Sensors & Transducers

Design and Analysis of Landing Gear Mechanic Structure for the Mine Rescue Carrier Robot

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Abstract: The landing gear is used as a channel for the secondary detecting robot to leave and return the first carrier robot in the coal mine rescue robot system. The planar linkage mechanism, which is composed of offset rocker-slider mechanism and double-rocker mechanism, is designed according to the function and working principle of the landing gear. It could realize the 120° rotation of the flap with a motor driving the slider. The size calculation of the planar linkage mechanism is completed according to its workspace. The geometric modeling of the landing gear is made in the SolidWorks, and the basic Kinematic analysis is carried out by the simulation module of Motion. And the movement rule about angular displacement and angular velocity of the linkage mechanism could be obtained under given input condition, which could verify the system's feasibility. It provides a theoretical basis for the structure design and engineering application of linkage mechanism and an applying basis for the coal mine rescue robot. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Mine rescue robot, Landing gear, Planar linkage mechanism, SolidWorks motion.

1. Introduction

Mine rescue two-stage robot system is used in the status that mine accidents occur in working faces away from the mine entrance, it adopts two-stage robot structure [1], the first orbital-carrier robot and the secondary crawler detecting robot. As the secondary complex-crawler robot moves slowly, which needs a long time to drive to the accident site, it would miss the golden period for rescue, so we use the first-stage carrier robot, driving on the orbit with a faster speed, to reduce the driving time. After a mine accident, the first-stage carrier robot [2] carries the second-stage detecting robot [3] along the underground transport orbit moving fast to the place where the accident happened. If the first-stage robot is obstructed, the second-stage would get off and keep on moving to the accident site, and it would get back with its work done. And the role of the landing gear is to form a road slope for the second-stage robot to get off and on.

The basic machine of the carrier robot including the car body, driving mechanism, travelling mechanism, braking mechanism, buffer mechanism and landing gear [4], as shown in Fig. 1, its main function is to guarantee the safe running of the carrier along the orbit.

In the design of landing gear, the planar linkage mechanism would be used to complete part of the complex movement according to its advantages and wildly use in engineering practice, such as using lower pairs, not easy to wear, easy to process with low cost and could achieve a variety of complex movement curves and movement rules.

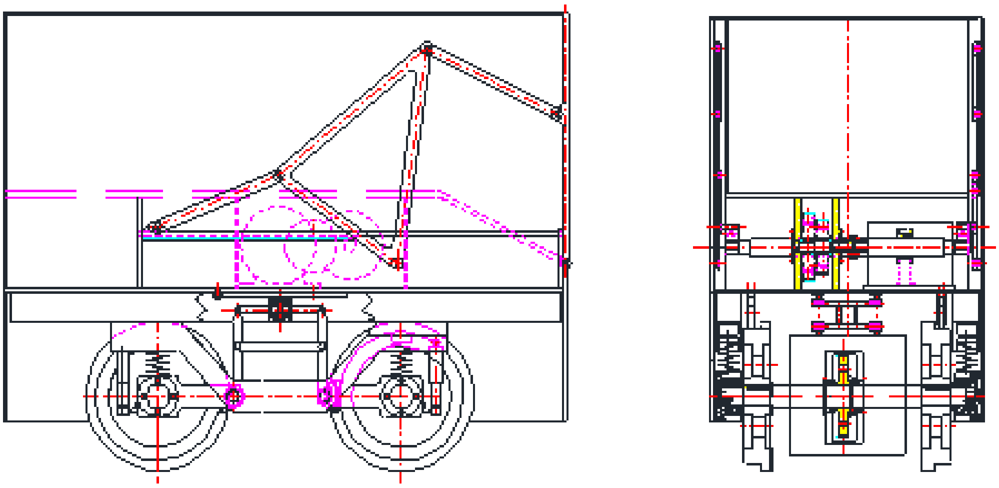


Fig. 1. The structure of secondary carrier robot.

2. Design of the Planar Six Bar Mechanism

The planar six bar mechanism [5, 6] is composed of the offset rocker-slider mechanism and double-rocker mechanism, the function of the first part is to transform the linear motion of the rack to the rotation motion of a bar, and the function of the double-rocker mechanism is to amplify the rotation angle and to make sure the 120° rotation motion of the flap.

2.1. The Size Calculation of the Offset Rocker Slider Mechanism

The offset rocker-slider mechanism is composed of slider, bar a and bar b. its target is to turn bar b over 60°in a clockwise direction. The slider is the input while the bar b is the output, and the linear motion of the slider would translated to the rotation motion of bar b. The extreme positions [7] are shown in Fig. 2 and Fig. 3 respectively.

The equation for the extreme position 1:

$$\begin{cases} a\sin\varphi_0 + e = b\sin\psi_0 \\ a\cos\varphi_0 - b\cos\psi_0 = S_0 \end{cases}, \qquad (1)$$

The equation for the extreme position 2:

$$\begin{cases} a\sin\varphi_i + e = b\sin\psi_i \\ a\cos\varphi_i - b\cos\psi_i = S_i \end{cases}, \qquad (2)$$

According to the overall structural size of the landing gear and carrier robot, define:

$S_0 = 800\ mm$, $e = 150\ mm$, $b = 500\ mm$, $\psi_0 = 150°$, $\psi_i = 75°$.

Simultaneous the equation could obtain:

$$\begin{cases} a = 490.66\ mm \\ S_i = 230.52\ mm \\ \varphi_0 = 24.51° \\ \varphi_i = 42.73° \end{cases}, \qquad (3)$$

For the position 2, the angle between the bar a and b is 32.27°, far away from the dead zone, and the operating requirement could be satisfied.

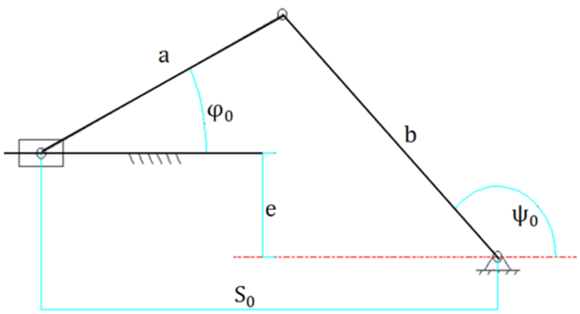


Fig. 2. Position 1 of the offset rocker slider mechanism.

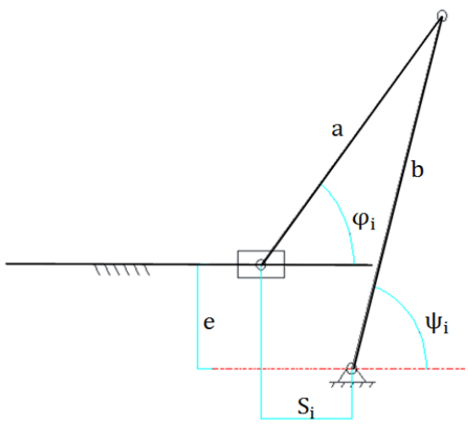


Fig. 3. Position 2 of the offset rocker slider mechanism.

2.2. Size Calculation of the Double Rocker Mechanism

The double rocker mechanism is composed of bar l_1, l_2, l_3 and l_4. It's target is to rotate the bar l_3, the flap, 120° in the clockwise direction, the rod l_1 is the input with a rotation of 60 degrees and the bar l_3 is the output with a rotation of 120°. The extreme positions [8] of this mechanism are shown in Fig. 4 and Fig. 5 respectively.

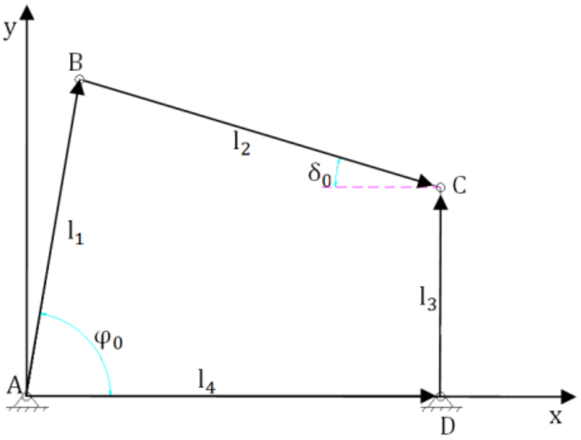


Fig. 4. Extreme position 1 of the double rocker mechanism.

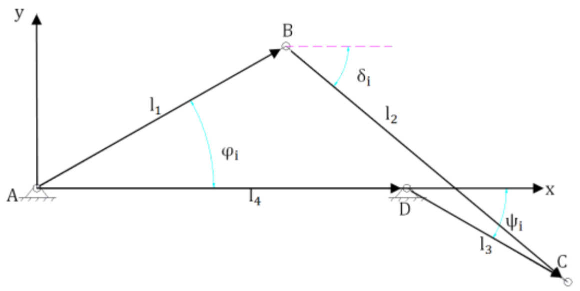


Fig. 5. Extreme Position 2 of the double rocker mechanism.

Components could be expressed as vectors, and according to the closed vector graphics, the following vector equation could be obtained:

$$l_1 + l_2 = l_3 + l_4 , \qquad (4)$$

Project to the X axis and Y axis, we could obtain:

1) The equation for the extreme position 1:

$$\begin{cases} l_1 \sin\varphi_0 - l_2 \sin\delta_0 = l_3 \\ l_1 \cos\varphi_0 + l_2 \cos\delta_0 = l_4 \end{cases} , \qquad (5)$$

After the elimination of δ_0, we could obtain:

$$l_2^2 = (l_1 \sin\varphi_0 - l_3)^2 + (l_4 - l_1 \cos\varphi_0)^2 , \qquad (6)$$

2) The equation for the extreme position 2:

$$\begin{cases} l_1 \sin\varphi_i - l_2 \sin\delta_i = -l_3 \sin\psi_i \\ l_1 \cos\varphi_i + l_2 \cos\delta_i = l_4 + l_3 \cos\psi_i \end{cases} , \qquad (7)$$

After the elimination of δ_0, we could obtain:

$$l_2^2 = (l_1 \sin\varphi_i + l_3 \sin\psi_i)^2 + (l_4 + l_3 \cos\psi_i - l_1 \cos\psi_0)^2 , \qquad (8)$$

According to the overall structural size of the landing gear and carrier robot, define:

$l_3 = 500\ mm$, $l_4 = 580\ mm$, $\psi_i = 30°$, $\varphi_i = 25°$, $\varphi_0 = \varphi_i + 60°$,

Simultaneous the equation could obtain:

$$\begin{cases} l_1 = 952\ mm \\ l_2 = 669.4\ mm \\ \delta_0 = 42.05° \\ \delta_1 = 77.03° \end{cases} , \qquad (9)$$

For position 2, the angle between the rod a and b is 17.03° and the operating requirement could be satisfied.

The bar b of offset rocker slider mechanism and the bar l_1 of double rocker mechanism would rotate around the same point, the angle between them is 50°, and the connecting bar is shown in Fig. 6.

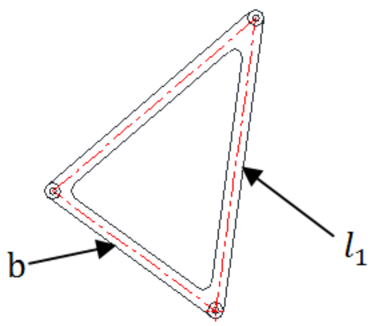


Fig. 6. Connecting bar.

2.3. The Structural Characteristics of the Landing Gear

All of the structural sizes of the combined mechanism could be obtained according to the dimension value we calculated, its CAD drawing of the two extreme positions are shown in Fig. 7 and Fig. 8. In position 1, the rack is on the left side while the flap is perpendicular to the ground, and in position 2, the rack is on the right with a linear motion while the flap rotates 120° in the clockwise direction.

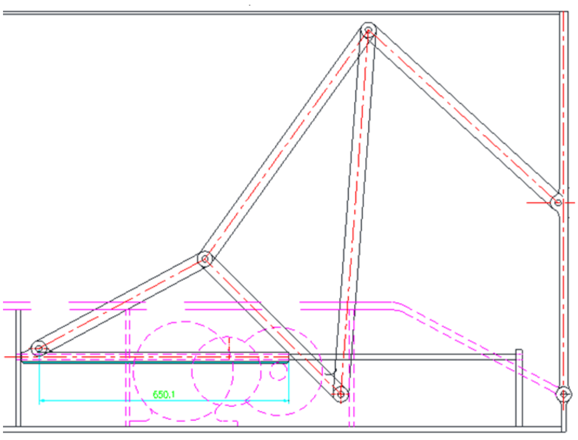


Fig. 7. Position 1 of the landing gear.

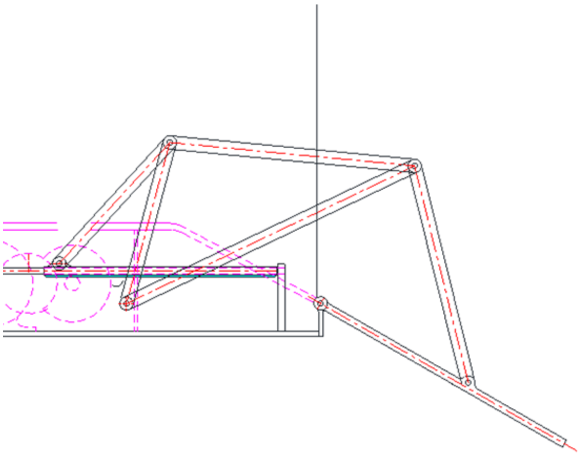


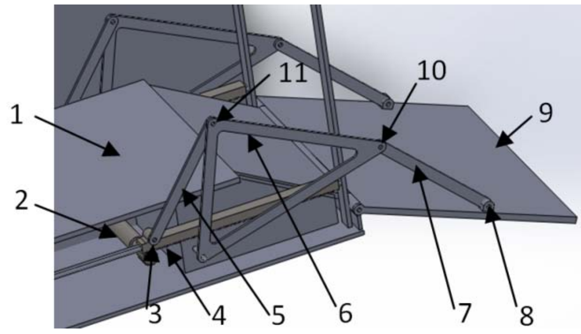
Fig. 8. Position 2 of landing gear.

3. The Kinematic Analysis of the Landing Gear

By using virtual prototype simulation tools SolidWorks Motion, Kinematics and dynamics simulation analysis of complex mechanisms can be done, and motion parameters could be obtained, such as displacement, velocity, acceleration, force and reaction force, etc. It's provided opportunities to do Kinematic analysis work without physical prototype manufactured.

3.1. Construction of Three-dimensional Model

In SolidWorks, all components of the landing gear should be modeled and assembled according to the actual conditions; the assembly model is shown in Fig. 9. The rack is the input while the flap 7 is the output, the linear motion of the rack could be transformed to the rotational motion of the flap.



1 – Car body, 2 – Gear shaft, 3 – Prismatic pair, 4 – Rack, 5, 6, 7 – bar, 8, 10, 11 – Rotation pair, 9 – flap.

Fig. 9. The model of landing gear in SolidWorks.

3.2. Motion Simulation and Analysis

In SolidWorks Motion, all components are regarded as the ideal rigid body, which means the deformation will not occurred inside of each bar and between the bars in simulation process. Connecting formats and constraints according to the movement characteristic of the mechanism should be appropriate, that's because those elements have a vital importance to the virtual assemble and motion simulation [9].

Considering the speed change of the motor at the starting and stopping moment and in order to avoid the collision between the car body and flap, an optimized velocity curve of the motor is given as shown in the Fig. 10.

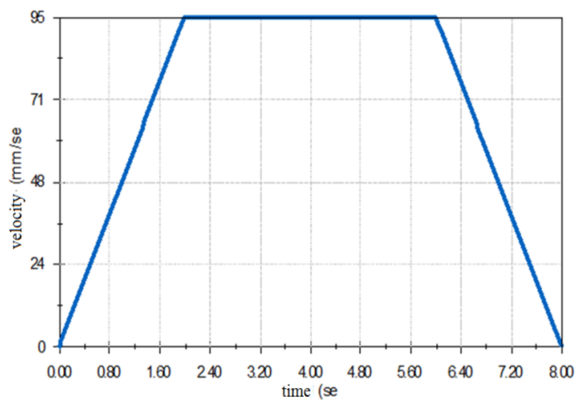


Fig. 10. Velocity-time curve of the rack.

In the motion simulation analysis, set the motion option as the functions, and the equation of the velocity is given as in equation 10.

$$\begin{cases} y = \frac{95}{2} & (0 \le x < 2) \\ y = 95 & (2 \le x < 8) \\ y = -\frac{95}{2}(x-6) + 95 & (6 \le x \le 8) \end{cases}, \quad (10)$$

The speed of the rack, the vice 3, would be increase to 95 mm/s from 0 mm/s on a constant acceleration, and it would be decrease to 0 mm/s on a constant acceleration after a constant movement of 4 seconds. After the calculation, the angular displacement-time curve of the flap could be obtained as shown in Fig. 11, and the angular speed-time curve of the flap, revolute pair 8, could also be obtained as shown in Fig. 12.

The rotation angle of the flap is 120°, and the angular speed would be increased from 0 deg/s gradually and reach the maximum at about 6 s, then it would be decreased gradually and reached 0 deg/s at 8 s. The collision between the car body and the flap at the extreme positions would be avoided and the expected goals could be achieved better under this speed curve.

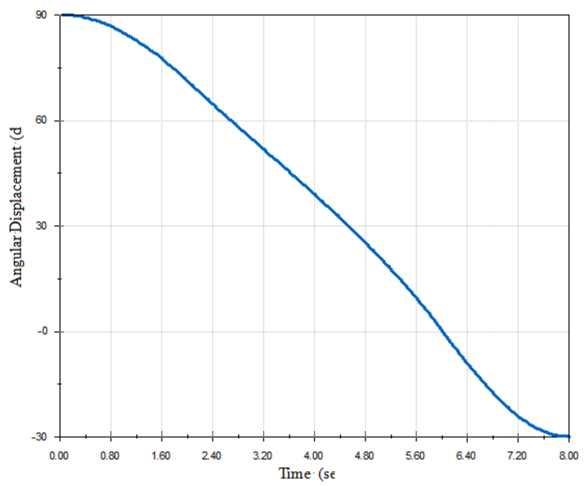


Fig. 11. Angular displacement-time curve of the flap.

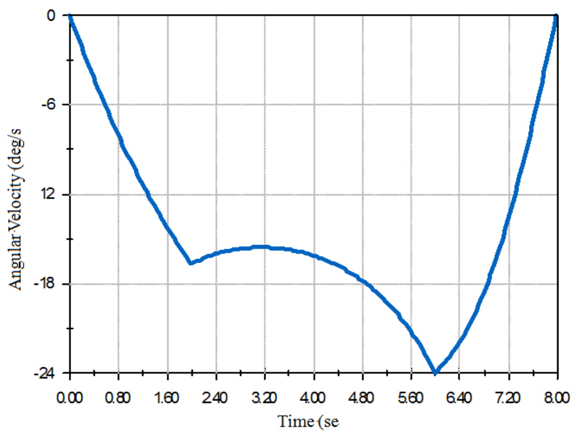


Fig. 12. Angular velocity-time curve of the flap.

The angular displacement-time and angular speed-time curves of the bar 6, the revolute pair 10 and 11, could also be obtained as shown in Fig. 13 and Fig. 14. The rotation angle is 60°, its angular speed-time curve is similar to the curve of flap with a different maximum, and the maximum of the flap is 24 deg/s while the maximum of the bar 5 is 11 deg/s. we could find that the expected target could be obtained well with the planar six rod mechanism from those curves.

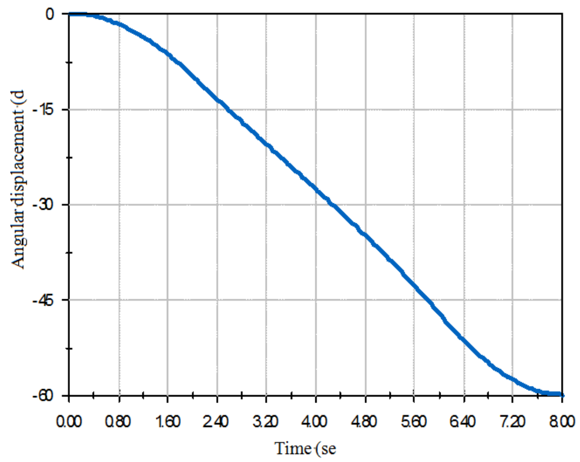


Fig. 13. Angular displacement-time curve of the bar 6.

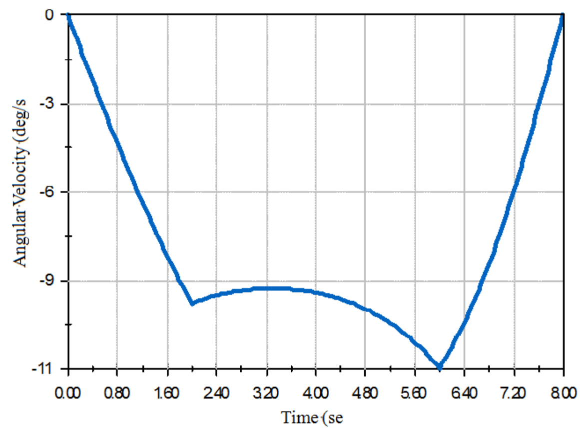


Fig. 14. Angular velocity-time curve of the bar 6.

4. Conclusion

The role of the landing gear in the carrier is to provide a pass way for the secondary detecting robot to leave and return, it requires not only strong operation reliability, running stability, a certain carrying ability but also the simple structure, easy to control and autonomous control.

1) The structure and geometry sizes of the landing gear mechanism were determined after the calculation of extreme positions of the offset slider rocker mechanism and double rocker mechanism under the sufficient analysis of the functional requirements of the landing gear.

2) Motion Simulation of the landing gear were carried out by using virtual prototype simulation tools, SolidWorks Motion, the angular displacement-time and angular velocity-time curves of the main components were obtained and the feasibility of the mechanism were verified. In order to avoid the

collisions between the flap and car body in extreme positions, the optimized input velocity curve were offered.

Acknowledgements

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