SIX LEGGED SPIDER ROBOT USING KLANN MECHANISM

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ABSTRACT

The invention of wheel laid a platform to run the automobiles and robots for a large period of years. Although it has many advantages, it is ineffective in rocky areas and on rough terrain. The Klann mechanism, which resembles the gait of a human, can curb the rough terrain with ease of control which cannot be done by wheels. The vital factor in this mechanism is that it does not require any microprocessor control or large amount of actuator mechanism. In this mechanism, the links are connected by pivot joints and converting the rotation motion of the crank into the movement of foot similar to that of animal walking. The proportions of each of the link are defined to optimise the linearity of the foot for one-half of the rotation of crank. The remaining rotation of the crank allows the foot to be raised to the predetermined height before returning to the starting position and the cycle continues. Two of these linkages coupled together at the crank and one-half cycle out of phase with each other will allow the frame of vehicle to travel parallel to the ground. This project is useful in hazardous material handling, clearing minefields or secures an area without putting anyone at risk. The military, law enforcement, Explosive Ordinance Disposal unit and security firms could also benefit from mechanical spider. This hexagonal locomotion will steer the robot to scale the obstacles which cannot be done with the help of wheeled robot.

I Introduction

A. *Why Klann Mechanism?*

The main advantage of Klann mechanism robots is their ability to access places impossible for wheeled robots. By copying to the physical structure of legged animals, it may be possible to improve the performance of mobile robots. To provide more stable and faster walking, scientists and engineers can implement the relevant biological concepts in their design. The most forceful motivation for studying Klann mechanism robots are

1. To give access to places which are rough terrain.
2. To give access to places those are dangerous.

Jobs which are highly difficult legged robots can be used for rescue work after earthquakes and in hazardous places such as the inside of a nuclear reactor, giving biologically inspired autonomous legged robots great potential. Low power consumption and weight are further advantages of walking robots, so it is important to use the minimum number of actuators. In this context, an objective is set in this project to develop an eight-legged mobile robot whosestructure is based on the biomechanics of insects.

II Background

Since time unknown, man’s fascination towards super-fast mobility has been unquestionable. His never ending quest towards lightning fast travel has gained pace over the past few decades. Now, with every passing day, man is capable of covering longer distances in relatively shorter duration of time. Today's automobiles are beasts on wheels which are designed for speed and comfort. However, most of today's automobiles are limited to roads or plain terrains. Even the off-road vehicles are of no use when the land is too rough. Needless to say, no vehicle can climb mountains. This is because all automobiles depend on rubber wheels which fare better only on roads. Man, who himself depends, on legs can travel on rocky terrains and climb mountains, but such journeys are never comfortable. Thus naturally the solution can be seen as an automobile which rests on and moves with legs.Simple, it may sound but the problems in building a working model are many. The mosttroublesome part is powering the gait of the legs. Rotation of wheels in wheeled vehicles ispowered by an engine or electric motors. Unlike wheels, legs move in an acute reciprocatingmovement. This is practically tough.This is where Klann Mechanism pitches in. It converts rotary action directly into linearmovement of a legged animal. Vehicles using this mechanism can travel on any type of surface.Also, they do not require heavy investments in road infrastructure.

III Mechanism

A. Overview

A six bar linkage is a one degree-of-freedom mechanism that is constructed from six links andseven joints. An example is the Klann linkage used to drive the legs of a walking machine.In general, each joint of a linkage connects two links, and a binary link supports two joints. Ifwe consider a hexagon to be constructed from six binary links with six of the seven jointsforming its vertices, then, the seventh joint can be added to connect two sides of the hexagonto forming a six-bar linkage with two ternary joints. This type of six-bar linkage is said to havethe Watt topology.A six-bar linkage can also be constructed by first assembling five binary links into a pentagon,which uses five of the seven joints, and then completing the linkage by adding a binary linkthat connects two sides of the pentagon. This again creates two ternary links that are nowseparated by one or more binary links. This type of six-bar linkage is said to have theStephenson topology. The Klann linkage has the Stephenson topology.The common mechanisms used in kinematic leg movement are Klann linkage mechanism andJansen linkage mechanism. Both will operate in a single plane provided a constant axle height,use only pivot joints and the rotating crank for input.

B. Klann Mechanism

The Klann linkage is a planar mechanism designed to simulate the gait of legged animal andfunction as a wheel replacement. The linkage consists of the frame, a crank, two groundedrockers, and two couplers all connected by pivot joints.The proportions of each of the links in the mechanism are defined to optimize the linearity ofthe foot for one-half of the rotation of the crank. The remaining rotation of the crank allows thefoot to be raised to a predetermined height before returning to the starting position andrepeating the cycle. Two of these linkages coupled together at the crank and one-half cycle outof phase with each other will allow the frame of a vehicle to travel parallel to the ground.The Klann linkage provides many of the benefits of more advanced walking vehicles withoutsome of their limitations. It can step over curbs, climb stairs, or travel into an area that arecurrently not accessible with wheels but does not require microprocessor control or multitudesof actuator mechanisms. It fits into the technological space between these walking devices andaxle-driven wheels.

IV Design and calculation

Testing of Dimensions

Joseph Klann says that all combinations of dimensions calculated by the above method maynot work. There are some sets of dimensions that do not give a smooth gait.

Length of upper Rocker arm = 26 mm
Length of lower Rocker arm = 13 mm
Length of Connecting arm = 62 mm
Length of Leg = 90 mm
Angle of Connecting arm = 170°

Calculation of DOF

In the design or analysis of a mechanism, one of the most important concerns is the number ofdegrees of freedom (also called movability) of the mechanism. It is defined as the number ofinput parameters (usually pair variables) which must be independently controlled in order tobring the mechanism into a useful engineering purpose. It is possible to determine the numberof degrees of freedom of a mechanism directly from the number of links and the number andtypes of joints which it includes.

In general, number of degrees of freedom of a mechanism is given by, n = 3 (l – 1) – 2 j
Where,
n – Degree of freedom
l – Number of links
j – Number of binary joints

This equation is called Kutzbach criterion for the movability of a mechanism having planemotion.

In Klann Mechanism, for a single leg,
We have, l = 6
j = 7
Hence,
Degree of freedom n = 3(6–1)–2x7
n = 15 – 14
n = 1

Calculation of Dimensions of Gears

Gears are very important for the movement of our model. Gears transmit power and whiledoing so, they reduce the undesirably high rpm delivered by the motors to useable levels.

Gear Nomenclature

Number of teeth in upper gear, Z1 = 13
Number of gear in lower gear, Z2 = 13
Gear Ratio, i = 1
Module, m = 1.5 mm
Speed on smaller gear N1=50rpm Speed on larger Gear N2=50rpm Circular pitch Pc=3.4mm Diametral pitch Pd=0.92mm Module pitch m=1mm Peripheral velocity v=0.72m/s

Calculations

Pitch Diameter, d1 = m.Z1
= 1.5*13
= 19.5 mm

Diameteral Pitch, DP = Z1/d1
= 13/19.5
= 0.666 mm^{-1}.

Outside Diameter, Do = (Z1+2)/DP
= (13+2)/0.66
= 22.72 mm.

Addendum, a = 1/DP
= 1/0.66
= 1.51 mm.

Dedendum, d = 1.157/DP
= 1.157/0.66
= 1.75 mm.

Working depth =2.25m
=2.25*1.08
=2.43mm

Tooth thickness t =1.5708m
=1.5708*1.08
=1.696mm

Minimum bottom clearance=0.25m
=0.25*1.08
=0.27mm

V Determination of Dimensions of Frame and Base Plate

The base plate carries the whole set up. Also, the frames have holes drilled at certain mountingpoints. Any misalignment would result in failure. Hence, the frames and base plate must bedesigned in such a way that the movement of linkages is not disrupted.After carefully considering all the constraints involved, we decided on the set of dimensionsthat best suited our needs. The dimensions are: Length of base plate = 360 mm
Width of frame = 230mm
Length of the shaft=110mm
Diameter of the shaft=15mm
Number of shaft =8
Thickness of the square rod =1mm
Length of the square rod =25.4mm

Frames and Base Plate

The model consists of a base plate and four frames which are fixed vertical to the base plate. The base plate and the frames are made of mild steel. Mild steel is a type of steel with carbon content up to 2.1% by weight.

Electric Motor

An electric motor is an electrical machine that converts electrical energy into mechanicalenergy. Electric motors are used to produce linear or rotary force (torque), and should bedistinguished from devices such as magnetic solenoids and loudspeakers that convert electric it into motion but do not generate usable mechanical powers. A motor is selected with respect tothe mass of the entire setup. For smooth movement in two directions, only one motor is necessary. One D.C. motors with ratedspeed of 50 rpm is used. The motor is placed in such a way that the motor drives six legs. The motor is powered by 230V AC supply from the mains.

Gears

Gears are very important for transmission. Gears are also useful in speed reduction. Two setsof gears are used for effective transmission. Each set consists of an upper gear and two lower gears. Smaller gear consists of 13 teeth and a larger gear consists of 13 teeth, thereby giving a speed reduction ratio of 1.68.

Shafts

A drive shaft, driveshaft, driving shaft, propeller shaft (prop shaft), or Cardan shaft is amechanical component for transmitting torque and rotation, usually used to connect othercomponents of a drive train that cannot be connected directly because of distance or the needto allow for relative movement between them.Drive shafts are carriers of torque: they are subject to torsion and shear stress, equivalent to thedifference between the input torque and the load. They must therefore be strong enough to bearthe stress, whilst avoiding too much additional weight as that would in turn increasetheir inertia. Eight shafts are employed to transfer the power from the motors to the legs. The shafts are 15mm in diameter and 115 mm in length. The shafts are made of wood.

Legs

A mobile robot needs locomotion mechanisms to make it enable to move through itsenvironment. There are several mechanisms to accomplish this aim, for example one, four, andsix legged locomotion and many configurations of wheeled locomotion. The focus of thiselaboration is legged and wheeled locomotion. Legged robot locomotion mechanisms are ofteninspired by biological systems, which are very successful in moving through a wide area ofharsh environments. To make a legged robot mobile each leg must have at least two degrees of freedom.

Linkage

A mechanical linkage is an assembly of bodies connected to manage forces and movement.The movement of a body, or link, is studied using geometry so the link is considered to berigid. The connections between links are modelled as providing ideal movement, pure rotationor sliding for example, and are called joints. A linkage modelled as a network of rigid links andideal joints is called a kinematic chain.Linkages may be constructed from open chains, closed chains, or a combination of open andclosed chains. Each link in a chain is connected by a joint to one or more other links. Thus, akinematic chain can be modelled as a graph in which the links are paths and the joints arevertices, which is called a linkage graph.The movement of an ideal joint is generally associated with a subgroup of the group ofEuclidean displacements. The number of parameters in the subgroup is called the degrees offreedom (DOF) of the joint. Mechanical linkages are usually designed to transform a giveninput force and movement into a desired output force and movement. The ratio of the outputforce to the input force is known as the mechanical advantage of the linkage, while the ratio ofthe input speed to the output speed is known as the speed ratio. The speed ratio and mechanicaladvantage are defined so they yield the same number in an ideal linkage.

Klann Linkage

A kinematic chain, in which one link is fixed or stationary, is called a mechanism, and a linkagedesigned to be stationary is called a structure. The Klann linkage is a planar mechanism designed to simulate the gait of legged animal andfunction as a wheel replacement. The linkage consists of the frame, a crank, two groundedrockers, and two couplers all connected by pivot joints.The proportions of each of the links in the mechanism are defined to optimize the linearity ofthe foot for one-half of the rotation of the crank. The remaining rotation of the crank allows thefoot to be raised to a predetermined height before returning to the starting position andrepeating the cycle. Two of these linkages coupled together at the crank and one-half cycle outof phase with each other will allow the frame of a vehicle to travel parallel to the ground.The Klann linkage provides many of the benefits of more advanced walking vehicles withoutsome of their limitations. It can step over curbs, climb stairs, or travel into an area that arecurrently not accessible with wheels but does not require microprocessor control or multitudesof actuator mechanisms. It fits into the technological space between these walking devices andaxle-driven wheels.

VI Control systems

Switched Mode Power Supply

A switched mode power supply is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a DC or AC source (often mains power) to DC loads, such as a personal computer, converting voltage and current characterist ics. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy. Ideally, a switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time. In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight.Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size or lighter weight is required. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor.

DPDT switch

DPDT is a double pole double throw switch; this is equivalent to two SPDT switches. It routes two separate circuits, connecting each of two inputs to one of two outputs. The position of the switch determines the number of ways in which each of the two contacts can be routed. Whether it is in ON-ON or ON-OFF-ON mode they functions like two separate SPDT switches operated by the same actuator. Only two loads can be ON at a time. A DPDT can be used on any application that requires an open and closed wiring system, an example of which is railroad modelling, which makes use of small scaled trains and railways, bridges and cars. The closed allows for the system to be ON at all times while open allows for another piece to be turned ON or activated through the relay. The connections A, B and C form one pole of the switch and connections D, E and F form the other. Connections B and E are common in each of the poles.If the positive power supply (Vs) enters at connection B and the switch is set to the top most position, connection A becomes positive and the motor will rotate in one direction. If the switch is set to the lower most position, the power supply is reversed and connection D becomes positive then the motor will rotate in the opposite direction. In the centre position, the power supply is not connected to the motor and it does not rotate. This type of switchis mainly used in various motor controllers where speed of that motor is to be reversed.

VII Working

The basic working principle of Klann Mechanism is that when the crank is rotated, a series ofrelative movements in the various links result in a gait-like movement of the leg.The operation of the mechanism can be by temporarily installing a wired control box. The boxconsists of a DPDT switches wired to control the forward and backward motion of the twolegs. The legs on each side should be positioned so that either the centre leg touches the groundor the front and back leg touch the ground. The leg is the same as an insect’s and provides agreat deal of stability. To reverse, one set of legs stops (or reverses) while the other

setcontinues. During this time, arrangement of the legs will be lost, but the robot will still besupported by at least three legs. An easy way to align the legs is to loosen the chain sprocketsand position the middle leg all the way forward andthe front and back legs all the way back. Retighten the sprockets, and look out for misalignmentof the roller chain and sprockets. If a chain bends to mesh with a sprocket, it is likely to popoff when the robot is in motion. During testing, lookout for things that rub, squeak,and work loose. Keep the wrench handy and adjust gaps and tighten bolts as necessary. The power is supplied from the main 230V AC supply. The AC to DC converter SMPS has an AC input. It is converted into DC by rectification process using a rectifier and filter. This unregulated DC voltage is fed to the large-filter capacitor or PFC (Power Factor Correction) circuits for correction of power factor as it is affected. This is because around voltage peaks, the rectifier draws short current pulses having significantly high-frequency energy which affects the power factor to reduce. The output is then supplied to the DPDT switch.

VIII Merits of spider robot

The main motive of making the Spider robot by Klann mechanism was to overcome obstaclescomes in the way where the wheeled robots are helpless. Like in rocky surface the wheeled botcannot pass over a rocks or even small stones and in desert or in sand the wheeled bots getstruck and slip. Whereas Klann robot locomotion is based on picking and pushing mechanismand its extensive stability can easily conquer rocky and sandy terrains. Due to this aspect Klannrobot can be used in defence and in military applications like mine detection and spying. It canbe used in research and exploration in such areas where men cannot reach such as in volcanicresearch. This concept can also be used for exploration and sample testing in other planets andasteroids.

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