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Designing and Use of Super Capacitors in Pipe Inspection Robots

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Abstract:
Project aims to create an autonomous robot used for in-pipe inspection and use of graphene super capacitors for better powering to the robot. Leak detection in gas pipelines has always been a great challenge for engineers, which prompts us to develop much better ways to inspect pipelines efficiently. Saving time and money at the same time are priorities of the pipeline inspection. One of the most important requirements in repairing and maintaining of pipelines is the ability to monitor and evaluate the pipes interior. The mechanism used involves a central rod upon which a translational element is fitted which in turn is connected to three frames of links and wheels. A pan and tilt camera and an ultrasonic sensor are mated on the robot. However, any kinds of tools and sensors may be mounted on robot. Graphene super capacitors are used in batteries to power the robots with fast charging technology to minimize the low battery problems.

Keywords:
Supercapacitors, autonomous, ultrasonic sensor, mechanism, battries.

I. INTRODUCTION:

The transport and distribution network of natural gas is a complex and continuously expanding task According to various studies, pipelines as a means of transport, are the safest, but this does not mean that they are risk-free. Main risk in this field is the leakage in the pipelines. Recent studies reveal that damages occurred due to in gas pipeline industries are most commonly due to the leakages in the pipelines[1].

The techniques for inspection are as follows

- In-pipe inspection
- Out-of-pipe inspection

Pipelines are proven to be the safest way to Transport and distribute gases and liquids. Periodic inspection is required to maintain that Status. Pipeline systems deteriorate progressively over time through various means. Robotics is one of the fastest growing engineering fields of today. The use of robots is more common today than ever and it is no longer exclusively used by the heavy production industrial plants. The specific operations such as inspection, maintenance, cleaning etc. are expensive. Thus, the application of the robots appears to be an attractive solution. In-pipe inspection means using the unit for detection inside the pipeline. This consists of moving and non-moving methods for detection. This methods rely mainly on the usage of special sensing devices in the detection of gas leaks. Depending on the type of sensors and equipment used for detection, hardware methods can be further classified as: acoustic, optical, cable sensor, soil monitoring, ultrasonic flow meters and vapour sampling[2].

In-pipe monitoring has a difficulty that correct position of leak can't be found out. Also a human cannot go inside the pipeline and check the position. The present work relates to an apparatus known in the industry as a pipe crawler. Pipe crawlers are frequently used to deploy monitoring equipment including sensors and/or cameras to monitor the pipe integrity and to help diagnose needed repair or maintenance. This work deals with the design and prototyping of an apparatus that traverses pipes for inspection, cleaning and or examination of the piping system. Many technologies and applications require energy storage systems that can store and deliver large amounts of energy quickly. The power delivery is often more important than the amount of stored energy.

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In these situations batteries are less suitable because they perform faradaic reactions and thus have a relatively slow energy transfer (Linden 1995). Super capacitors are based on electrostatic charge separation (Conway 1999) and therefore show much faster charge-discharge cycles. Furthermore, super capacitors have a higher power density and a significantly longer cycle life compared with batteries.[3]

II. MECHANISM DESCRIPTION:

We will first consider a 6-bar planner mechanism; comprise linear and revolute joints (Figure 1). As it is shown in the figure when link 2 moves, link 6 lifts. It has translational motion when it is lifted and remains parallel to the prior position. Because links 4 and 5 have equal length and are parallel so we have a parallel-crank mechanism with an adjusting screw. The mechanism has one DOF with assumption of fixed link 1 as the ground.

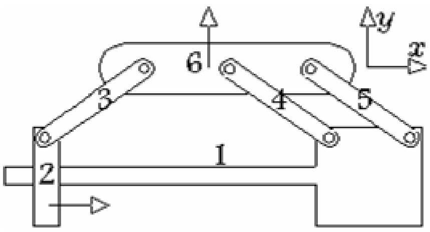

Fig. 1 . A 6-bar planner mechanism

In order to obtain equivalent plan mechanism for our robot we have developed a new and improved mechanism on the basis of the one shown in Fig.1. New links have been added namely 3',3",4',4",5',5" and 6',6" as seen in Figure 2.[4]

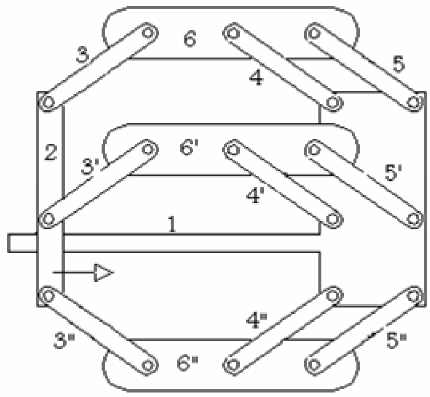

Fig. 2 . Equivalent planner mechanism for robot

If the links are deployed in a tripod format around the axis parallel to the links (6,6',6"), this will result in a spatial mechanism. Now, if we consider that a device with the above mechanism is deployed in a pipe in a way that links (6,6',6") be parallel to the pipe axis, then assuming the slider link(2) is the driver, the driven links (6,6',6") have translational motion parallel to the pipe axis and are pushed to the internal surface of the pipe. This arrangement thus corresponds to one DOF due to below calculation. Furthermore, if links (6,6',6") are able to drive independently as a transporter of mechanism then the device will move within the pipe. To calculate the DOF we use the equation:

$DOF = 3^* (n - 1) * 2^* f_1 - f_2$

In spatial mechanism we have n= 14, f1=19 & f2= 0 so the DOF is : DOF =1[5]

If the links(3,3',3") are further improved by introducing

Links (7, 7’,7") as shown in Figure 3 then, by using equation 1by n=17, f1=22 and f2 =0 we have: DOF= 4

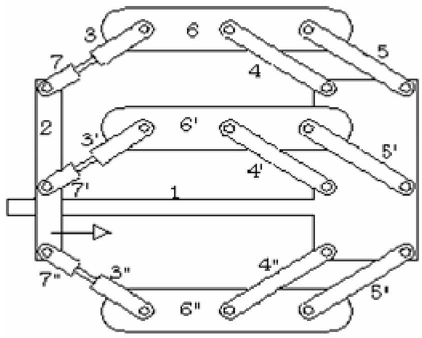

Fig. 3. Improvement of the equivalent planner mechanism

This improvement gives more flexibility to the robot which will be later discussed in this paper. Let us call links (6,6',6") as a “tracked unit” and links (3,3',3",4,4',4",5,5',5") as the “arm” and the links (1,2) as the “chassis”.[5] Figure 4 shows the robot assembled with the above mechanism.

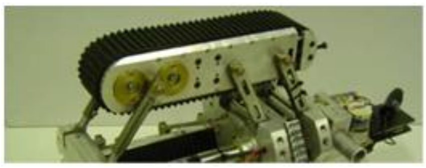

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Fig. 4 . Assembly of final mechanism

As shown in the Figure we have double arms parallel to each other in each position such that one has no effect on the other in computing the DOF of the mechanism. It only increases the structural stability of the device. Computing the DOF of the mechanism is by using n=17 and f1=22 and with the assumption of keeping the link (1) as the ground. So when the fixer 1 becomes freely movable we have an extra link and by using n=18 & f1=22 we have:

DOF=7.

The Robot can also adapt itself to the pipe size as a result of turning the adjusting screw that expands or contracts the linkage pair thereby rising or lowering the tracked units. As explained previously each tracked unit has independent motion caused by a separate dc driver motor. Moreover, each unit is completely independent of the other, providing the system with excellent steering and maneuvering capability. Each motor transfers its power through a right angle gearbox to the driver pulley.

Then the pulley's movement transfers to the belt by friction and the friction between the track and the inner surface of the pipe causes the whole system to move forward[8]. A significant achievement in this part of the work was that the motor, the pulley and the gearbox were placed in the minimum possible space. As the space in each tracked unit was mainly filled by the driver motor, so an optimized motor must be chosen that has minimum size with respect to its power. Needed power is estimated due to the most critical situation which is ascending the vertical pipe so the motor power is taken with respect to a safety factor[6].

III. MODELING AND SIMULATION:

All the parts and pieces are modeled with a mechanical Engineering software tool, Visual Nastram. After completing the modeling and design, then the parts are drawn in detail for prototyping. Robot motion inside the pipe is modeled with the Visual Nastram software.

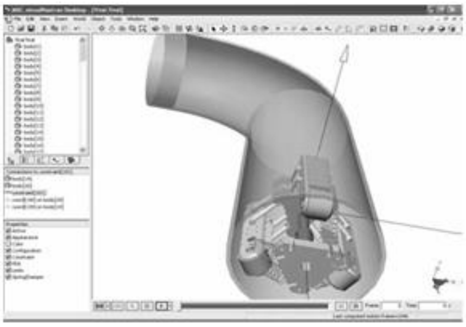

Fig. 5 . Modeling the mechanism with the Visual Nastram software

The Robot model is simulated in different situations taking into consideration both vertical as well as elbowed pipes. Good performance of model certain the designing. This modeling has some advantages.[7] As an example deflection of the spring in the rear arms of the robotic model are compared with the results we obtained by designing the robot. Spring deflection of the two rear arms while traversing a horizontal and elbowed pipe during 1.5 seconds is shown in Figure 6and 7. The arms are located at 120o of each other. Stress in the third arm, in symmetric position on third part of triangle, is shown in Figure 8.

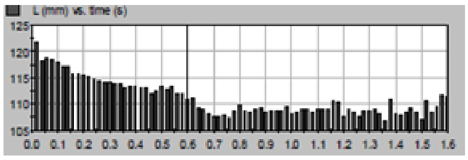

Fig. 6 . Spring deflection of one rear arm

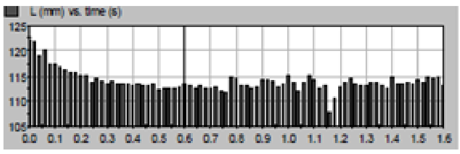

Fig. 7 . Spring deflection of another rear arm

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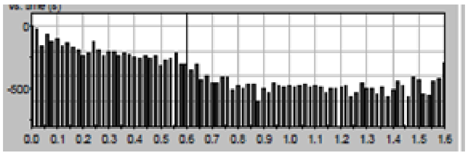

Fig. 8 . Stress in the arm, in symmetric position on third part of triangle

In the first 0.6 seconds the robot moved through the horizontal pipe and in the remaining 0.9 seconds the robot navigates the elbow. As seen in Figures the largest deflection is on arms 3 and the least deflection is on arm 2. Deflection of arm 3 is compared with the results we obtained by designing the device. Due to the stiffness of spring (cmk = 280 N) deflection can be derived from figure 13. The Rear arm length is 113 mm while traversing a horizontal pipe which is reduced to 105 mm while navigating the elbow so the deflection is about 8 mm that has agreement with our design values. It must be mentioned that the pipe diameter used in this
model is 25cm.

IV. Electronic Circuit and Components:

The assembled robot needs to start or stop instantaneously. Also, its direction of motion ought to be easily switched over. This can be achieved by using a relay circuit and a remote control. Double Pole Double Throw (DPDT) relay is an electromagnetic device used to separate two circuits electrically and connect them magnetically. They are often used to interface an electronic circuit, which works at a low voltage to an electrical circuit which works at a high voltage.[8]

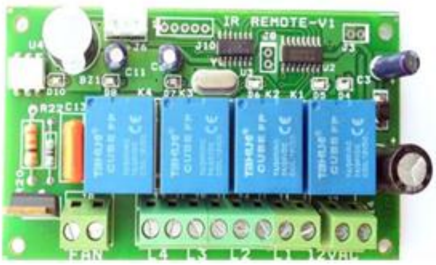

Fig. 9 –IR 4 Channel Remote Control Relay (Courtesy: hitechlogics.com)

Four channel relay circuit: IR Remote control relay is a combination of Infrared Transmitter and Receiver which contains 4 Relays and 1 Fan with Speed Control through TRiAC which can be controlled wirelessly is shown in Fig.9. This makes the unit very easy to operate and integrate with existing systems. The remote control operates the corresponding relay on the receiver board.[10]

Power supply board:

The power supply board as seen in Fig. 10 is used to regulate the voltage to the camera plate. A potentiometer present on the board can be used to change the resistance, thereby changing voltage. This results in control of the speed of the motor.

Fig.10Power supply board (Courtesy:nskelectronics.com)

Wireless camera: Wireless cameras are wireless transmitters carrying a camera signal. The components are shown in Fig.11. The camera is wired to a wireless transmitter and the signal travels between the camera and the receiver. This works much like radio. Wireless cameras also have a channel. The receiver has channels to tune in and then the picture is obtained. The wireless camera picture is sent by the transmitter the receiver collects this signal and outputs it to a Computer or TV Monitor depending on the receiver type.

Fig.11 Wireless camera with radio receiver (Courtesy: Google images)

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DC motors: DC (direct current) motor works on the principle, when a current carrying conductor is placed in a magnetic field; it experiences a torque and has a tendency to move. If the direction of current in the wire is reversed, the direction of rotation also reverses. When magnetic field and electric field interact they produce a mechanical force, and based on that the working principle of dc motor established. DC motors are used to achieve the drive on wheels and rotation of rods. Two types of DC motors used in the project are shown in Fig.12 .[9]

Fig. 12. 200 and 60 rpm DC motor (Courtesy: tomsonelectronics.com)

V. Graphene Super capacitors used in Batteries:

Many technologies and applications require energy storage systems that can store and deliver large amounts of energy quickly. The power delivery is often more important than the amount of stored energy[11]. In these situations batteries are less suitable because they perform faradic reactions and thus have a relatively slow energy transfer (Linden 1995). Super capacitors are based on electrostatic charge separation (Conway 1999) and therefore show much faster charge-discharge cycles. Furthermore, super capacitors have a higher power density and a significantly longer cycle life compared with batteries[12]. The super capacitors are made of paper coated with grapheme. It increases the capacitance and they have the potential to produce super capacitors more cost effective[13]. Another advantage is that thin and flexible super capacitors can be designed with this approach. Therefore we studied methods to prepare paper-based super capacitors with grapheme electrodes[14].

VI. Results for Super capacitors Coated with Graphene

The charge/discharge curves were evaluated with regard to their curve progression and the resulting capacitance. All samples showed an almost linear behavior, see Fig 13.

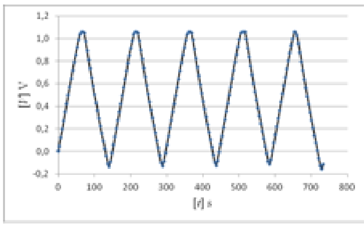

Fig 13. Charge discharge curves of a supercapacitor with GSS/PVA electrodes

The super capacitors showed a pressure dependence, as it was reported by Gourd in et al. (2011). When pressure is applied on top of the super capacitor, the metal foil contacts are pressed on the electrodes and the contact between the graphene electrodes and the separator is improved. This results in a decreased resistance and an increased capacitance. Moreover, the contact material itself influenced the performance to a great extent. We observed that the silver contacts were oxidized during the cycling of the super capacitor. Silver is not suitable as contact material for this system (Takeno 2005) due to its oxidation in the cycled potential range at the given pH. First tests of graphite foil as contact showed a stable behavior of the material. Another important factor is the electrochemical window of the electrolyte. The risk of water electrolysis was avoided by cycling the super capacitor below 1 V.

VII. Project Future Scopep:

The project is limited in several ways and can be worked upon to broaden its features and applications. A few of the improvements that can be implemented are mentioned below .Use of tilted and guide wheels for traver sing curves and bends in pipes. Use of lighter material for the links to reduce the weight. Infrared/Ultrasonic inspection for better detection of defects.

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Implementation of long range sensors. Implementation as a bore well rescue robot. Alternate design without links to facilitate better motion.

VIII. Conclusion:

Robots can be effectively used as tools to carry out work in labor intensive, hazardous and unreachable work environments. Pipeline systems are one such environment. Robots can be successfully implemented in pipe line inspections for better detection of defects. The project aimed to create an in-pipe robot with adaptable structure, autonomy and achieve vertical motion. The following conclusions can be drawn from the project. This paper has given an overview of the currently available inspection robots. The features and of the present robots are dealt briefly. The classification of the robots based on their mobility has being presented briefly. Presence of obstacles within the pipelines is a difficult issue.

In the proposed mechanism the problem is solved by spring rear arms and increasing the flexibility of the mechanism. The robot is designed to be able to traverse elbowed and vertical pipes. This is done in the proposed mechanism with the help of rear spring arms. Thus the rear spring arms are not only useful in negotiating obstacle but also help the robot to pass elbows. An adjusting power screw is proposed to adapt the robot with the interior pipe diameter. Furthermore, the adjusting power screw by contracting tracked units can be useful in passing through an elbow. A camera monitors the elbow and the operator contracts the tracked units by driving the power screw motor.

Supercapacitors can be prepared by using graphene coated paper sheets as electrode material. The working principle allows a simple stacking of the components. Thus supercapacitors with paper components can be produced by using proven paper making technologies. The main advantages of supercapacitors with graphene-paper electrodes are the scalable low cost production, the inexpensive materials and the large variety of possible applications.

These benefits can be achieved because of the combination of excellent paper and graphene properties. The deposition of gold nano particles on graphene further increases the supercapacitors capacitance.

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