Dynamics Modeling and Simulation of A Six-wheel All-terrain Mobile Robot Based on ADAMS

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Abstract. A novel structure of a six-wheel all-terrain mobile robot with the integration of active and passive control is presented in this paper. According to different complex terrain environments, three-dimensional simulation models of the six-wheel all-terrain mobile robot were built using ADAMS software and the dynamic simulation analyses under different terrain conditions were accomplished. Using the ADAMS model, the kinematic and dynamic characteristics curves of the whole robot and parts of robot were obtained. The simulation analyses provide the theoretical basis for the optimization of the mechanical structure, control system design and the selection of drive motors. Simulation results show that the structure of this kind of robot has good mobility and obstacle-climbing performance.

Introduction

Dynamics research of the six-wheel all-terrain mobile robot provides the basis for achieving its motion control. While facing with complex terrain changes, the robot needs not only the multi-rigid-body, series-parallel multi-joint compliant subtle structure but also application of autonomous control due to the harsh environment. Autonomous control of the robot should have good manipulate smooth, stability and security. Because terrains are unknown and unstructured, tests of simulating complex terrain environment are relatively difficult. With the help of ADAMS, the six-wheel all-terrain mobile robot can be treated as a complex multi-body system and the dynamic simulation under complex terrain can be completed. The simulation analyses provide the theoretical basis for the optimization of the mechanical structure, control system design and the selection of drive motors.

Basic structure of six-wheel all-terrain mobile robot

The mechanical structure of the six-wheel all-terrain mobile robot is composed of three parts including two front parallelogram rockers, the rear parallelogram rocker and the main body. The structure is shown in Fig. 1. The relationship between the two front parallelogram rockers is parallel. The series connection of front parallelogram rockers and the rear parallelogram rocker are linked using the main body. The whole mobile robot is a multi-rigid-body, series-parallel and multi-joint compliant system. The mobile robot has 6 wheels and symmetrical structure. The pitching of main body depends on the pitching of parallelogram rockers. When the moving robot climbs over the obstacles, the pitch angle of main body is only half of the pitch angle of parallelogram rocker, so the favorable condition for the stationary and normal operation of scientific instruments and control circuits can be provided. The six-wheel all-terrain mobile robot adopts the work pattern of six-wheel independent driving and four-wheel independent steering. While facing with obstacles, the robot adjusts the gravity distribution on each wheel through coordinate pitching of front parallelogram rockers, rear parallelogram rocker and main body due to its parallelogram rockers in the front/rear of
the main body, which can improve the motion stability and obstacle-climbing performance compared with the general six-wheel mobile robot. Because it adopts the independent servo driving mode, the six-wheel all-terrain mobile robot has greater freedom, stronger adaptability and mobility.

![Fig. 1 Six-round all-terrain mobile robot principle diagram of mechanism](image1)

Three-dimensional modeling of the six-wheel all-terrain mobile robot based on ADAMS

The three-dimensional simulation model of the six-wheel all-terrain mobile robot was built using ADAMS 2005 software. The parameters of the simulation model are listed as follows: quality of six-wheel all-terrain mobile robot is 30 kg (no-load); overall size is 700 mm × 400 mm × 200 mm; the wheel diameter is 100 mm; the wheel width is 40 mm. The simulation model of the six-wheel all-terrain mobile robot is shown in Fig. 2. Dimensions of the model, quality of the parts, motor speed and output torque were set according to the actual parameters of the robot. The contact ground condition was provided as hard ground.

![Fig. 2 Six-round all-terrain mobile robot simulation model](image2)

The dynamics simulation of the six-wheel all-terrain mobile robot based on ADAMS

Comparison of dynamics simulation under various complex terrain environments. The weight of the six-wheel all-terrain mobile robot is 30 kg, and assuming that the robot carries a 6 kg payload. Respectively using active rocker and passive rocker the obstacle-climbing capability of the robot was simulated by ADAMS under complex terrain conditions. The environments of simulation contain passive going upstairs and downstairs (Fig. 3), reverse passive going upstairs and downstairs (Fig. 4), positive going upstairs and downstairs, passive driving on the rugged ground (Fig. 5), passive going upstairs with vertical barrier (Fig. 6), active going upstairs with vertical barrier (Fig. 7), passive going across the gulf whose width is four times radius of wheels, and positive going across the gulf whose width is four times radius of wheels (Fig. 8). The comparison of simulation results shows that, using passive obstacle-navigation way, the six-wheel robot can go upstairs (requiring of friction between the ground and wheels is more than 0.6), go downstairs and drive on rough roads smoothly, the control method of the robot is simple and energy consumption is low. But it is difficult to climb steps with vertical barrier, unless the wheel diameter is increased and the coefficient of friction between the ground and wheels is more than 1.0. It also can not go across the gully whose width is four times radius of wheels and climb steps in tilt direction. Using the active way to run over obstacles, the six-wheel robot which use laser ranger finders in former parallelogram rockers and the rear parallelogram rocker respectively finding obstacles can climb not only stairs positively but also steps.
in tilt direction. It can also go across the gulf four times radius of wheels easily. In addition, the requirement of the friction coefficient between wheels and the ground is very low. But due to active rocker drive motors add to the six-wheel robot in the active control mode, the control strategy becomes difficult and energy requirement is larger. Synthesizing the comparison of the above, we consider whether the ability of adapting to the complex terrain or the consumption of energy, it is very necessary for the six-wheel rocker robot to use the structure which is an integration of the active obstacle-navigation way and the passive obstacle-navigation way.

**Fig. 3** Passive going upstairs and downstairs  
**Fig. 4** Reverse passive going upstairs and downstairs  
**Fig. 5** Passive driving on the rugged ground  
**Fig. 6** Passive going upstairs with vertical barrier  
**Fig. 7** Active going upstairs with vertical barrier  
**Fig. 8** Active going across the gulf 

**Dynamics simulation curves of the robot in the simulation environment of passive going upstairs and downstairs.** Due to limitations of space, only the simulation curves of the six-wheel all-terrain robot under passive going upstairs and downstairs condition is shown in Fig. 9-18.

**Fig. 9** Left front wheel displacement, velocity, acceleration, angular velocity and angle acceleration curves  
**Fig. 10** Left rear wheel displacement, velocity, acceleration, angular velocity and angle acceleration curves
Fig. 11  Left rocker displacement, velocity, acceleration, angular velocity and angle acceleration curves

Fig. 12  Middle front wheel displacement, velocity, acceleration, angular velocity and angle acceleration curves

Fig. 13  Middle rear wheel displacement, velocity, acceleration, angular velocity and angle acceleration curves

Fig. 14  Rear rocker displacement, velocity, acceleration, angular velocity and angle acceleration curves

Fig. 15  Main body displacement, velocity, acceleration, angular velocity and angle acceleration curves

Fig. 16  Main body momentum and kinetic energy curves
Conclusions

A new structure of a six-wheel all-terrain robot is presented in this paper. Using dynamic simulation software—ADAMS2005 the dynamics models were built and simulation analyses for six-wheel all-terrain mobile robot were achieved under different complex environmental conditions. The simulation shows that the robot in active and passive rocker way can go upstairs and downstairs. In detail, the robot in passive rocker way can drive on rugged ground smoothly, but can not climb inclined stairs and the steps with the barrier in the vertical direction, while the robot in active rocker way is easy to accomplish it, and is able to run cross the gulf whose width four times the radius of wheels. The dynamic simulation curves of the main body and parts of the six-round all-terrain mobile robot were achieved, including the curves of displacement of front and rear rockers, velocity, acceleration, angular velocity and angular acceleration; curves of each wheel in complex terrain environments of displacement, velocity, acceleration, angular velocity, friction, torque and angle acceleration; curves of whole body’s kinetic energy ,momentum and moment of momentum which relative to the centroid of main bodywork. These curves provide the theoretical basis for mechanical structure optimization design, motor selection, power selection and design of the strong robustness control system of the six-round all-terrain mobile robot.

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