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Analysis Of Theo Jansen Mechanism (Strandbeest) And Its Comparative Advantages Over Wheel Based Mine Escavation System

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ABSTRACT:- *I decided to implement linkage based locomotive systems on standard load carrying tippers and trucks as a replacement for the conventional tyres. The first mechanism which I came across for such purpose was Klann mechanism which actually mimics the motion of the biological organism (crab). On observing further in detail I found that there were lot of drawbacks with the Klann mechanism, the drawbacks being jerky motion and difficulty in the turning of the vehicle. The next step to be taken was to find a better mechanism which had a smooth walking pattern on any given terrain and could easily function as per requirements. The most flexible mechanism which I settled with is THEO-JANSEN MECHANISM (STRANDBEEST). My final contribution would be to do compressive load analysis to determine the load carrying capacity of the system and compare it with that of a standard wheel based truck or tipper. Finally, all vehicles must be controlled - by a human or other means. Therefore it is necessary to investigate methods of controlling such vehicles.*

I. INTRODUCTION

1.1 General

It is well known that animals can travel over roughterrain at speeds much greater than those possible withwheeled or tracked vehicles. Even a human being, by "gettingdown on all fours" if necessary, can travel or climb overterrain which is impossible for a wheeled or tracked vehicle. Nature, apparently, has no use for the wheel. It is thereforeof considerable interest to learn what machines for landlocomotion can do if they are designed to imitate nature.

With this idea in mind I started studying linkages and the comparative function of a set of linkages with certain degrees of freedom arrested. It turned out numerous implementations could be done so as to bring forth set of linkages so designed as to perform locomotion.

1.2 Mining Excavation System.

Since the time of industrial revolution mining has been a crucial and financial base of any running industry. With growing need of manufactured products the requirement of raw material has escalated exponentially. Engineers have always tried to improvise and improve the utility of vehicles which help in transport of raw materials from the mining site to the industrial transportation unit.

With growing technology many improvements have been made in such vehicles (trucks, tippers, etc). Some of those improvements include:

- Conversion of tipper units from a single wheel drive (front/rear) to an all wheel drive system.
- Improvement of the suspension system.
- Implementation of differential in vehicles to prevent skidding.
- Development of advanced and heavy duty tyres.

All these improvements did help improve transportation of raw materials and also increased the rate of transfer. With improvement and implementation of new technology the cost expenditure also increased and industries have had to setup roads (haul roads) for smoother movement of these wheel based vehicles.

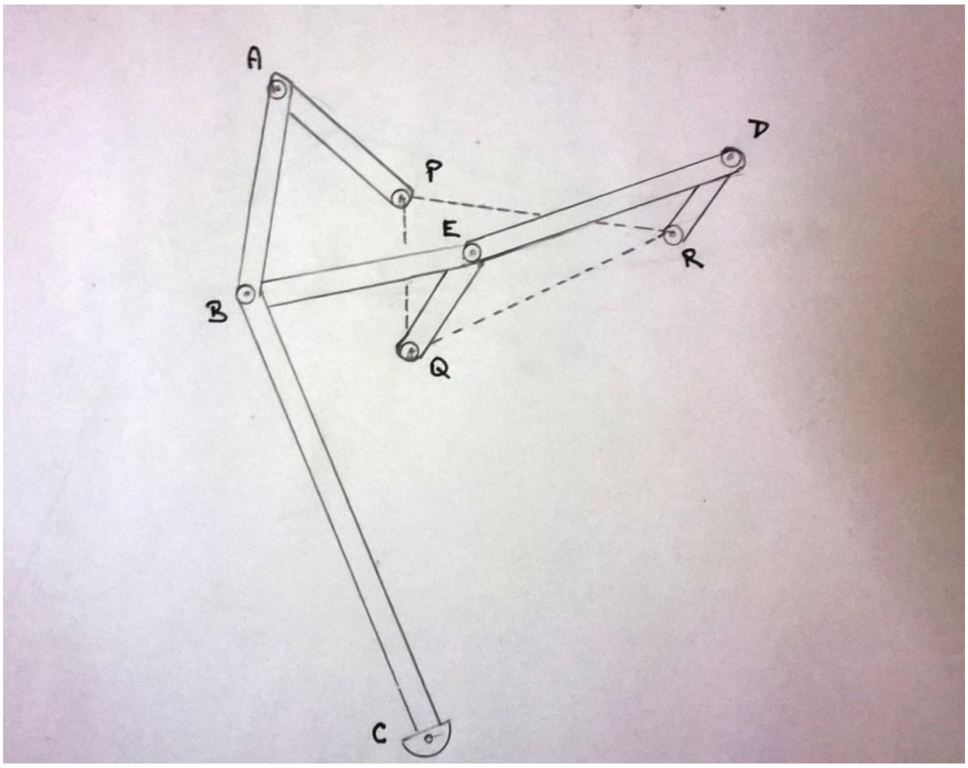
1.3Walking Mechanism

As mentioned above nature has always chosen legs as the best mode of locomotion so using linkages we tried to mimic nature and come up with certain walking mechanism which will suite all terrain. After reviewing certain mechanisms we came across two of them which proved to be more efficient.

1.3.1 Klann Mechanism

The Klann linkage was developed by Joe Klann in 1994.This mechanism is a planar mechanism designed in such a way that it mimics the walking of a crab and acts as a replacement for modern day wheels.

The linkage consists of a fixed frame, a crank and 2 rockers all connected using pivot joints. The linkage provides many benefits over standard locomotive vehicles.Below is the pictorial representation of the Klannmechanism.



1.3.2 Theo Jansen Mechanism

Using eleven small rods, Dutch kinetic sculptor Theo Jansen has created a planar mechanism that, when used in tandem with many others identical to it, can walk in a smooth forward motion. The resulting device has a very organic look, much like a creeping animal. His "beasts" have been made to be wind powered, using a combination of wind sails and empty plastic bottles that can be pumped up to high pressures.

Using inspiration from Jansen's"Strandbeest"kinetic sculptures, this project aims to create an alternate for tyres which can be used for rough terrains.

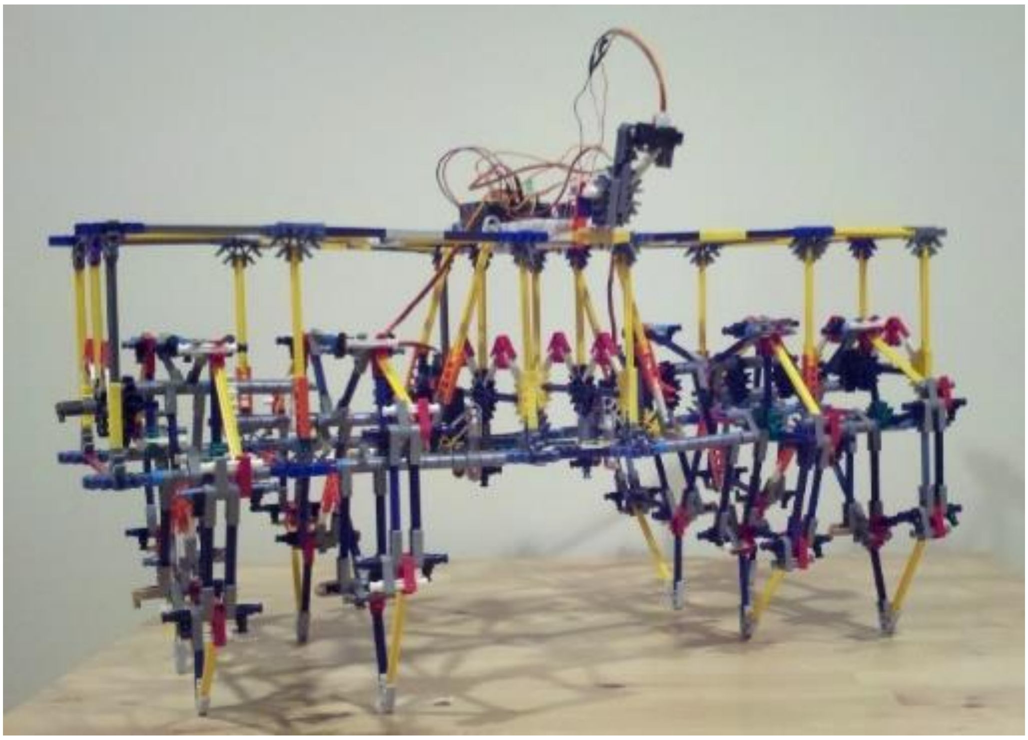
II. LITERATURE SURVEY

After researching about mining and excavation industries I came across with these data. The statistics suggests that about 50% of mining cost is spent on roadway and rail transports in the vicinity of the mines (haul roads & side rails). Haul roads cause a great damage to tyres of transporting vehicle requiring frequent and regular replacement.Maintenance cost of haul roads is also high and it needs a separate wing.Weight distribution is uneven in haul roads causing higher stress problems in transport vehicles.

On a rough terrain legs have advantage over tyres so I came on Klann Mechanism. After researching through this mechanism on internet and going though few reports and watching its motion in the YouTube videosI found that Klann Mechanism has its own demerits which include steering and stability.

After crossing out the Klann Mechanism from the list I stumbled on Theo Jansen Mechanism. This mechanism gave me the smoothest motion and is able to carry loads without much high forces applied to it.

With the inspiration from Jansen’s walking mechanisms, I began searching for various applications of the Jansen leg mechanism. I found several images and videos on the Internet showing different applications of this design large and small that helped me identify what I wanted my design to look like. The appropriation of the Jansen mechanism has ranged from tiny motorized robots to large multi-legged two-seater vehicles. This mechanism is very simple to build and it requires very less energy to run itself. But the only drawback found about this mechanism is its speed. How fast can it run? Except for that one point the Jansen design is incomparable with any other leg mechanism with such simplicity.



Strandbeest Computerized Robot

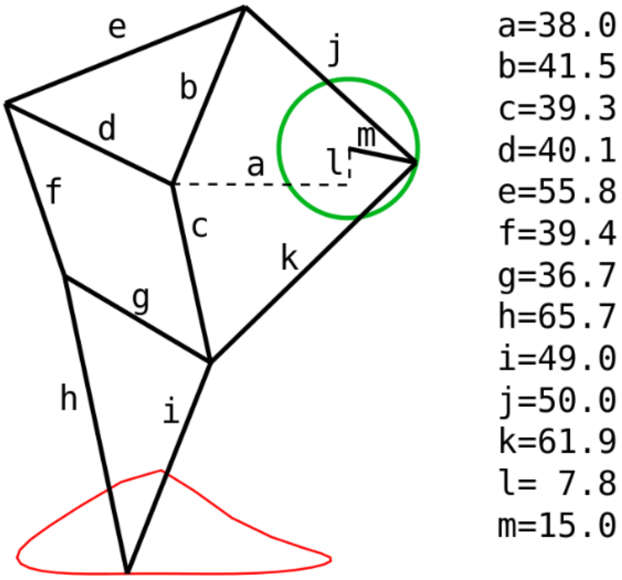
Further research from patents, academic papers, and articles show that nobody’s yet created such a model that I aim to design.

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 tyre”. This issue belongs to (Journal of achievements in material and manufacturing engineering-Volume 31 Issue 2 December 2008).

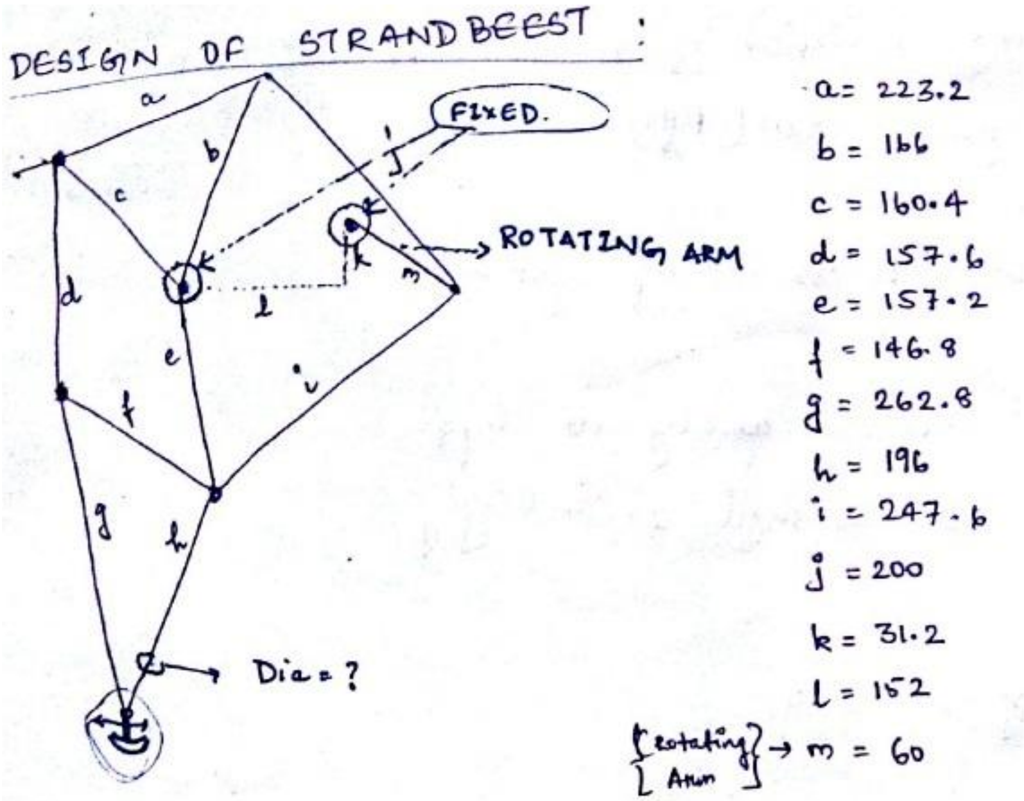
The report involves the standard Finite element analysis of a solid tyre and deflections produced in it on application of load. The detail related to the analysis is given further in the report. With reference to the Journal report I decided the dimensions of our setup.

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.



(Dimensions not to scale)

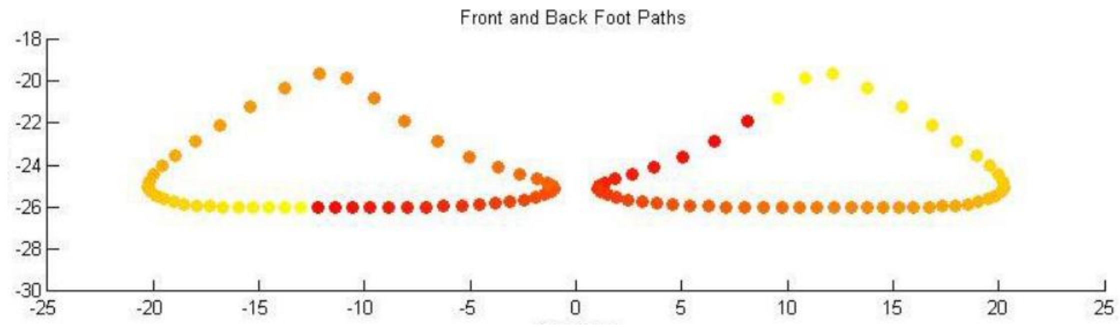
As we show above, these dimension sets are standard and can be used as a scaling reference. During the course of the research it was also found during rough designing that irrespective of the length of the linkages involved the system worked perfectly and the only drawback faced was low stride height.



On scaling 4 times the standard model

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.



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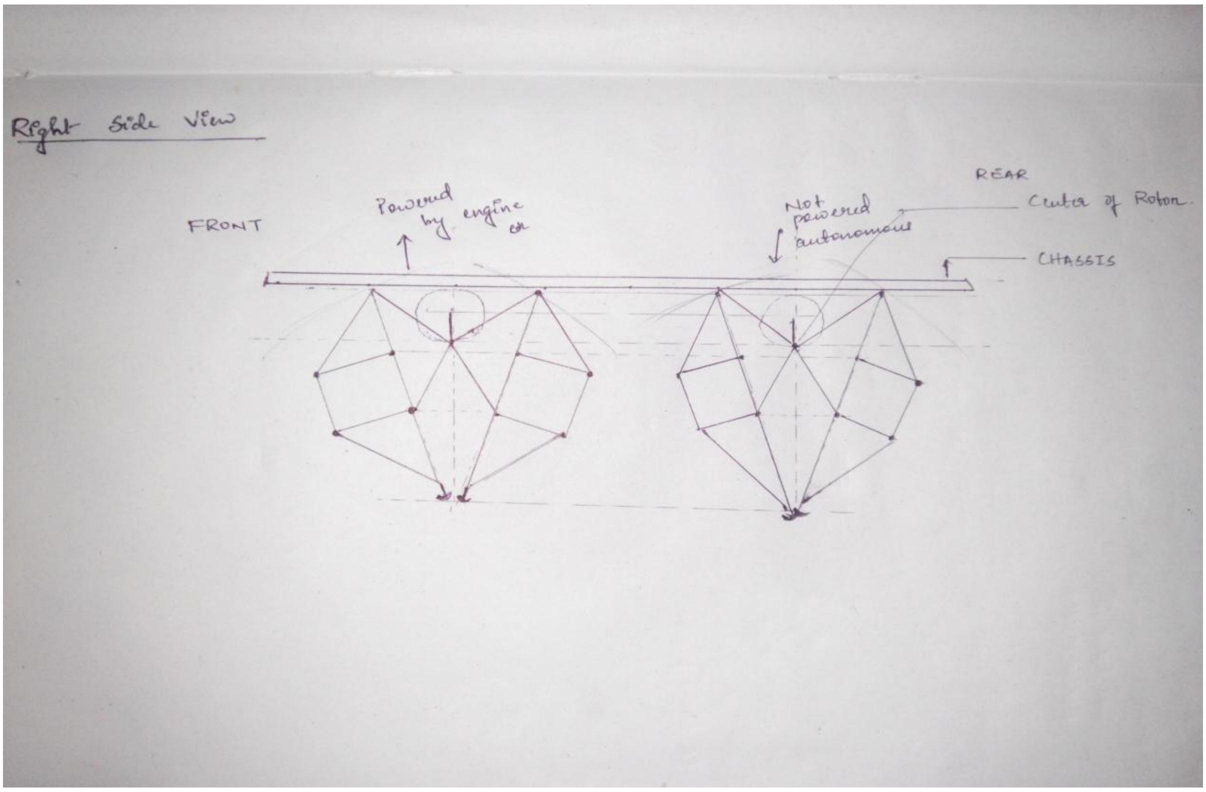
With these references for help I started to develop a design for the system considering dimension in comparison to the tyre analysis report. Initially I came up with a rough line diagram of the design as seen from the right side view and depicted its motion pattern segregated into three unique diagrams.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



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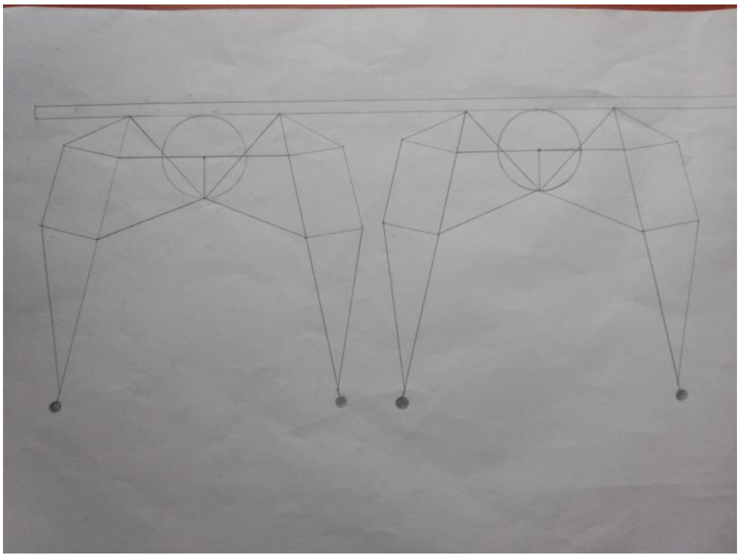
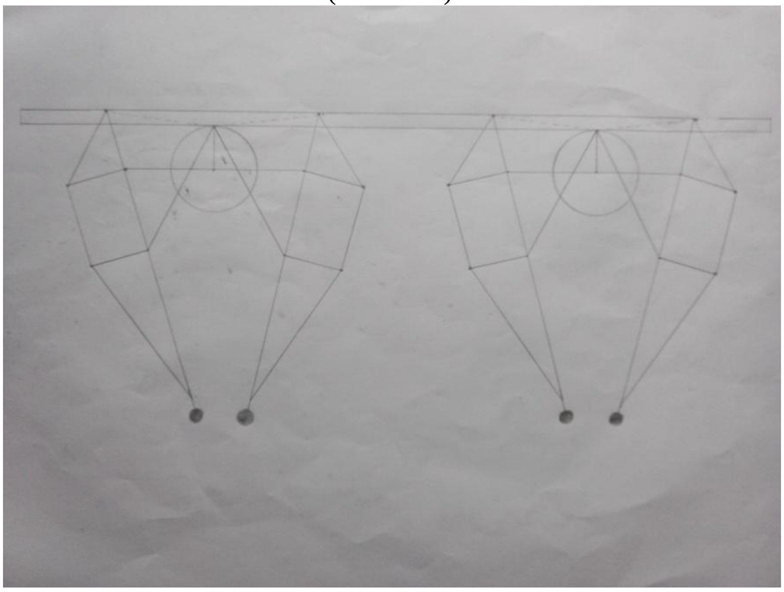
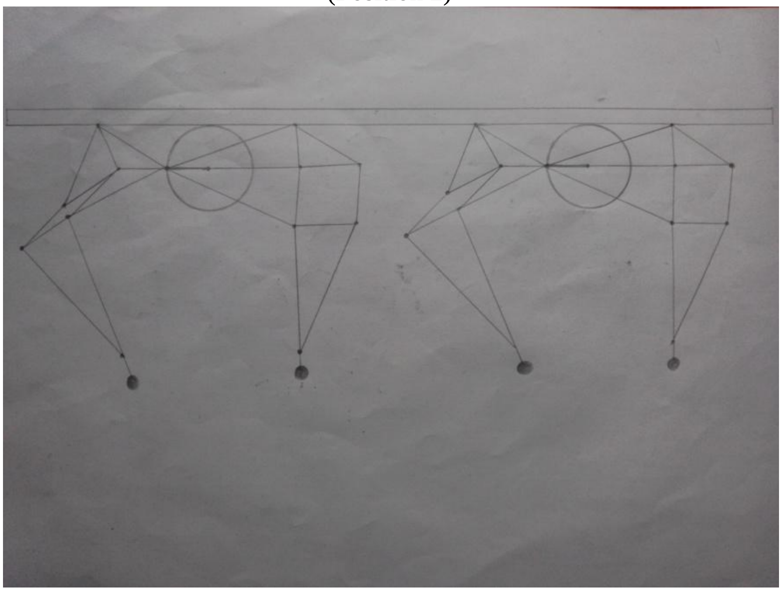


(Position 1)



(Position 2)



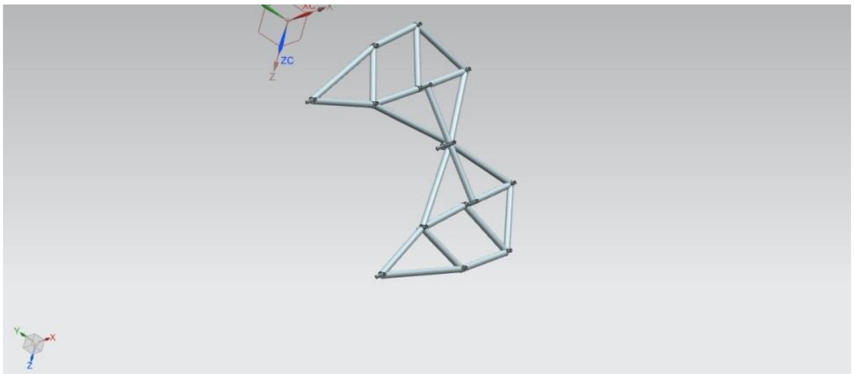
(Position 3)

The above 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.

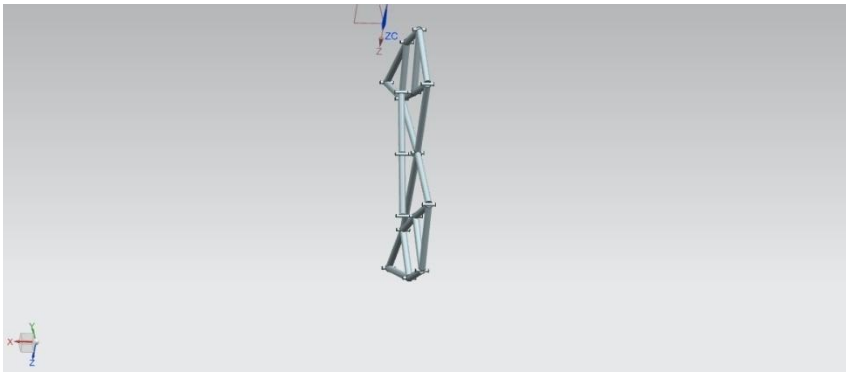
From our survey related to mining and transport we found that a standard truck while loaded has to bear a load upto 16,000 kg. Keeping that in mind I intend to design the system to bear static load of 16,000 kg and accordingly carry out compressive stress analysis across its T joint sections while the body is in static condition.

Taking into consideration the analysis report of the tyre I found that the dimensions of a standard tyre. The tyre model has an outer diameter of 518 mm, 218mm inner diameter and a tyre width of 144 mm.

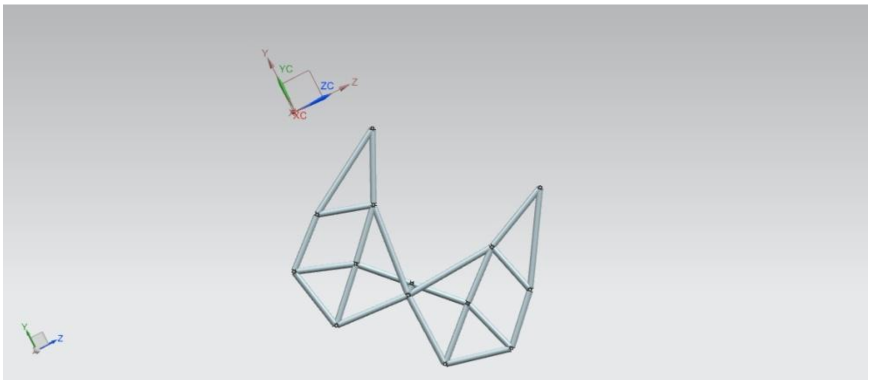
On further calculation I found the standard dimensions of the mechanism has to scaled 4 times its original and that is how I came up with the standard model which I drew using NXCAD. The following depicts a brief model of on unit, i.e. two sister pairs



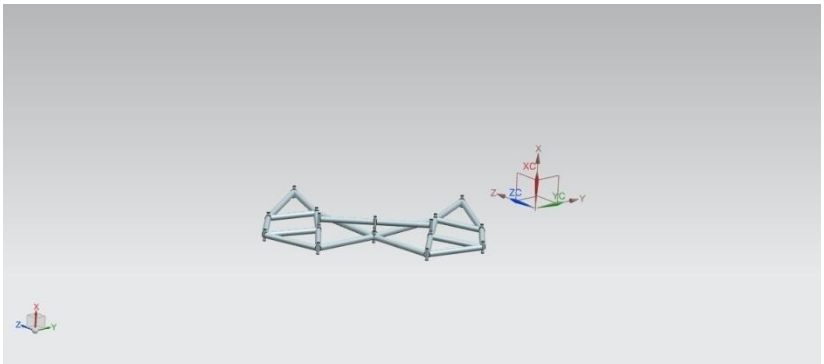
View 1



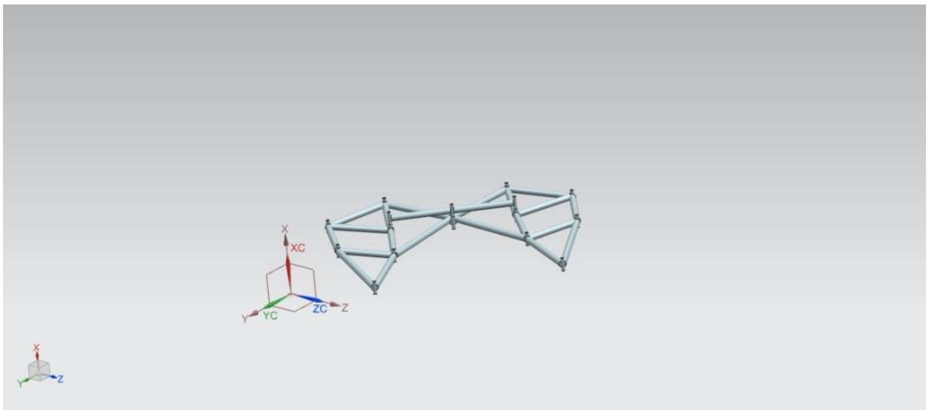
View 2



View 3



View 4

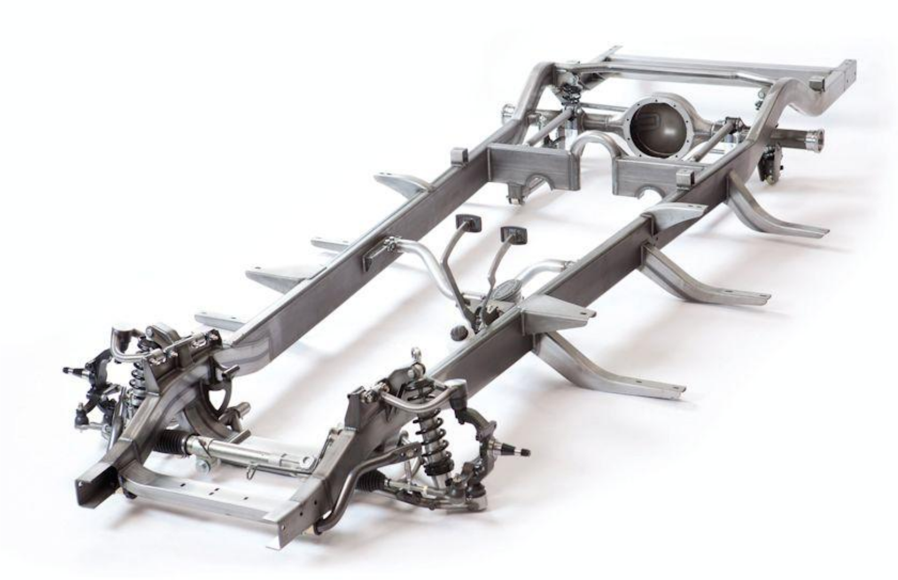


View 5

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.

Having completed the design it is now our turn to implement these design in a standard cross bow chassis so as to understand the placement of the feet under the chassis. For this reason we need to collect the standard values of a standard chassis and implement our mechanism under the structure.



(Standard chassis of a tipper)

As we can see from the above chassis diagram we have to mount the fixed frame of our mechanism under the chassis at the point of the front and rear tyre and weld the two consecutive at equidistant space so as not to hinder the performance of the mechanism by coming under its path.

Using our calculated dimensions Iwas 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 depicts the motion of the leg.

III. SYSTEM ANALYSIS

We want to replace the tyre with the Theo Jansen Linkage mechanism. So I performed a tyre analysis which we will compare to Theo Jansen Mechanism.

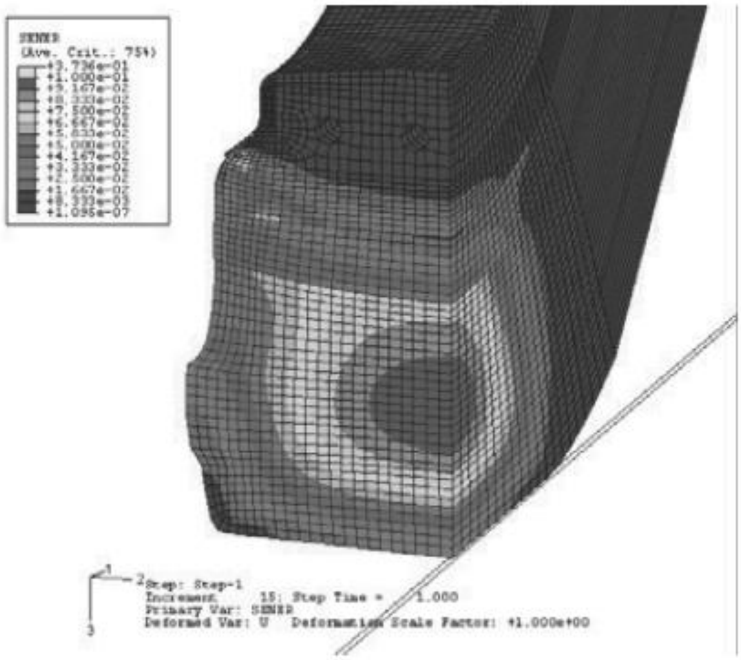
3.1 Tyre Analysis:
A finite element model of a solid tyre was constructed to simulate the loading condition.

It was constructed to simulate the static compressive loading condition. The 3D FE model for static loading analysis of solid tyre constructed in this study can give reasonably good prediction of load-deflection behaviour of a real solid tyre. It can also be deduced that the distributions of analysis parameters such as strain energy density and Von Mises stress given by the FE analysis are acceptable.

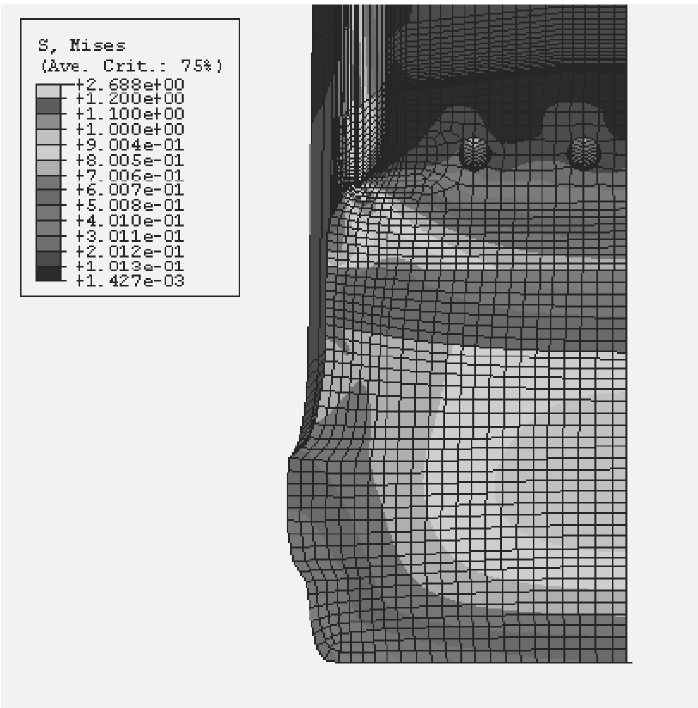
A 3-D finite element model was constructed using ABAQUS finite element package to simulate the static load bearing conditions and to study the load-deflection characteristic. In the present study, a tyre model has an outer diameter of 518 mm, 218 mm inner diameter and a tyre width of 144 mm. For reason of symmetry and economy in the numerical calculations, only one quarter of the tyre model was constructed.

Distribution of strain energy density and stress

The distribution of strain energy density and Von Mises stress over the half tire cross section obtained from FE analysis were examined. These parameters are generally important in mechanical design stage. The distribution of strain energy density shown indicates that strain energy density is concentrated in the middle region of the tread layer which is undergoing large deformation. This region of high strain energy density is the same as "hot region" where temperature rises extensively leading to heat blow out failure during endurance tests. Thus area of high strain energy density can be related to the area with high heat generation. To reduce the risk of failure due to heat build up, the strain energy density should be kept minimum.



Below figure shows that regions of high Von Mises Stress is in the middle region of the tread layer and also apparently in the shoulder area of the base layer. This indicates high distortional stress in this area which could affect the gripping contact to the rim.



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