

Selection of Wheels in Robotics

Jigar J. Parmar, Chirag V. Savant

Abstract—Robotics is an emerging field in coming years. Today robots are used in wide applications, like material handling, mechanical controls, welding etc. For locomotive purpose robots are made with integrated driving system wherein wheels and driving motors are coupled to drive robots. This paper explains and gives details about the wheels and the significance of selecting the optimum one for the respective Robots which are required to compete in the challenge. The Wheels were selected on the factors and methods based on the degrees of freedom, weight distribution, wheel geometry, field material and wheel material. The system defined in this paper, is cost effective and rugged. This system can be implemented for various types of Robots and provides the perfect fit in terms of mobility, locomotion and ideal stability.

Keywords—Holonomic drive, Mecanum wheels, Omni wheels, Robotics

1-INTRODUCTION

1.1 Cylindrical wheels

These are wheels that have a cylindrical periphery. The periphery may or may not have tracks on it. These can be conventionally made out of different materials by turning them on turn centres according to the required wheel base and diameter. To give additional friction to the surface some high traction material like, rubber or polyurethane grip can be put over it.



Fig.1 Cylindrical Wheel

1.2 Omni wheels

Omni wheels are wheels having rollers mounted on the periphery of the wheel such that the axis of the rollers is perpendicular to the axis of the base wheel. For smooth operation, rollers are mounted over bearings.



Fig.2 Omni-Wheel with rollers

1.3 Mecanum wheels

These are wheels quiet similar to Omni but the rollers are inclined at an angle of 45 degrees with respect to the axis of the base wheel. Here the rollers are always mounted over bearings. Depending on the position of the wheel the rollers are inclined by 45 degrees either to the left direction or right direction.



Fig.3 Mecanum Wheels with rollers

JigarParmar is currently UG student pursuing degree program in Production engineering in Fr. CRCE, Bandra, University of Mumbai, India, PH-+91 9664114902. E-mail: jparmar1994@gmail.com
ChiragSavant is currently UG student pursuing degree program in Production engineering in Fr. CRCE, Bandra, University of Mumbai, India, PH-+91 9819774249. E-mail: chiragsavant94@gmail.com

2-Details

2.1 Cylindrical Wheels

These are normal circular wheels of a particular wheel base and diameter. These wheels are capable to roll only on its periphery. Lateral roll is not possible. These can be made out of metal, non metals, plastics, composites, etc. while rolling slippage over the periphery is zero. Manufacturing cost is very less because of its simple geometry.

2.2 Omni Wheels

Omni wheels or Omni-directional wheels are wheels having rollers over the periphery with its axis at an angle of 90 degrees to the base wheel axis. Roll in two directions is possible, one along the base wheel periphery and second along the rollers. Generally the base wheel is made up of plastic or metal alloys, while the rollers are made up of high traction material (rubber composite) to provide more coefficient of friction. Slippage is there when these wheels are in motion. These wheels work on slippage. Manufacturing of these wheels is an expensive affair. For smaller wheel base single layer of the setup is used, but for wider base, two or more layers are attached to each other. Typically 3 or more wheels are mounted over the chassis for multi directional motion. The orientation of mounting of these wheels is in the form of a polygon.

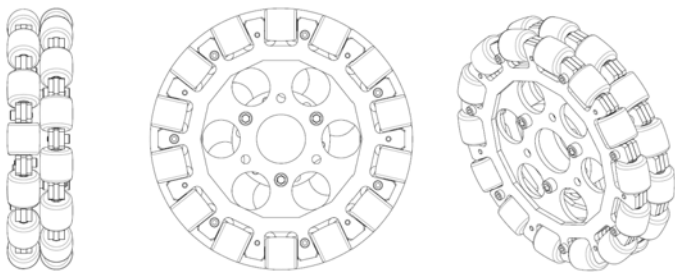


Fig.4 Geometry of Omni-Wheel

2.3 Mecanum Wheels

These wheels are similar to Omni wheel construction except the rollers are mounted with its axis at an angle of 45 degrees to the axis of the wheel base. It was first developed by a company "Mecanum AB" in the year 1973. Since its design is very complex, manufacturing cost is greater as compared to Omni wheels. Here only one layer of the setup is used for any size of the wheel base. These wheels are capable to roll about the axis of the base wheel and also

about the axis of the rollers at an angle of 45 degrees. Rollers are compulsorily mounted over bearings to reduce wear loss because these rollers partially roll even when the wheel is rolling about the base wheel axis unlike Omni wheels where the rollers don't have any relative rolling when the wheels are rotating about the primary axis.

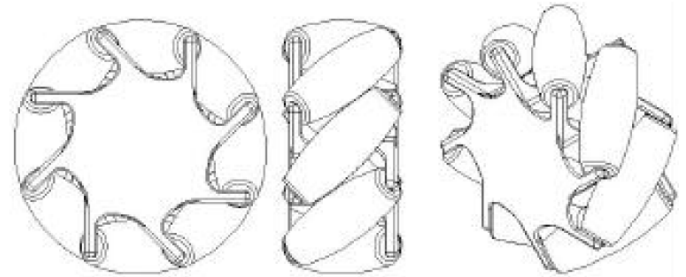
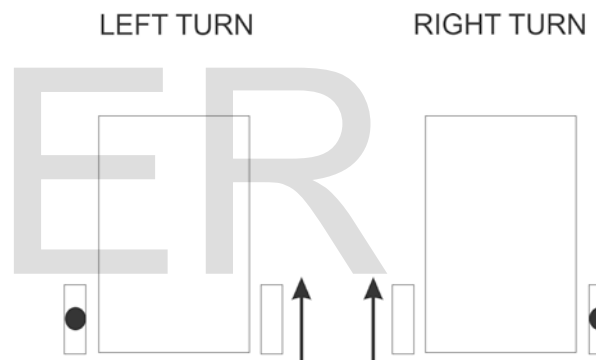


Fig.5 Geometry of Mecanum Wheels

3- DIRECTIONS POSSIBLE

3.1 Cylindrical Wheel



(● centre of rotation)

Fig.6 Driving of Cylindrical Wheels and castor

The figure shows two driving wheels and a castor mounted over the front part. In this type of configuration only 4 directions (front, back, left rotate and right rotate) are possible. Motion along an arc with variable radius is not possible.

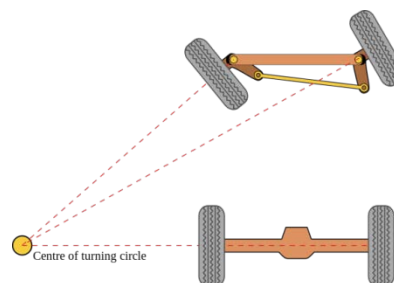


Fig.7 Steering Mechanism of Cylindrical Wheels

The problem of turning can be solved by steering mechanism, where four wheels are used, out of which minimum two, max four wheels are rotated by motors and either the front two wheels or the rear two wheels are given a steering mechanism to adjust the direction of turn. In this case, one must also control the rpm of each motor according to the direction in which the body is turning.

3.2 Omni Wheel

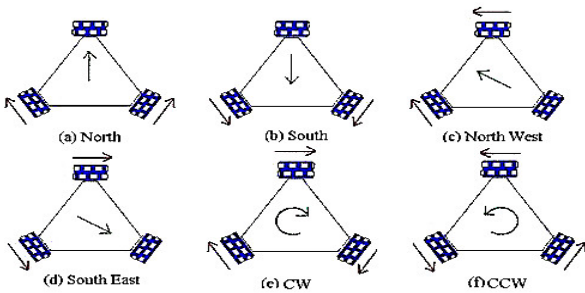


Fig.8 Driving directions of Omni-Wheel for triangular chassis.

The figure shows three Omni wheels mounted over a triangular shaped chassis. The axes are inclined at 120deg to each other. This is the advantage of Omni direction wheels where without implementing steering mechanism, it is possible to turn and move the body in multi directions. These wheels work on the principal of the parallelogram law. Two forces act at an angle to each other, and the output motion is in the direction of the resultant vector calculated using parallelogram law. Omni-wheeled robots can move in any angle and in any direction, without rotating beforehand. This enables the wheels to move holonomically, which means it can instantaneously move in any direction

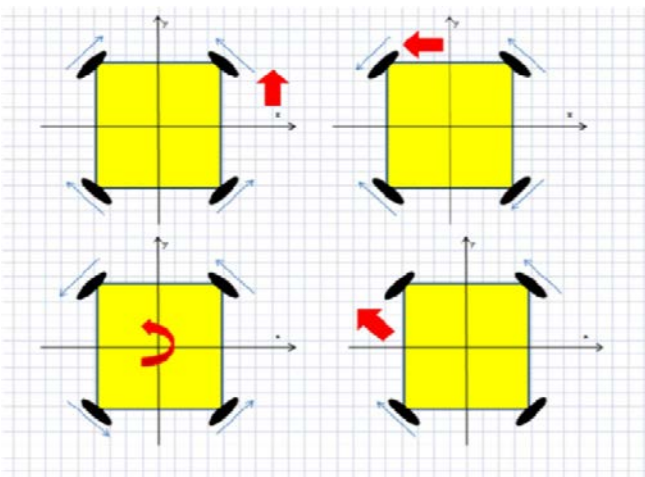


Fig.9 Driving directions of Omni Wheels for Rectangular Chassis

The figure shows Omni wheels mounted at an angle of 45degrees on a rectangular chassis. Here the directions achieved by this type of configuration is same as to what a triangular configuration achieves, but the advantage here is that for the same motor specifications, the body can accelerate faster and the speed achieved is greater because slippage is min and also the body's weight is distributed over 4 wheels.

One can mount as many Omni wheels as possible on the Robot chassis, the angle of alignment of the wheels on the chassis is given by

$$\text{Theta} = 360/n$$

where n = number of Omni wheel

Theta = angle between two wheels from the geometrical centre of the body

Disadvantages:

- In a triangular arrangement only one wheel will be rotating in the direction of travel; however three wheels are guaranteed to be on the same plane, so each wheel is in contact with the ground.
- They have poor efficiency as, not all the wheels are rotating in the direction of movement, which causes loss from friction, and are more computationally complex because of the angle calculations of movement.

3.3Mecanum

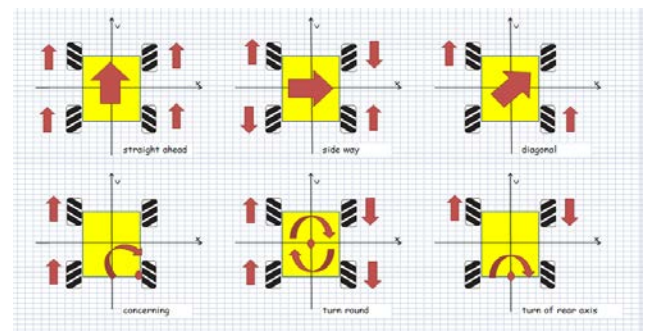


Fig.10 Driving directions of Mecanum Wheels for Rectangular Chassis

Mecanum wheels are always mounted inline to each other; in most of the case only four wheels are used. Unlike Omni wheels the rollers of the Mecanum wheels are already inclined at 45 degrees. Here the advantage is that the chassis body fabrication becomes easy because the wheels are mounted inline.

The directions are given in above fig. In case one wants to take a turn along an arc, just the rpm and direction control is required.

4-PRACTICAL SETUP

4.1 Omni wheels

4.1.1 3 wheel chassis

At the time of fabrication of such a chassis, one must ensure perfect orientation of the wheel axis at perfect 120degrees to each other. If the wheels are not properly aligned, calibration of wheel speeds becomes a difficult task. Also, the weight carrying capacity is less because the weight is concentrated on the 3 wheels only. Calibration of the motors is a bit tedious task to do. If the motors are in sync there are chances that the chassis won't go in a linear path.



Fig.11 Omni wheel mounted at an angle of 120 degrees

4.1.2 4 wheel chassis

Fabrication is simple because it is easy to maintain wheel axis at 90 degrees to each other. Load carrying enhances because here the load is shared between 4 wheels. Calibration of motors is simpler.

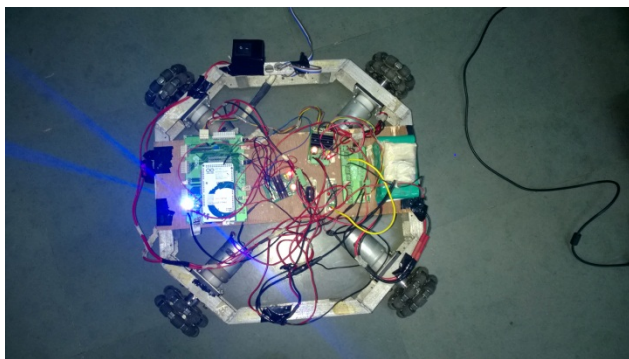


Fig.12 Omni wheel mounted at an angle of 45 degrees

4.2 Mecanum chassis

Fabrication is cost effective and simplest. Since these are mounted linearly, mounting of wheels and motors are easy.

Here a large traction is achieved due to the large wheel base. They are usually used for heavy load carrying application.

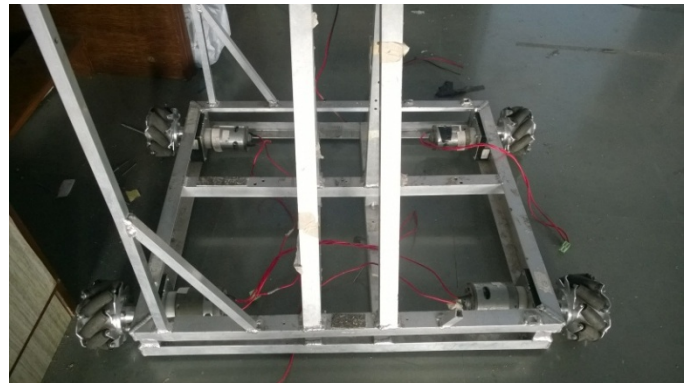


Fig.13 Mecanum wheel mounted on a rectangular base

5-MECHANICAL FACTORS

		Standard	Omni	Mecanum
kinematics	V_f	$\omega \cdot r$	$\omega \cdot r \cdot \sqrt{2}$	$\omega \cdot r$
	V_r	-	$\omega \cdot r \cdot \sqrt{2}$	$\omega \cdot r$
	V_d	-	$\omega \cdot r$	$\omega \cdot r / \sqrt{2}$
force	F_f	$4\tau / r$	$4\tau / (r\sqrt{2})$	$4\tau / r$
	F_r	-	$4\tau / (r\sqrt{2})$	$4\tau / r$
	F_d	-	$2\tau / r$	$2\tau\sqrt{2} / r$

Fig.14 Comparison based on velocity and pushing force for different wheels

The three columns are for standard (Cylindrical), Omni and Mecanum four wheeled vehicles respectively. The Omni vehicles wheels are mounted at 45 degrees. All wheels are of same diameter.

The first three rows are vehicle velocity: forward, sideways and diagonal, for a given wheel speed ' ω '.

The second three rows are vehicle total pushing force: forward, sideways and diagonal, for a given wheel torque ' τ '.

These last three rows assume a) frictionless Mecanum and Omni roller bearings, and b) sufficient traction to support floor reaction forces.

We notice that Mecanum wheels have maximum pushing force in Forward, Sideways and in diagonal direction and Omni wheels have maximum velocity in the given three directions.

6 FUTURE SCOPE

These wheels provide an emerging system; called the holonomic drive system. This is currently being used in robots and industrial equipment such as the forklift. They are under prototyping stage in future vehicles.

7 CONCLUSION

In our particular manual robot weighing 26 kilograms for the ROBOCON COMPETITION, 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 direction 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.

ACKNOWLEDGMENT

The authors wish to thank Dr.Jayaramulu Challa, Mr.D.S.Sudhakar and Dr.V.S.Bilolikar for their guidance and technical support. This work was supported in part by a grant from Fr.Conceicao Rodrigues College of Engineering.

REFERENCES

- [1] Ilon B.E., 'Wheels for a course stable self-propelling vehicle movable in any desired direction on the ground or some other base', US Patent and Trademarks office, Patent 3.876.255, 1975.
- [2] Cylindrical wheels
<http://www.intorobotics.com/overview-of-wheels-used-in-robotics/>
- [3] omni wheels <http://www.vexrobotics.com/omni-wheels.html>
- [4]Omni as holonomic drive
<http://www.firstroboticscanada.org/main/wp-content/uploads/Omnidirectional-Drive-Systems.pdf>
- [5]Motions in Omni wheels
http://www.societyofrobots.com/robot_omni_wheel.shtml
- [6]Details about Omni Wheels
<http://www.omnixtechnology.com/omnidirectional.html>