Design and fabrication of prototype model of Mecanum wheel forklift-A review

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ABSTRACT

In this paper, we review researches on multi-directional automobile design with Mecanum wheel as component in the forklift vehicle. Multi-directional automobile has vast advantages over conventional design likes differential drive in term of mobility in congested environments. Multi-directional automobile could perform important tasks in environments congested with static and/or dynamic obstacle and narrow aisles, such as those commonly found in manufacturing floor, warehouses, offices and hospitals. A variety of designs of Mecanum wheel installed forklift have been developed in recent years in order to improve their Multi-directional maneuver and practical applications. These features are expanded at the expense of improved mechanical complication and increased complexity in control mechanism. Mecanum wheel systems work by applying rotating force of each individual wheel in one direction similar to regular wheels with a different in the fact that Mecanum wheel systems are able to slide freely in a different direction, in other word, they can slide frequently perpendicular to the torque vector. The main advantage of using Mecanum wheel systems is that 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.

Keyword:- *Mecanum wheel,Omni-directional.*

1.INTRODUCTION:

One of the common omni-directional wheel designs is Mecanum Wheel or Ilon wheel. Mecanum wheel was design and invented in Sweden in 1975 by Bengt Ilon, an engineer with Swedish company Mecanum. Mecanum wheel is based on the principle of a central wheel with a number of roller placed at an angle around the periphery of the wheel. The angled peripheral roller translates a portion of the force in the rotational direction of the wheel to force normal to the wheel directional. Depending on each individual wheel direction and speed, the resulting combination of all these forces produces a total force vector in any desired direction thus allowing the platform to move freely in direction of resulting force vector, without changing the direction of the wheel. Figure 1 shows a traditional Mecanum wheel design by Ilon with the peripheral roller with 45° degree slope held in place from the outside[1].

Figure 1: Mecanum wheel based on Ilon's concept. Source from

This design only can operate in even work surface. When encountering an inclined or an uneven work surface, the rim of the wheel can make contact with the surface instead of the roller, thus preventing the wheel from operating

correctly. To encounter this problem a simple alternative design, also proposed by Ilon, which consist two spilt roller mounted centrally on the periphery of the wheel as shown in figure 2

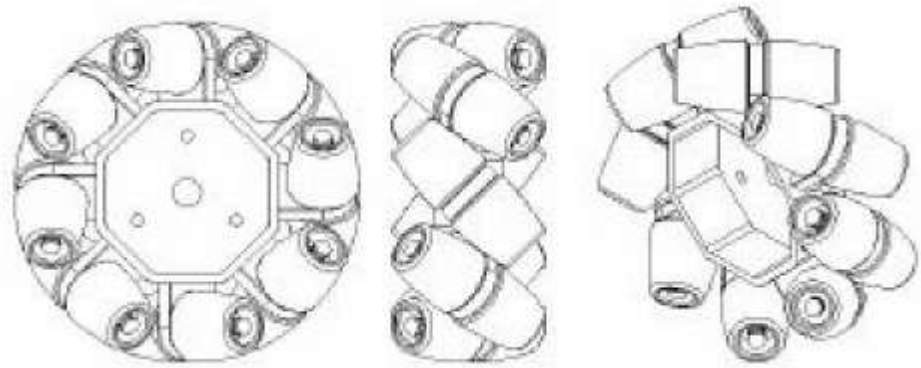


Figure 2: Mecanum wheel with centrally mounted rollers.

This design ensures that the rollers are always in contact with the work surface, thus allowing better performance on uneven surfaces. Using four of Mecanum wheels provides omni-directional movement for a vehicle without needing a conventional steering system. Slipping is a common problem in the Mecanum wheel as it has only one roller with a single point of ground contact at any one time. Due to the dynamics of the Mecanum wheel, it can create force vectors in both the x and y-direction while only being driven in the y-direction. Positioning four Mecanum wheels, one at each corner of the chassis (two mirrored pairs), allows net forces to be formed in the x, y and rotational direction. Refer to Figure 3. A difficulty with this strategy is that there are four variables to control three degrees-of-freedom. In this case the system is said to be over determined and it is possible to create conflicts in the actuation. As a result of the constraints associated with the Mecanum wheel some form of controller is required to produce satisfactory motion[2].

2. PROBLEM DEFINITION AND OBJECTIVES:

2.1. PROBLEM DEFINITION

The main problem is of maneuvering of loader vehicle in constrained space in industry. Absence of remote controlled feature in current loaders. Increasing efficiency of material movement by reducing travelling distance.

Mecanum wheel is a unique wheel that allowing a vehicle to move at any degree translation when moving at a certain speed and rotation direction. This wheel is designed by Swedish Inventor Bengt lon, an engineer from a Swedish company named Mecanum AB[3].

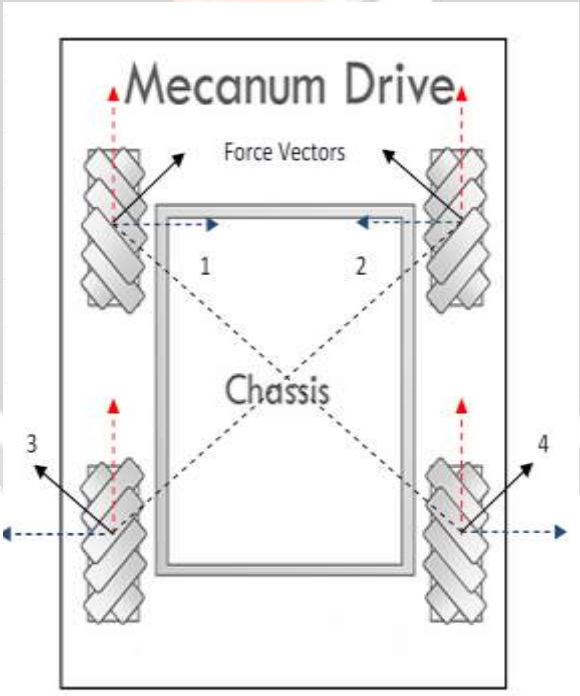
Usually, robotic vehicles are designed to perform planar motion. In a two dimensional space, a body has three degrees of freedom, being capable of translating in both directions and rotating about its centre of gravity. However, most conventional vehicles do not have the ability to control every degree of freedom independently, because conventional wheels are not capable of moving in a direction parallel to their axis. These so called non-holonomic constraints of the wheel prevent vehicles using skid-steering from moving perpendicular to its drive direction. To reach every location and orientation in a two dimensional space it can require complicated maneuvers and complex path-planning. Non-holonomic vehicles can move in some directions (forward and backward) and can describe some curved trajectories, but cannot crab sideways. For example, to realize a parallel parking, a differential drive vehicle should make a number of maneuvers[4].

2.2. OBJECTIVES

- To design a wheel who can take the vehicle in multi-directions.
- Applications of wheels should in various fields.
- To develop the low cost proto type model[5].

3. METHODOLOGY:

Direction of Movement	Wheel Actuation
Forward	All wheels forward same speed
Reverse	All wheels backward same speed
Right Shift	Wheels 1, 4 forward; 2, 3 backward
Left Shift	Wheels 2, 3 forward; 1, 4 backward
CW Turn	Wheels 1, 3 forward; 2, 4 backward
CCW Turn	Wheels 2, 4 forward; 1, 3 backward



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[6].

4. CALCUALATION:

Material = C 45 (mild steel)

Why Mild steel C-45 is selected in our project.

1. Easily available in all sections.
2. Welding ability
3. Machinability
4. Cutting ablity
5. Cheapest in all other metals.

Take fos 2

$\sigma_t = \sigma_b = 540/fos = 270\ N/mm^2$

$\sigma_s = 0.5\ \sigma_t$

$= 0.5 \times 270$

$= 135\ N/mm^2$

The total weight of machine is not more then 20kg, this weight is distributed on all four wheels. So weight on each wheel(W) is 5 kg.

Power of motor is 12 V, 15 watt and 20 rpm.

W=5 kg= 5 x 9.8 = 50N say

M= FxL

M= 50x25=1250 N-mm

$P=2\pi NT/60$

$T= 15 \times 60/2x\pi x20$

T= 7.16 N-m= 7162 N-mm

$T_e= \sqrt{(M^2+T^2)} = \sqrt{1250^2+7162^2}$

$= \sqrt{1562500+51294244}$

$= \sqrt{52.86 \times 10^6}$

$T_e=7270.26 = 7.27 \times 10^3$N-mm

$T_e=\pi/16 \times\sigma_s x d^3$

$d^3=7.27x10^3x16/\pi x135=274.26$

$d=3\sqrt{274.26}=6.49$mm

d=7mm

But we are using 10 mm shaft so our shaft is safe.

The rollers are mounted on pins of 6mm dia

M = W x L = 50 × 40

` = 2000 N-mm

$Z = \pi/32 \times d^3$

$Z = \pi/32 \times 6^3$

$Z = 21.2\ mm^3$

σ_b (induced)= M/Z = 2000/21.2 = 94.33 N/mm²

As induced bending stress is less then allowable bending stress i.e. 270 N/mm^2 design is safe.

Now, rollers are mounted on ms flat of size 12x3 and length is 74mm
W = maximum force applied = 50 N

M = W x L

M = 50 x 74 = 3700 N-mm

And section modulus = $Z = 1/6\ bh^2$

$Z = 1/6 \times 3x12^2$

$Z = 72\ mm^3$.

σ_b (induced)= M/Z = 3500/72 = 48.61 N/mm²

As induced bending stress is less then allowable bending stress i.e. 270 N/mm^2 design is safe.

Design of transverse fillet welded joint.
Hence, selecting weld rod size = 3.2mm
Area of Weld = 0.707 x Weld Size x L
= 0.707 x 3.2 x 12
= 27.15 mm^2
Force exerted = ---N
Stress induced = Force Exerted / Area of Weld
21 = F / 27.15
F= 570.21 N = 58.12 kg
Maximum Allowable Stress for Welded Joints = 21 N/mm^2
Linear velocity of machine

Diameter of mecanum wheel 198

$V = \pi DN/60$

= 3.142 x 0.198 x 20/60

= 0.2073m/sec

= 0.75 km/hr

Battery 12v 7.5 amp = 90 watt

15 x 4= 60 watt

90/60= 1.5 hr

Fork lift motor 10 watt, 15 rpm

$P=2\pi NT/60$

$T= 10 \times 60/2x\pi x15$

T= 6.36 N-m= 6360 N-mm

Dia. Of sprocket,

Periphery = π × dia. Of sprocket

$40 \times 6.35(\text{pitch}) = \pi \times D$

$$D = \frac{40 \times 6.25}{\Pi}$$

D = 80.8 mm

Torque transmitted,

T = Force × radius

$7.16 \times 10^3 = F \times 40.4$

F = 177.22N

$$F = \frac{177\ N}{9.81}$$

F = 18.06 Kg

F = 176 N

We know,

Stress = (force/2) / area

Stress induced $=176 / (3.14 * 2.3^2 / 4) \times 2$

Stress induced = 5.29 N /mm^2

As induced stress is less than allowable

stress = 640N /mm^2design of sprocket is safe.

5.ADVANTAGES:

- The Mecanum wheel is a design for a wheel which can move a vehicle in any direction.
- Compared to skid steer, Mecanum wheels have no additional friction when turning which is an advantage[7].
- Tracked vehicles and skid steer vehicles utilize similar methods for turning. However, these vehicles typically drag across the ground while turning and may do considerable damage to a soft or fragile surface. The high friction against the ground while turning also requires high-torque engines to overcome the friction. By comparison, the design of the Mecanum wheel allows for in-place rotation with minimal ground friction and low torque.
- Mecanum wheels will be simpler and perhaps more reliable than a swerve/crab drive system[8].

6.DISADVANTAGE:

- Disadvantages are weight (commercially available wheels are ridiculously heavy) and cost. For a given tread material traction will be along the lines of 65-70% that of a regular wheel due to the smaller contact area and 45% roller.[7].
- It cannot be used in regular car because it is usually used for low speed drive[8].

7.APPLICATION:

7.1INDUSTRIAL FIELD

Airtrax ATX-3000 industrial forklifts excel in applications requiring tight manoeuvring or transporting long loads sideways through standard sized doors or narrow aisle ways. The ATX's unique, Omni-Directional movement allows it to travel in all directions thus making it an ideal vehicle to work in tight spaces where turns are not possible and finite control is a necessity. The truck features 48 volt transistor controls with state-of-the-art technology, infinitely variable travel, lift and lower speeds, excellent visibility, ergonomic controls and operator comfort . The unique design of the four 21x12 independently driven Mecanum wheels enables the ATX's Omni Directional capabilities. Each wheel is directly driven by individual transaxles. The wheels consist of a large, heavy-duty hub with 12 uniquely designed polyurethane rollers. The wheel and roller design provides the Omni-Directional movement of the vehicle based on the speed and direction of each wheel as determined by the operation of the traction joystick. Each roller incorporates bearings that do not require periodic greasing or maintenance under most conditions. Since each roller rotates freely, scrubbing against the floor is minimized while turning or moving sideways[9].

7.2.MEDICAL FIELD

Powered wheelchairs are known to provide benefits for older adults by enabling them to have a means of independent mobility. These benefits include: participation in self-care, productivity, and leisure occupations; as well as, socialization opportunities, and positive self worth. Overall powered wheelchairs are linked to an improved quality of life for older adults who have a reduced ability to walk and do not have the stamina, strength, or ability to propel themselves in a manual wheelchair . Without a powered wheelchair these older adults would be dependent on others to complete life tasks and unable to have independent mobility. The OMNI (Office Wheelchair for High Maneuverability and Navigational Intelligence for People with Severe Handicap) is a standalone wheelchair developed with two goals in mind: 1) to allow high mobility in complex environments; and 2) to have modes of operation that will help the user have higher degrees of independence. This wheelchair has been designed for individuals with severe mental and physical disabilities. It consists of Mecanum wheels that provide 3-DOF (degrees of freedom) for the wheelchair; a specialized joystick for 3-DOF movement; a sensor ring around the wheelchair that has IR (infrared) and ultrasound sensors to provide obstacle detection capabilities; a bumper sensor for fail-safe detection of collisions; wheel odometers for knowledge of the wheelchair's location; an elevating seat to raise the user; and a specialized display for the user select modes of operation.The omnidirectional wheelchair being developed at the University of Western Australia's Centre for Intelligent Information Processing Systems (CIIPS)

allows the user to easily manoeuvre in what would otherwise be an extremely complicated environment. This project made improvements to the Mecanum wheels, batteries, motor driver cards, human interface, control software, chassis and suspension system. These improvements transformed the partially working prototype into a fully usable wheelchair. The result is much higher driving accuracy and a greatly improved overall experience for the user in both comfort and ease of use. On the whole, the project was extremely successful and will provide a very solid test bed for advanced driving and mapping projects in the future[9].

7.3.MILITARY FILED

The maneuverability provided by Omni-directional vehicles can be utilized and can be very important in numerous outdoors applications, such as search and rescue missions, military activities, planetary explorations and mine operations.

This wheel is commonly used in robotic applications requiring a high degree of maneuverability, such as those experienced by NASA for hazardous environment exploration. The objective of the OmniBot project is to develop a hazardous duty mobile base as an advanced development test bed to research alternate technical approaches for remotely controlled operations in hazardous areas. In addition, this base will be used to test various automated umbilical technologies for autonomous mobile vehicles[10].

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