Design and Fabrication of Stair Climbing Robot

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Abstract— **This project deals with the designing and manufacturing of a vehicle, which can climb stair or move along very rough surface. The technical issues in designing of this vehicle are the stability and speed of the vehicle while climbing stairs. However, the steepness of the stairs is also the important concern of this study. The uses of this special vehicle are in the frequent lift of goods such as books for library, medicines for hospital, regular mails for any institutes, or transportation any toxic material for industries and give freedom to the retarded person or paralyzed patients to move anywhere over flat surface as well as stairs. The vehicle has four set of wheels arrangement to support its weight when it moves over the flat terrain. Each wheel frame consists of three sub-wheels attached with the sun wheel through three idler gears. Using of this vehicle, the labour cost can be reduced as well as huge amount of loads can be transferred uniformly with less power consumption. Moreover, considering some drawbacks due to lack of implementation of all techniques during manufacturing phase the test and trial run showed considerably significant and encouraging results that might help the future researchers to incorporate a gear box and steering mechanism to make the vehicle more versatile.**

***Key point*— Stair climbing vehicle, wheel frame, planetary gear system, sun wheel.**

INTRODUCTION

Wheeled and tracked vehicles, while cheaper than bipedal or jumping robots, often have problems with slippage. The Loper robotic platform has solved this problem with an innovative wheel design for mobile robots consisting of three lobes connected by to a central hub that essentially act as cogs for the purpose of stair climbing. The design enables fast stair climbing at a reduced platform weight. The chassis design provides a light, flexible and rugged platform that is ideal for agile operation.

An epicyclic gear train consists of two gears mounted so that the centre of one gear revolves around the centre of the other. A carrier connects the centres of the two gears and rotates to carry one gear, called the planet gear, around the other, called the sun gear. The planet and sun gears mesh so that their pitch circles roll without slip. A point on the pitch circle of the planet gear traces an epicycloids curve. In this simplified case, the sun gear is fixed and the planetary gear(s) roll around the sun gear.

An epicyclic gear train can be assembled so the planet gear rolls on the inside of the pitch circle of a fixed, outer gear ring, which is called an annular gear. In this case, the curve traced by a point on the pitch circle of the planet is a hypocycloid.

Lifting recurring loads like books, food grains etc. to store upper level, or even patients to move upper level is not easy job, especially where there is no lifting facilities (elevator). Moreover, in most of the buildings in the world does not elevators or escalators. In this case human labors are considered to be the only solution. Labor is becoming costly in the developed countries, where growth rate is getting negative. This problem can be solved if a vehicle can lift loads while traveling through strains. The project introduces a new horizon for the transportation of the loads over the stair. Most of the buildings of the country are structurally congested and unavailing of elevator facility so it is difficult and laborious to lift up heavy loads. The stair climbing vehicle can play an important role in those areas to lift loads over a short height, like libraries, hospital, and in construction area. The vehicle, which can move upper level through strain, or run in very rough and rocky surfaces, is called stair climbing vehicle.

In various research projects all over the world the different locomotion concepts for mobile robots have been analysed and new concepts have been proposed. Good general surveys are provided. In over 300 mobility concepts and more than 400navigation concepts have been generated and discussed, yielding to three candidate systems, a symmetrical walker with six identical legs, a four-wheeled vehicle and a so called attached scout concept with six wheels.

In this article the design and manufacturing of a stair climbing vehicle has been presented. The vehicle is designed in such a way that it can climb a stepped path (like stairs) with its modified wheel structure. Not only on the stairs, can it also move with load over flat or rocky surface. This is the individuality of this vehicle. Different speed combinations are incorporated depending on the working condition through simple gear arrangement, powered by the local motor drive. Speed reduction at any desired rate, is possible to establish over the existing ratio. Wheeled rovers are the optimal solutions for well structured environment like roads or habitations. But off-the road, their efficiency is very dependent on the typical size of encountered obstacles that have to be overcome in a standard motion mode. This is the case for, which can typically overcome obstacles of their wheel size, if friction is high enough. Adding real climbing abilities to a wheeled rover requires the use of a special strategy and often implies dedicated actuators or complex control procedure

I. PROBLEM STATEMENT

Design and develop a prototype model of stair climbing robot based on the principle of tri-wheel epicyclic (planetary drive) gear train which can be able to drive and climb the steps or stairs with forward and reverse direction.

Also fabricate the model of same which should be able to give same results as expected to climb the stairs and to test the model which would have different applications in defence, automation and various other fields.

II. OBJECTIVE

1 To design and develop the concept of an epicyclic-planetary wheel drive stair climbing robot.

1. To design and develop the fabrication design for prototyping the planetary gear drive based stair climbing robot.
2. To fabricate the model of the same which can be able to climb the stairs as guided by the driver or controller.
3. To test the model of the same under different conditions of surfaces and stairs to give results and conclusion about the quality of project model.
4. To present and discuss a concept and further developments for applications of this project is different fields like defence, automation, rescue applications etc.

III. SCOPE

There is a lot of scope for improvement and this mechanism can be further modified and used in various other applications such as carrying heavy loads and thus further reducing human effort. Another scenario where this mechanism can be employed is during disaster management. A camera can be fitted on the robot to have a wide field of view of the affected areas which can further help in search and rescue operations. This robot can further be integrated with mobile devices to process the images fed by the camera and act accordingly to the stairs.

IV. METHODOLOGY

Epicyclic gearing or planetary gearing is a gear system consisting of one or more outer gears, or planet gears, revolving about a central, or sun gear. Typically, the planet gears are mounted on a movable arm or carrier which itself may rotate relative to the sun gear. Epicyclic gearing systems also incorporate the use of an outer ring gear or annulus, which meshes with the planet gears. Planetary gears (or epicyclic gears) are typically classified as simple and compound planetary gears. Simple planetary gears have one sun, one ring, one carrier, and one planet set. Compound planetary gears involve one or more of the following three types of structures: meshed-planet (there are at least two more planets in mesh with each other in each planet train), stepped-planet (there exists a shaft connection between two planets in each planet train), and multi-stage structures (the system contains two or more planet sets). Compared to simple planetary gears, compound planetary gears have the advantages of larger reduction ratio, higher torque-to-weight ratio, and more flexible configurations.

The design enables fast stair climbing at a reduced platform weight. The chassis design provides a light, flexible and rugged platform that is ideal for agile operation.

An epicyclic gear train consists of two gears mounted so that the centre of one gear revolves around the centre of the other. A carrier connects the centres of the two gears and rotates to carry one gear, called the planet gear, around the other, called the sun gear. The planet and sun gears mesh so that their pitch circles roll without slip. A point on the pitch circle of the planet gear traces an epicycloids curve. In this simplified case, the sun gear is fixed and the planetary gear(s) roll around the sun gear.

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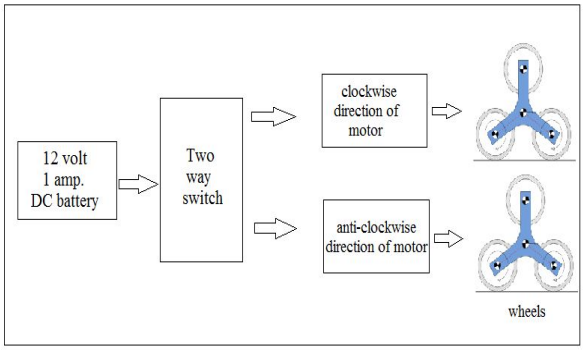

Fig1. block diagram showing working of the project

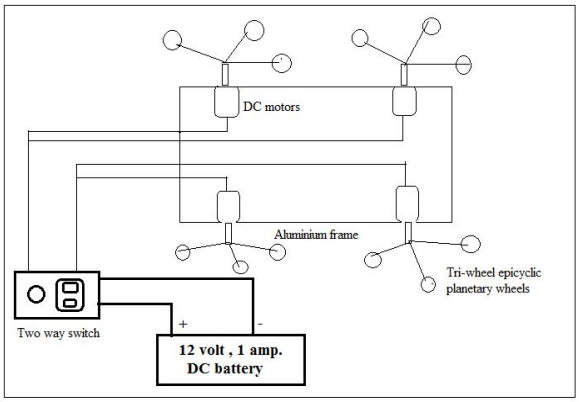

Fig2. Schematic working of the project

V. LITERATURE REVIEW

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Today, due to technological advances of robotic applications in human life, it is necessary to overcome natural and virtual obstacles such as stairs which are the most known obstacles to

the motion of such robots. Several research have been conducted toward the design of stair climbing and obstacle traversing robots during the past decade. A number of robots have robots have been built for climbing stairs and traversing obstacles, such as quadruped and hexapod robots. Although these robots can climb stairs and traverse obstacles, they do not have smooth motion on flat surfaces, which is due to the motion of their legs. Buehler built a hexapod robot (RHex) that could ascend and descend stairs dynamically. He has also built a quadruped robot (SCOUT) which could climb just one stair (M. Buehler, (2002), U. Saranli, (2001), Martin Buehler , (2002) C. Steeves1,(2002)). Furthermore, a few wheeled and legwheel robots have been proposed that either can climb only one stair or can not climb stairs individually and need to be supported by a person; Therefore, they are not good enough to be practical. Koyanagi proposed a six wheeled robot that could climb a stair (Eiji KOYANAGI). Kumar offered a wheelchair with legs for people with disabilities which could climb a stair (Parris Wellman, (1995) ,VenkatKrovi, (1995)) . Halme offered a robot with movement by simultaneous wheel and leg propulsion (AarneHalme (2001)). Quinn built Leg-Wheel (quadruped and hexapod) robots (Mini-Whegs) that could ascend, descend and jump stairs (Roland Siegwart, (1998), Nakayama R (1998)). Kmen invented a wheelchair with wheels (iBOT 3000) that could climb stairs by human support (A. Crespi) . Also NASA designed Urban Robot which was a Tracked robot. It could climb stairs and curbs using a tracked design instead of wheels. The Urban Robot (Urbie) led to the PackBot platform of iRobot. Besides, Dalvand designed a wheeled mobile robot that has the capability of climbing stairs, traversing obstacles, and is adaptable to uphill, downhill and slope surfaces (Dalvand and Moghaddam (2003)).

Md. A. Hossain. Nafis A. Chowdhury, Rubaiat I. Linda, and Shamiuzzaman Akhtar

This article deals with the designing and manufacturing of a vehicle, which can climb stair or move along very rough surface. The technical issues in designing of this vehicle are the stability and speed of the vehicle while climbing stairs. However, the steepness of the stairs is also the important concern of this study. The uses of this special vehicle are in the frequent lift of goods such as books for library, medicines for hospital, regular mails for any institutes, or transportation any toxic material for industries and give freedom to the retarded person or paralyzed patients to move anywhere over flat surface as well as stairs. The vehicle has four set of wheels arrangement to support its weight when it moves over the flat terrain. Each wheel frame consists of three sub-wheels attached with the sun wheel through three idler gears. Using of this vehicle, the labour cost can be reduced as well as huge amount of loads can be transferred uniformly with less power consumption.

Moreover, considering some drawbacks due to lack of implementation of all techniques during manufacturing phase the test and trial run showed considerably significant and encouraging results that might help the future researchers to incorporate a gear box and steering mechanism to make the vehicle more versatile. Though this project had some limitation as a first step of making any Stair Climbing Vehicle, it was a pioneer project. During the test run of this project, it was realized that it would capable of carrying heavy load without suffering any deformation or local fractures if it would go into real world production at an ideal scale. Though the initial cost of the project seemed to be higher but more accurate manufacturing would shorten this.

VI. THE DESIGN PROCESS

TRI-STAR WHEEL

The Tri-Star wheel was designed in 1967 by Robert and John Forsyth of the Lockheed Aircraft Corporation. They were first developed as a module of the Lockheed Terrastar, a commercially unsuccessful amphibious military vehicle. A Tri-Star wheel functions as an ordinary wheel on flat ground, but has the ability to climb automatically when an impediment to rolling is encountered. This wheel design consists of three tires, each mounted to a separate shaft. These shafts are located at the vertices of an equilateral triangle. The three shafts are geared to a fourth, central shaft (to which a motor may be attached). When geared in this quasi-planetary fashion, these triangular sets of wheels can negotiate many types of terrain, including sand and mud; they can also allow a vehicle to climb over small obstructions such as rocks, holes, and stairs. The wheel assembly may be gear-driven, with two wheels in rolling contact with the ground. The third wheel idles at the top until the lower front wheel hits an obstruction. The obstruction prevents the lower front wheel from moving forward but does not affect the motion of the driving axle. This causes the top wheel to roll forward into position as the new front wheel.

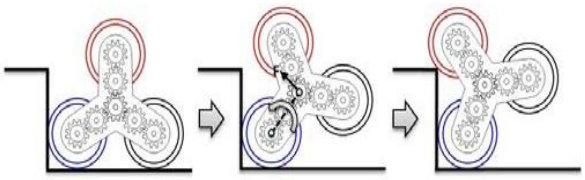

Fig5. Tri- star wheel arrangement

This wheel usually lands on top of the obstruction and allows the rest of the assembly to vault over the obstruction. Tri-Star wheel in motion is shown in figure.

WHEEL FRAME

A specially designed wheel frame is required to hold the three wheels together on each side of the shaft. In the existing design, the power transmission to the single or double wheel trolley is useless to climb the stairs due to height factor of stairs. The design of the straight wheel frame became more complicated and was needed to be modified with its curved-

spherical shape to give proper drive, which creates more frictional force. For these reason, three wheel set on each side of vehicle attached with frame was introduced to provide smooth power transmission in order to climb stairs without much difficulty. Frame arrangement is suitable to transmit exact velocity ratio also. It provided higher efficiency and compact layout with reliable service. Easier maintenance was possible in case of replacing any defective parts such as nut, bolt, washer, etc.

VII. DESIGN

In this project, the final design was an outcome of a sequential analysis and modification of stages which had been started with a simple roller based design. To attain higher efficiency and greater stability the design was replaced with a gear based curved wheel frame (figure 2).

In the initial design, each wheel contained frame, a sun wheel and three planetary wheels. The planetary wheel was connected with the sun wheel through an idler. The purpose of using the idler was to rotate the planetary wheels in the same direction of sun wheel. Each planetary wheel was aligned in a straight line with idler and sun wheel. Planetary wheels were 120° apart from each other (figure 7). The tapered idler was also planned to disengage the planetary wheel from the sun wheel, while it was not used to save power. However, the idlers generate frictional force, which requires more powerful motor. Slip might occur if adequate friction is not available. So finally an especial type gear arrangement have been designed which is more stable and consume less power.

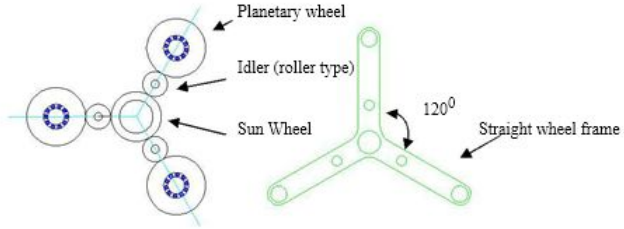

Figure 7: Initial design of Roller based wheel arrangement and wheel frame

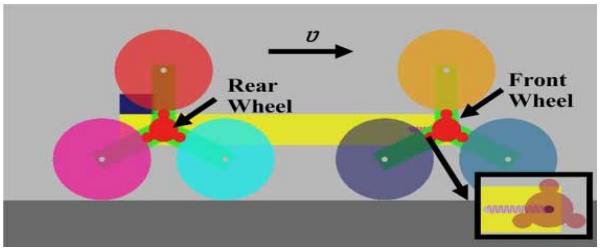

Fig8. Basic design of developed climbing mechanism

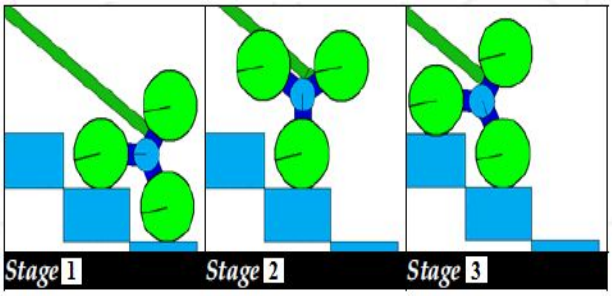

Figure9. Stages 1, 2 and 3 while ascending stairs.

VIII. ADVANTAGES

The concept of this climbing robot has some interesting advantages. Firstly, it does not really matter how much weight you want to lift. The only factor that decides how much weight can be lifted is the gear on the DC-motor to lift the robot. It is advisable to make the gear a little bit smaller, so the motor has to revolve more to make the gear rack move an even distance. As a result, the robot will go slower up and will be able to carry greater amounts of weight.

The smaller size and stair climbing ability is much useful in home and security conditions.

The size can be further reduced for only climbing purpose where material handling is not required but virtual presence with cameras and small LCD screen is needed, for spying, rescue operations, etc.

With the advancement of technology, new exciting approaches enable us to render mobile robotic systems more versatile, robust and cost-efficient. By combining climbing and walking techniques with a modular approach, a reconfigurable approach, or a swarm approach to realize novel prototypes as flexible mobile robotic platforms featuring all necessary locomotion capabilities.

IX. APPLICATIONS

1. Has the potential to serve as a base on which to mount data acquisition devices, surveillance equipment, or object-manipulation tools
2. Wireless/wired video surveillance possible
3. Public safety & military applications (surveillance, search & rescue)
4. Consumer applications (material handling in home, offices, industries)
5. Inspections, spying etc.

X. CONCLUSION

Stair climbers are a great invention. Not only do they allow you to go upstairs, or indeed downstairs with those clever three point wheels, but they also make the process of doing so much smoother, reducing the chances of upsetting the loads being transported and having it all fall off half way down.

Though this project had some limitation as a first step of making any Stair Climbing Vehicle, it was a pioneer project. During the test run of this project, it was realized that it would capable of carrying heavy load without suffering any deformation or local fractures if it would go into real world production at an ideal scale. Though the initial cost of the project seemed to be higher but more accurate manufacturing would shorten this.

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