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Design of a Sewer Robot to Detect Blockages in Sewer

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Abstract: The purpose of developing a sewage system in a society is to channelize the waste coming out from houses, industries and other facilities. Due to multifarious discharge coming out from different sources the pipeline tends to get blocked. Generally the length of a sewage pipeline is underground and the pipes are for several kilometers; therefore detecting the point of blockage in the sewage pipeline is difficult. In this paper, we are presenting a solution of using an underwater vehicle that can move in the sewers. This is remotely operated using a tether. The robot is designed to sustain in harsh conditions and to detect the blockages in the sewer pipelines. This proposed model of robot can be used to replace the traditional method of using manual scavengers to detect and remove blockages.

Key words: Sewage system · Blockage · Detection · Underwater vehicle · Remote · Tethered

INTRODUCTION

Sewage system is present in every society. Increasingly, the sewage systems are becoming underground. Pipelines are being laid underground and these pipelines are used to carry the sewage across the city. As the sewage pipelines are underground, the maintenance of these sewers become difficult. The traditional method that is followed is to employ manual scavengers to maintain the sewers. Due to the different effluents that travel through the sewage, at times, the sewage gets blocked. Since the sewage system is underground, it becomes difficult to detect the blockage and the employment of manual scavengers is a dangerous option as it injures their health, might even cause death due to poisonous gases present in the sewage system. Especially in India, the employment of manual scavengers is still prevalent as there is no other technological substitute which is economical to do the detection of blockages. Several reports in the newspapers claim that many a manual scavengers have died cleaning the sewers.

To avoid this, there are sewer robots that were built in the recent past which are being used in developed countries. They are expensive and the operation requires the personnel to know the technical know-how. There are several problems with the existing technologies as well. The water in the sewer pipeline must be drained out before employing the robots as they are not water proof. The robot is sent and the blockage locations are determined. [1] These are the problems existing in the present system and this paper attempts to solve them to a considerable extent.

The present work endeavors to provide an economical solution to the existing problem with a sewer robot. The robot is simple in design and operation. It can travel underwater and is easily maneuverable in the sewer pipelines. This feature does not require the pipelines to be drained. An Infrared camera is used to view the pipeline and to navigate in the sewers. The display of the infrared camera is connected to a laptop and the personnel monitors the movement of the robot within the sewer pipeline. This helps in the detection of the blockage in the sewer by the personnel. Usually the blockages are removed using a water jet. A water jet pipe can be attached to the robot to remove the blockage as soon as the blockage is detected.

Design: The sewer robot is designed to be an underwater vehicle. Therefore, the components assembled in the robot must be made water proof to prevent them from being damaged. One of the essential parameters while designing is drag and it must be reduced so that there is effective motion under water. The mechanical parts of the sewer robot is described in detail below.

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Chassis: The chassis for the underwater sewer vehicle is cylindrical in shape. A cuboids shaped underwater vehicle is susceptible to cracks as the edges will not be able to withstand the pressure under water. A cylindrical chassis will be able to withstand the pressure as the pressure distribution is even along the surface of the robot. Therefore, a cylindrical chassis is chosen. The chassis is made of a PVC pipe as the material is hard, waterproof and inexpensive. Along with the cylindrical chassis, two cylindrical pipes are attached to it on either sides to hold the thrusters.

Power: The power supply to the robot is given from a 12 volt DC lead acid battery [2]. The voltage supplied tends to reduce with the increase in length of the power supply cable. Therefore, the tether length is kept optimum. The wire is sufficiently insulated and water proof.

Propulsion System: The robot's propulsion system consists of thrusters which are a combination of motors and propellers. Twin thrusters are placed on either side of the robot to bring about effective uniform motion in forward and backward directions as well as the turning motions. The motor used in the thruster is made of brushless geared DC motor with high torque and high rpm. The motor is not water proof but it is sealed appropriately to make it water proof. Propellers are connected to the motor using a coupler and a shaft. The propellers are made of iron, coated with zinc to make it waterproof. These propellers are specially designed with high rake so that there is maximum propulsion.

A thruster is placed at the bottom of the robot for the vertical motion of the robot. The center of mass is calculated and the robot is placed equidistant between the front and the rear. The thruster is a combination of a motor and a propeller similar to the other thrusters. The thruster propels the robot in vertical motion, upward and downward. Thus, the motion along both the axes are established.

Camera: Camera provides the vision to the robot. We have chosen an infrared camera as it provides vision in complete darkness. The camera is mounted on the front end of the robot. The output of the camera is received using a USB 2.0 cable and it is displayed on the computer screen. The personnel involved can view the path that the robot travels through the display and the robot is controlled. The camera used in this robot has a range of 25 meters with 600 TVL resolution. The camera requires a voltage source of 12 volts.

Controls: The sewer robot is controlled using Double pole double throw (DPDT) switches to drive the motors. DPDT switches are used to provide versatility to the control as we can have two modes of control in a single switch.

Calculations: We made the following calculations to determine the dimensions of the robot. It was important to determine the pressure applied on the robot during its operation as this helps in deciding the material to be used for the robot.

Pascal's principle states that pressure exerted anywhere in a confined incompressible fluid is transmitted equally in all directions throughout the fluid such that the pressure variations (initial differences) remain the same. [1] Mathematically,

$$P = \square gh \quad (1)$$

where P – Pressure (Pa), $\square$ – Density (cm^3), g – Acceleration due to gravity, h – Depth (m)

$P = 1000 * 9.8 * 1$
$P = 9800$ Pa.

The pressure exerted on the robot at a depth of one meter inside the water is very less than the atmospheric pressure exerted on a body on surface. Therefore, any material with that is water resistant can be used to build the sewer robot.According to our design, the robot must stay afloat when it is static on water. By the use of downward thrusters, the robot is taken underwater. Now, the robot must stay afloat and the dimensions of the robot are the important parameters to make them stay afloat. Therefore, the length of the robot is calculated using Archimedes principle.

According to Archimedes principle, the upward buoyant force that is exerted on a body immersed in a fluid, whether fully or partially submerged, is equal to the weight of the fluid that the body displaces. The weight of the robot must not be greater than the upward buoyant force. The approximate payload to the robot according to our estimate is three kilogram. According to Archimedes principle, three kilograms of mass will displace three litres of water. The sewer robot is made of cylindrical chassis as mentioned in the previous sections due to its advantages. The height of the cylindrical chassis to be used is calculated by the following equation,

$$V = \Pi r^2 h \quad (2)$$

where V – volume of the cylinder (cm^3), r – radius of the chassis (cm), h – height of the cylinder (cm).

It is not possible to calculate without assuming arbitrary constants. The diameter of the pipe is assumed to be 5 inches (12.7 cm). The volume of the pipe is also assumed to be 3000 cm^3 based on the payload of the robot including the weight of the chassis.

$3000 = 3.14 * 6.35 * 6.36 * h$
$h = 23.69$ cm.

The length of the chassis was approximated to 24 cm. The dimensions of the robot is determined by these calculations. Further, the placement of the thruster that brings the vertical motion must be placed at a point in the axis through which the center of gravity passes through. The following table displays the measurement of the robot and its components.

Table 1: Measurements and values

Sl. No.	Component	Mass (g)	Coordinates x	Coordinates y
1.	Long pipe	1200	16	10
2.	Short pipe	55*2=110	12.5	4
3.	Motors	125*2=250	19.5	4
4.	Battery	1500	5	5.5
5.	Camera	500	23	5.5

$x' = (m_1x1 + m2x2 + ...+m_n x_n)/(m_1 + m2 + ...+ m_n)$
= (1200 * 16 + 55 * 12.5 + 55 * 12.5 + 125 * 19.5 + 125 * 19.5 + 1500*5 + 500 * 28) / (1200 + 110 + 250 + 1500 + 500)
x' = 13.18 cm.
$y' = (m_1y1 + m2y2 + ...+m_n y_n)/(m_1 + m2 + ...+ m_n)$
= (1200 * 10 + 55 * 4 + 55 * 4 + 125 * 4 + 125 * 4 + 1500 * 5.5 + 500 * 5.5) / (1200 + 110 + 250 + 1500 + 500)
y' = 6.86 cm.

Fabrication: The fabrication of the robot is done by fabricating the individual components of the robot. They are assembled together to build the sewer robot. The individual components that were fabricated are discussed below.

Chassis: The chassis is made of PVC, cylindrical in shape with a diameter of 5 inches. The chassis holds a thruster that is responsible for the vertical motion and the infrared camera. The chassis has two caps at either ends and these are made water proof using rubber O-rings. A cylindrical glass is attached to one of the caps with a hole drilled in the cap. This provides visibility to the camera that is placed inside. Grease is applied to the closing caps to make them water resistant.

Fig. 4.1: An individual thruster.

Thrusters: As mentioned earlier, the thrusters that are used in the present work are not waterproof by manufacture but are sealed to make them waterproof. The motors are attached to the closing caps of the side PVC pipes. The shaft of the motor projects outside to which a coupler is attached. The propeller blade is attached to the coupler. The caps are waterproofed with rubber O-rings. Grease is applied to make the holes water resistant. An individual thruster is shown in the Fig. 4.1.

Controls: The robot is tethered using cables. The cables are drawn out from the top of the main chassis. The DPDT switch box is used to control the robot.

Camera: The IR camera is fixed to a cylindrical wooden piece as shown in the diagram. The wooden piece with the camera is fixed inside the cylindrical chassis near the cap which has an opening. This keeps the camera without movement and damage in harsh conditions. Figure 4.2 displays the camera mounted on the wooden piece.

Fig. 4.2: IR camera.

Fig. 5.1: Assembled sewer robot. (Front view and rear view)

Assembly and Testing: The individual components are fabricated and they are assembled together using clamps, nuts and bolts. It is shown in the Fig 5.1.

The robot is tested initially for its ability to float and maneuver in the water and the camera is also tested separately to work, even in complete darkness.

CONCLUSION

The detection of sewer blockages is one of the existing problems in the sewer systems of the society. In India, manual labor is still prevalent for the detection and removal of the blockages in sewer. The work presented here has been aimed at providing a specific solution to the existing problem. The sewer robot that is designed can maneuver through the sewers and can detect the blockages that are existing in the sewers.

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