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Analysis of Variable Freedom Jumping Robot Based on Tripping and Singular Mechanism

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Abstracts: Jumping robot has a good capability of passing unstructured environment barriers, it also has a wide range of applications in anti-disaster relief, military reconnaissance, anti-terrorism and other fields. A new jumping robot is proposed and it is composed of energy transformation mechanism and singular point support mechanism . The transformation of topology and DOF in different jumping states are researched. The mechanism has the characteristics of short duration of action, high energy conversion rate and big instant impact force on the ground. It provides a theoretical basis and foundation for further innovation and research .

Keywords: Jumping robot; Singular point; Variable freedom;

I. Introduction

Jumping robot has a huge advantage over the traditional robot in working out obstacles, it can pass the obstacles or ditches of several times or even ten times the size of itself, which greatly increased the scope of its activities. The jumping movement with sudden and explosive impact on the ground enhances its ability to avoid the risks, most of all, it can play a great role in planetary exploration. In addition, jumping robot has a wide range of applications in anti-disaster relief, military reconnaissance, anti-terrorism and other fields.

The mode of jumping robot can be classified as follows: Single leg robot [3] makes use of compressed air cylinder acting to achieve its jumping action; Spherical jumping robot [7] is based on the use of screw compression spring's drive to achieve energy storage and jumping action; Small jumping robot [8] can be moved with a single twisted rope butterfly reed way through the release of elastic energy storage and realization jumping leg; Six pieces jumping robot [1] by changing gear-six metamorphic mechanism topology to achieve its jumping action. Such robots have the characteristics of fewer degrees of freedom, simple structures and easy to achieve jumping motion; However, they also have many defects, for example: lower jump height, small instantaneous impact on the ground and lower energy efficiency.

A new type of jumping robot based on the characteristic of linkage dead point to finish the jumping action is proposed. It greatly improved the efficiency of collision energy and energy conversion, it also has its strong points such as simple operation, lower cost and better stability.

II. Overview of the jumping robot

The whole jumping robot consists of three parts: storage-releasing energy mechanism, landing stabilization mechanism (supported by three legs of flexible elastic damping), singular point supported mechanism. Its main process of movement can be described as follows: The driving cam rotates clockwise and comes into contact with the loading rod; When the cam continues to rotate, toggling the loading rods and makes the power lever generates upward movement; Loading rod continues to be struck, energy storage spring compressed and the tripping contacts are locked; Cam continues to rotate, the loading rod conducts the reset process and the spring energy storage comes to the end; the slave trigger is separated from tripping pieces while cam rotates clockwise，then unlock tripping process was initiated, spring releases the stored energy and the robot pops up. The robot's working process is composed of energy storage, tripping, releasing, jumping, cushioning and reset. This can ensure the stability and reliability of the robot, the jumping robot's model can be shown as follows:

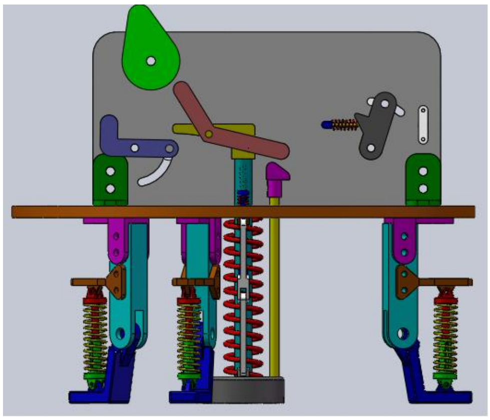


Fig.1: Front view of the jumping robot

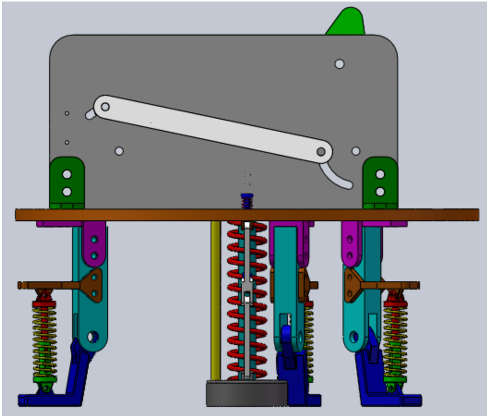
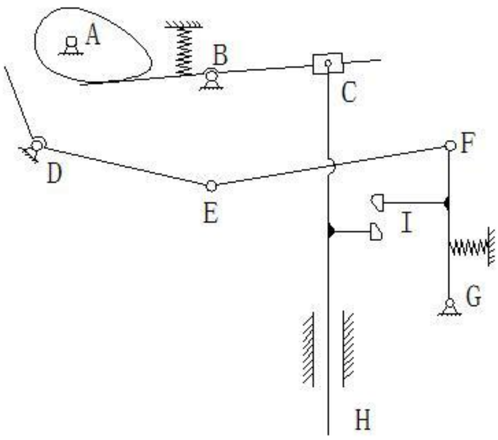


Fig.2: Rear view of the jumping robot

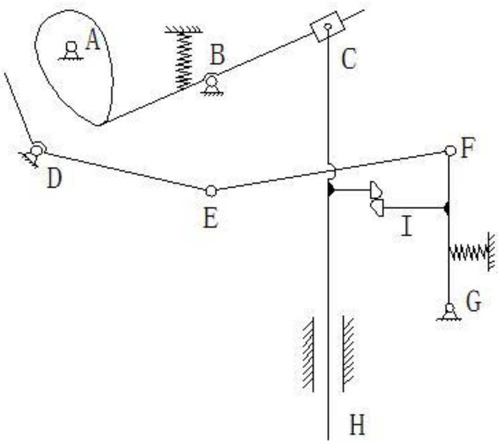
III. The analysis of the mechanism

3.1 The energy storage-releasing mechanism

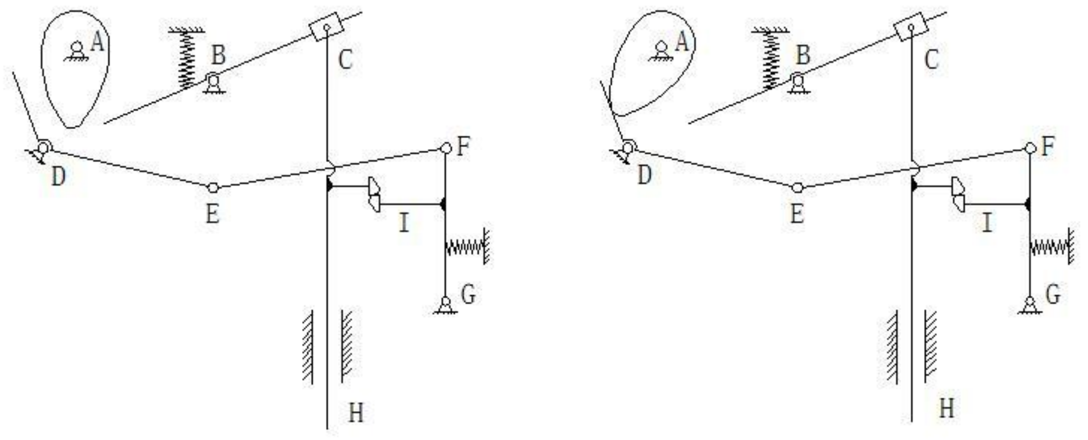
Jumping robot's energy storage mechanism is used for storing and releasing energy, the energy storage-releasing mechanism is mainly composed of tripping and spring-loaded mechanism, it ensures the stability of the entire energy transformation circulation. Tripping and latching are two states of energy storage-releasing mechanism. The mechanism's tripping state is to conduct the process of energy storage, and the latching state indicates the completion of energy storage. Other features and advantages of the mechanism and the manners of its working process will become more apparent and the mechanism itself will be better understood by reference to the following description with the accompanying drawings. The process of energy storage and releasing can be divided into six steps corresponding to Fig.(3a,3b,3c,3d,3e,3f) respectively.



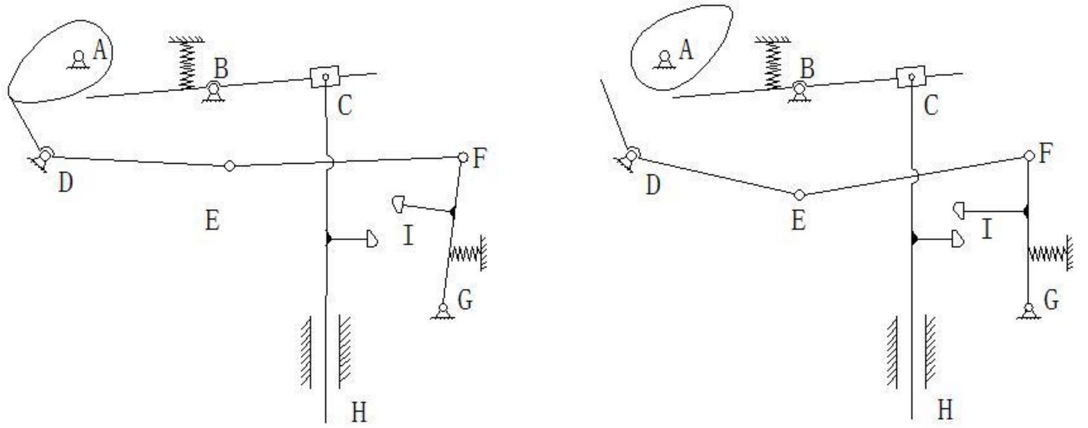
(a)



(b)



(c) (d)



(e) (f)

Fig.3: Kinematic diagram of the energy storage-releasing mechanism in different states

The driving cam rotates clockwise, as is shown in fig.3(a), when it contacts with the loading rod BC, making the loading rod rotates counterclockwise, the rotation of the loading rod makes the linkage CH a vertically upward movement, and the energy storage spring is compressed for energy storage. In this state, the DOF of the mechanism can be calculated as follows:

$$F = 3n - 2P_L - P_H = 3\times 7 - 2\times 9 - 1 = 2 \tag{3.1}$$

When the power rod comes to a certain position, as is shown in fig.3(b), the tripping-contacts connected with the pull rod CH will automatically locked on the rocking rod FG, the pull rod's motion stops, and the process of spring energy storage comes to the end, this is a latching state. In this state, the DOF of the mechanism can be calculated as follows:

$$F = 3n - 2P_L - P_H = 3\times 7 - 2\times 9 - 2 = 1 \tag{3.2}$$

As is shown in fig.3(c), the driving cam separated from loading rod when the spring energy storage process is over, and in this state, the DOF of the mechanism can be calculated as follows:

$$F = 3n - 2P_L - P_H = 3\times 7 - 2\times 9 - 1 = 2 \tag{3.3}$$

The driving cam continues to rotate as is shown in fig.3(d), when it contacts with DE and toggles it to rotate counterclockwise, the rocking rod FG turns to the right side which is driven by four bar linkage's connecting rod EF, the tripping-contacts separated and the mechanism conducts the energy releasing process. At this time, the foot has a great impact on the ground under the effect of the compressed spring and complete the entire jumping process. In this state, the DOF of the mechanism can be calculated as follows:

$$F = 3n - 2P_L - P_H = 3\times 7 - 2\times 9 - 2 = 1 \tag{3.4}$$

The fig.3(e) shows that the driving cam continues to rotate and the tripping-contacts separated from the tripping rod FG, in this state, the DOF of the mechanism can be calculated as follows:

$$F = 3n - 2P_L - P_H = 3\times 7 - 2\times 9 - 1 = 2 \tag{3.5}$$

The rocking rod comes to the initial state under the effect of the spring , and this state can be shown in fig.3(f).

3.2 The singular point support mechanism

The jumping robot uses the singular point support mechanism to finish the jumping action, this mechanism transforms the spring's elastic energy into the entire jumping robot's kinetic energy. The mechanism based on the principle of singular point, its working process mainly includes the following aspects: establishment of dead point, energy storage and releasing, destruction of dead point. The work manners of the singular point support mechanism will become more apparent and the mechanism itself will be better understood by reference to the following description of this mechanism combined with its kinematic diagrams in different working states:

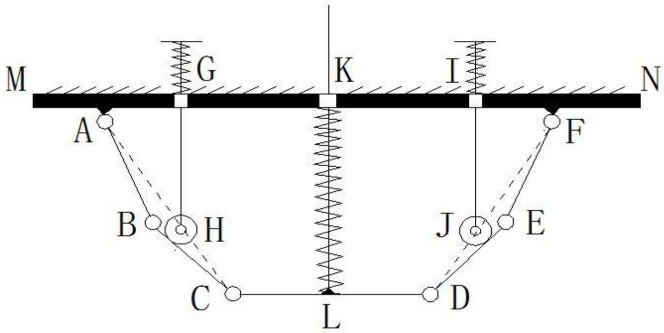


Fig.4: Kinematic diagram in initial state

Fig.4 is the kinematic diagram in initial state of singular point support mechanism, at this moment, the pushrods GH and IJ pushing the linkages AC and DF slightly under the effect of gravity to make them deviated from the dotted line position (dead point position). The DOF of the mechanism in this state can be calculated as follows:

$$F = 3n - (2P_L + P_H - P') - F' = 3\times 9 - (2\times 11 + 2 - 0) - 2 = 1 \tag{3.6}$$

As the DOF is 1, in this state, the mechanism is prepared for the energy storage.

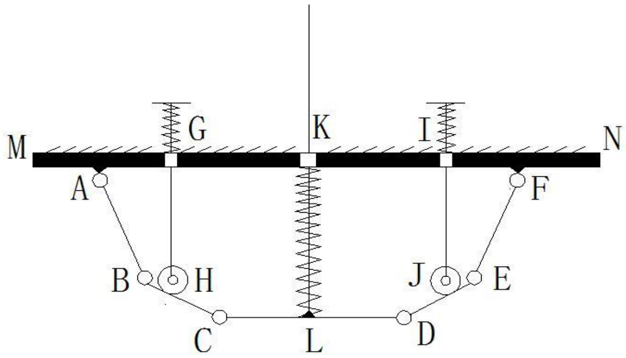


Fig.5: Kinematic diagram in energy storage state

As the driving cam rotates clockwise, toggling the loading rod and making the power rod KL an upward movement, the energy storage spring is compressed for energy storage, its kinematic diagram can be shown in fig.5. The DOF of the mechanism in this state can be calculated as follows:

$$F = 3n - (2P_L + P_H - P^{'}) - F^{'} = 3\times 9 - (2\times 11 + 2 - 0) - 2 = 1 \tag{3.7}$$

In this state, the mechanism conducts the process of energy storage.

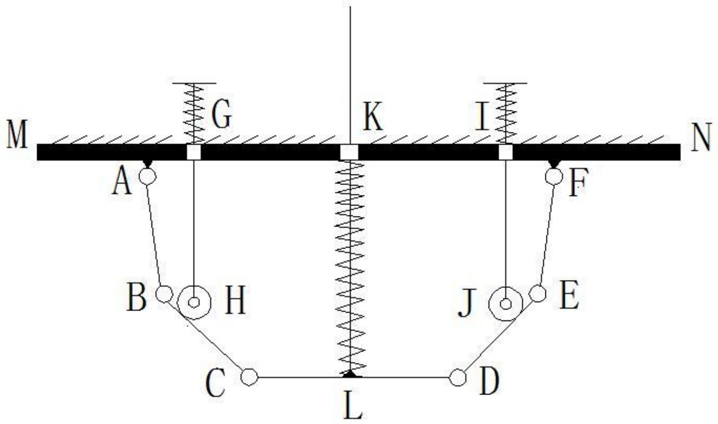


Fig.6: Kinematic diagram in adaptive state

After the energy storage process is completed, In order to increase the instantaneous impact on the ground when conducting the energy releasing process and improve the jumping height, the adaptive mechanism is designed. It ensures the moment when the mechanism contacts ground is coincided with that mechanism dead position condition is constituted. As is shown in fig.6, the points A and F move a certain distance toward the jumping mechanism's axial direction under the effect of the adaptive mechanism, decreasing the distance between the feet and ground to increase the feet's instantaneous impact on the ground and the jumping height. The DOF of the mechanism in this state can be calculated as follows:

$$F = 3n - (2P_L + P_H - P^{'}) - F^{'} = 3\times 9 - (2\times 11 + 2 - 0) - 2 = 1 \tag{3.8}$$

As the DOF is 1, the mechanism is prepared for the energy releasing.

When the driving cam continues to rotate, the slave trigger contacts and the tripping rod rotates clockwise, performing the tripping action, the compressed spring releases the stored energy and this is the energy releasing process. At this time, the kinematic diagram of singular point support mechanism is shown in fig.7.

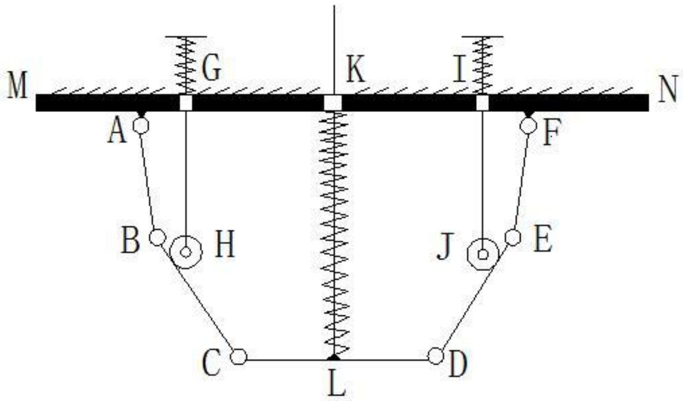


Fig.7: Kinematic diagram in energy releasing state

The DOF of the mechanism in this state can be calculated as follows:

$$F = 3n - (2P_L + P_H - P^{'}) - F^{'} = 3\times 9 - (2\times 11 + 2 - 0) - 2 = 1 \tag{3.9}$$

In this state, the power rod has the downward movement and the energy storage spring is stretched, conducting the energy releasing process. The feet pound the ground and the robot pops up.

When the energy releasing process reaches the critical point, links AB and BC are located on the same line, links DE and EF are also located on the same line. At this time, the mechanism is just in the initial state where the feet pounding the ground and reaching the dead point position. The pushrods are at rest state, the kinematic diagram of singular point support mechanism in this state can be shown in fig.8.

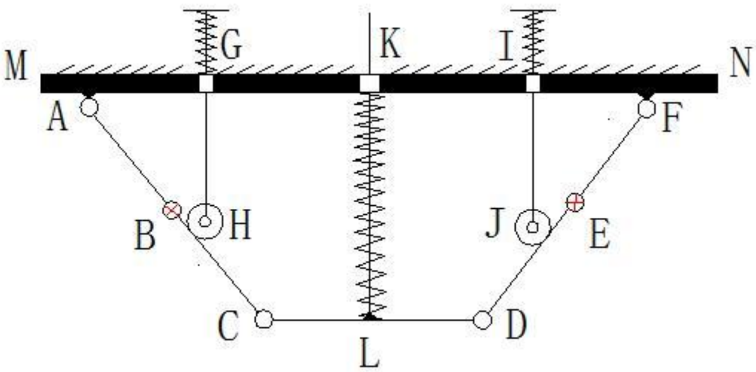


Fig.8: Kinematic diagram in critical state of energy releasing process

The DOF of the mechanism in this state can be calculated as follows:

$$F = 3n - (2P_L + P_H - P^{'}) - F^{'} = 3\times 7 - (2\times 9 + 2 - 0) - 2 = -1 \tag{3.10}$$

The mechanism is statically in indeterminate state and unable to produce a specific motion, the dead point for destruction is required before next energy storage process.

In the energy releasing process, as the feet pounding the ground surface, the energy storage spring's elastic energy transformed into kinetic energy of the base plate and makes the base plate an upward movement, at this time, the dead point rods JH and IJ obtain the downward acceleration relative to the robot's base, it overcomes the spring's force and pushes the rods AC and DF, and then, destroy the dead point of the mechanism. The kinematic diagram of singular point support mechanism at this time is shown in fig.9.

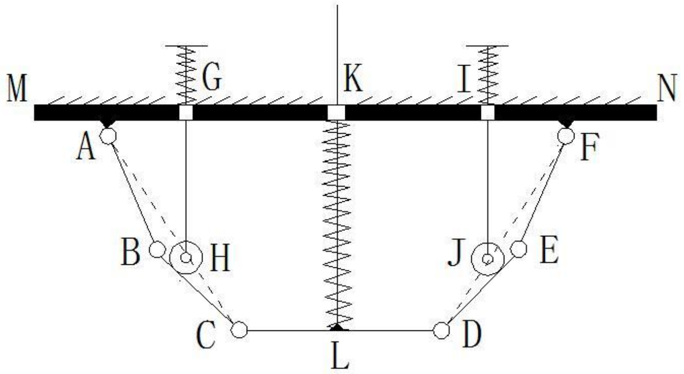


Fig.9: Kinematic diagram in dead point destruction state

The DOF of the mechanism in this state can be calculated as follows:

$$F = 3n - (2P_L + P_H - P^{'}) - F^{'} = 3 \times 9 - (2 \times 11 + 2 - 0) - 2 = 1 \tag{3.11}$$

As the DOF is 1, the mechanism finished the destruction of dead point and recovered to the innitial state, prepared for the next energy storage process. The above-mentioned is a complete circulation of the jumping mechanism.

By analyzing the above-mentioned singular point support mechanism, we can come to the conclusion that the jumping mechanism achieved a transformation of DOF in a working cycle, the variable freedom mechanism can adapt to mangy different occasions and it has a bright future.

IV. Conclusion

(1) A new type of jumping robot based on the characteristic of linkage dead point to finish the jumping process is proposed. It is composed of energy transformation mechanism and singular point support mechanism.

(2) The DOF of energy storage-releasing mechanism in different states was analyzed. The manner of energy loading is simple; energy latch is stable; tripping mechanism is flexible and the trigger is convenient.

(3) The transformation of DOF of the singular point support mechanism in different jumping states was analyzed. The jumping mechanism has a high efficiency conversion rate and a great instant impact on the ground.

(4) The jumping robot model has a wide range of applications in rugged and other complex environment and it also has a broad prospects.

V. Acknowledgements

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