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"Design and Fabrication of Pipe Inspection Robot"

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Abstract: The methods for inspection of gas pipelines are very troublesome, expensive and also inefficient. The extreme environment underground and the large variety of the pipe materials, sizes and bad accessibility makes the design of the robot very challenging. The main focus of this paper is on the mechanical design of the in-pipe inspection robot. Although many different types of the pipeline exploration robot have been proposed they were suffered from various limitations like adaptability according to different pipe dimension. So we have implemented the chuck-jaw mechanism for getting the required adaptability for different pipe size and shapes. In this paper, we have presented the design and implementation of a single module semi-autonomous wall-press pipeline exploration robot.

Keywords: Chuck-Jaw Mechanism, Size and Shape Adaptability, Pipeline Exploration

1. INTRODUCTION

Robotics is one of the fastest growing fields they are used for wide variety of works in manufacturing industries. They are mainly designed to reduce human intervention from labor intensive and hazardous work environments. Designing of new in-pipe inspection robot is carried out in this research work it involves dynamic analysis of semi-autonomous wall press type robot. In the industries having gas pipelines and also in nuclear power plants there is a need for a robot for surveillance from inside the pipes which are of different diameters. The pipeline exploration robot is needed for inspection of cracks, corrosion, sludge formation inside the pipe. As the industrial pipelines might have different pipe dimension diametrically we need the shape adaptability of the robot so we have implemented chuck-jaw mechanism so that robot can be adaptive according to different pipe dimensions.

1.1 Chuck Jaw Mechanism

The radial positioned Pinion transmits the power via a bevel gearing to the Spiral Ring where the spiral transmits it to the Jaws. Steel or cast-iron body, Control edge, Cover. Here we supply power through the electric motor. The electric motor is mounted on bevel gear pinion. As the electric motor is switched on, power is transmitted from the motor to bevel gear pinion. Since this bevel pinion is in contact with the spiral ring, this spiral starts rotating. The three jaws are mounted on this spiral ring. Hence, ultimately the power is transmitted from the electric motor to bevel gear pinion to the spiral ring to jaws. These jaws convert the rotary motion of the electric motor to linear expansion and expand linearly. All the three jaws have same linear expansion. Since we had mounted wheels on these jaws, as jaws expand wheels also get expanded. And we get the same linear expansion to all the wheels. Since these wheels are getting expanded linearly it provides size and shape adaptability to our robot. The working mechanism is very simple and straight forward. We can get linear expansion depending on the length of jaws. Hence in order to get high linear expansion we have to increase the length of the jaws.

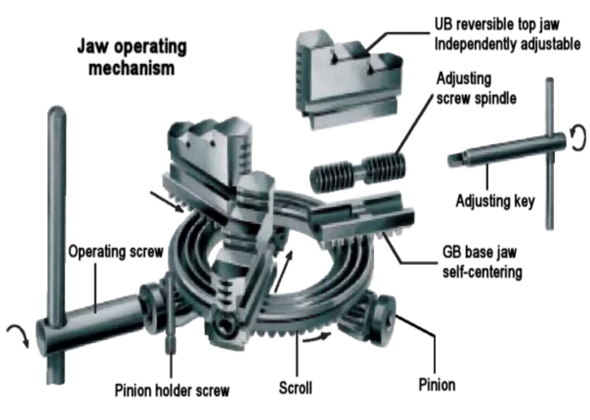


Fig. 1.1 Chuck Jaw Mechanism

2. DESIGN AND OPTIMIZATION

The schematic diagram of in pipe inspection robot is shown in figure 1.4. Total 12 wheels are mounted on two sets of 3 jaw chuck. As the jaws expand wheels also get expanded and the primary objective of the robot is satisfied. We used 3 threads rods for support. Actual expansion of the jaw is through lead screw so the primary objectives are completed.

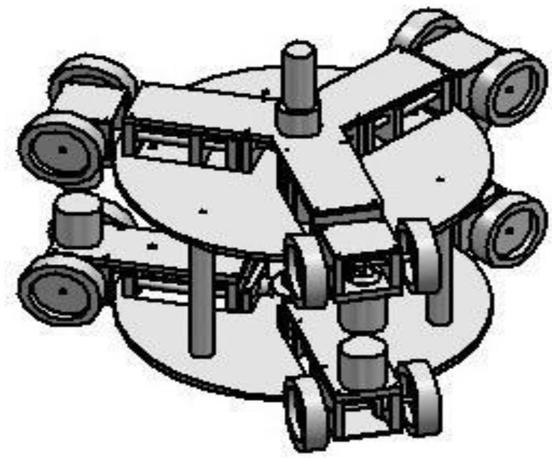


Fig.2.1 Theoretical Model of Robot

Design Calculations

Formulae for Gear and Pinion [2]

For this purpose, we use bevel gear because it is able to transmit power through the perpendicular shaft.

For gear ratio

$\frac{N_D}{N_d} = \frac{r_B}{r_A} = \frac{\omega_A}{\omega_B} = G$

In order to mesh with gears smoothly we have same-sized teeth and therefore, they have same pitch p, which means

$p = \frac{2\pi r_A}{N_A} = \frac{2\pi r_{N_B}}{N_B}$

this equation shows that the ratio of the circumference, the diameter, and radii of the meshing gears is equal to the ratio of their number of teeth

$\frac{r_B}{r_A} = \frac{N_B}{N_A}$

the speed ratio of two gears rolling without sleeping on their pitch circles is given by

$G = \frac{r_B}{r_A} = \frac{\omega_A}{\omega_B}$

Therefore,

$G = \frac{\omega_A}{\omega_B} = \frac{N_B}{N_A} = 3$

in other words, the gear ratio, the speed ratio is inversely proportional to the pitch circle and the number of teeth of the input gear.

Pitch diameter = $\frac{N}{p}$

Diametral pitch = p = $\frac{N}{D}$

Number of teeth = N

Whole depth $H_t = \frac{2.188}{p} + 0.002$

Addendum = a = $\frac{1}{p}$

Dedendum = b = $H_t - a$

Clearance = $H_t - 2 \times a$

Outside diameter = $D_o = D_P + 2 \times a \times \cos(L_P)$

Virtual number of teeth = $V_P = \frac{N}{\cos \cos (L_p)}$

From above equations, we have calculated actual dimensions for gear and pinion.

Table 4.3 Actual Gear Dimensions

Parameter	Pinion	Gear
Diametral Pitch(P)	0.66	0.66
Teeth (N)	15	45
Pitch Diameter(D)	22.72	68.18
Whole Depth(Ht)	3.31	3.31
Addendum	1.5151	1.5151
Dedendum	1.8	1.8
Clearance	0.2868	0.2868
Outside Diameter	25.6	69.14
Virtual Number of Teeth	15.81	46.84

Torque Calculations for Wheels

Wheel diameter = 72mm

T = F x d

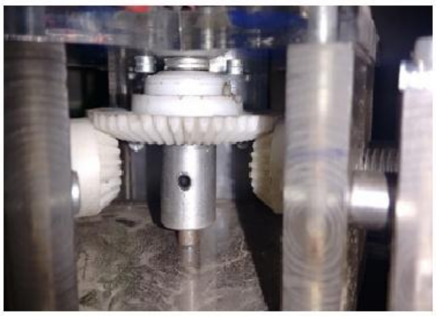
F = $\frac{mxg}{6}$

1. F = $\frac{mxg}{6} = \frac{7x\,9.81}{6}$ = 11.44 N
2. T = F x d = 11.44 x 36 x 10^{-3} = 0.4120 N.m = 4.0419 kg.m

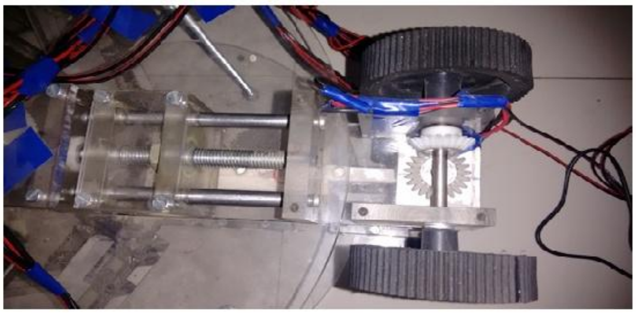
Implementation of Robot

The proposed system provides improvements to the existing system design. It tries to make the existing system more efficient, convenient and user- friendly.

The proposed system has following important components:
1.Three Jaw Expansion Mechanism Using Gears
2.Temperature sensor
3. Technotech Webcam ZB029
4. Big Rocker Double Pole Switch



A



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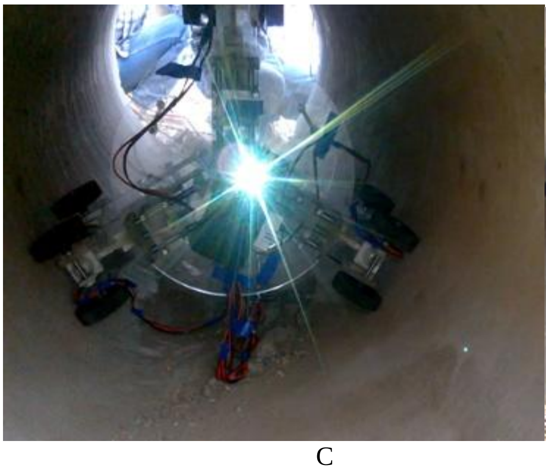

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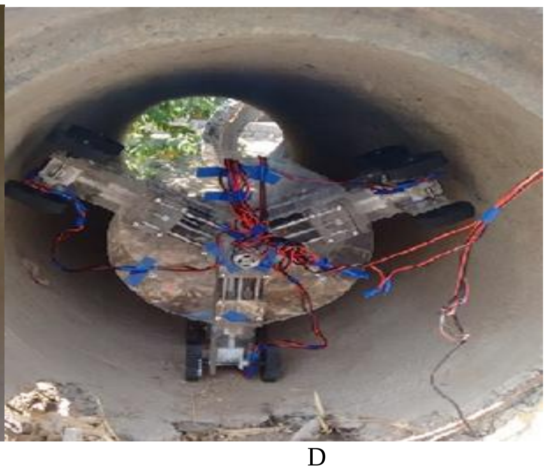

D

The above images can show a detailed view of the components of the robot.

Figure “A” shows the bevel gear mechanism on the top of which a 30 RPM motor is mounted .The rotating gear transmits the motion to the pinion that results in lateral expansion of jaws. All the three jaws have equal displacement expansion. Wheels are mounted on jaws they expand linearly and provide required size and shape adaptability.

Figure “B” shows the actual guiding mechanism of robot. It comprises of Roller Mounting Plate, Roller Rod, Guiding Screw, Moving Plate, Motor Mounting Plate.

Figure “C & D” shows the footage of the robot through the cement pipe through which video footage is taken and required objective is achieved.

3. CONCLUSION

This report proposed a mobile robot for pipeline exploration, that can be used for the inspection of 16 to 20 inches’ pipelines. We have also described the chuck jaw mechanism that provides for the excellent size and shape adaptability according to the diameter of the pipe in vertical as well as horizontal pipelines, Mechanical design of-of all robot components is safely done. Modeling and assembly of all robot components are done on CATIA V5. Stress analysis of major components of the robot is separately carried out on ANSYS 14.5. Stress analysis results are matching with the analytical result and both values are less than permissible values. It also shows that optimization method is successfully applied to various parameters of robot .by using the chuck jaw mechanism the robot is optimally designed to crawl through the different pipe diameters smoothly which ensures the mobile stability as well as adaptability in various diameter pipes. The stresses on the parts are more when the motion of in vertical pipes and low in the horizontal pipe as it has to sustain its weight against gravity while moving in vertical pipes. This robot will reduce the human interference in the hazardous environment. It can do the pipe inspection beyond human reach.

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