DRIVING MODULE FOR MODULAR ROBOTIC SYSTEM

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Abstract: The possibilities to use robots for inspection, exploration and maintenance of the pipes are highlighted in this paper and the authors' contribution in this field is discussed. The presented driving module is composed of slider-crank mechanisms and uses three geared mechanisms which are driven by a DC geared motor placed in the central region of the module. By using two of these driving modules and a passive module, an in-pipe inspection and exploration modular robotic system was developed.

Key words: driving module, passive module, in pipe, robotic system

1. INTRODUCTION

The in-pipe mobile robots play more and more major roles for replacing the human work in the petroleum, the chemical industry, the power plant and other some special professions. Recently, many in-pipe inspection robot systems have been developed and described [1], [2], [3], [4], [11].

The mobile robots can be classified according to their method of locomotion: wheels type, walking type, crawler type, inchworm type, screw type, pig type, wall pres type [5], [6], [8]. The wheeled robots are the simplest, most energy efficient, and have the best potential for long range. Loading the wheels with springs, robots also offer some advantages in manoeuvrability with the ability to adapt to in-pipe unevenness, move vertically in pipes, and stay stable without slipping in pipes.

These types of robots also have the advantage of easier miniaturization.

Pipe diameter, which is one of the important size parameters, limits the working space occupied by the inspection robot. Therefore, it is necessary to be considered that a robot is designed for a certain size of pipe diameter.

2. THE DRIVING MODULE

The driving module that is presented in this part is composed of slider-crank mechanisms placed at 120° angles around the central axle. This structure can adapt more easily to the variation of the pipe's diameter. The driving module's propulsion is achieved by using three drive wheels. The drive wheels are placed into motion using three geared mechanisms which are driven by a DC geared motor placed in the central region of the module. The driving module also has in its structure two sliding elements and two helicoidal springs which generate the force needed for the wheel to press against the inner surface of the pipe. The structural scheme and the 3D model are presented in figure 1, [9].

![Figure 1. The structural scheme of the driving module (a) and the mechanism positioned in a plan of its structure (b)](image)
This solution has the advantage that the drive wheels can independently adapt to the pipe diameter. One of the problems that appeared while designing this module was represented by the geared motor's dimensions, which resulted in the six crank mechanisms not being identical. Also, the two springs which were used have different dimensions. The movement transmission from the motor to the drive wheels is achieved by using three chains placed on gears and driven by the worm gear placed on the motor's axle (Fig. 4).

In figure 4 we have the following annotations: ME - DC motor with gear reducer (1/53 ratio motor/gearbox drives, 6V), l – worm, 2, 3, 4 – gears, \( z_1 = 1 \) one thread, \( z_2 = 42, z_3 = 38, z_4 = 38 \) teeth, module \( m = 0,75 \) mm, the worm gear thread inclination angle \( \theta = 4^\circ \), the normal gears and the inclination angle of the gear's teeth \( \beta = 4^\circ \), \( n_M \) the motor rotation frequency and \( n_R \) motor wheel rotation frequency.

The wheels have a radius \( r = 25 \) mm, a length of \( 7 \) mm and the component elements have the lengths: \( h_1 = 95 \) mm, \( h_2 = 58 \) mm, \( h_3 = 53 \) mm \( (h_1 = O_1A_1 = O_2A_2 = O_3A_3), h_2 = E_1B_1 = E_2B_2 = E_3B_3, h_3 = E_1F_1 = E_2F_2 = E_3F_3 \). The mass of the driving module, including the power wires, is of 630 [g]. The angle \( \theta \) is limited by construction \( 15 \div 60 [^\circ] \).

The angular speed of the driving wheels of the driving module is obtained

\[
 n_R = \frac{z_1}{z_4} n_M 
\]

The photography of the driving module is presented in the figure 5.

In the figure 6 is presented the driving module in pipe with diameters of \( \Phi 145 \) and \( \Phi 150 \) mm.
This driving module has movement capacities for inspection in (140 – 180) mm diameter pipes [10]. It can be used separately as an in-pipe inspection minirobot or it can be connected with another passive module for obtaining a modular robotic system for in-pipe inspection and exploration.

3. THE PASSIVE MODULE

The passive module (connected between the two drive modules) uses six wheels placed at 120° angles for locomotion. All the six wheels are mounted on springs in order to adapt to the changing diameter of the pipe. In figure 7 we have the 3D model and a picture of the passive module [7]. The passive module has a total length of L=204 [mm], a wheel radius of r = 17 [mm], the width of the wheels of 7 [mm] and it weights 700 [g].

The movement of the wheels is done on a radial direction along the central axis of the module and the value of the travel distance is of 25 mm. This distance can be increased if the diameter of the inspected pipe is larger, the wheel sustaining rods being provided with two holes and a detachable bolt (Fig. 8 a, b). If the travel distance needs to be increased, the springs that generate the force that presses the wheels on the interior of the inspected pipe have to be changed as well. The springs used are compression springs.

With three connected modules by universal joints, it was developed a prototype of a modular robotic systems with adaptable structure that is presented in the figures 9 and 10.
The robotic system can be used for inspecting pipes with diameters ranged between 150 and 190 [mm]. The total length of the system is of 856 [mm], [10].

Fig. 10. The developed inspection and exploration modular robotic system

4. CONCLUSION

The driving module which is described in this paper is characterized by an adaptable structure, based on linkages mechanisms. A very important design goal of this driving module is the adaptability to the inner diameters of the pipes. This module is a component of a complex modular robotic system for in-pipe inspection-exploration.

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REFERENCES


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