Design and Fabrication of Mechanical Walking Robot using

"Theo Jansen Mechanism"

Mrunal S. Sahastrabuddhe, Ravina R. Pathak, Bhushansingh N. Patil, Rishikesh R. Mane, Prof. Miss.Sana Shaikh, prof.A.M.Dharme

Mechanical Engineering Department, SKNCOE, SPP University, Pune-411041 ,India

Abstract

The wheels are ineffective on rough and rocky areas, therefore robot with legs provided with Theo Jansen mechanism is beneficial for advanced walking vehicles. It can step over curbs, climb stairs or travel areas that are currently not accessible with wheels. The most important benefit of this mechanism is that, it does not require microprocessor control or large amount of actuator mechanisms. In this mechanism links are connected by pivot joints and convert the rotating motion of the crank into the movement of foot similar to that of animal walking. The proportions of each of the links in the mechanism are defined to optimize the linearity of the foot for one-half of the rotation of the crank. The remaining rotation of the crank allows the foot to be raised to a predetermined height before returning to the starting position and repeating the cycle. Two of these linkages coupled together at the crank and one-half cycle out of phase with each other will allow the frame of a vehicle to travel parallel to the ground. This project is useful in hazardous material handling, clearing minefields, or secures an area without putting anyone at risk. The military, law enforcement, Explosive Ordinance Disposal units, and private security firms could also benefit from applications of mechanical spider. It would perform very well as a platform with the ability to handle stairs and other obstacles to wheeled or tracked vehicles.

***keywords**- Theo Jansen's Mechanism, synthesis of mechanism ,design, mechanism linkage.*

1.INTRODUCTION

A legmechanism (walking mechanism) is an assembly of links and joints intended to simulate the walking motion of humans or animals. Mechanical legs can have one or more actuators, and can perform simple planar or complex motion. Compared to a wheel, a leg mechanism is potentiallybetter fitted to uneven terrain, as it can step over obstacles.

Jansenlinkage is a planar leg mechanism designed by the kinetic sculptor Theo Jansen to simulate a smooth walking motion. Jansen has used his mechanism in a variety of kinetic sculptures which are known as strandbeesten Jansen's linkage bears artistic as well as mechanical merit for its simulation of organic walking motion using a simple rotary input. These leg mechanisms have applications in mobile robotics and in gait analysis. When two Jansen linkages are connected to each other by a rotating horizontal shaft, both the legs help the machine to move forward or backward depending on the clockwise or anticlockwise rotation of the shaft.

This is closely comparable to a wheeled arrangement in cars where two wheels are connected on both sides of a rotating axle and the shaft rotates by 120 degrees per stride. Interestingly, the relationship of the hind limb with the fore limb is antiphase, thus helping them to move forward cooperatively. The parallel link in the Jansen linkage helps the linkage to attain the required step height by folding during the cycle angling of the leg. These leg mechanisms have applications in mobile robotics.The central crank link moves in circles as it is actuated by a rotary actuator such as an electric motor.

All other links and pin joints are unactuated and move because of the motion imparted by the crank. Their positions and orientations are uniquely defined by specifying the crank angle and hence the mechanism has only one degree of freedom. The Theo Jansen mechanism, which is a single degree of freedom mechanism composed of eight or more legs. Applications of this legged mechanism go beyond human-powered machines such as multi terrain personal transport, multi terrain wheel chair, beach vendor carts, robotic house pets, and steam punk walking ship.

2.THEO JANSEN MECHANISM

Legged robots are a type of mobile robot which use mechanical arm for movement. These robots are more versatile than wheeled robots. It is known that animals can travel over rough surface at speeds much greater than wheeled or tracked vehicles. Wheeled vehicles are not suitable for rough surface due to some reasons. It is also practically impossible for most automobiles to move over vertical surfaces. Even on very sandy and circular edge surfaces most automobiles slip frequently. The facts are that, there is still a lot of scope left for changing the way in which humans or vehicles exchange in the 21st century.

The invention of new ways of modifying an existing mechanism can enable various applications of the science and technology. One of the most useful applications for these new mechanisms could be easy movement of a vehicle over off-road or roads destroyed because of earthquake, tsunami or any other natural disaster. Another useful application is use of locomotive mechanism of vehicle used for mining. Mining site are extreme bumpy and rough, so roads have to be made for it but it will cost more to mining industry and also increases emission level but making road separately enable smooth mining operation. The problem can easily be solved with mechanisms that can help the vehicle to move easily over any type of surface. The main advantage of Theo Jansen mechanism robots is their ability to access places impossible for wheeled robots. Copying the physical structure of legged animals, it may be possible to improve the performance of mobile robots. To provide more stable and faster walking, scientists and engineers can implement the relevant biological concepts in their design.

The most forceful motivation for studying Theo Jansen mechanism robots is 1.To give access to places which are dirty and 2.To give access to places those are dangerous. Highly difficult jobs can be easily done by legged robots used for rescue work after earthquakes and in hazardous places such as the inside of a nuclear reactor, giving biologically inspired autonomous legged robots great potential. Low power consumption and weight are further advantages of walking robots, so it is important to use the minimum number of actuators. the figure below shows the actual leg based on Theo Jansen linkage mechanism.

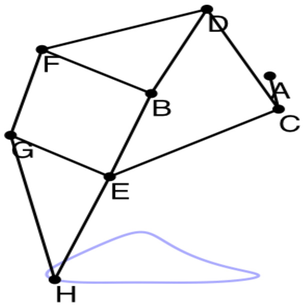

fig.1.Theo Jansen linkage [5]

3.DESIGN

The easy aspect of Theo-Jansen Mechanism is that it has been provided with a specific set of dimensions which can be scaled to any level. standard dimensions are as given below;

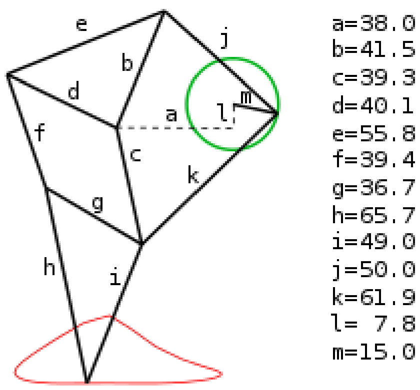

fig.2.standard link dimensions [1]

Here, the standard dimensions are multiplied by 1.5 for the purpose of scaling. To produce the 3D CAD model, CATIA software we have used.

There are total three types of synthesis of mechanism,

1. function generation
2. path generation
3. motion generation (rigid body guidance)

among above 3 types of synthesis of mechanism with reference to the demand of application and previous research papers, we have decided to use function generation.

Based on data relevant to the application, we decided the function $y=5x$ where x varies 1 to 5. Initial position of the input link is 10 deg. and the final position of the same link is 50 deg. with reference to the vertical axis. while doing the synthesis during the function generation, we will assume the length of input link and fixed link in that mechanism. length of the remaining two linkages(output link and coupler link) can be determined. Here, the output link is considered as the leg of the robot.

As there as two methods; Analytical method(freudeinstein's equation) and graphical method (Inversion and relative pole method),as we can extend the analytical method the programmable solution also, it is convenient to use this method. the above synthesis technique is used to synthesize the mechanism where three finitely separated positions of input and output links are known. Here according to this type, the movement of the driver or the input link can be represented by input variable x and that of the driven link or the follower by the dependent variable y. Both of them may have some prescribed functional relationship as *y=5x.*

The following steps are followed to determine the length ratios,

1. Obtained three accuracy points by using Chebyshev's spacing i.e. x_1, x_2 and x_3 from the equation

   x_i=a+$b\cos\frac{(2m-1)\pi}{(2k)}$where m = 1,2,3 ....(1)

   where $a=(x_i+x_f)/2$. and $b=(x_f-x_i)/2$, k= number of accuracy points.

2. Obtained he corresponding values of y_1,y_2 and y_3 by using given function *y=5x.*
3. By using equations $(\theta - \theta_i)/(x - x_i) = (\theta_f - \theta_i)/(x_f - x_i) = k$ and similarly

   $(\phi - \phi_i)/(y - y_i) = (\phi_f - \phi_i)/(y_f - y_i) = k$ ....(2)

   Determined (θ_1, θ_2, θ_3) and (ϕ_1, ϕ_2, ϕ_3) corresponding to values of x and y.

4. Obtain three equations in k_1,k_2 and k_3 by substituting the three related pairs of the angles θ_1 and ϕ_1, θ_2 and ϕ_2, θ_3 and ϕ_3, in equation $\cos(\theta\text{-}\phi)= k_1\cos\phi- k2\cos\theta=k_3$...................................(3)

   where $k_1=p/q$, $k_2=p/t$ and $k_3=(p^2+q^2-s^2+t^2)/(2qt)$.

5. Solved these three equations for k_1,k_2 and k_3.
6. Determined length ratios from values of k_1,k_2 and k_3.
7. Assumed one link length and determined other lengths which can be determined from the length ratios.

Following figures show the CAD model of links designed using CATIA software.

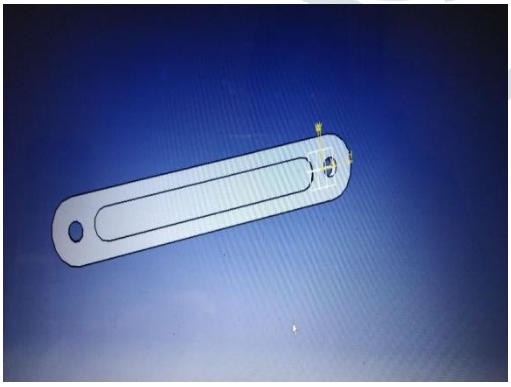

fig.3. binary link (total 4 in number)

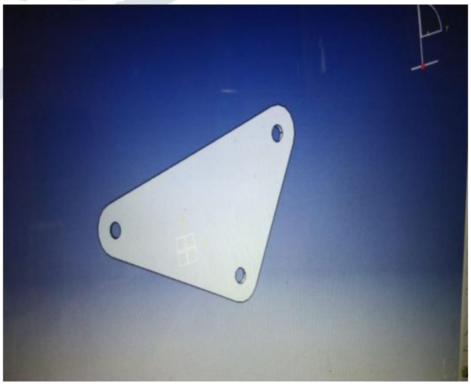

fig.4 .ternary link (total 2 in number)

so the final dimensions of the links are as given below.

1. length of link a = 57mm.
2. length of link b = 62.25mm.
3. length of link c = 58.95mm.
4. length of link d = 60.15mm.
5. length of link e = 83.7mm.
6. length of link f = 59.1mm.
7. length of link g = 55.05mm.
8. length of link h = 98.55mm.
9. length of link i = 73.5mm.
10. length of link j = 75mm.
11. length of link k = 92.85mm.
12. length of link l = 11.7mm.
13. length of link m = 22.5mm.

4.CONCLUSION

A new type of walking robot based upon Theo Jansen mechanism is presented. From the Kinematical analysis results it appears that the acceleration of the end point of the foot has a low value. This is important to obtain a smooth motion and a reduced impact at the contact with the ground during walking and it represents an advantage in using this type of mechanism for building a walking robot. This is the study about the Theo-Jansen four leg walking robot. The objective is built up new mechanical robotic walker using eight bar link mechanism. In future we have to use this robot to perform different type of operations automatically by using sensors.

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