



AN OVERVIEW OF ELECTRIC VEHICLE TRANSMISSION SYSTEMS: PITFALLS AND PROSPECTS

S.Muthuveerappan,

Assistant Professor, Department of Electrical and Electronics Engineering, J.J. College of Engineering and Technology, Trichy, Tamilnadu

S.Karthikeyan,

Assistant Professor, Department of Electrical and Electronics Engineering, J.J. College of Engineering and Technology, Trichy, Tamilnadu

P.Rathidevi,

Assistant Professor, Department of Electrical and Electronics Engineering, J.J. College of Engineering and Technology, Trichy, Tamilnadu

ABSTRACT:

Electric vehicle transmission systems play a critical role in transferring power from the electric motor to the wheels, enabling efficient and smooth operation of electric vehicles. While single-speed transmissions are commonly used in electric vehicles, multi-speed transmission systems are also being explored for specific applications. This abstract provides an overview of electric vehicle transmission systems, highlighting their importance in optimizing power delivery, efficiency, and overall driving performance. The advantages and disadvantages of different transmission types are discussed, along with the future prospects of electric vehicle transmission systems. The abstract emphasizes ongoing advancements in gear technologies, lightweight designs, advanced control systems, and continual efficiency improvements. The collaborative efforts of manufacturers, suppliers, and researchers are expected to drive further innovation and optimization of electric vehicle transmission systems, contributing to the continued growth and acceptance of electric vehicles in the automotive industry.

Keywords: electric bicycle, single speed transmission, electronic continuously variable transmission

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INTRODUCTION:

Electric bikes, also known as e-bikes, have emerged as a popular and sustainable mode of transportation in recent years. Combining the convenience of a traditional bicycle with the power of electric motors, these vehicles offer a thrilling and efficient way to navigate urban environments, commute to work, or simply enjoy leisurely rides. One of the crucial components that contributes to the performance and functionality of electric bikes is the transmission system. E-bikes have

gained popularity among commuters, fitness enthusiasts, and individuals seeking a greener alternative to traditional transportation methods.¹The transmission system of an electric bike plays a crucial role in optimizing power delivery from the motor to the wheels. It ensures that the energy generated by the motor is efficiently transferred to the drivetrain, allowing the bike to achieve optimal performance. There are two main types of transmission systems commonly found in electric bikes: hub gears and



derailleur gears. Hub gears, also known as internal gears, are situated within the rear hub of the bike. This system consists of multiple gears housed inside a protective casing, which helps keep them clean and protected from external elements. Hub gears offer several advantages, including smooth and seamless shifting, reduced maintenance requirements, and the ability to shift gears even when the bike is stationary. However, they tend to be slightly heavier and can result in a less efficient power transfer compared to derailleur gears.² Derailleur gears, on the other hand, utilize a system of sprockets and a chain to transfer power from the motor to the wheels. This system features a rear derailleur mechanism that moves the chain across

different gears, enabling the rider to adjust the gear ratio to suit various riding conditions. Derailleur gears are lighter and offer a wider range of gear ratios, allowing for more precise control over speed and cadence. However, they require more frequent maintenance due to their exposure to the elements and can be more prone to mechanical issues. Research conducted by Electric Bike Research Center (EBRC) at the University of Tennessee, Institute of Transportation Studies (ITS) at the University of California, Davis shows that the use of electric bikes is on the rise.³ The data given below has been collected from these reports to show the rise in the utility of electric bikes:

YEAR	GLOBAL MARKET SIZE (IN BILLION USD)
2021	27.73
2022	30.52
2023	33.60
2024	36.98
2025	40.70
2026	44.8
2027	49.31

Table 1

The data has been plotted below. It shows a constant rise in the utility of electric bikes

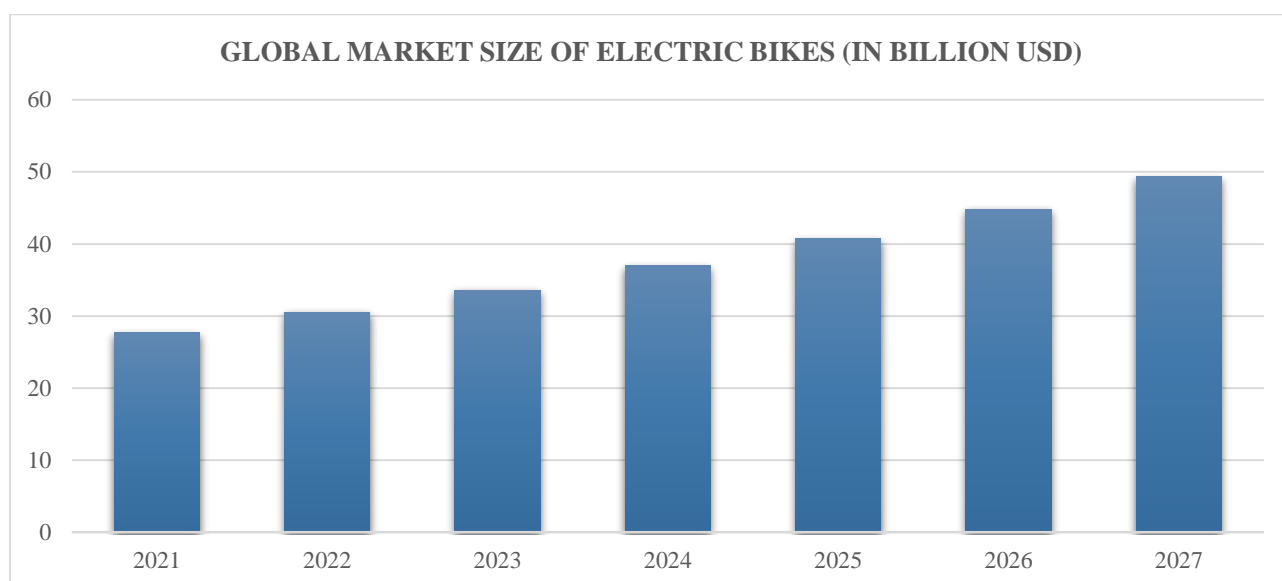


Fig. 1

ELECTRIC VEHICLE TRANSMISSION SYSTEMS: TYPES

Electric vehicle transmission systems, also known as drivetrains, are responsible for transmitting power from the electric motor to the wheels, enabling the vehicle to move. Unlike traditional internal combustion engine vehicles that require complex mechanical transmissions, electric vehicles (EVs) have simpler and more efficient transmission systems due to the nature of electric motors.⁴ There are primarily two types of electric vehicle transmission systems:

- **Single-Speed Transmission**

Apologies for the incorrect information in the previous response. In the context of electric vehicles, a single-speed transmission refers to a system that does not incorporate traditional multiple gears or gear ratios. Instead, it utilizes a fixed gear ratio between the electric motor and the wheels, resulting in a single-speed transmission. The term "single-speed" can be misleading, as it suggests that the vehicle operates in only one gear.² However,

electric motors have a wide operating range, providing ample torque and power across various speeds. As a result, many electric vehicles, especially those designed for everyday commuting or city driving, can function optimally with a single-speed transmission.⁵

The single-speed transmission system simplifies the drivetrain and eliminates the need for gear shifting, reducing mechanical complexity and the associated energy losses. By maintaining a fixed gear ratio, the electric motor can operate efficiently and deliver instant torque, enabling quick acceleration and smooth power delivery to the wheels. One of the primary advantages of a single-speed transmission in electric vehicles is its simplicity, which leads to increased reliability and lower maintenance requirements compared to multi-speed transmissions. Moreover, the absence of gear shifting enhances the driving experience, providing seamless acceleration without any interruptions.⁶

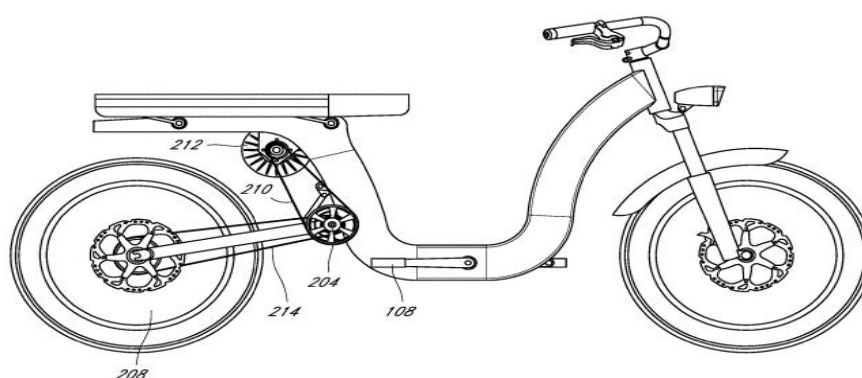


Fig. 2 Drivetrain layout features of an electric vehicle(Ref. US 10, 358, 133 B2 Dt.: April 13, 2017)

However, it is worth noting that some high-performance electric vehicles or those designed for specific purposes, such as off-road capabilities or higher top speeds, may incorporate multi-speed transmissions. These transmissions allow for a wider range of gear ratios, enabling better optimization of efficiency, power delivery, and overall performance. In summary, a single-speed transmission in an electric vehicle refers to a system that operates without the need for multiple gears or gear shifting. While it simplifies the drivetrain and offers benefits such as increased reliability and smooth power delivery, it is important to recognize that multi-speed transmissions may still be utilized in certain electric vehicles for specific performance requirements.⁷

• **Multi-Speed Transmission:**

Multi-speed transmission systems in electric vehicles (EVs) are designed to provide multiple gear ratios, allowing for optimized power

delivery, efficiency, and performance across a range of driving conditions. While single-speed transmissions are commonly used in many EVs, some vehicles, particularly high-performance models or those aiming for specific driving characteristics, may incorporate multi-speed transmissions. The purpose of a multi-speed transmission in an electric vehicle is to enable the electric motor to operate at different speeds and torque levels by changing gears. This allows for better control of power output and enhances the overall driving experience. By utilizing multiple gear ratios, the electric motor can operate at its most efficient speed range for a given driving condition. This can help maximize energy efficiency and extend the vehicle's range. Multi-speed transmissions allow for gear ratios that optimize torque output, resulting in enhanced acceleration.⁸ The ability to adjust the gear ratio based on the

desired balance between torque and speed provides greater flexibility in performance.

By employing higher gear ratios, multi-speed transmissions can allow electric vehicles to achieve higher top speeds. This is particularly beneficial for sports cars or EVs designed for high-speed driving. Some multi-speed transmissions are designed to work in conjunction with regenerative braking systems. By selecting the appropriate gear ratio during regenerative braking, the transmission can maximize the amount of energy captured and fed back into the battery, further enhancing the vehicle's overall efficiency.

While the majority of electric vehicles on the market today employ single-speed transmissions due to their simplicity and efficiency, the use of multi-speed transmissions is more prevalent in high-performance electric vehicles, certain hybrid models, or EVs designed for specific purposes.⁹ As EV technology continues to evolve, we may see further developments in multi-speed transmission systems to enhance efficiency, performance, and driving dynamics in electric vehicles.

In addition to these basic transmission systems, electric vehicles may also incorporate regenerative braking systems. Regenerative braking allows the electric motor to act as a generator when the driver applies the brakes or decelerates. This process converts kinetic energy into electrical energy, which is then fed back into the battery for recharging. Regenerative braking systems help improve overall efficiency and range by recapturing energy that would otherwise be lost as heat during traditional braking.

Overall, electric vehicle transmission systems are designed to provide efficient power transfer from the electric motor to the wheels. The simplicity and efficiency of electric drivetrains contribute to the smooth and quiet operation of electric vehicles while minimizing energy loss and maximizing performance. As electric vehicle technology continues to evolve, we may see further advancements in transmission systems to

optimize efficiency, range, and driving experience.¹⁰

ELECTRIC VEHICLE TRANSMISSION SYSTEMS: MECHANISM

The general mechanism of electric vehicle transmission systems involves the transfer of power from the electric motor to the wheels, enabling the vehicle to move. Unlike traditional internal combustion engine vehicles that require complex mechanical transmissions with multiple gears, electric vehicle transmission systems are generally simpler and more efficient due to the characteristics of electric motors.

Electric vehicles are powered by one or more electric motors, which generate rotational motion to drive the wheels. These motors can be either AC (alternating current) or DC (direct current) motors, depending on the vehicle's design and specifications. The electric motor is connected to an inverter, which converts the DC power from the vehicle's battery into AC power that the motor can utilize. The inverter controls the speed, torque, and direction of the electric motor. In many electric vehicles, a gear reduction mechanism is used between the electric motor and the wheels. This mechanism consists of a series of gears or gearsets that reduce the high-speed rotation of the motor to a lower speed suitable for the wheels. The gear reduction system helps to increase torque and provide better acceleration while maintaining optimal efficiency.

Electric vehicles also incorporate a differential, which allows the wheels to rotate at different speeds during turns. The differential ensures that power is evenly distributed to the wheels while allowing them to rotate independently. Drive shafts transmit the rotational power from the transmission to the wheels. In some electric vehicles, each wheel may have its own electric motor, eliminating the need for drive shafts and axles. The transmission system is controlled by a sophisticated electronic control unit (ECU) that monitors and adjusts various parameters such as speed, torque, and power delivery. The control system ensures smooth operation, efficient power transfer,

and optimal performance of the electric vehicle. Some electric vehicles, especially those with a single-speed transmission, may not include gear reduction mechanisms and instead use a direct-drive system, where the electric motor is directly connected to the wheels. The general mechanism of electric vehicle transmission systems revolves around the electric motor, inverter, gear reduction (if present), differential, drive shafts, axles, and the control system. These components work together to convert electrical energy from the battery into rotational motion, delivering power to the wheels and enabling the vehicle to move.

DISADVANTAGES OF ELECTRIC VEHICLE TRANSMISSION SYSTEMS

While electric vehicles (EVs) offer numerous advantages, including environmental sustainability and improved efficiency, their transmission systems also have certain disadvantages. It is important to note that these disadvantages are relative and can vary depending on specific vehicle models and technologies. Although electric vehicle transmission systems are generally simpler compared to traditional internal combustion engine transmissions, they can still involve complex components, such as power electronics, inverters, and controllers. The integration and management of these systems require advanced engineering and can add complexity to the overall vehicle design and manufacturing process.

Electric vehicle transmission systems, especially those incorporating multi-speed transmissions, tend to be more expensive than single-speed systems. The additional components, such as gears, gearsets, clutches, and control systems, contribute to higher manufacturing costs and can make electric vehicles more expensive for consumers. Multi-speed transmission systems in electric vehicles often involve additional weight due to the inclusion of gears, gearboxes, and associated components. The added weight can negatively impact the overall efficiency and range of the vehicle. Lighter single-speed transmission systems are generally preferred for maximizing efficiency and range. Traditional

mechanical transmissions in internal combustion engine vehicles can suffer from energy losses due to friction and mechanical inefficiencies.⁵ Electric vehicles, especially those with direct-drive single-speed transmissions, can achieve higher overall efficiency by eliminating the need for complex gear changes. Multi-speed transmissions, on the other hand, may introduce additional mechanical losses, leading to slightly reduced overall efficiency.

Electric vehicle transmission systems, particularly those with multi-speed transmissions, may require more maintenance compared to single-speed systems. The additional components and moving parts increase the chances of wear and tear, necessitating periodic inspections and potential repairs. Electric vehicle transmissions require less maintenance compared to internal combustion engine transmissions due to fewer moving parts and the absence of fluids, such as transmission oil. Single-speed transmission systems in electric vehicles offer a fixed gear ratio, which may limit their performance in certain driving conditions. While electric motors have a broad torque range, a multi-speed transmission can provide more flexibility to optimize power delivery and efficiency across various driving situations, such as high-speed cruising or climbing steep inclines. Therefore, some electric vehicles with single-speed transmissions may experience limitations in terms of top speed, acceleration, or performance in specific scenarios. Electric vehicle transmission systems are still relatively new compared to their conventional counterparts. Ongoing research and development are focused on optimizing electric drivetrain technologies, including transmission systems. As the technology evolves, further advancements may address some of the current limitations and challenges, resulting in more efficient and effective transmission systems for electric vehicles. Despite these disadvantages, it's important to emphasize that electric vehicle transmission systems continue to improve and evolve. As technology progresses,

manufacturers are likely to overcome many of these challenges, enhancing the efficiency, performance, and reliability of electric vehicle transmissions. Additionally, it's worth noting that many electric vehicles today utilize single-speed transmissions, which offer simplicity, efficiency, and lower maintenance requirements while still providing satisfactory performance for most everyday driving scenarios.

FUTURE PROSPECTS: ELECTRIC VEHICLE TRANSMISSION SYSTEMS

The future prospects of electric vehicle transmission systems are promising, with ongoing advancements aimed at enhancing efficiency, performance, and overall driving experience. While single-speed transmissions are currently prevalent in electric vehicles, there is ongoing research and development focused on improving multi-speed transmission systems. Advanced gear technologies, such as dual-clutch or eCVT (electronic continuously variable transmission), are being explored to optimize power delivery and efficiency across a wider range of driving conditions. Multi-speed transmissions can potentially offer improved acceleration, higher top speeds, and enhanced efficiency by allowing the electric motor to operate in its optimal speed and torque range. Future electric vehicle transmission systems are expected to become lighter and more compact. Advancements in materials, such as lightweight alloys and composites, will help reduce the weight of transmission components, improving overall vehicle efficiency and range. Additionally, compact designs will enable better integration with electric motors, battery packs, and other vehicle components, maximizing available space and enhancing overall vehicle design.

An emerging trend is the integration of electric motors and transmissions into a single unit, often referred to as motor-transmission assemblies. By combining these components, manufacturers can reduce weight, simplify the drivetrain, and improve overall system efficiency. Integrated motor-transmissions can also enhance power density, allowing for more compact vehicle designs. Future electric

vehicle transmission systems will incorporate advanced control systems and algorithms to optimize power delivery and efficiency. Intelligent control units will continuously monitor and adjust parameters such as motor speed, torque, and gear selection based on driving conditions, battery status, and driver input. These systems will enable seamless transitions between gears, efficient power distribution, and improved overall vehicle performance. Research and development efforts are focused on minimizing energy losses and improving overall efficiency in electric vehicle transmissions. Innovative lubrication systems, reduced friction materials, and optimized gear designs will contribute to minimizing mechanical losses. Furthermore, advancements in electric motor technology, including higher power density and improved thermal management, will enhance overall drivetrain efficiency. Electric vehicle transmission systems will increasingly integrate with other vehicle systems, such as power steering, air conditioning, and cooling systems.⁶ By electrifying these auxiliary systems and connecting them to the transmission, energy efficiency can be improved through better energy management and reduced reliance on traditional mechanical components. As electric vehicle technology continues to evolve, the future of transmission systems holds significant potential for innovation, efficiency gains, and enhanced driving performance. Continued research, technological advancements, and collaboration among manufacturers, suppliers, and researchers will drive the development of more sophisticated and optimized transmission systems for electric vehicles in the years to come.

CONCLUSION:

In conclusion, electric vehicle transmission systems play a crucial role in transferring power from the electric motor to the wheels, enabling electric vehicles to move efficiently and deliver a seamless driving experience. While single-speed transmissions are prevalent in many electric vehicles, multi-speed transmission systems are also being explored for specific applications. Despite

some disadvantages, the future prospects for electric vehicle transmission systems are promising, with ongoing advancements and research aimed at enhancing their efficiency, performance, and overall integration within electric vehicles. The development of multi-speed transmissions holds potential for optimizing power delivery and efficiency across a wider range of driving conditions. Innovations in gear technologies, such as dual-clutch or eCVT systems, are being pursued to improve acceleration, increase top speeds, and enhance overall efficiency. These advancements will provide electric vehicles with greater flexibility and performance capabilities, making them more attractive to a wider range of consumers. The future of electric vehicle transmission systems also lies in lightweight and compact designs. Advances in lightweight materials will help reduce the weight of transmission components, resulting in improved vehicle efficiency and extended range. Furthermore, the integration of electric motors and transmissions into a single unit offers opportunities for weight reduction, simplified drivetrains, and increased power density.

Advanced control systems will be a key factor in optimizing electric vehicle transmission systems. Intelligent control units that continuously monitor and adjust parameters based on driving conditions, battery status, and driver input will enable efficient power distribution, seamless gear transitions, and enhanced overall performance. These systems will contribute to a more refined and efficient driving experience. Continual improvements in efficiency will be a major focus in future electric vehicle transmission systems. Efforts to minimize energy losses through advanced lubrication systems, reduced friction materials, and optimized gear designs will contribute to overall system efficiency. Additionally, advancements in electric motor technology and thermal management will further enhance drivetrain efficiency. As electric vehicle technology continues to evolve, collaboration among manufacturers, suppliers, and researchers will be essential in driving innovation and the development of

optimized transmission systems. The industry's collective efforts will push the boundaries of electric vehicle transmission systems, resulting in improved efficiency, performance, and reliability. In conclusion, while there are certain challenges and limitations associated with electric vehicle transmission systems, the future prospects for these systems are bright. Ongoing advancements, such as multi-speed transmissions, lightweight designs, advanced control systems, and continual efficiency improvements, will shape the future of electric vehicle transmissions and contribute to the broader adoption and acceptance of electric vehicles in the transportation landscape.

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