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Why Precision Ball Cycloidal Reducer Drives Mobile Robot to Perfect at Unmatched Cost Benefit!!

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Abstract

Mobile robot business grows fast at a high CAGR with the emergence of e-commerce and winning Covid 19 struggle, while there are apparent needs for technology advance in hardware drive performance. Besides high positioning accuracy upon carrying heavy loads, mobile robot will need all-directional free movement at good compactness, high efficiency, long stable service life, easy manufacturing with good price, more environmental friendly experience, these put forward challenges to current mobile wheel drive, esp. Precision Wheel hub gearbox, which largely, and directly influence mobile robotâ€™s motion performance. Based upon customerâ€™s experience, we will suggest adopting zero backlash precision Cycloidal replace planetary reducer, to build into wheel, thus bestow excellent performance from all aspects at unmatched cost benefit, carrying robot evolution to next level advanced stage.

Keywords: Mobile robot • Precision cycloidal gearbox • Wheel hub reducer • Motion • Drives • planetary gearbox

Introduction

Mobile robot business grows fast at a high CAGR with the emergence of e-commerce and Covid 19 struggle, while there are apparent needs for technology advance in hardware drive performance. Besides high positioning accuracy upon carrying heavy loads, mobile robot will need all-directional free movement at good compactness, high efficiency, long stable service life, easy manufacturing with good price, more environmental friendly experience, these put forward challenges to current mobile wheel drive, esp. Precision Wheel hub gearbox, which largely, and directly influence mobile robot's motion performance. Based upon customer's experience, we will suggest adopting zero backlash precision Cycloidal replace planetary reducer, to build into wheel, thus bestow excellent performance from all aspects at unmatched cost benefit, carrying robot evolution to next advanced stage.

Applications

In addition to logistics warehousing and manufacturing industries, mobile robots have also been widely applied in aerospace and defense, automotive manufacturing, pharmaceutical manufacturing, 3C electronics, oil and gas, construction, agriculture, as well as commercial services such as hospitals, hotel infection, city petrol services, last mile delivery etc. (Figure 1).

Why mobile robot sees great increase: According to fortune business Insights, the significant growth for mobile robot is majorly due to thriving E-commerce and retailing industry to incite development. There is also rising demand for material supply and storage, transit purpose in manufacturing; Labor shortage, labor cost increase, tight space and narrow aisle in factory which arise operation difficultly and risks, prevention of Covid 19 infection, all these require mobile robots to play a role.

Challenges behind the "bustling" scene: The industry is full of expectations for development of more advanced mobile robots, but the actual pace of realizing them is still far less than expected, and they are caught in the dilemma of being called exciting but not good enough. For any robot, large-scale applications must be based on either significant value creation or efficiency improvement. In general, robots will do the same work faster and more durable than human, operate with more power, faster speed, more accuracy and free from health issues. In future, there will be some major potential innovation methods for mobile robotics companies: continuous improvement on mobile driving capabilities; moving from single intelligence to multiple intelligence; the integration of mobile + perform capabilities, which are expected to help mobile robots break through the existing embarrassment. Along with technological improvements, the business model of mobile robots will undergo promising changes in the future. Now let us focus on the first advance, precision mobile drive, esp. Precision wheel hub reducer (Figure 2).

Figure 1. Representative omni-directional mobile robot.

Major concerns about mobile robot performance: In large-scale, highly automated industrial environments, the advantages of robotic solutions over human operators lie primarily in either greater availability or the ability to move typically large loads with extremely high positioning accuracy and at high speeds. The efficient and stable operation of all types of AGVs and AMRs is largely dependent on the performance of the key components and core parts. Like in most applications, AMR's motion system must typically meet the following requirements:

Compact size and light weight

High torque

Long durability and long life

Low noise, especially when used in medical and defense equipment

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High efficiency and low current

For example Lightweight design for mobile robotic systems, lower weight means greater autonomy. High compactness brings advantages in maneuverability and interaction comfort. Higher efficiency means lower losses, leads to lower energy consumption, which contributes directly and positively to both the operating costs and the environmental footprint of the machine. For mobile robotic devices, higher efficiency also helps reduce the weight of the system, requiring smaller batteries and ultimately leads to greater autonomy and better usability. Also, inertia is particularly important when the speed or torque of the mobile end-effector changes rapidly and frequently (Figure 3).

Important role of the wheel reducer and requirements: For autonomous mobile robot applications, to achieve accuracy and optimal performance, robot designers and engineer must focus their efforts on optimizing the motion system, choosing the right motion components. So the markets for precision gearboxes and motion control systems are closely related. Precision gearboxes and motors have seen considerable growth over the past few years. From 2021 to 2022, the market for precision gear products grew by 17%. By 2027, this market will grow to more than $5 billion. The requirements of the mobile robot for the reducer are short axial length, large radial load, and high accuracy of movement. Precision gearboxes are designed to have low or zero backlash, which means that the clearance between meshing transmission elements is much smaller than in standard gearboxes. Other requirements will include: wide speed reduction ratio, easy mounting method, high reliability, low noise, long service life, and free maintenance. In a word, precision gearboxes for industrial applications will need to deliver a top-class performance.

Challenges for mobile robot gearboxes: Typically, the motion system of an autonomous mobile robot consists of a DC motor and a compact planetary gearbox. Before introduction of ball cycloidal wheel reducer, according to an analysis of the precision gear products market, precision planetary gearbox was regarded as the 'currently most probable' choice for mobile robotic segment. 70% of gearbox failures are related to bearing damage and 26% to gears. The cost of purchasing precision reducers is relatively high, this is one of the main bottlenecks in robot development. Technology and cost constraints lead to the robot manufacturers and mobile robots facing conflict to meet customer's growing demands.

Figure 2. Traditional wheel drive components-wheel, gearbox, motor, encoder and bolts. AGV driving wheel BLDC motor drive unit assembly for electric vehicle.

Figure 3. Mecanum wheel, a conventional wheel with a series of rollers attached to its circumference with an axis of rotation at 45° to the plane of the wheel in a plane parallel to the axis of rotation of the wheel.

The RV and strain wave gear: The Rotary Vector (RV) speed reducer uses a two-stage reduction mechanism based on a rigid drive, combining the ends of a planetary gear reducer and a cycloid reducer. Due to complex structure, (contains more than 30 parts with complex composition and requires micron-level assembly precision), the requirements for production are skyrocket high. There is the top level barrier to achieve seamless cooperation between various processings, resulting in high technical barriers in the selection of materials, precision machining, heat treatment of gear tooth surface, grinding and other production aspects. Harmonic gear reducer (also as strain wave gear) consists of wave generator, flexible and rigid wheel, relying on the wave generator to produce controlled elastic deformation of the flexible wheel to transmit motion and power. It has the advantages of high accuracy of motion, large transmission ratio, light weight, small volume and small transmission inertia. Unfortunately, flexible wheel occurs elliptical deformation twice per revolution, easy to cause fatigue damage of the material, which is prone to high impact, if running on the road with high speed, it could cause trouble soon. Last but not least, if installed on mobile robot, engineer will need to refill lubrication periodically on rv and harmonic reducers. This also brings additional jobs and cause potential risks.

Challenges facing planetary gearboxes: The issue is, though compare to rv and strain wave gearbox, planetary gearbox is better, it is still far away from perfectness. As we know, precision planetary gearboxes can be found in a variety of industries and applications, including the fast-growing field of mobile robotics, by far the fastest growing segment, with a projected 55% CAGR from 2022-2026. The main transmission structures of planetary gear reducers include: planetary wheel, sun wheel, and outer gear ring. Due to structure, single-stage reduction ratio is 3:1 at minimum, the maximum generally does not exceed 10:1, if you want a >10, such as 30:1, 1000:1 speed ratio, you will need to switch to two-stage, three-stage, even four-stage, the total volume and size will become heavy and clunky, efficiency will run lower, structure turns to be more complex (Figure 4).

Planetary gear reducer has high rigidity, high precision (for premium line and reduced backlash), high transmission efficiency (single stage at 97% to 98%), high torque ratio, lifetime maintenance-free, etc. The disadvantages are complex structure, high requirements for parts processing accuracy, and more difficult manufacturing and installation, high noise and heavy weight. It is true that the use of several stages of gearheads can best take advantage of high gear meshing efficiency and lead to efficient gearboxes, it usually further increases the size and weight of the reducer, leads to heavy and bulky solutions, which cannot be used on robots. Furthermore, most of them are connected in series, and each stage will have accuracy and motion loss, and the final output accuracy error is larger. On the other hand, compact configurations can achieve high gear ratios in a very compact shape, but they suffer from surprisingly high losses from high virtual power (Figure 5).

Related tests show, there is abnormally high losses that exist in some planetary topologies. Some gear meshes may encounter both high speeds

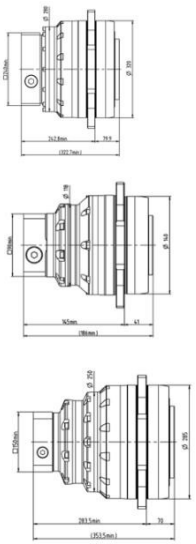

Figure 4. Design of the mount, socket and connector.

and high torques. Gear meshes can easily achieve efficiencies of 98% or more, but unexpectedly large losses can occur in those highly loaded meshing configurations. To partially compensate for the large impact of topological efficiency on overall efficiency, configurations with large latent power ratios therefore require very high meshing efficiencies: in order to achieve system efficiencies >70%, systems require average meshing efficiencies above 99.5%. Also compact configuration shows the highest input speeds (up to 8500 rpm), but they also lose the most motion of any conventional gearbox (4-6 Arcmin). So the compact type has declined significantly over the last few decades, largely due to their limitations in reducing backlash. Although mechanisms exist to limit the large backlash inherent in compact configurations, these are actually based on the introduction of a certain amount of preload that negatively affects their efficiency.

In additional, reduced backlash for planetary gearbox usually means higher cost than standard, backlash have usually been classified into three or even four levels by manufacturer, like premium, advance, standard, or standard, reduced, micro etc range of assignment, higher level accuracy within 2 arcmin means higher cost and longer waiting time, more complicated techniques. No pain, no gain, so where is the future way to go?

Precision cycloidal replace planetary reducer for mobile robot use: Precision cycloidal reducer is the recommended gearbox that provides the outstandingly excellent accuracy and repeatability, through its Full-contact, All-involve simple steel-ball-rolling cycloidal mechanism. This zero backlash structure achieves perfect precision, keeps strong stiffness, shows longer stable service life, esp. suitable for high precision robotic and automation areas. This is a significant technological event in the field of precision motion control. It overturns the hundred Year traditional gear drive, and has epoch-making significance (Figure 6).

Now precision cycloidal replace planetary wheel gearbox has great advantages: By replacing gear mechanism, it shows highest positioning accuracy zero backlash, retention as always 《3arcmin during lifetime, high stiffness: four wheels traveling 100,000 kilometers, rated load 1000kgs; small and compact: entirely in-built within the wheel, totally flat; zero maintenance; wide speed ratio 3 to 10K, now provide 15, 20, 25, 30, 35; efficiency: 》90%, all ratios will be the same; noise:《60dB; mounting: simply to put in [1-3] (Figure 7).

Cost: unmatched benefit, your premium is our standard.

It successfully and innovatively remove,

Figure 5. Traditional wheel drive components-wheel, gearbox, motor, encoder and bolts. AGV driving wheel BLDC motor drive unit assembly for electric vehicle.

Figure 7. HSOAR precision cycloidal wheel reducer for mobile robot platform.

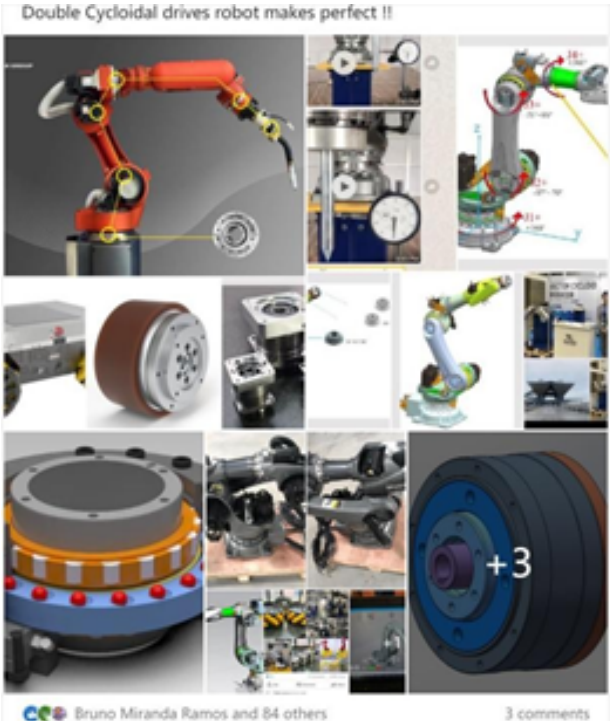

Figure 8. Automated welding robot, manifold with vent, configuration of the 6-DOF heavy payload industrial robot, drive wheel, gearbox.

Figure 6. HSOAR precision cycloidal reducer gear box, precision cycloidal ball reducer, anthropometric robotic arms, shaped hard alloy steel balls, ball steering set power A-head.

Figure 9. En.china-hsoar.com. Erica Li at IREX robot exhibition, Tokyo Japan.

the complexity and skyrocket high barriers for manufacturing;

the multiple stage, higher cost to gain higher precision;

the material fatigue, less rigidity

and actually substitute all following successfully:

Replace “tooth profile modification” with “vector cycloidal”

Replace “30” parts with “5” parts

Replace “long transmission” with “short chain”

Replace “ 6000 hours service life” with “20,000 hours service life”

Replace “refilling lubricants” with “none”

Replace “lubricants degradation” with “none”

Replace “partial contact, partial engagement between gears” with “full contact” “all involve”

Replace “multi-stage” when meet high speed ratio with “single-stage” at all ratios

Replace “low efficiency due to multi- stage” with “keeping high efficiency”

Replace “premium, advance, standard” backlash, with “All premium” levels

Replace “material deformation” with “high impact shock resistance”

Replace “vibration” with “none”

Replace “tooth crack, pitting, diaphragm crack, rim crack, red cross section crack,

buckling, ratcheting” with “none”

Is there any mobile robot that dislikes it?

Now it’s time to speak to precision cycloidal reducer about your robot!! (Figures 8 and 9)

Conflict of Interest

None.

Acknowledgement

No potential conflict of interest was reported by the authors.

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