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Design and Manufacturing of Mecanum Wheel

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Abstract

In this study an attempt has been made to design and manufacture a special type of wheel (in this case, Mecanum Wheel) is presented. The study was further extended to find practical application for mobile robotic platforms using mecanum wheels. When mobile robots are equipped with mecanum wheel, it gets the ability to move in any direction instantaneously without changing its orientation. The basic working of a system using mecanum wheel is by applying rotating force of individual wheel in one direction like regular wheels with difference in the fact that mecanum wheel systems can slide freely in a different direction. By using mecanum wheel the robot gets omni-directional abilities. Hence, when compared to conventional wheels, these wheels pose multiple advantages. The main advantage of using mecanum wheel system is, translational and rotational motions are decoupled for simple motion although in making an allowance for the fastest possible motion this is not essentially the case. The aim here was to construct a mobile robot which can be used in medical field. This paper describes some of the characteristics of mecanum wheel and its advantages over conventional wheel.

Keywords- Mecanum wheel, Mobile robots, Omni-directional, Conventional wheels, Translational and Rotational motion.

I. INTRODUCTION

This project was based on the Mecanum wheel design which was introduced in 1973 by Bengt Ilon, an engineer with the Swedish company Mecanum AB. Recently many researchers have worked on various applications and development of mecanum wheels. Especially, mecanum wheels are nowadays widely used in various industries such as military, storage, transportation, factories, hospitals, etc. As compared to conventional wheels, omni-directional wheels possess multiple advantages in terms of mobility in narrow spaces and crowded environment. Mecanum wheel uses the principle of a central wheel with several rollers placed at an angle around the periphery of the wheel. The angled peripheral roller translates a portion of the force in rotational direction of the wheel. Depending on each individual wheel direction and speed, the resulting combination of all these forces produce a total force vector in aby desired direction thus allowing the system to move freely in direction of resulting force vector, without changing the direction of the wheel. The traditional mecanum wheel design by Ilon with peripheral roller with 45˚ slope held in place from outside. This design worked only on even surfaces. When encountering an inclined or uneven surface, the rim of the wheel can make contact with the surface instead of the roller, thus preventing the wheel from performing correctly. To overcome this problem a simple alternative design, also proposed by Ilon, which consists of two split rollers mounted centrally on the periphery of the wheel. This design ensured that the rollers were always in contact with the surface, which allowed better performance on uneven surfaces. A four-wheeled robot with mecanum wheels, which is driven by four independent motors, can move in any direction on a plane without the necessity to rotate. A system equipped with mecanum wheels is holonomic, so the number of controlled degrees of freedom is equal to the number of degree of freedom is equal to the number of degree of freedom that are held. This is of particular significance in the case of systems that operate in very limited spaces. Despite the larger number of designs, all designs have the same principle, and as a result, all current design perform poorly on rough terrain. In this project we have attempted to design and manufacture a system using mecanum wheel which can be used for clinical purposes.

II. DESIGN PROCEDURE

A. Design for Mecanum Wheel

The main idea behind designing the above Mecanum Wheel was to make sure that the roller contour was sticking out enough so that there could contact with the surface. But, for this wheel design also the rollers are assembled with the wheel plate to get a proper idea about the complete wheel structure. Also, this Mecanum Wheel is designed using both part design and generative sheet design. The bolts were implemented after placing the rollers at the desired location. For the design which is done in GSD workbench, rollers and plate are designed in part design while flanges are designed in GSD workbench. All these parts are assembled to get the full assembly.

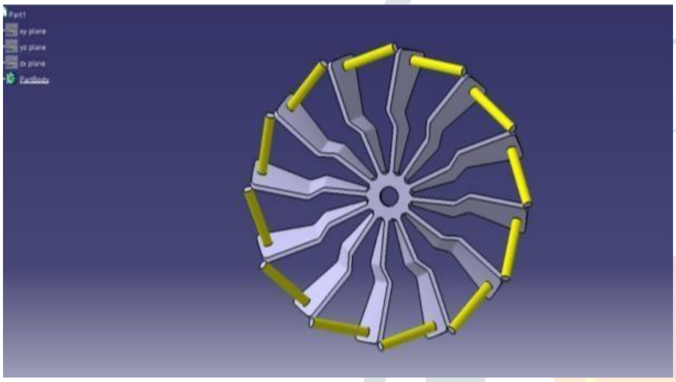

Fig. 1 Design of wheel without roller

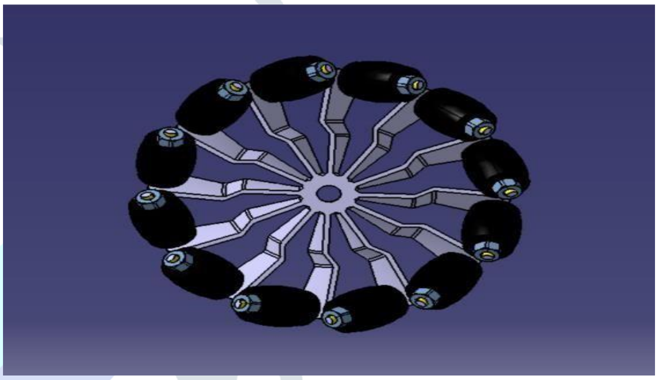

Fig.2 Design of wheel with roller

B. Design for roller

As per CATIA design select diameter of wheel as 35 mm and roller with dimension. To check dimensional accuracy of mecanum wheel, Here use formula from reference, as improper selection of dimension of roller and wheel will lead to bumpiness in wheel. Bumpiness seen in mechanical wheel roller decrease efficiency of wheel if no. of roller not chosen properly it gives rise to bumpiness which is seen in roller. Increase in no. of roller decrease vibration. Selecting no. of rollers of certain size become important in mecanum wheel. Rollers are placed at 450. Wheel is assumed to be lying in XX plane. Value of S varies from zero to half to length of roller axis. To calculate different values of other parameters some of derived formulas.

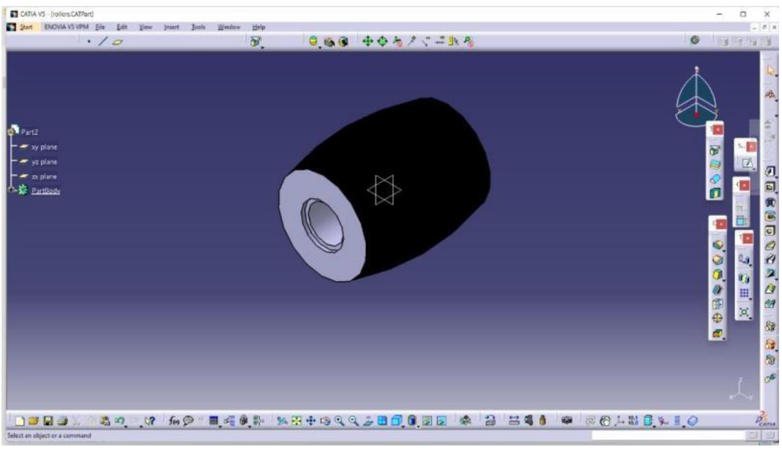

Fig. 3 Design of Roller

III. METHOD AND CONTROL ALGORITHM

To the right: This is a top view looking down on the drive platform. Wheels in Positions 1, 4 should make X- pattern with Wheels 2, 3. If not set up like shown, wheels will not operate correctly.

Mecanum drive is a type of holonomic drive base; meaning that it applies the force of the wheel at a 45° angle to the robot instead of on one of its axes. By applying the force at an angle to the robot, you can vary the magnitude of the force vectors to gain translational control of the robot; In plain English, the robot can move in any direction while keeping the front of the robot in a constant compass direction. The figure below shows the motions that can be achieved for various combination of wheel rotation.

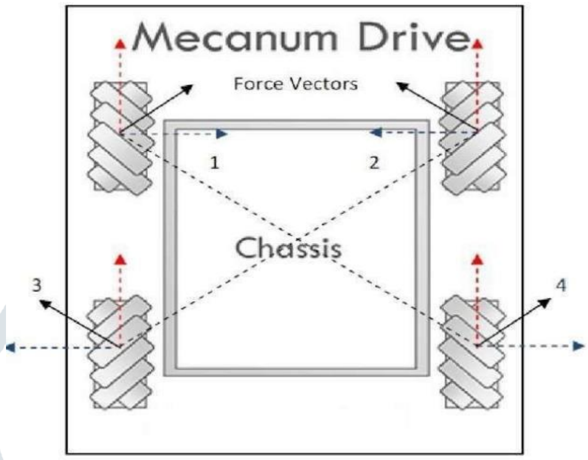

Fig. 4 Mecanum Drive Diagram

Direction of Movement	**Wheel Actuation**
Forward	All wheels forward same speed
Reverse	All wheels backward same speed
Right shift	Wheel 1, 4 forward and wheel 2, 3 backward
Left shift	Wheel 2, 3 forward and wheel 1, 4 backward
CW turn	Wheel 1, 3 forward and wheel 2, 4 backward
CCW turn	Wheel 2, 4 forward and wheel 1, 3 backward

Table.1 Drive Mechanism for Mecanum Wheel

IV. CALCULATIONS

A. *For Roller*

$a = tan^{-1} S/\sqrt{2}/(R- \ )$

$D = R - r / \cos a$

$l = R - d$

$\theta = cos^{-1}(\sin a/\sqrt{2})$

$h = S + \sin a/\sqrt{2}$

$Rr = l \sin \theta$

Where, R= wheel Radius.

S= Distance measure along roller axis to intersection with L.

θ = Angle between line L and roller axis.

From all following equations the radius of roller which will best suit to avoid bumps can be found and will at a distance h from center of roller. [2] So, from the above calculation conclude that roller with evaluate profit with diameter of 24mm at the end and diameter of 28 mm at the middle can reduce the bumpiness of mecanum wheel.

$F = \sqrt{2} * D 2 + S 2$

$G = \sqrt{(4 * D 2 + S 2)}$

$T = \sqrt{2} * R / F$

h = (S/2) * (T+1)

Rr = (G/2) * (T-1) D = R-r = 70-14 = 56

Force Calculation: -

When calculating force for mecanum wheel the forward, strafe and diagonal force can be obtained by,

$F F$ =(4*T) r= (4*10.61*103)/14=3031.42N

$F r$ =(4*T)/r= (4*10.61*103)/14=3031.42N

$F D$ =(2T*√2)/r= (2*√2*10.61*103)/14=2143.54N.

Calculating velocity for mecanum wheel: -

For calculating forward velocity, strafe velocity and diagonal velocity equations are [2].

Vf = w*r = 4.71 * 14 = 65.97 mm/s

Vr = w*r = 4.71 * 14 = 65.97 mm/s

VD = w*(r/√2) = 4.71* (14/√2) = 46.65 mm/s

A. For Motor

We are using motor having specifications I = 3.5/5A

N = 40/60 ± 5 rpm Stall torque = 29N.m

Stall current = 31A (max)

Motor power = VI = 3.5*12 = 42 Watt ~ 50 Watt

P = 2πNT/60

50 = 2π*45*T/60

T = 10.61 Nm

M = W*L = 5*9.81*65 = 3188.25 N.mm

Therefore approx.. torque on each wheel will be 10.61 Nm, also shaft undergoes both torsional and bending moment, so calculating equivalent torque for diameter calculation.

Now, Te = $\sqrt{M 2 + T 2}$ = √ (106102 + 3188.252) = 11078.67 N.mm

Te = 11.078 N.m

Now,

Te = (π/16) * d3 * σ s

11078.67 = (π/16) * d3 * 730

d = 4.26 mm

As our motor shaft diameter is 10 mm so design is safe.

Stress induced on roller pin: -

Total weight of machine is not to more than 20 kg. Weight distributed on all four wheels. So, weight on each wheel is 5 kg is coming on roller pin so shaft will fail in bending. We are using M4 bolts with 3-inch (75mm).

M=WL/4 -----------as SSB

M= 5*9.81*75/4 = 937.5 N.mm

And Z = $\pi/32 * d 3$ = (π/32) * 43 = 6.28 mm3

σ = (M/Z) = (937.5/6.28) = 149.28 N/mm2 = 150 N/mm2

As allowable bending stress for pin material (C45) is 730 N/mm2. So, our design is safe.

II. CONCLUSION

In our particular manual robot weighing 20 kilograms for, we used four Omni wheels at an angle of 45 degrees to achieve desired direction of motion. With calculated combination of the wheel alignment and the direction of rotation of motor shaft, we had achieved 8 directions of motion. If the speed of individual motors can be monitored and changed, we can achieve curved path and also simultaneous rotational and linear motion. The results offer new insights on modeling and simulation of the Mecanum wheels, including information regarding the frictional contact in the kinematic analysis. Concluding results were also achieved in the Rigid Dynamics environment, offering information on rollers behavior during a complete rotation of the Mecanum wheel. In this paper, an Omni-directional mobile industrial robot is introduced and a navigation scheme for the robot is demonstrated. Mechanical design of the system has been validated in terms of performance of the suspension-wheel mechanism. For 4 wheeled omni drive system, main design consideration is a proper suspension mechanism to distribute equal ground reaction force in all four wheels. Load on a particular wheel is estimated from the amount of current drawn by the particular motor. Also, one of the factors that was to be taken care of was the weight of the wheel structure. The wheel structure was designed in such a way that the weight reduction is seen which has proven to be the biggest advantage 8 directions subjects were asked to control the vehicle using conventional DPDT (Double Pole Double Throw) control to traverse a predefined path.

Fig. 5 Final Fabricated Model

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