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Design Development of Dual Mode Six Leg Walking Robot

Prachiti Pravinkumar Adsul [1]

[1] Student of B.E., Department of Mechanical Engineering, Marathwada Mitra Mandal College of Engineering Pune, Pune-411052, India

ABSTRACT :

In many applications of material transport or surveillance it is required to move on different terrains or road conditions. Thus, the vehicle under consideration will have two modes of transport, namely the wheel transport and the kinematic walking mechanism transport mode. The present project combines the advantages of both the mechanism where in the wheel transport mode will make vehicle move faster on plain road, where as the walking mechanism mode will make it possible to move on roads which is muddy or rough. The project designs either mechanism, as well as it designs the jacking mechanism. The solid modeling of the components of six leg walking robot is done using Catia. The analysis of the components is done using Ansys work bench. The two-way configuration of the robot offers versatility of application of the robot in either condition of plain road with the wheels offering agility and speed to the robot, at the same time the six-leg configuration is suitable in places like swampy areas and uneven terrain.

Keywords: System design, Mechanical design, Six leg Walking robot, Jacking mechanism, Wheel mechanism, Kinematic Analysis

1. INTRODUCTION :

Wheels are used for locomotion in robots. However, there are some limitations for wheeled robots in complex terrains. Legged robots have discrete contacts with the ground that are good for walking over obstacles and navigating complex terrain. Legged robots can be protected against breakdowns due to mechanical redundancy of legs. The primary benefit of wheel locomotion is the ease with which it can be operated. It is very energy-saving and can achieve speeds using wheels. However, it has drawbacks, one of which is that it requires smooth terrain. More than half of the earth's terrain is inaccessible to wheeled robots because it is uneven. It also won't be able to move up or down a long vertical step. Therefore, there is a need for another mechanism which can overcome these limitations. Legged locomotion on the other hand does not demand any special terrain. Legged locomotion has a number of benefits versus wheeled locomotion: One can go up and down stairs and step over barriers. Legged locomotion can even transport a vehicle across large chasms or uneven terrain. The current project combines the benefits of both mechanisms, with the wheel transport mode allowing vehicles to travel faster on flat roads and the walking mechanism allowing vehicles to travel on muddy or difficult roads. Both the mechanisms and the jacking mechanism are designed in this project.

2. LITERATURE REVIEW :

A detailed literature survey was carried out, by studying various research papers. Different types of mechanisms such as two-legged, four legged, six-legged, wheel mechanisms were studied.

- **Kinematic and dynamic models if a six-legged robot is developed by A. Trigo, et al [1]:** It discusses that the Free Body Diagram method is based on dynamic equations of rigid bodies which is used to overcome the difficulties in dynamic modelling of the legged robots.

- **'Designing, 3D Printing of a Quadruped Robot and Choice of Materials for Fabrication' by Akash Maity, et al (2019) [2]:** It focuses on the advantages of additive manufacturing rather than conventional manufacturing techniques and also highlights its limitations. The bot can be used for autonomous navigation in areas where it is almost impossible for humans to access into.

- **'Control of a Six-Legged Robot Walking on Abrupt Terrain' by Enric Celaya and Josep M. Porta (1996) [3]:** It is assumed that walking on abrupt terrain is the typical situation for a legged robot. A controller is developed for a six-legged robot that allows it to walk over difficult terrains in an autonomous way and with limited use of sensory information.

- **'Torque distribution in a six-legged robot' by Mustafa Suphi Erden, Kamal Leblebicioglu (2007) [4]:** It presented the problem of free gait generation and adaptability with reinforcement learning for a six-legged robot. Continuous walking pattern with a larger average stability margin. The robot is guaranteed to have stable walk and the reinforcement learning only improves the stability.

- **'Fabrication of Kinematic Walker' Praveen, Sumantha Raj P T, et al (2019) [5]:** In this paper current state of many walkers are compared and advantages of a legged systems against wheeled walker are described.

- **'Fabrication of Six-Legged Kinematic Moving Mechanism' by R. Arjunraj, et al (2016) [6]:** The kinematics of the movement for a six-legged mobile robot is inspired from the living world. The author also discussed that the command-and-control system, an important benefit of this mechanism is that, it does not require microprocessor, controller and other actuator mechanisms. It has command and control system that allows it to travel on different kinds of terrains with different speeds. The rotating motion of the crank is converted into movement of foot which is similar to that of animal walking. This is achieved by connecting mechanism links by pivot joints. The main objective of constructing the hexapod was to overcome the obstacles that comes within the way wherever the wheeled robots are helpless.

After careful review of the research work, it is clear that the six-leg walking robot is developed using kinematic four bar linkage. Although the research is limited to the walking mechanism only. Almost no researcher has attempted to combine the six-leg robot to wheel drive. The research work earlier also does not consider any jacking arrangement. Thus, this project work involves the design of the walking as well as the wheel drive. The jacking mechanism is thus an essential subsidiary required to toggle between the six-leg walking drive and the four-wheel drive.

3. DESIGN METHODOLOGY :

3.1. System Design & Mechanical Design:

- The system has been designed according to theoretical derivation of dimensions of the walking mechanism. The various components of walking mechanism have been modelled on CATIA V5 software and its analysis was carried out on Ansys Workbench.
- The entire system design of the jacking linkage and walking mechanism was derived by kinematic linkage system.
- For theoretical derivations of linkage, strength criterion for four-wheel drive mechanism was adopted.
- Selection of motor and drive was done for walking mechanism and wheel mechanism.
- The drive system of walking linkage consisted of three sprockets driven by one driving motor.
- The entire system was powered by Exide battery.
- The materials selected for parts was Aluminum Alloy for frames and various grades of carbon steel like EN9, C40 and EN24 were used for cranks and shafts of the mechanisms.

3.2. List of Components

Table 1 – Parts Table

Sr. No.	Part Name
1	Motor
2	Sprocket
3	Front / rear crank shaft
4	Eccentric crank
5	Leg
6	Connecting link
7	Frame
8	Hinge shaft
9	Ball Bearing
10	Wheels
11	Rack
12	Pinion

3.3. Design of Jacking Mechanism

The material used for rack and pinion is Nylon-66. The number of teeth on rack and pinion was selected to be 26. The module of gears was designed on the basis of Lewis Strength Equation which was 1.25mm.

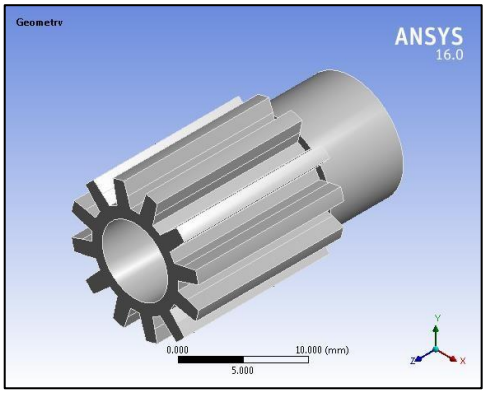


Fig. 1- Geometry of Pinion

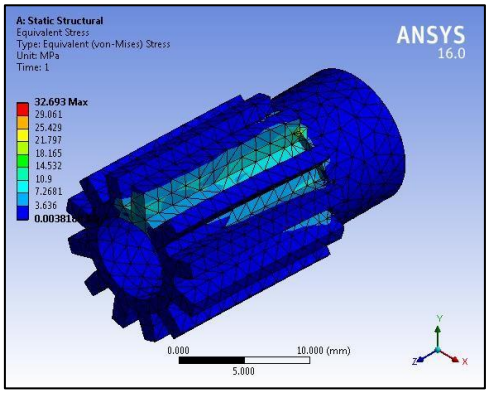


Fig. 2- Structural Analysis of Pinion

The Pinion was modelled in CATIA V5 and its Structural analysis was performed in Ansys Workbench. A Fixed support boundary condition was applied on the gear shaft and a force of 70.8 N was applied on the tooth in contact with the rack at the time of engagement.

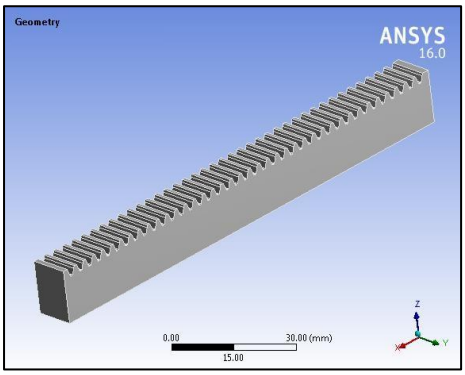


Fig. 3 Geometry of Rack

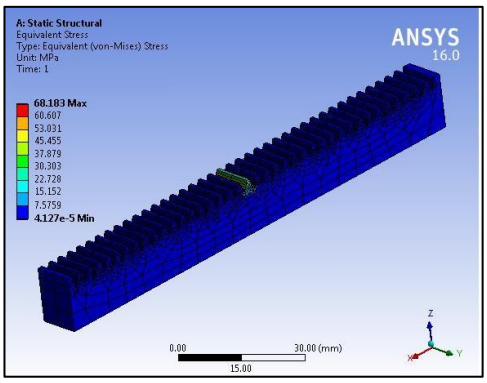


Fig. 4 Structural analysis of Rack

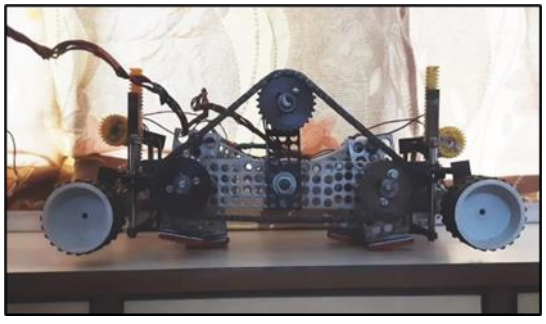
The rack was modelled in CATIA V5 and its Structural analysis was performed in Ansys Workbench. A fixed support boundary condition was applied on the base of rack whereas a force of 212.6 N was applied on the tooth in contact with pinion at the time of engagement.

4. FUTURE SCOPE :

- **Surveillance robot:** The robot with a 360^0 rotatable camera and indexing head can be used as a surveillance robot.
- **Non-destructive testing:** The non-destructive testing tool with ultra sound mechanism can be fitted onto the robot and used for Non-Destructive Testing of gas pipe lines.
- **Agriculture Trimming and spraying device:** The robot can be fitted with agriculture sprayer arrangement to spray pesticides and trim outgrowth in poly-houses, horticulture etc.
- **Defense applications:** The robot can also be used for military purpose, by placing bomb detectors in the machines which can easily detect the bombs and prevent any harm to humans.
- **Space Applications:** This unmanned robot can be used in space applications as a rover, by sending it to other planets and carrying out various activities for study purposes.

5. CONCLUSION :

Fig. 6- Assembly



In many applications of material transport or surveillance it is required to move on different terrains or road conditions out of which not all areas are accessible for humans. This robot can perform such tasks which could be otherwise hazardous to humans. Thus, the vehicle under consideration will have two modes of transport, namely the wheel transport and the kinematic walking mechanism transport mode.

This paper gives an overview of the design of walking mechanism of six-legged robot. A carefully outlined procedure was followed in order to design the walking mechanism. By following the mentioned procedure various components of the mechanism were designed and analyzed and also found out to be safe under their respective constraints. The main idea of walking mechanism was based on extended four bar kinematic linkage mechanism. The walking mechanism concept was inspired from locomotion of animals and insects like spiders, crab, etc. Further the designing of wheel and jacking mechanisms was completed. Based on these designs, the robot was manufactured and its testing was successfully done.

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