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MODELLING AND FABRICATION OF QUADRUPED ROBOT BASED ON THE OJANSEN MECHANISM BY USING MATLAB

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ABSTRACT

Legged off-road vehicles exhibit better mobility while moving on rough terrain. Development of legged mechanisms represents a challenging problem and has attracted significant attention from both artists and engineers.The Theo Jansen mechanism is gaining widespread popularity among the legged robotics community due to its scalable design, energy, efficiency, low payload-to-machine-load ratio, bio-inspired locomotion, and deterministic foot trajectory. It bears artistic and mechanical merit for its ingenious simulation of walking legs from a simple rotary motion. In this paper, the model of four legged robot is made by using The oJansen kinematic link. the perform the dynamic modeling and analysis on a four–legged robot driven by asing leactuator and composed of The oJansen mechanism the projection is made by using MATLAB and linear motions are observed on the graph for the oJansen based quadruped robots.

Keywords: Mechanism kinematic chain, kinematic pairs, crank, The oJansen mechanism, MATLAB

I. INTRODUCTION

A four-bar linkage, also called a four-bar, is the simplest movable closed chain linkage. They perform a wide variety of motions with a few simple parts. This paper involves the design, synthesis and fabrication of one such mechanism (four bar mechanism). In this paper four Leg Kinematic movement works on Theo jansen walking mechanism motion which deals the relation between the links. This mechanism satisfying his condition and fall into slider crank mechanism. A frame, connecting rod, crank & a lever constitute to obtain the required motion.

1.1 Linkages

A linkage is a collection of links connected by joints. Generally, the links are the structural elements and the joints allow movement. Perhaps the single most useful example is the planar four-bar linkage. However, there are many more special linkages:

Watt's linkage is a four-bar linkage that generates an approximate straight line. It was critical to the operation of his design for the steam engine. This linkage also appears in vehicle suspensions to prevent side-to-side movement of the body relative to the wheels. Also see the article Parallel motion.

The success of Watt's linkage lead to the design of similar approximate straight-line linkages, such as Hoeken's linkage and the ojansen linkage The Peaucellier linkage generates a true straight-line output from a rotary input. The Sarrus linkage is a spatial linkage that generates straight-line movement from a rotary input. Select this link for an animation of the Sarrus linkage. The Klann linkage and the Jansen linkage are recent inventions that provide interesting walking movements. They are respectively a six-bar and an eight-bar linkage.

1.2 Mobility

The configuration of a system of rigid links connected by ideal joints is defined by a set of configuration parameters, such as the angles around a revolute joint and the slides along prismatic joints measured between adjacent links. The geometric constraints of the linkage allow calculation of all of the configuration parameters in terms of a minimum set, which are the input parameters. The number of input parameters is called the **mobility**, or degree of freedom, of the linkage system.

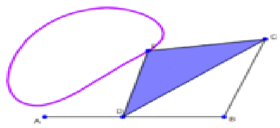

Fig 1.1 Simple linkages are capable of producing complicated motion.

A system of *n* rigid bodies moving in space has *6n* degrees of freedom measured relative to a fixed frame. Include this frame in the count of bodies, so that mobility is independent of the choice of the fixed frame, then we have M=6(N-1), where N=n+1 is the number of moving bodies plus the fixed body.

Joints that connect bodies in this system remove degrees of freedom and reduce mobility. Specifically, hinges and sliders each impose five constraints and therefore remove five degrees of freedom. It is convenient to define the number of constraints *c* that a joint imposes in terms of the joint's freedom *f*, where *c=6-f*. In the case of a hinge or slider, which are one degree of freedom joints, we have *f=1* and therefore *c=6-1=5*.

Thus, the mobility of a linkage system formed from *n* moving links and *j* joints each with f_i, $i=1, ..., j$, degrees of freedom can be computed as,

$$M = 6n - \sum_{i=1}^{j}(6 - f_i) = 6(N - 1 - j) + \sum_{i=1}^{j} f_i,$$

where*N* includes the fixed link. This is known as **Kutzbach - Gruebler's equation.**

1.3 Four Bar Mechanism

When one of the links of a kinematic chain is fixed, the chain is known as mechanism. It may be used fortransmitting or transforming motion e.g. engine indicators, typewriter etc. A mechanism with four links isknown as simple mechanism, and the mechanism with more than four links is known as compoundmechanism. When a mechanism is required to transmit power or to do some particular type of work, it thenbecomes a machine. The mechanism, as shown in figure1.1 has four links and four binary joints, i.e.l = 4 and j = 4. (l=No. of links, J=No. of Joints)

n=3(l-1)-2*J

n = 3 (4 – 1) – 2 × 4 = 1- One Degree of Freedom

In this paper, researchers used 4 set of four bar mechanism.

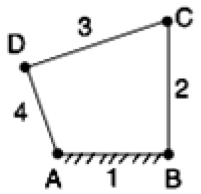

Figure 1.2 Four bar Mechanism

II. LITERATURE REVIEW

A large number of research papers have been studied on four bar link mechanism. A review of related literature has been described as under:

In thischapter I will describetwo existingcrank-based walking linkagesand assesstheirenergy efficiency and thequality oftheirloci both quantitatively and qualitatively. I will begin with the Hrones-Nelson four bar linkage and continue on to the more complex Theo Jansen mechanism. I have chosen to compare thesetwo linkages becausethey are both comprised solely ofrigidtriangular bodies attached to four-bar linkages. As demonstrated in Figure2.1.1 when two hinges ofa three-barlinkageare fixed, then the third hinge must also be fixed. Inother words,a triangle with sides of fixed lengths must also have anglesof fixed lengths. However, when two hinges of a Four bar linkage are fixed the other two hinges are free two move in one dimension.

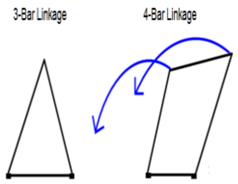

Figure 2.1.1: Three bar and four bar linkages with two fixed hinges demonstrating movement of remaining hinges.

The Hrones-Nelson and Theo Jansen mechanisms are shownbelow demonstrate the similarity oftheir designs. The Hrones- Nelson mechanism is comprised of one triangular structure attached to a fourbar linkage whosemovement is driven directly by a crank. TheTheo Jansen mechanismis comprisedoftwo fourbar linkagesattached to each other in series withonly one ofthe four barlinkages driven directlyby the crank;

Thefour barlinkages share one hingein commonand are separated bya rigid triangular structure onone side. Additionally, another rigid triangle is attached to the linkage to create the“foot” ofthemechanism,as is the case in the Hrones-Nelson model.

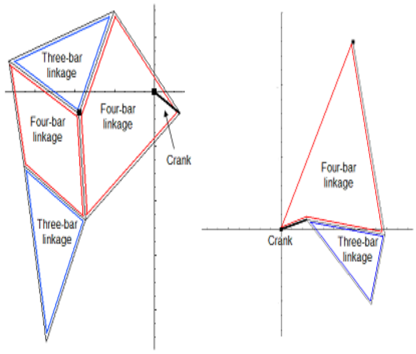

Figure 2.1.2: Theo Jansen (left) and Hrones-Nelson (right) Mechanisms with four bar linkages highlighted in red and three bar linkages highlighted in blue to show similarity of design.

In this analysis I used Wolf ram Mathematical to solve for andplot the center of mass, position, velocity, acceleration, and kinetic and potential energies of the elements ofthe linkage. I used this information to determine the potential and kinetic energy of the linkage throughout the locomotive cycleandevaluate theloci ofeach mechanism for quality oflocus. All Mathematical code is locatedin Appendix A for reference.

2.1 Early walking machines

History records many attempts to create machines that use legsn place of wheels. The following table lists early walking machines that have been identified during research.

1.In the year 200AD the china maker Zhunge Liang was designed a walking mechanism i.e Wooden ox, a transport vehicle used for military supply. Something it refers to the wheel barrow.

2.in the year 1770 the UK maker Richard Edge worth was designed a walking mechanism i.e A wooden horse with eight legs, capable of leaping over high walls. In spite of forty years work and hundreds of models, he was never able to make the idea work.

3.in this year 1968 the U.S.A maker General Electric was designed a walking mechanism i.e Walking truck. Capable of up to5 mp hand could climb over large obstacles.

4. in this year 1976 U.S.A maker Frank & McGhee was designed a walking mechanism i.e “Phony Pony”. First computer controlled walking machine

III. MODELING AND FABRICATION OF THEO JANSEN MECHANISM

The optimized Theo Jansen mechanism and numbering system are shown in the figure below. The linkage lengths were taken directly fromTheo Jansen’sbook TheGreat Pretender.Theblack squares at points 0and 3 in thediagramindicateto location of fixed points in the linkage. Point0 is thecrank axis and maintains a constantrelative positionto point 3 throughout thelocomotive cycle. Inthisanalysis I will always fix point 0 at the origin andpoint three at (-38,-7.8).

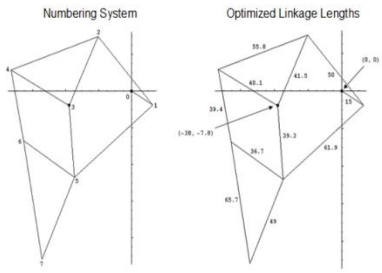

Figure 3.3.1: Diagram of The o Jansen mechanism

DiagramofTheo Jansenmechanismshowing numbering systemand optimized linkage lengths to be used later inthis analysis. In this paperhinge 1 maybe called "the crank" and hinge seven may be called"the foot."Hinges 0 and 3 have fixed positions relativeto eachother for the entire locomotive cycle; theconvention inthis analysis willbe fix hinge0 at the origin and hinge3 at (-38,-7.8).

The following figure shows the results ofthe previous plots with an image ofthe full Theo Jansen mechanism at an arbitrary time step plotted on top.

IV. PROCESS INVOLVEMENT

For Fabrication of four leg kinematic walking machine involved the following process.

Selection of sizes of all components lie links and legsetc

Cutting the materials

Selection of Motor

Drilling of centre rod

Fixing motor

Final finishing work, etc

V. PARTS OF THE WALKING MACHINE

A complete walking machine is as shown in figure 5.1 and their components details are given below:

(i) Complete link set: Four sets of links were used for this machine. Sheet metal 25 mmX4 mm thicknesses is used. Cutting, drilling and grinding processes have been involved.

(ii) Crank : It is made up of sheet metal rod of 26 mm gauge . Turning, facing and Drilling processes have been involved.

(iii) Body: It is made up of sheet metal plate of 25 mm gauge having dimension mm.

Cutting, bending, drilling and processes have been involved.

(iv) Bushing: It is made up of brass in eight numbers. Cutting, facing, turning, drilling reaming andchamfering processes have been involved.

(v) Eccentric: It is made up of wood of 5 mm thickness of dimension mm and the Carpentry, drilling and processes have been involved.

(vi) Motors: A DC Motor of 12 Volt with a current rating of 14 Amps is to produce the movement ofthe machine. The motor is internal geared one. So it is strong enough to give the required torque.It can give two different speeds in one direction and two different speeds in the opposite and its rpm is 500. direction.

(viii) Final Finishing: After connecting the links, lot of adjustments was did to make the perfectalignment and reduce the friction. After that the remote control unit and sensor unit is fixed.Finally the cover was made and painted.

(viii) Programming Board: linear control system board used in the mechanism

(ix)microcontroller: AT89c52 controller used in this programming Board and it have the 40 pins.

VI. RESULTS AND DISCUSSION

When the linkages are connected as per the drawing, it produces the motion same like Theo jansen mechanism. The path of the legs was analyzed by using the AutoCAD software and MATLAB software. Forevery 30° rotation of the driving arm, the path of the end point (M) was identified and joined. The path trace by leg is The first point is at the position where the driving link is at horizontal. At 0° the leg (point M) is at the maximum height. The analysis starts when the driving link rotates counter clockwise. It is noted that afterthe third point (60°) the leg remains straight line position approximately till the 11th point (300°). At the 11the point the leg is raised till the first point or 13th point. After the first point the leg moves downward towardsthe ground till the third point (60°). Out of 360°, the leg remains parallel (straight) for 240° rotation. There maining120° angle is used for the next step movement of the leg. During the angles 270°, 300°, 330° theleg goes left side of the driving arm. In the remaining angles the leg is at the right side of the crank only. The coordinate point (x,y) of four bar link mechanism using empirical equation (i) and (ii) are given in the tableby placing the value $p = 50$, $r = 30$, $a = 60$ and $\theta = 0°,30°,60°,120°,180°,270°$ and360° from the table

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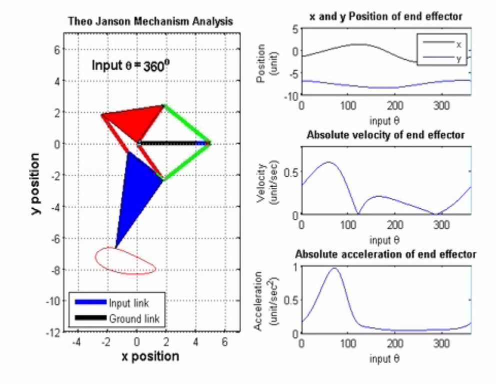

Figure no 6.1

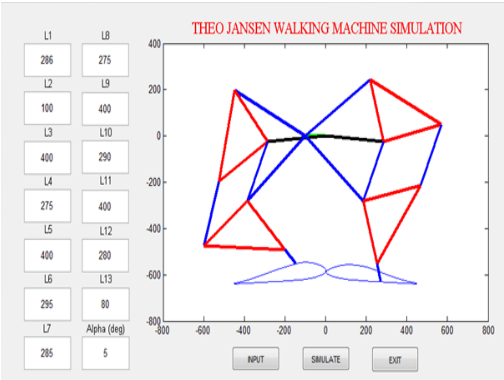

Figure 6.2 the trajectory of the legs movement of the Theo Jansen mechanism

In this figure 6.2 Explains the trajectory of the legs movement of the Theo Jansen mechanism.

Table 1.

In the below table represents the coordinate systems of the Theo Jansen leg path in this crank angles considered from 0^0 to 360^0 but incorporated only seven positions as given .its path is shown in the figures 6.1 and 6.2

Position. No.	∂	**X**	**Y**
1	0	30	126
2	30	109.6	92.3
3	60	115.5	89.1
4	120	88.3	92.1
5	180	30	89.5
6	270	-8.6	81.2
7	360	30	126

Table 1. the coordinate systems of the Theo Jansen leg path

VI. CONCLUSION

It has been compared and noted that the path tracing of the leg by using MATLAB is same.Since this is a moving mechanism, lot of problems were encountered during fabrication and assembling. Initially it was started with little big dimensions. Because of that, it was more weight and lengthy legs. When the assembly moved, the legs tends to bend and so that the motor could not drive it. Then the dimensions of the links are reduced and it was repeated.The main problem faced in this machine fabrication is the alignment of the rotating and moving parts. Anyhow researcher has tried our level best and completed. This walking machine can be upgraded with sensors and microcontrollers.

VII. FUTURE SCOPE

In future for the Theo Jansen mechanism there is provision to upgrade by using different optimization techniques are suitable to fulfill the different mechanism in kinematic links.

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