Overview and Design of Mecanum Wheel

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Abstract.

Mobile robots are quite sophisticated and have many difficulties to overcome. The capacity to manoeuvres in small spaces is one of the key obstacles. This ability mostly relies on the wheel's design. The primary goals of this project are to increase wheelchair mobility and, as a result, the quality of life for users. Mecanum wheels were used for this project for that reason. This essay discusses the recently developed mechanical design as well as the best way to create a circular-shaped roller.

Keywords. Mecanum wheel, automobile, rollers, vehicle, omnidirectional.

1. INTRODUCTION

Recently, researchers have been concentrating on studies concerning the utilisation of wheeled omnidirectional running mechanisms. Storage and transportation, military, social services and many other field areas have all made extensive use of magnum omnidirectional vehicles in particular [1]. Omnidirectional robotic vehicles have several benefits over traditional vehicles when it comes to manoeuvrability in congested areas. They are capable of carrying out activities with ease in crowded areas that are predicted to have static impediments, dynamic obstacles, or restricted spaces. These kinds of settings are often present in industries, workshops, warehouses, hospitals, etc. Traditionally, omnidirectional vehicles have been specially designed to move on hard, flat and smooth surfaces. On ground, omnidirectional vehicles have three DOF. They are suited for highly manoeuvrable, constrained, or precise placement situations since omnidirectional vehicles can do motions such as longitudinal, lateral, center point steering and any composite motion of the previously mentioned three. The wheel velocity of an omnidirectional wheel may be broken down into the sections that are in the active and passive direction. The active component of the force is oriented parallel (‖) to the axis of the roller which is in contact with the ground, whilst the passive component of force is perpendicular (⊥) to the axis of the roller. Figure 1 illustrates basic mecanum wheel's design. Minimum of one and a maximum of two rollers are in touch with the ground while a mecanum wheel is turning. The roller only makes touch with the ground at one point, however, theoretically. Depending on how the wheel is rotating, this surface area moves across the roller from side to side. This forces the force of traction to be determined by the traversing feel of the contact of the roller with the surface.

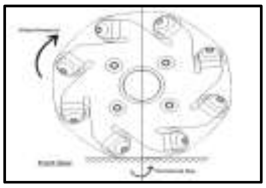

Figure 1. Degrees of Freedom in Mecanum Wheel

According to tests carried out for numerous researchers around the world, the Mecanum wheels' biggest problem is that they are unable to move laterally in the sand because the dirt and sand particles piles up between the rollers and on the side of the wheels and stops it from motion after the dirt and sand pile reaches a certain height with respect to the wheel size [2],[3]. They also have difficulty triumphing over obstacles during the motion in lateral direction. The main key goals of our study, which was motivated by these issues, was to develop a new kind of mecanum wheel capable of resolving those issues.

2. REGULAR MECANUM WHEELS

In a mecanum wheel, a group of k congruent rolls are assembled and arranged symmetrically around the wheel body. Each roll's face is a component of a revolution surface (R), whose b axis is skewed to the wheel's a axis [4]. There have been several comparable ideas put out, however these designs vary in terms of the number (k) of rollers, the manner of linkage of the rollers to the hub, the fixed angle at which rollers are in relation to wheel, the various materials utilised, etc. [2]. Some of the major issues faced are large vibrations and limited loading capacity. Slippage is another issue with them; as a consequence, even with the equivalent rotation of the wheel, the lateral and longitudinal movement of vehicle distances vary. In figure 2, a classic mecanum wheel is shown.

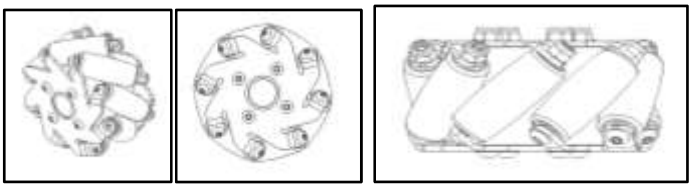

Figure 2. Conventional Mecanum Wheel

3. DESIGN OF ROLLERS

To ensure motion continuity is one of your primary concerns when building a new drive system. The true significance of this is that there are sufficient rollers and contact lines to cover the wheel's curvature, in this example, a circumference. Additionally, there is a certain count of rollers used in the wheel that creates an optimal balance between possessing a few big size rollers per wheel and a number of small size rollers per wheel. Equation 1 is used to compute the moving continuity, which is denoted by.

$$\varepsilon = \frac{N(y-2\theta_o)R}{2\pi R} = \frac{N}{2\pi}(y - 2\theta_o)$$

There are five parameters listed in equation (1). These variables (R, N, ε, y, θ) are utilised to construct the rollers for the circular wheel components. As shown in Figure 3, R is the wheel's overall radius, N is number of rollers requires, y is angle at which the helical line is rotated around the z-axis of wheel, and θ is angle between the starting motion of point C travelling adjacent to the helical line (Figure 3).

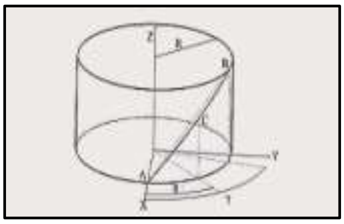

Figure 3. Configuration of the Rollers Scheme

A value of ε<1 in Equation (1) indicates that the length of the roller will be inadequate and will not function because the rollers will be small in comparison to the number of rollers in the wheel. The motion continuity may be ensured even when ε>1, but ε=1 is the best number since in this instance the length of the rollers satisfies all necessary wheel features. The number must therefore be as near to 1 as feasible because as it rises, the wheel becomes thicker, the roller's length increases, and the generatrix begins to oscillate, which renders the curve insufficient. The rollers in this paper's new design have a circular form, and changes have been made to the materials and the technique the rollers are attached to the hub. Figure 4 shows an example of the new design that is suggested.

Figure 4. Proposed and exploded view of macanum Wheel

The form of the rollers is defined in this design by the circular shape. In this instance, the coordinates A, B, and C in Figure 3 must be defined. These are how those points are defined:

A (R, 0, 0) | B (R cos γ, R sin γ, R γ) | C (R cos θ, R sin θ, R θ)

The vectors "A" and "B" are then established using the definitions listed below.

$$\overrightarrow{AC} = \begin{Bmatrix} R(\cos\theta - 1) \\ R\sin\theta \\ R\theta \end{Bmatrix} = \begin{Bmatrix} P_1 \\ P_2 \\ P_3 \end{Bmatrix}$$
$$\overrightarrow{AB} = \begin{Bmatrix} R(\cos\gamma - 1) \\ R\sin\gamma \\ R\gamma \end{Bmatrix}$$

The unit vector parallel to A and B is written as follows:

$$\vec{u} = \frac{\overrightarrow{AB}}{|\overrightarrow{AB}|} = \frac{\overrightarrow{AB}}{R\sqrt{2 - 2\cos\gamma + \gamma^2}} = \begin{Bmatrix} u_1 \\ u_2 \\ u_3 \end{Bmatrix}$$

$$u_1 = \frac{\cos\gamma - 1}{D} u_2 = \frac{\sin\gamma}{D} u_3 = \frac{\gamma}{D}$$

$$D = \sqrt{2 - 2\cos\gamma + \gamma^2}$$

The curvature of the roller may be efficiently determined using this information. However, to do this, vectors A and C must be rotated around vector at an angle to produce numerous contact lines. Using this approach, the equations shown below are produced.

$$\begin{aligned}
P_1' = {} & [\cos\tau + u_1^2(1 - \cos\tau)]P_1 \\
& + [u_2 u_1(1 - \cos\tau) - u_3 \sin\tau]P_2 \\
& + [u_3 u_1(1 - \cos\tau) + u_2 \sin\tau]P_3 \\
P_2' = {} & [u_2 u_1(1 - \cos\tau) + u_3 \sin\tau]P_1 \\
& + [\cos\tau + u_1^2(1 - \cos\tau)]P_2 \\
& + [u_3 u_2(1 - \cos\tau) - u_1 \sin\tau]P_3 \\
P_3' = {} & [u_3 u_1(1 - \cos\tau) - u_2 \sin\tau]P_1 \\
& + [u_3 u_2(1 - \cos\tau) + u_1 \sin\tau]P_2 \\
& + [\cos\tau + u_3^2(1 - \cos\tau)]P_3
\end{aligned}$$

The roller's surface equation is thus stated as follows

$$\begin{aligned}
x = x(\theta, \tau) &= R + P_1' \\
y = y(\theta, \tau) &= R + P_2' \\
z = z(\theta, \tau) &= P_3'
\end{aligned}$$

After that, the roller's maximum and minimum radii were calculated using the roller's surface equation in order to create a circular profile for the roller with the highest potential efficiency. Here, the other parameters of the equation, (L, l, l), may be determined by defining the number of rollers. L is the roller's length, is the angle formed by the hub and roller axis, and l is the width of the wheel are used to determine the roller's maximum and lowest radii. If N, the number of rollers, is known, may be used to determine roller length:

$$L_r = 2R\frac{\sin{}^{\varphi}/_{2}}{\sin\alpha} = 2R\frac{\sin{}^{\pi}/_{N}}{\sin\alpha}$$
$$\varphi = \frac{2\pi}{N}$$

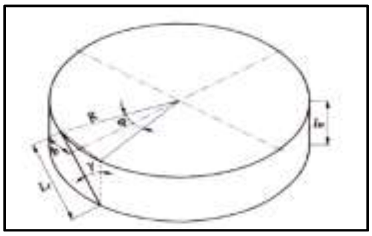

Figure 5: Wheel specifications

The wheel width will therefore be:

$$l_w = L_r \cos\alpha = 2R\frac{\sin {}^{\pi}/_{N}}{\tan\alpha}$$

The maximum radius of the roller may be calculated from these, and it is represented as:

$$r_{max} = R - \left(\frac{L_r \sin\alpha}{2\tan {}^{\pi}/_{2}}\right)$$

And the following equation is used to get the minimum radius:

$$r_{min}^2 + (2R - 2r_{max})r_{min} + R^2\left(\sin {}^{\varphi}/_{2}\right)^2 + r_{max}^2 - 2Rr_{max} = 0 \qquad (3)$$

The terms, r(max) and r(min) stand for the roller's maximum and lowest radii, respectively.

4. MECHANUM WHEEL SIMULATION

MATLAB programme was written with the goal of identifying the ideal silhouette for the roller. 750 interactions were performed in order to get the optimal outcome, with the number of rollers set between 8 and 14. The moving continuity coefficient was chosen between 1.008 and 1.031, and the width range is between 30 and 40 mm. The parameters α, θo, τ and R were previously specified in order to determine the roller's surface curve. The final set of required parameters were 45, 11, and 70. Regarding the parameter R, it was established in accordance with the project's goal, which will be covered in the next issue. As a result, the vehicle’s top speed was set at 5 km/h, and its weight limit was set at 100 kg. Accordingly, the mecanum wheel's radius R should be 50mm. The driving torque was given to each of the four revolute joints that joined the body and the four mechanical wheels. Table 1 is a list of the wheel's primary properties. Figure 6 shows that the curve is simply rotated 360 degrees to create the roller.

Table 1. Parameters to define the curve of the roller

Parameters to define the curve of the roller					
Width (mm)	Maximum radius of roller (mm)	Minimum radius of roller (mm)	Helical Line Angle (°)	Roller Length (mm)	Continuity Coefficien t
35	12	9	67.5	50	1.01

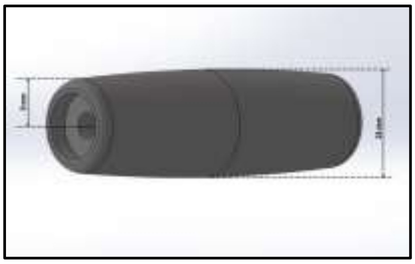

Figure 6. Roller’s 3D model (Dimensions in millimetres)

5. OUTCOMES

On the basis of continuity coefficient, simulations were run with varying values for the number of rollers, with a range chosen between 8 and 14. In the end, the number of rollers set at 12 produced the best performance. This occurred as a result of the rollers touching one other while being displaced with 10 and 11 rollers, which caused unfavourable vibrations. The wheel becomes thicker and the curve that creates the roller is insufficient when using 13 and 14 rollers because the length of the rollers is too long.

Table 2. Fixed parameters to define the curve of the roller

Fixed parameters to define the curve of the roller				
Number of Rollers	Rotational axis of wheel (α)	Starting angle of Helical Line (θo)	Rotation of wheel contact line around roller axis of rotation (τ)	Radius of the wheel (mm)
12	45º	11º	70º	75

Table 2 lists the primary variables that were fixed to produce the roller's curve when the number of rollers was set at 12. Figure 7 illustrates the outcomes after setting the roller's maximum radius to a range of 10 to 12 mm.

As shown in Figure 7, the roller length will rise as the maximum radius decreases, necessitating a thicker wheel. Additionally, the generatrix has a tendency to fluctuate, making the curve insufficient for the roller's creation. As a consequence, the Maximum radius setting of 10 to 12 mm produced the greatest results, as indicated in Table 3.

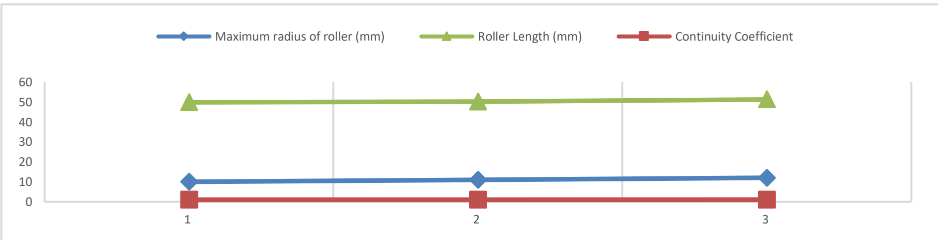

Figure 7. Relation among the main parameters (Maximum radius range: 10 to 12 mm’s)

Table 3. Results of the parameters when the Maximum radius range is between 10 and 12

Results of the parameters when Maximum radius range is between 10 and 12

Maximum radius of roller (mm)	Minimum radius of roller (mm)	Helical Line Angle (°)	Roller Length (mm)	Continuity Coefficient
10	7	67.1	49.8	1.008
11	8	67.5	50.1	1.012
12	9	67.9	51.2	1.031

6. CONCLUSION AND DISCUSSION

In this research, an investigation of how the roller's geometry was created in accordance with the project concept was carried out. To create the most ideal roller curvature and improve the agility of the vehicle utilising this mechanical wheel, simulations using MATLAB and SOLIDWORKS were done. The mecanum wheel-based platform whose concept design is analysed, can be utilised in the future for multiple purposes as its final application.

REFERENCES

[1] Yunan Zhang, Tao Huang. ‘Research on a Tracked Omnidirectional and Cross-Country Vehicle”. Mechanism and Machine Theory 87 (2015) 18-44.

[2] A. Ramirez-Serrano, R. Kuzik, G.Solana. “Elliptical double Mecanum wheels for autonomously traversing rough terrain”.

[3] S. Ransom, O. Krömer, and M. Lückemeier, “Planetary rovers with mecanum wheels,” 16thISTVS Intl Conf, 25-28 Nov, 2008, Torino, Italy.

[4] A. Gfrerrer. “Geometry and kinematics of the Mecanum wheel”. Computer Aided Geometric Design 25 (2008) 784-791

[5] Ioan DOROFTEI, Bogdan STIRB. “Design, modeling and Control of an Omni-directional Mobile”. Solid State Phenomena Vols. 166-167 (2010) pp 173-178.

[6] SOLIDWORKS Inc., 2016. SolidWorks help Guide. s.l.: s.n.

[7] MATLAB Inc., 2018. MATLAB Help Guide.s.l.: s.n.