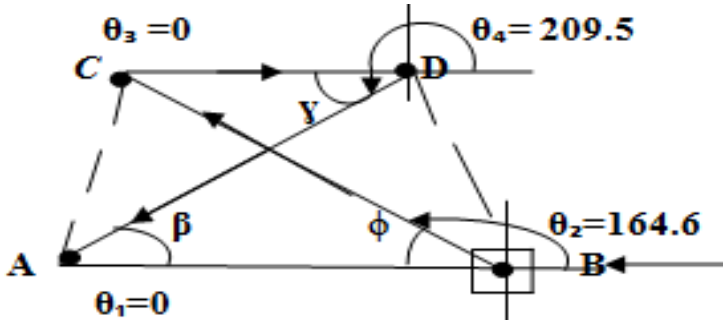

Fig 7: Acceleration analysis

Where :

$r_1 = AB = r_1 \cos\theta_1 \, i + r_1 \sin\theta_1 \, j$

$= 60 \, i$

Velocity for link 1 $(V_1) = 0$, and Acceleration of link 1 =0 (fixed link)

Velocity for link 2 (V_2) , $W_2 = 10.5$ rad /sec

$\bar{r}_2$ = -57.8 i+ 15.9 j
$\bar{V}_2$ = - 106.9 i- 607.67 j
Acceleration of link 2
$\bar{a}_2 = a^c{}_2 + a^t{}_2$
$a^c{}_2 = W_2 (W_2 * \bar{r}_2)$, $a^t{}_2 = \alpha_2 \bar{r}_2$
$\bar{a}_2 = W_2 (V_2) + \alpha_2 \bar{r}_2$, $\alpha_2 = 0$
= i (0- (- 607.67 * 10.5) –j (0 – (- 106.9 *10.5)+k (0)
a_2 = 6.47 mm / sec ²
For link 3
CD =r_3 = 33 mm, $\theta_3 = 0$
$\bar{r}_3$ = 33 i
Velocity of link 3 = 795.3 j
Acceleration of link 3 $\bar{a}_3 = a^c{}_3 + a^t{}_3$
$\bar{a}_3 = W_3 (V_3) + \alpha_3 \bar{r}_3$
V_3= 33 W_3 j , V_3 = 795.3 j
$\bar{a}_3$ = -19166.7 i+ 33 α_3 j
for link 4
DA = r_4 = 60 mm , θ_4 =209.5 °
$\bar{DA}$ = - 52.2 i – 29.5 j
Velocity for link 4 (V_4) = 215.8 mm/sec
Acceleration for link 4 , $\bar{a}_4 = a^c{}_4 + a^t{}_4$
$\bar{a}_4$ = 676.4 i+ 382.3 j +29.5 α_4 i- 52.2 α_4 j
$a_4 = a_2 + a_3$
compare i term and compare j term
29.5 α_4 = 6381.48 -19166.7 -676.4 …1
- 52.2 α_4 -33 α_3 = -1122.45 - 382.3 ……2
Solved equation 1 & 2
α_4 = -456.3 rad/sec², α_3 =767.4 rad /sec ²
a_3 = 31. 7 mm/sec ², a_4 = 27.37 mm/sec²
as shown in table 3 and fig 8

Table 3: Acceleration for links 2,3,4

Φ	a_2 m/sec²	a_3 m/sec²	a_4 m/sec²
15.4°	6.47	31.7	27.3
22.2°	6.6146	51.6	46,3
28.6°	6.614	51.5	45.7
35.7°	6.611	51.4	45.2
40.2°	6.613	43.7	37.4
48.8°	629.4	825	27.9

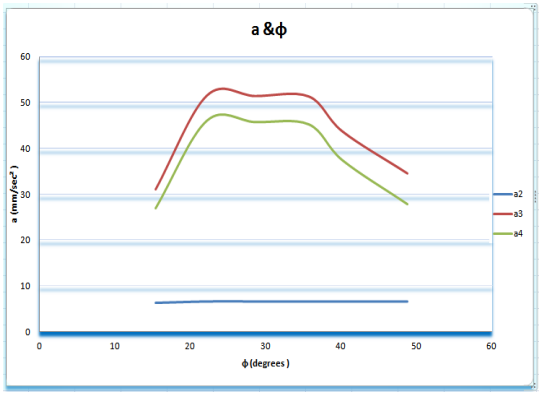

Fig 8: Acceleration for links 2, 3, 4

INSPECTION ROBOT STAGES

Mobile robot tested for functionally and found suitable for inspection of defect in pipeline with camera attach to it, which moves freely in the pipe line. The robot can be applied to 250 mm pipeline maximum diameter and it has flexibility to adjust links to another diameter less 250 mm from 175 to 250 mm.

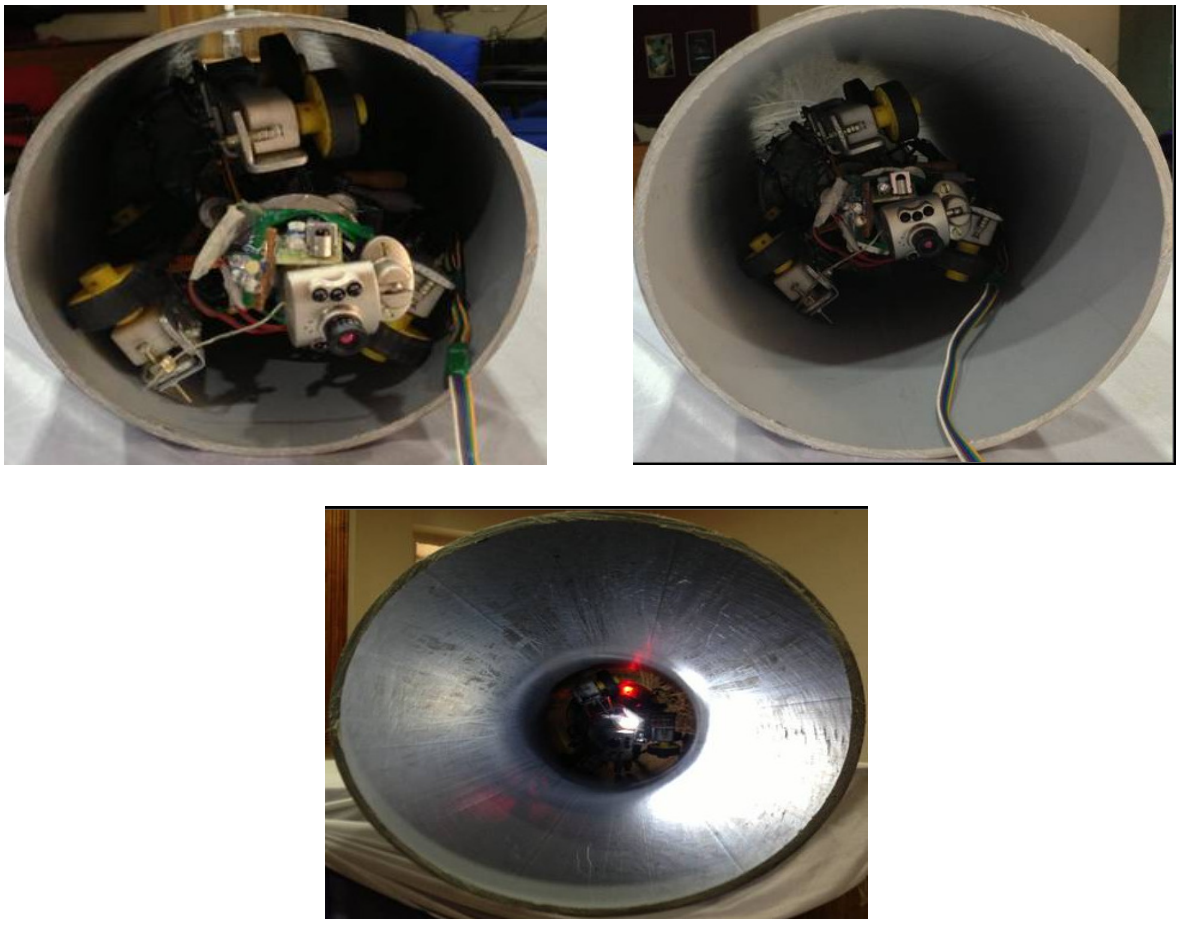

Fig 9: Mobile robot in action

CONCLUSIONS

A real prototype are fabricated from aluminum material and finally robot tested for functionally. The link mechanism designed and control system 8051 chosen has improved the mobility of the robot in pipeline. The control system used consists of microcontroller 8051 to control all motion, the simulation has been carried out in embedded system. The communication system used two section one transmitter and another receiver. By using GSM it helped in building interactive capabilities decrease the time taken for solving the problem, All relation of different parameters (v ,a, w, α) for each links with angular position of input link ϕ investigated.

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