Design, Fabrication and Control of a Hexapod Robot

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ABSTRACT:

The aim of the project is to build a six-legged walking robot that is capable of performing basic mobility tasks, such as walking forward and backward. The project involves, designing the robot on CAD software SolidWorks, followed by its fabrication and control and finally, analyzing the velocity of the robot with its testing. The legs of the robot would have 'one' degree of freedom each. This robot would serve as a platform upon which, additional sensory components could be added or programmed to perform increasingly complex motions. When modified, it can be used in the field of defence, handling technology, manufacturing automation, machine tools etc. The robot is designed to be used for both off-road and on-road applications.

INTRODUCTION

The need for creation of machines, that could operate autonomously, dates back to classical times when humans were not able to do the tasks assigned to them effectively and in the most efficient way. Fully autonomous robots only appeared in the second half of the 20th century. The first digitally operated and programmable robot, "The Unimate", was installed in 1961 to lift hot pieces of metal from a die casting machine and stack them.

So, a *robot* can be called as a mechanical device that can perform tasks automatically. It may – but need not – be humanoid in appearance. Some robots require some degree of guidance, which may be done using a remote control, or with a computer interface.

One of the robots developed was the 'Hexapod' robot. As the name suggests, a *hexapod* robot is a mechanical vehicle that walks on six legs. Since a robot can be statically stable on three or more legs, a hexapod robot has a great deal of flexibility in how it can move.

Objectives

The objectives of the project include – (1) To do a literature review of the hexapod robot, which involves knowing all the theories and the pre-requisites regarding the motion and dynamics of the robot. (2) Designing the model of the hexapod robot on CAD Software SolidWorks. (3) To do a market survey which includes enquiring about the robot parts available in the market and their characteristics and designing the hexapod robot according to the market needs, making it available for selling in the market. (4) Modifying the design (if any changes are required). (5) Analysis and Simulation of the design made. (6) Fabrication of the hexapod robot. (7) Controlling the robot: Automatic control (remote- control) is used. (8) Testing the hexapod robot.

Applications

Hexapod robots are used in external (non structured) environments as in mining companies, sewer tubes, agriculture, forests. It is also possible to use mobile robots to motivate the teaching and formation in Mechatronics and Artificial Intelligence, as for example; through robot's soccer competitions. Hexapods may be used to test biological theories about insect locomotion, motor control, and neurobiology.

Other applications of hexapod robot include Medical robots, Machine tools, handling technology, Manufacturing automation and Decoration Technology in the porcelain industry.

LITERATURE REVIEW

This section includes knowing all the theories and the pre-requisites regarding the motion and dynamics of the robot, like studying about the kinematics of the robot which consists of the kinematics terminologies like link, joint, end effector, base, kinematic pair and kinematic chain. Different types of robotic joints were also studied like rotational, revolving, orthogonal, twisting and linear joints. The relative velocity method was studied to do the velocity analysis of the robot and finally, various theories regarding the design of the chain/ sprocket part of the robot were studied, which also includes the design of the crank mechanism and study of various factors responsible for the motor selection. Before starting the project previous work done on a hexapod robot was studied and important works were noted, like control of a hexapod robot using servomotor control interface CPLD. Control method used significantly reduces the workload on the MCU to allow it to communicate better with external devices. The servomotor conversion device used here simplifies control and reduces the power needed by the single chip. This allows it to work with more external sensors and accomplish more communications tasks. Other important works that were studied includes design of a hexapod robot with a wind detection sensor, controlling an electro-hydraulically actuated hexapod robot with a fuzzy controller and designing an underwater hexapod robot – AQUA.

DESIGN AND DRAFTING

The designing of the hexapod robot was initiated with designing different parts on software like CATIA V5R20 and SolidWorks like Chassis (Robot body and support), Robot leg, Robot arm, Motor Base, Motor support, crankshaft, fixed shaft, motor shaft and finally the assembly of the robot. Design of the robot was initiated with chassis making by making the body and body support part followed by their sub assembly to make the base or the chassis. Holes were made in the body to accommodate fixed shaft and crankshaft. Robot arm was attached to the fixed shaft and robot legs were attached to the robot arm later. Robot legs were attached to the crankshaft which was accommodated in the holes of the body part. A phase difference of 180 degrees was made in both crankshafts such that three legs touch the ground at a time. Motor support was attached to the body part such that motor can be attached to it. Motor connects the transmission gears or the sprockets via motor shaft.

Prior to the market survey the robot design was based on a nut bolt based crankshaft but after the market survey and the velocity analysis some changes were done in the design like – instead of the nut bolt based crankshaft, welded crankshaft was used which involves fabrication of square mild steel pieces with the rod, modification in the robot leg with additional holes such that it can be attached with the robot arm and hence, the overall effective height of the robot can be adjusted for off-road applications. Also the fixed shaft was made threaded, so that it can impart additional strength to the parts attached to it. It was further planned to attach rubber pads to the robot legs which were in contact with the ground so that the movement of the robot would not be noisy and proper noise insulation would be achieved. Also, no scratches were produced on the ground in this way. There was one more modification to be done while fabricating the robot i.e. clippings were mounted on the threaded fixed shaft, so that unnecessary movement of the robot arm was prevented. The final robot came out to be like as shown in Fig.1.

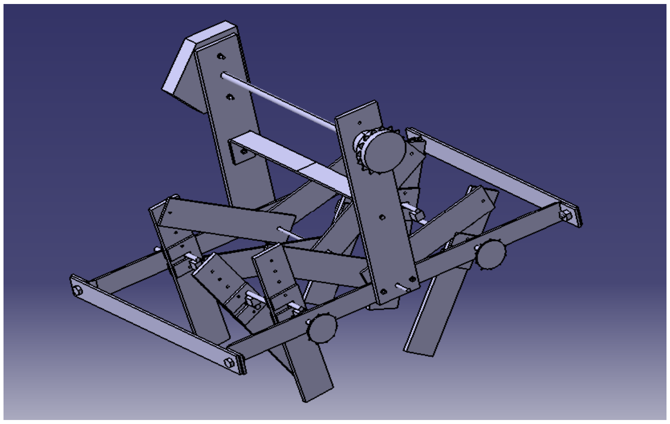

Fig.1. Final Assembly of the Hexapod Robot

FABRICATION

Fabrication started with the chassis making, in which body support and body were fixed together. Two pairs of aluminium strips were cut to the size 480x25x3mm and 290x25x3mm. A 480mm long strip was bent from the ends with a fillet radius of 10mm (30 mm from both ends), to be fixed with body support easily, and holes of 5mm were drilled in the bent part. A hole of diameter 5mm was drilled in the centre of the body and two holes of 3mm were drilled 18mm from the center of the body.

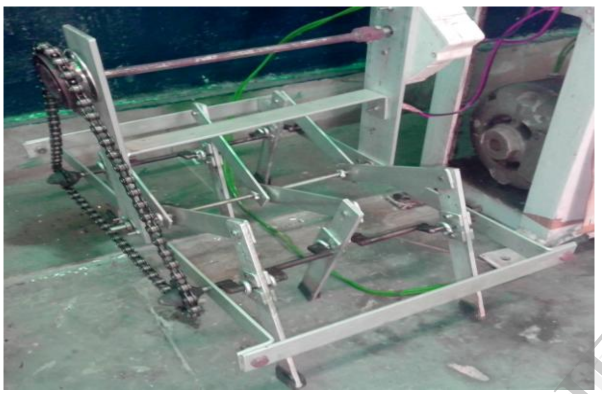

Fig.2. Fabricated model of hexapod robot

Now crankshaft was made by cutting a mild steel rod of 290mm x 6mm diameter into three parts of 50mm each and then welding these parts with the original rod using square pieces of dimensions 1cm x 1cm. Similarly one more crankshaft was made by following the same process. The crankshaft was fixed in the 6mm holes of the body by fixing nuts on both sides.

Now robot leg was made by cutting an aluminum strip of dimensions 205mmx35mmx5mm. A rectangular slot of 17.5mm x 7mm was made by producing a hole of diameter 7mm and then extending it by a hack-saw in the robot leg, so that it can be fixed on the crankshaft. This slot was made 125mm from one of the ends. Now, two holes of 3mm were made 10mm from both ends of the slot. Another hole of 3mm was made 13.5mm from an end and then, two more holes of 3mm diameter were made at a distance of 15mm from them. These two holes serve the purpose of changing the effective robot height and robot leg length, by fixing the robot arm in either one of them. *Rubber pads* were attached to the other end which was in contact with the ground so that any scratches or harm to the floor could be avoided. Similarly, five more robot legs were made by following the same process.

Now, robot leg fixtures were made by cutting an aluminium strip of 40mm x 35mm x 3mm. A rectangular slot was made of 17.5mm x 7mm by using the same technique as in robot leg. Two holes of 3mm were made 5mm from both ends of the robot leg fixture. Similarly, eleven more parts were made. Now, robot leg was fixed to the crankshaft by mounting it on the crankshaft using the rectangular slot and fixing it with the robot leg fixture on both ends and finally, bolting them with nuts and bolts in the 3mm diameter hole.

Robot arm was also made by cutting an aluminium strip of 165mm x 35mm x 3mm and then drilling two holes of diameter 5mmX 3mm and 15mm X7.5mm resp. from both ends of the arm. Five more robot arms were made by the similar process. The robot arm was fixed to the threaded fixed shaft via the 5mm diameter hole and to the robot leg via the 3mm diameter hole. The robot leg and robot arms were fastened together by nuts and bolts.

Finally, transmission gears were attached to the crankshafts and the motor shaft by the use of suitable adhesives. The sprocket attached to the motor shaft consisted of 16 teeth and was of diameter 50mm. Sprockets attached to the two crankshafts were of 10 teeth and 35mm dia.

VELOCITY ANALYSIS

Theoretical Analysis

Let the speed at the crankshaft be N r.p.m and ω be the angular velocity of the crank OC.

Velocity of crank = V m/sec

Velocity of Robot arm = 0.967 V m/sec

Velocity of robot leg, lower part = 0.367 V m/sec

V is the linear velocity and ω is the angular velocity of the crank that is being rotated by motor with the help of chain drive. The above details have been measured from the velocity diagram according to the scale.

1. Direction of velocity of crank is perpendicular to the crank

2. Direction of velocity of robot arm is also perpendicular to the robot arm
3. Direction of velocity of robot leg is perpendicular to the robot leg
4. The velocities of links attached to a fixed point emerge from the same point.
5. Thus, the triangle is made by joining all the directions of the velocities.

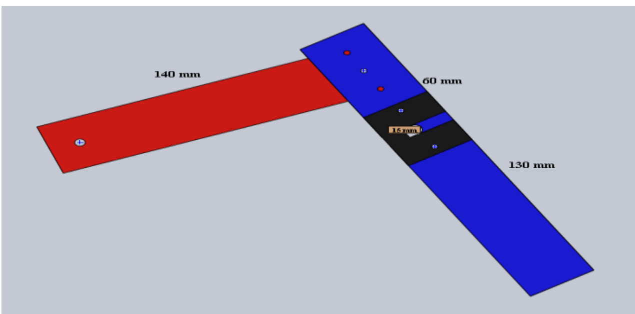

Fig. 3 Image of hexapod arm leg configuration

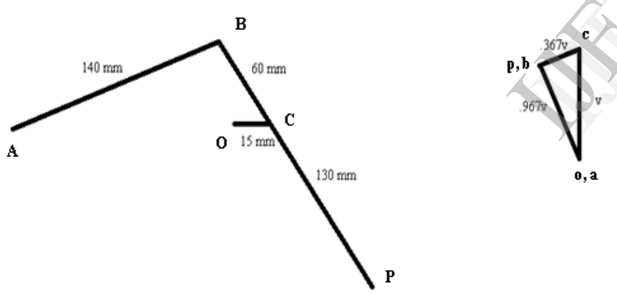

Fig. 4 Line diagram for velocity analysis and velocity triangle

By measuring the lengths of the sides of the velocity diagram

$\omega = 2*\Pi*N/60$

$\omega = 3.0353$ rad/sec

According to velocity analysis

Angular velocity of robotic leg = 1.113 rad/sec

Velocity of robotic leg = 1.113*.13 = 0.14469 m/sec

TESTING

After the control and fabrication hexapod robot was tested. It was controlled by a DPDT switch and has four degrees of freedom. Its motion was tested in forward and reverse direction, along with its upward and downward movement.

When the robot was tested for the first time, it was moved forward and backward. The motion was smooth but it made noises while moving due to presence of mechanical parts.

This noise was ignored as it was unavoidable.

The following data was obtained when it was tested for first time.

Distance moved = 85cm

Time taken= 6 seconds

Speed of the robot was calculated after obtaining the distance and time.

Speed = .1416 m/sec

Its speed was very close to the speed calculated theoretically.

Theoretically, the speed of the robotic leg that was obtained from the velocity analysis was 0.14469 m/sec.

The difference was presumed to exist due to the slipping of the legs while moving and also due to the presence of mechanical joints without any bearings.

RESULT AND DISCUSSION

The final year project had many difficulties associated with it. The project started with the selection of basic mechanism, for which the crank mechanism was selected as the result of literature review. After the research was carried out, the design was made on virtual designing platform from the literature obtained during the research. Accordingly, the robot was fabricated and tested.

During its fabrication, many problems came across. Firstly, the fabrication of crankshaft in the design that was made of nuts and bolts wasn't stable and it fluctuated and wobbled a lot. So, the method of fabricating the crankshaft was changed

Secondly, there was difficulty for robot to move on uneven terrain. So, the robot leg was made with little adjustments and two extra holes were drilled so that the effective height could be changed.

Thirdly, the centre fixed shaft was threaded. It provided extra strength to the parts attached to it.

Lastly, the moving legs and arms displaced laterally as well. So, the clips were attached to avoid lateral displacement.

All these difficulties were overcome and the final model was fabricated. The model persisted problems such as vibration noise and the noise of scratching on ground. Rubber pads were mounted at the end of the legs. Whereas the other noises had to be ignored due to unavoidable mechanical friction.

The project was successfully completed.

CONCLUSION

The final year project taught many concepts of engineering. Some of them are Designing, kinematics, material science, CAD, manufacturing. The project started with the Literature review that was the most important step of designing the robot. Literature review gave the conceptual ideas that could possibly be used in order to design the robot. Various research papers, websites and books were considered before designing it (Mentioned in the references section). The designing was done on the SolidWorks platform. After designing, the basic velocity analysis was performed. This led to the market survey, which brought many changes in the design of the robot. It had to be redesigned completely. It was redesigned on CATIA platform. After these processes, manufacturing was done. It has been explained in the fabrication and control chapter of this report. After the fabrication, control mechanism was built. The control included simple forward and backward motion. After the successful fabrication and control of robot, the robot was tested for its movement in comparison with the theoretical calculations. The robot was hence built and completed to the best of our efforts with future possibility of improvement. We look forward to working on other possibilities of improvements as well and further improve our mechanical skills and knowledge.

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