Design and Simulations of Walk Link

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Abstract**—***since the wheel was invented back in the Stone Age, it was the primary component used in all forms of mechanical transportation. Even today it is the component of choice for almost any type of moving machine like cars. However, the wheel has always had a major disadvantage with short instant elevation changes like stairs. For most uses, climbing stairs or steep jagged rock piles is not a problem which is why the wheel is still almost always used. For the other applications, people looked at animal and human legs which are already proven to work effectively on this type of terrain. The two most effective leg mechanisms are currently Joe Klann's mechanism which resembles a spider leg and Theo Jansen's mechanism which resembles a human leg. We have chosen Theo Jansen's mechanism which has more advantage than Klan's mechanism. The main objective of our paper is to replace the function of wheel with an alternative in order to overcome the difficulty of travelling in uneven terrain. This paper is useful in hazardous material handling, clearing minefields or secures an area without putting anyone at risk, walking in slant positions, walking in mud without struck.*

Keywords—*Joe Klann's Mechanism, Theo Jansen's Mechanism, Steep Jagged Rock piles, Material Handling.*

I. INTRODUCTION

Transporter vehicles have traditionally used wheel mechanisms like cars and trains. Wheels are ideally suited for movement without vertical fluctuations of the body, and tires with inner rubber tubes absorb shock from a rugged road. On the other hand, biologically-inspired robotics learn mobile flexibility from the morphology of multiple legs and their coordination [1]. Good examples of this are arthropods, like spiders, and the robots are conventionally designed with actuators placed in every joint. In such implementation, robots are good tools to investigate how an animal moves, but they are unable to be a substitute principle for wheels because they don't much take into account the maximum load capacity [2]. Joint's actuators promise mobile flexibility, while the actuator's torque performance impacts on the toughness of the robot's body.

Therefore, in the design of disaster robots, which need to move on rubble and carry rescue devices, continuous tracks or crawlers are popular [3].

Theo Jensen, a Dutch kinetic artist who has attempted to create a bridge between art and engineering by focusing on biological nature, proposed a linkage mechanism to mimic the skeleton of animal legs. This is called "Theo Jansen mechanism," and provides the animal with a means of moving in a fluid manner. Interestingly, his artificial animals require no electric power for actuators, and do work by weak wind power to drive the gates of multiple legs through a transformation of internal cyclic motion to an elliptical orbit of the legs [4-6].

Even in a version where the body was heavy and five meters in height, the linkage mechanism worked smoothly for walking with minimal power loss. Concepts of the linkage mechanism are in fact found extensively in heavy industrial machines, which are accompanied with hydraulic actuators, such as cranes and shovels. Thus, the linkage has the potential to act as a substitute for wheels, especially in rugged fields. A problem with the Theo Jansen mechanism is the availability and extensibility of walking patterns under bumpy conditions.

The current mechanism concentrates on smoothness at the precise moment the legs touch the ground, and minimizes the force of impact in the toe in order to prevent vertical fluctuations of the body and the breakage parts in the case that the body is heavy. It brings weakness in adaptation to changes of walking fields especially in the presence of obstacles. In order to lift the legs during locomotion, an extension mechanism is crucial for transitions between walking and climbing modes. We investigate the possibility of designing a Theo Jansen mechanism involving multiple modes and the generation of a continuous orbit of the legs connecting them. Finally, we propose a solution by using an additional up-and-down motion placed at the joint center [7-9].

A. *Materials Used*

Circular wooden Discs

Aluminum rod (Shaft)

Thin Chain Drive

Ball Bearings (6000 RPM)

Speed Resistor

3 HP Motor

Cut Wooden Pieces

Nuts, Bolts and Washers

M-Seal

Fig. 1Materials used for the walk link.

B. *Other Materials*

Drilling Machine, Drill Bits, Hacksaw Blade, Measuring and Drawing Instruments, Screw Drivers, Spanners, 1.2 module gears (2 nos.)

The materials used for the link mechanism are plank wood material for legs to walk and a general wood strips of 5-7 mm thickness for joining. Using measuring and drawing instruments, mark the required markings on the material. Hacksaw blade is used to cut the wood material. Drilling machine is used to drill holes on the wood and assembled using nuts, washers and bolts. The circular discs are attached in such a way that the links attached to the rod (i.e. Shaft) rotates in opposite direction to each other. Two 1.2 module gears, one attached to shaft and other to a 3 HP motor are connected by a chain drive. A speed resistor is connected to the motor to regulate the speed of the motor to a required speed. The motor is given power supply for the operation. The following data is tabulated as per the observations [10-13].

TABLE I

Variance in speeds with respect to change in module.

S. No	Module	Speed (RPM)	Steps/min
1	Red	6000	603
2	Black	3000	354
3	Yellow	1000	180

II. System Design

As mentioned earlier we intend to design a replacement for tyres in load carrying trucks in mineral excavation belts which face a lot of wear and tear due to poor haul road construction. To make the design possible I needed reference data. Using the information power of the internet I came across a report journal on "Finite Element Stress analysis of a solid tire".

This issue belongs to (Journal of achievements in material and manufacturing engineering-Volume 31

Issue 2 December 2008). The report involves the standard Finite element analysis of a solid tire and deflections produced in it on application of load. The detail related to the analysis is given further in the report. With reference to the Journal report I decided the dimensions of our setup. The easy aspect of Theo-Jansen Mechanism (STRANDBEEST) is that it has been provided with a specific set of dimensions which can be scaled to any level, bet it on a small scale as in toys or an industrial scale, i.e. my idea.

As we show above, these dimension sets are standard and can be used as a scaling reference. During the course of the research it was also found during rough designing that irrespective of the length of the linkages involved the system worked perfectly and the only drawback faced was low stride height.

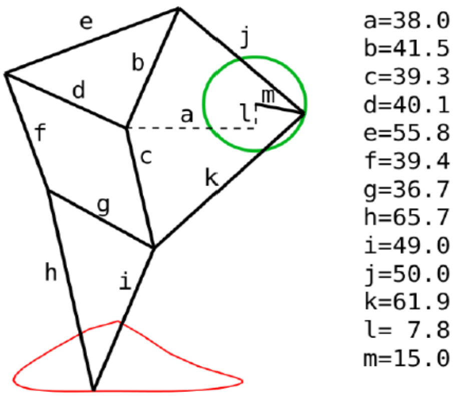

Fig. 2Dimensions scale taken as reference

Fig. 3Prototype model as per the dimensions

Before proceeding further I need to explain about the stride pattern in walking mechanisms. Every linkage based walking mechanism either autonomous or manually operated follows a certain pattern while moving. These patterns can be represented as imaginary geometric figures which can be further studied to improve the walking and make it smoother. The more edgy the stride pattern the more jerky the motion of the mechanism. A lot of online reports have been prepared where students from different universities have come up with ideas to replace wheels in cycles and also mechanism for bearing heavy loads and can be moved smoothly. With reference to these projects I referred to the stride pattern of the Jansen mechanism.

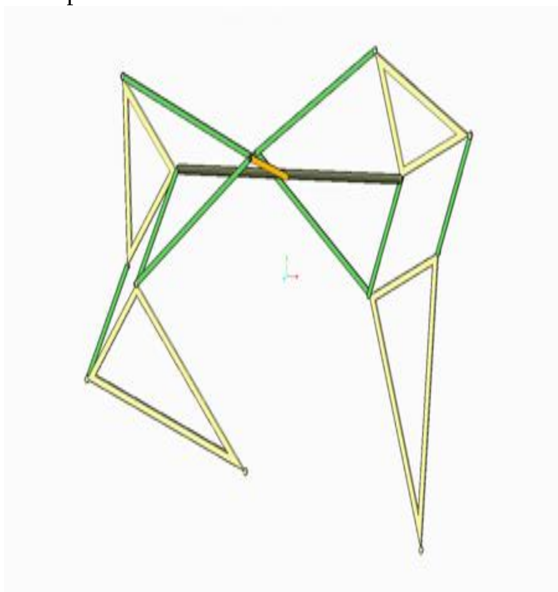

Fig. 4Software Designed Model (Auto CAD)

With these references for help I started to develop a design for the system considering dimension in comparison to the tyre analysis report. Initially I came up with a rough line diagram of the design as seen from the right-side view and depicted its motion pattern segregated into three unique diagrams. The following gives a brief description of the motion of the vehicle and its relative placement under the chassis of the truck.

The below figures give a brief idea of how the system might work. On considering a practical model of the above line diagram, we intend to replace the front and rear axle along with the tyres with this unique mechanism where in each axle both front and rear will have 4 sister pairs. Thus, we would have 8 pairs in total and overall all 16 legs to support the system.

From our survey related to mining and transport we found that a standard truck while loaded has to bear a load up to 16,000 kg. Keeping that in mind I intend to design the system to bear static load of 16,000 kg and accordingly carry out compressive stress analysis across its T joint sections while the body is in static condition. Taking into consideration the analysis report of the tyre I found that the dimensions of a standard tire. The tire model has an outer diameter of 518 mm, 218mm inner diameter and a tyre width of 144 mm. On further calculation, I found the standard dimensions of the mechanism has to scaled 4 times its original and that is how I came up with the standard model which I drew using NXCAD. The following depicts a brief model of on unit, i.e. two sister pairs.

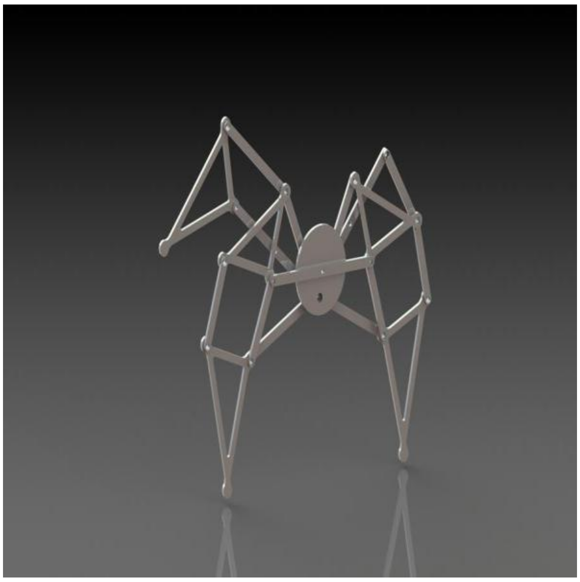

Fig. 5Software Designed Model (PTC Creo)

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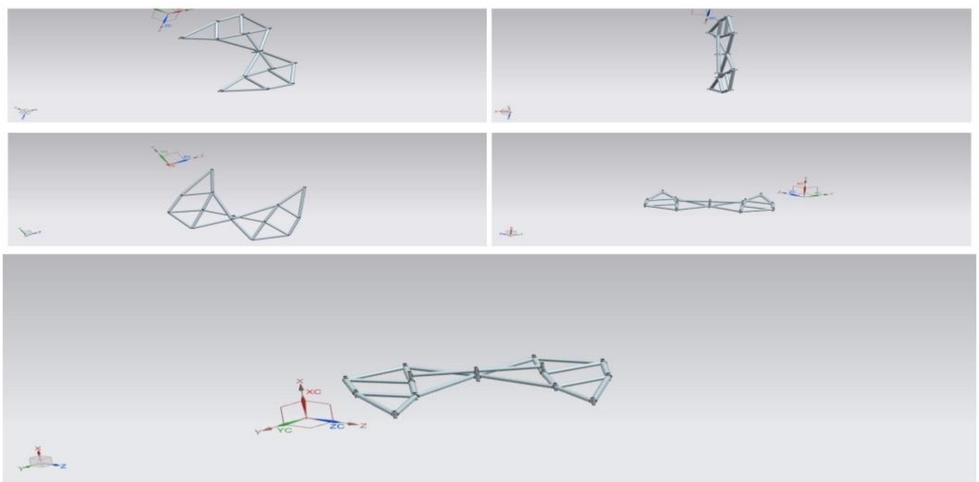

Fig. 7The Views of the links in different positions

It can clearly be pictured from the above view that how the sister pairs would look like and their connection with each other using T joints. In order to establish the dimensional stability I matched the dimensions of a reference tyre module whose analysis is report is given further and limited the dimension within the diametrical vicinity of our module.

Using our calculated dimensions I was finally able to apply it on one leg and create a simulation where in the one sister unit is used for walking. The following images depict the motion of the leg.
The prototype views are shown in the fig 8&9.

Fig. 8Front and top view of proto type

Fig. 9Side view of the proto type

III.Evaluation Of Final Design

No more The final designed Theo Jansen device was evaluated through a walking test and its PTC Creo model was also simulated through a computer. The test results indicated that the designed linkage system performed very well in the walking test and successfully met all design requirements. It was proved that the Theo Jansen's ratios ('13 Holy Numbers') can be used to determine the link lengths for a linkage system. By using these numbers, the designer only needs to choose an arbitrary length for one link and all the other link lengths can be easily calculated. Also, the method of construction was proved to be practical, allowing only a small amount of looseness in the link joints.

From the assembly test, it was evident that a high precision in fabricating and assembling is critical to guarantee the clearance between crank throw and link so as to avoid binding. In order to eliminate warping, heat-resistant material such as plywood was used to make the base plate and the wood materials were given enough time to cool down before the clamps were released.

Critical to the design of any Theo Jansen device is the power input to the crank shaft. As found in this project, gear transfers and adapters should be omitted in a design if possible because they would reduce the drive train efficiency and may cause slip. Also, motors with sufficient torque need to be selected based on the walker/linkage design. In this project, AC motors were selected to provide enough input torque. However, in the future, powerful DC motors need to be used instead of AC motors, which allow the use of remote control electronics in the original design and enable independent control of each linkage set. All the machining, fabricating and assembly works were finished in the manufacturing workshop of the Mechanical Engineering Department at the GMRIT.

IV.Problem Analysis

Assuming all of our calculations are correct and that we are able to obtain all materials specified in this design, we should be in good shape going forward with his project. It is of utmost importance that we do not fall behind schedule. Because of the amount of machining necessary for the completion of this project, we need to be proactive and begin as soon as possible in creation of parts so that we leave plenty of time for assembly, testing, and troubleshooting. Aside from staying on schedule, we will most certainly run into problems of our machined parts not fitting together exactly as we had expected. This will have to be dealt with on a part-by-part basis to come up with a workable solution.

V. APPLICATIONS

- AGRICULTURE MACHINERY EQUIPMENT.
- RESEARCH AND DEVELOPMENT IN ARMY AND OTHER TECHNOLOGIES.
- IT CAN REPLACE DAILY WAGE WORKERS.
- MINING EXCAVATIONS SYSTEM.
- ROBOTICS.

VI. CONCLUSION

This paper introduces a way to enhance teaching effects in an engineering design course by using the Theo Jansen 'Extreme' design project. Feedbacks from the students indicated that this project is an educational and rewarding task, in which diverse knowledge and techniques such as engineering design, computer modeling and drawing, kinematic analysis, materials, machining, fabrication, electronics and many other aspects of engineering were applied. In this project, students were able to apply their previous experience in machining and fabrication, use design techniques learned from the Engineering Design course and even refer to the knowledge attained from other resources (Internet, library, etc.) to make logical decisions and attain an optimal prototype along the process. The experiences of teamwork and budget control in the project exposed the students to real-world industrial or research problems. After finishing this design project, each group explained their design procedure and demonstrated the prototype through oral presentations. They also documented all the design works, analysis results and conclusions in a technical report. The experiences of oral presentation and drafting a technical report developed students' oral and written communication skills.

As for the actual walker mechanism, much was learned about Theo Jansen devices during the course of this project, including joint quality, required number of linkage sets for stability, weight considerations and driven power availability, etc. With all the knowledge and techniques acquired from the project, the students were confident about designing and fabricating a greatly improved Theo Jansen device within a shorter time.

In summary, the project gave students unique experiences in team-based design, build and analysis; thus, all the objectives of the Engineering Design course as required by ABET were satisfyingly met. An assessment from the students also verified the effectiveness of this instructional method. In spite of all its advantages, in the future new elements can be integrated into this project to enhance its efficacy and better simulate a real industrial design environment. For example, the improved design project will give students an opportunity to work with other engineers in small design teams, to develop client relations and to consider more non-technical constraints (ethical, political, aesthetic, environmental, economic, culture) in their work.

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