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Investigation on obstacle-surmounting capacity of biped-wheel unmanned platform based on kinematic and kinetic analysis

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Abstract

The biped-wheel unmanned platform has the obvious advantages of high flexibility, high maneuverability, well controllability, great promptitude, fine adjustability, and a low manufacturing cost. A novel structure of the walking device of a biped-wheel platform has been investigated in this study, which is similar to the structure of airplane undercarriage. The structure is a plane four-bar linkage mechanism, which is composed of a side link, a connecting rod, a bracket, and a hand-spike. Swing range of the walking device determines the obstacle-surmounting capacity of biped-wheel unmanned platform. Therefore, the swing range of the modified novel walking device is calculated through theoretical derivation. Afterwards, the obstacle-surmounting capacities of the biped-wheel unmanned platform, including the ditch-crossing and the stair-climbing, are investigated based on the kinematic and kinetic analysis. Relative to the common type, reliability of the modified walking device can be improved. The research would increase the development level of the biped-wheel unmanned platform and promote its application in military and industrial fields.

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Keywords: Biped-wheel unmanned platform; Obstacle-surmounting capacity; Kinematic analysis; Kinetic analysis; Biped-wheel structure; Airplane undercarriage.

1. Introduction

Unmanned platform has been gradually applied in many military actions [1]. In Afghanistan and Iraq, SWORDS robot, PACKBOT robot, MAARS (Modular Advanced Armed Robotic System) robot, and many other unmanned platforms have been used by the American army, which are aim to decrease the loss of soldiers [2]. Through installations of the manipulator, scatter-gun, camera, lidar, GPS, or other functional modules, unmanned platform can accomplish many tasks, such as reconnaissance, defence, rescue, and so on.

Obstacle-surmounting capacity is the key ability of an unmanned platform, which determines practicability and applicability of a robot. Many kinds of unmanned platform have been developed, such as wheel robot, tracked robot, legged robot, wheel-tracked hybrid robot, biped-wheel hybrid robot, and the wheel-tracked-legged robot [3]. Among

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these robots, biped-wheel unmanned platform has the advantages of high flexibility, high manoeuvrability, well controllability, great promptitude, fine adjustability, and a low manufacturing cost [4].

The common structure of the walking device of a biped-wheel unmanned platform consisted of a driving motor, swing motor, cantilever, wheel, and some connecting parts, as shown in Fig. 1(a). The maximal excellence of this structure is that swing of the leg is easy to control. However, the reliability and stability of this structure is low, because gearing of the swinging module bear a large force [5]. Thus, we have developed a novel structure of the walking device of a biped-wheel unmanned platform, as shown in Fig. 1(b), which is similar to the structure of airplane undercarriage [6, 7]. The structure is a plane four-bar linkage mechanism, which is composed of a side link, a connecting rod, a bracket, and a hand-spike. The wheel and its driving motor are fixed on terminal of the bracket. Different from swing motor of the common type in Fig. 1(a), swing of the leg in the modified novel type is realized by the hand-spike, which is driven by electricity or hydraulic fluid, as shown in Fig. 1(b). Relative to the common type, reliability of the modified walking device can be improved.

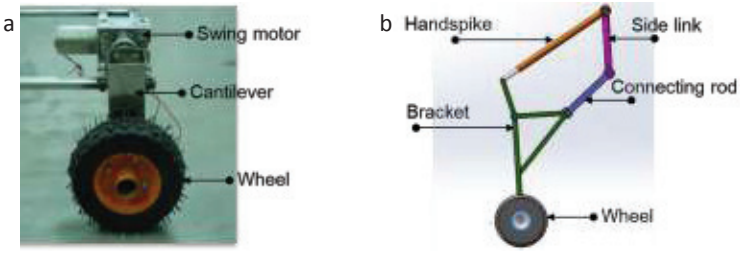

Fig. 1. Structure of the walking device of a biped-wheel unmanned platform. (a) the common type; (b) the modified novel type.

Swing range of the walking device determines the obstacle-surmounting capacity of biped-wheel unmanned platform. Therefore, the swing range of the modified novel walking device is calculated through theoretical derivation. Afterwards, the obstacle-surmounting capacities of the biped-wheel unmanned platform, including the ditch-crossing and the stair-climbing are investigated based on the kinematic and kinetic analysis. Finally, significance of this study is given in the conclusion part.

2. Theoretical calculation of swing range

Critical factor of the biped-wheel structure is front-swing and back-swing of the swing arm, as shown in Fig. 2. Supposing the hand-spike is represented by l; four rods of the bracket are represented by l_1, l_2, l_3, and l_4; angle between prolongation line of l_1 and l_3 is β; connecting rod and side link are represented by l_5 and l_6, respectively. Angle between l and l_1 is set to β in the original installation process, and angle between l_1 and horizontal direction is set to 2β; thus, the angle between l_1 and horizontal direction is β, and the maximal front-swing angle is $90°-\beta$, as shown in Fig. 2(a). The distance between the platform and the ground is maximal when the rod l_3 is in the perpendicular direction. Meanwhile, the maximal back-swing angle is also $90°-\beta$, as shown in Fig. 2(c). Through designing the length and position of the rods, the swing range can be obtained in $\pm(90°-\beta)$.