Overall Scheme of the Pipes Robot for Charging Using Fluid Kinetic Energy

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Abstract. According to the design requirements of the pipeline robot and the influence of the surrounding environment on the robot, in this paper, the overall structure of the robot is designed. Including the shape of the robot, the wall thick, structure. The stepping motor is used to drive the driving wheel to roll to realize the robot's walking; the oil dirt on the pipe wall is cleaned by steel brush; the internal and external pressure balance method of the body is used for the sealing of the robot.

Keywords: Pipeline Robot, Overall Design, Driving Wheel

1 Introduction
The kinetic energy of the fluid is converted into electric energy to charge the robot and ensure the robot have enough energy in the process of cleaning up and complete cleanup work. Reduce the weight of the robot and the inconvenience caused by cables. The robot design scheme of this article is proposed below to meet the actual needs of its normal operation in oil pipelines.

2 Shape Design of Pipeline Robot
Curves [1-3] are obstacles that pipeline robots often encounter when they work. If pipeline robots want to successfully complete the task of removing grease, they must be able to pass curves smoothly. Otherwise, the robot will easily get stuck in the pipeline. In this paper, the situation of right-angle elbow are considered and discussed the geometric constraints that the robot should meet in this type of pipeline. The robot can be approximately regarded as a cylinder with length L and diameter d, its model in a right-angle elbow is shown in Figure 1.
Figure 1. Geometric constraints in elbows

A) The diameter of the robot is less than half of the pipe diameter, namely:

\[ 0 < d \leq \frac{D}{2} \]

B) The diameter of the robot is greater than half or less than the pipe diameter, namely:

\[ \frac{D}{2} < d < D \]

It is derived from the following formula [4-6]:

\[
\frac{L}{2} + R^2 = \left( R + \frac{D}{2} \right)^2 + a^2
\]

\[\text{(1.1)}\]

(A is the distance between the contact between the two end faces of the robot and the pipe wall and the tangent point between the curved part and the straight part of the elbow in Figure 1), the length is:

\[
L = 2\sqrt{\frac{D^2}{2} + (2 - \sqrt{2RD}) + (1 - \sqrt{2})^2 R^2}
\]

\[\text{(1.2)}\]

In the case of B), Figure 1 (b)

\[
L = 2\sqrt{(2R+d)(D-d)}
\]

\[\text{(1.3)}\]

Derivation of the radius of curvature (Figure 1):

\[
a + \sqrt{2}R = R + \frac{D}{2}
\]

\[
a = (1 - \sqrt{2})R + \frac{D}{2}
\]

When \(a < 0\), that is, the two end faces of the robot are exactly in the elbow part, that is, the above B) situation meets this condition, Now the standard pipe diameter \(d = 325\text{mm}\), \(r = 3D\) is adopted, and \(R = 975\text{mm}\) can be calculated. In order for every part of the robot to pass through the smallest corner of the pipe smoothly, if the diameter is large, the length must be short. According to the actual situation, considering the shape error of the pipeline, the welding seam, the size of each part of the robot, etc., from equation (1.2), known the diameter of the robot \(d = 230\text{mm}\), \(L = 570\text{mm}\).
3 The Wall Thickness Design of the Robot

The wall thickness of the robot is designed by fully considering the requirements of the working environment of the robot, as well as the requirements of the material, price and weight of the robot itself. The pressure inside the robot is normal pressure, which is mainly used to withstand the action of external pressure. The pressure inside the oil pipeline is generally P≤6MPa. When the pressure P=6MPa, the diameter of pipeline robot d = 230mm, and the safety factor of wall thickness related to material properties is ɛ=12.

Wall thickness calculation formula [7-9]:

$$S = \frac{Pd}{20\varepsilon}$$  \hspace{1cm} (1.4)

After calculation, the wall thickness of the robot is S=5.75mm, which is approximately taken as S=6mm.

4 The Structure Design of Robot

The pipeline robot designed in this paper is composed of three systems, namely the power generation system, main body system and cleaning system. The three systems are connected by bellows and the outer wall is connected by elastic protective cover, which can play a buffer role when the robot turns. Figure 2 shows the composition schematic diagram of the pipeline robot discussed in this paper.

![Composition schematic diagram of the pipeline robot](image)

**Figure 2.** Composition schematic diagram of the pipeline robot

After the robot enters the pipeline, it is started by the electric energy of the battery itself, and the stepping motor of the main system starts to rotate, and the walking of the robot is realized through the transmission of the worm gear; cleaning mechanism, start cleaning work. When the oil flows through the impeller, which in turn drives the rotor of the generator to rotate, the generator converts the kinetic energy of the oil flow into electrical energy to charge the battery and provide continuous energy for the robot; the internal and external pressure balance method is used to seal the robot. Using the pressure sensor outside the robot body, the liquid nitrogen is discharged through the liquid nitrogen bottle in the fuselage, achieving equal pressure inside and outside the robot fuselage.

5 Conclusions

The robot designed in this paper has the following characteristics:

1) The robot converts the kinetic energy of the oil flowing in the pipeline into electric energy, and an external power supply, and improves the working efficiency of the robot;

2) The robot’s walking mechanism has three sets of driving wheels, and a stepper motor is used to drive the robot’s walking mechanism to ensure the stability of the walking process;
3) The cleaning process of the robot is driven by a DC motor. As long as the motor rotates, the steel brush can work continuously, making the cleaning work efficient;

4) Compared with the pipe pig, it has strong adaptability to the pipeline, and will not be stuck in the curve; this robot has a guiding mechanism, and can enter the designated pipeline according to the requirements when it encounters a fork;

5) Sealed design. When the pressure inside and outside the robot body is not equal, the pressure sensor sends out a signal, and the solenoid valve of the liquid nitrogen bottle is opened through the control of the single-chip microcomputer to fill the robot body with nitrogen to balance the internal and external pressure, which is beneficial to realize the robot body sealing reduces the strength requirements for the robot, reduces the size of the robot, reduces the resistance of the robot to the fluid in the pipeline, and improves the performance of the robot.

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