Study on the Connecting Rods for Wheel-rod Hybrid Robot

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Abstract. This paper presents a model of wheel-rod hybrid robot and analyzes the performance and function of connecting rods. The wheel-rod hybrid robot can not only effectively walk on a flat ground, but also own better crossing ability on an irregular surface. The wheels with connecting rods are simply introduced and described firstly. The wheel-rod robot is mainly classified four types by the number of links and all of them are analyzed for the purpose of improving the obstacle-climbing robot. And then, some of the parameters of connecting rods is given to analyze the performance of obstacle-surmounting for the robot. All of the analysis and research results are verified by real machine. Through studying on the connecting rods for wheel-rod robot, the best obstacle performance and walking efficiency of mobile robot is given in this paper.

1. Introduction

In previous works, a lot of researchers committed to the mobile robot research, especially, the obstacle-climbing robots. The mobile robots can be divided into three types: wheeled robots, legged robots, and tracked robots [1].

However, the three main types of mobile robots always own some disadvantages in the ability of obstacle-surmounting or walking efficiency [2]. The wheel-rod hybrid robots are proposed to solve these problems in this situation. This wheel-rod mechanism can keep high obstacle-crossing ability and not influence walking efficiency of robots. To further improve the performance of obstacle-climbing, the number and parameters of connecting rods must be analyzed and studied.

In this paper, a brief introduction to the structure of the wheel with connecting rod is provided firstly. And the classification of the wheel-rod robot is given based on the number of connecting rods and wheels. And then, this paper emphatically studies on the connecting rods from two aspects: the number, and the parameter of links, by using kinematic and dynamic analysis and calculation. It was discovered that the number and parameters of links can influence, and even decide the performance, especially, the obstacle-climbing ability of the hybrid robot.

2. Classification of the Wheel-rod Robot

In this section, a structure of wheel with connecting rod is given. And then, we classify the wheel-rod robot based on the number of connecting rods and wheels.

2.1 Wheel with Connecting Rod

The wheeled mobile robots can keep a high walking efficiency and sufficient velocity [3][4], but, it can only cross the obstacles which are low to the radius of wheels. Indeed, the wheeled robots own a fatal drawback: the low performance of obstacle-climbing. For the purpose of developing a mobile robot which has a strong climbing ability and walking efficiency, this paper presents a model of wheel with connecting rod. The connecting rods can help the robot cross obstacles by using structural features itself and not influence the locomotion of the robot.

The length and material of the connecting rods must be a reasonable choice to keep the links getting obstacles easily relying on static friction. When the mobile robot encounters any types of terrains, it can pass breezily through the connecting rods and the wheels switch to each other.

The wheel with connecting rod is not only the barrier ability, and simple structure. The structure of wheel with connecting rod mainly includes a round wheel and a connecting rod. Link can rotate

around the wheel by bearing or any other mechanical device. The round wheel can be seen as a driving wheel in this moving mechanism and the link moves with wheel by physical connection. The installing position of bearing should be closer to the edge of the wheel, the better is, which can let the mechanism keep more strong ability of obstacle-surmounting [5]. A simplest structural type of the wheel with a connecting rod is shown in Fig. 1.

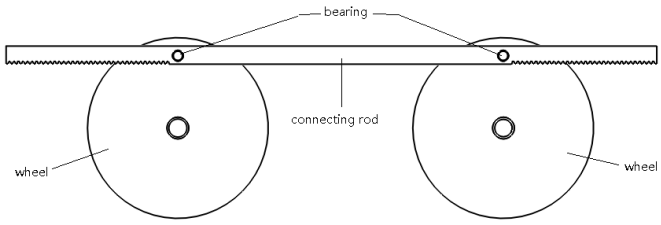

Fig. 1 A simplest structural type of the wheel with a connecting rod

2.2 The Main Types of the Wheel-rod Robot

The wheel-rod hybrid robot uses a symmetric structure design. It includes n wheels with connecting rod which is already described above and a machine body which is used to put some control components, power sources, and so on. In here, n is integer and even number, $n = 2, 4, 6, \cdots\cdots$. There are n same type of electric motor in machine body, which can drive each wheel independently [6].

Based on the number of connecting rods and wheels, we can classify the wheel-rod mobile robot simply. The main types of the robot are shown in Table 1 below.

Table 1 The main types of the wheel-rod robot

Number of Connecting Rods	*Number of Wheels*	*Types of Robot*
One Links	*Two Wheels*	*Single Wheel-rod Robot*
	Four Wheels	
	Six Wheels	
	……	
	N Wheels	
Two Links	*Four Wheels*	*Two Wheel-rod Robot*
	……	
	N Wheels	
Three Links	*Four Wheels*	*Three Wheel-rod Robot*
	……	
	N Wheels	
Four Links	*Four Wheels*	*Four Wheel-rod Robot*
	……	
	N Wheels	

In Table 1, it is concluded that there are four types of wheel-rod robot. They are single, two, three, and four wheel-rod robot respectively. However, in practical application, the three wheel-rod mobile robot is not often used for some reason. In every type of the robot, there are four to N wheels to correspond, and the single wheel-rod robot can own a model of two wheels. In the next section of this paper, an analysis of all types of the mobile robot will be given in detail.

3. The Number of Connecting Rods

The number of connecting rods will influence the performance of the mobile robot, which has been proved by the modeling and analysis of the kinematics and kinetics, and experiments in previous work.

3.1 Single Wheel-rod Robot

Single wheel-rod robot is that the moving mechanism owns one connecting rod on each side of it. It includes two, four, six or any other even numbered wheels. Fig. 2 shows a single wheel-rod robot for four wheels which is the most classic and representative single link. There is a simple structure and control for it. But, it owns a fatal flaw: stuck phenomenon of connecting rods. Link can rotate around the wheel which has been described above, and the links are rigid and nonflexible. When the link moves to the position that the connection to the front and rear wheel and the link are at the same level, the whole mechanism may not move continuously for the reason of resultant force function.

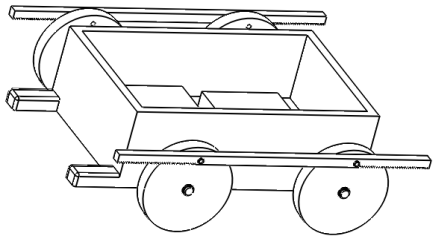

Fig. 2 A single wheel-rod robot for four wheels

In short, although the obstacle capability and walking efficiency of single wheel-rod mobile robot is strong, there is stuck phenomenon and the whole mechanism is not stable.

3.2 Two Wheel-rod Robot

For the stuck phenomenon of single link, two wheel-rod robot is presented in this paper. It, too, includes four, six or any other even numbered wheels.

Unlike single connecting rod, two wheel-rod robots own two connecting rods which has been resolve the stuck phenomenon. When one link moves to the position that the connection to the front and rear wheel and the link are at the same level, the other link must be not at the position and it can keep move continuously. Therefore, the whole robot can keep continue locomotion through mutual switch of two links. A simple structure design for two links is shown in Fig. 3.

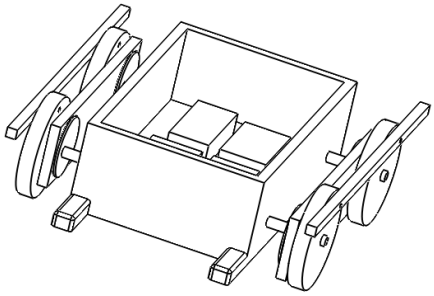

Fig. 3 One type of two wheel-rod robot for four wheels

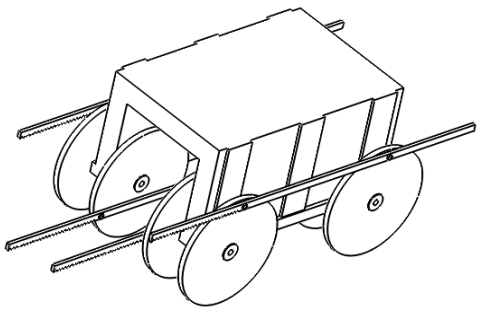

Fig. 4 A model of four wheel-rod robot

In Fig. 3, the two links is distributed in both sides of each wheel, which let them not influence each other. In the side of wheel close to fuselage, the link adopts a new type of eccentric round rotating driving shaft.

3.3 Three or Four Wheel-rod Robot

In fact, there is a better effect for obstacle-crossing ability to adopt a form of dual connecting rod, which is shown in Fig 4. All of the motors in the robot is two-output and they can connect two wheels for each of them [7]. And, at the same time, each of wheel can install two links for each side of it. Therefore, the robot can install three or four connecting rods. The three or four links can be in different phase position respectively. Through the number of more connecting rods switch each other, the robot owns stronger obstacle ability.

In fact, a series of the experimental results for real machine show that the dual connecting-rod robot [8], which is three or four wheel-rod robot, has the best obstacle ability. All types of wheel-rod robot own a good walking efficiency and sufficient velocity.

4. Parameters of Connecting Rods

Through a series of the experiments for real machine, this paper concludes that the parameters of connecting rods can influence the performance of obstacle-surmounting for the robot. The parameters of links include the material, the oblique angle, the length of front and rear part for connecting rods, and so on. In this section, the single wheel-rod robot with two wheels will be given to analyze, which can be also on behalf of all other wheel-rod hybrid robot on the parameter of links.

Through calculation and analysis, it can be known that the front parts of connecting rods must make to be jagged or skid proof to keep ability of crossing obstacles [8]. Even though, an original angle should be owned by the front parts of connecting rods, which is defined the angle ψ that the end of the connecting rod is relative to the horizontal plane.

The maximum height of obstacle-climbing for the robot can reach $3R$. In addition, when it comes to $3R$, we consider the angle between link and ground is θ and ψ is equal to θ [5].

$$\psi = \theta = \arctan\left(\frac{2R - e}{R}\right) \tag{1}$$

Fig. 5 shows the principle of obstacle-climbing for the two-wheel-rod robot, and the connecting rods of the robot own an initial angle.

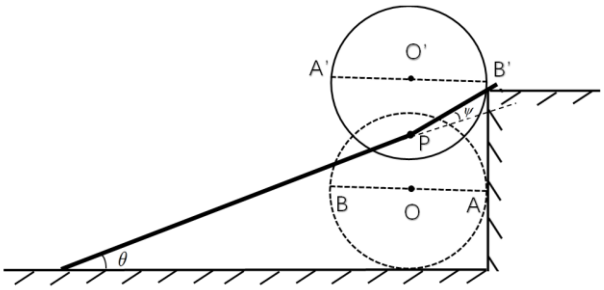

Fig. 5 The principle of the robot obstacle-climbing with initial angle

Therefore, considering the extreme situation, this paper can conclude that the length of front and rear part for connecting rods are respectively L_1 and L_2. In Fig. 5, the point P divides the connecting rods into L_1 and L_2.

$$L_1 = \frac{R}{\cos 2\theta} = \frac{R}{\cos 2\psi} \tag{2}$$

$$L_2 = \frac{R + e}{\sin\theta} \tag{3}$$

5. Summary

In this research, all kinds of wheel-rod hybrid robots are introduced and the connecting rods for the robot are studied, especially, the classification and parameters of the connecting rods. A model of wheel with connecting rod is proposed in this paper. This mechanism has a strong climbing ability and walking efficiency on any terrains, which has combined with the advantages of round wheels and connecting rods. The connecting rods can help the robot cross obstacles by using structural features itself and not influence the locomotion of the robot.

There are four types of wheel-rod robot: single, two, three, and four wheel-rod robot. They each have advantages and disadvantages. However, synthesizes each kind of situation, the four wheel-rod mobile robot owns the best performance, especially, it has super strong ability of obstacle- crossing, which has been verified by the modeling and analysis of the kinematics and kinetics.

In addition, changing and adjusting the parameters of connecting rods can improve the performance of the robot. For example, the material of links, the oblique angle of front parts for links, and the length of front and rear parts for connecting rods, and so on. This paper presents the optimal mobile obstacle-surmounting robot through studying on the connecting rods.

Acknowledgements

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