

# Differential for Electric Vehicle

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**Abstract:** This paper discusses the role of differential systems in electric vehicles (EVs). It aims to explain how differential mechanisms work, their importance in enhancing vehicle performance, and the challenges associated with their integration in EVs. The methodology includes a review of existing literature and examples of EV designs that utilize differential systems. The findings show that while traditional differentials provide benefits in terms of handling and stability, new designs specifically for electric vehicles are needed to address unique challenges

**Keywords:** Electric Vehicle, Function of differential, Types of differential with advantages & disadvantages

## I. INTRODUCTION

Differentials are vital components in vehicles, allowing wheels to rotate at different speeds while turning. In electric vehicles, which often have unique powertrain configurations, understanding the role and design of differentials becomes essential. EVs face distinct challenges, such as instant torque and weight distribution, that influence how differentials should be designed and implemented. This paper explores these elements, highlighting their importance for safety, performance, and efficiency.

### Understanding Differential Systems

Differentials are mechanical devices that enable the wheels on the same axle to turn at different speeds. This is particularly important when a vehicle turns, as the wheels on the outside of the turn travel further than those on the inside. In traditional vehicles, differentials are found in both front and rear axles. They help improve tire wear and enhance handling, making driving smoother and safer.

In electric vehicles, the situation can be somewhat different. Many EVs utilize electric motors on each wheel or axle, which can make traditional differential systems less necessary. However, understanding how to integrate differentials within these systems is still crucial for achieving optimal performance.

### Types of Differential Systems in EVs

#### 1. Open Differential



Among the common types of differences easily found in passenger cars, these are the most prevalent. It can only change the speed or slip of a single wheel. The outer wheel can spin faster than the inner wheel in good road conditions. When the road is not in good condition, such as when it is wet, snowy, icy, or sand-covered, the problem occurs. An open differential lets your car's engine transmit torque even when the wheel has no traction so that the sliding tire can spin freely.

Many cars today have open differentials, so repairing one is less expensive than repairing another.

#### **Advantages of Open Differential**

As the outer tire travels further, there will be no wheel slip when going around a corner because multiple speeds can be achieved on each axle.

From an efficiency standpoint, the differential will cause less energy loss than other types.

#### **Disadvantages of Open Differential**

The amount of power produced by the vehicle is greatly reduced when traction is reduced in one wheel. If one wheel cannot dissipate as much power, the other will receive an equally small amount of torque.

#### **Limited-slip Differential**



Limited-slip differential

A Differential with limited slip behaves similarly to differentials with open slip. In good road conditions, they transfer torque independently to each wheel.

Under hard cornering or heavy acceleration, an open differential can cause tire slippage. But limited-slip differentials prevent torque from being transferred to the sliding tire (the one with the least resistance).

This is accomplished through the use of clutches and plates inside the differential. As a result, the vehicle can power through corners, as opposed to one with an open differential. Performance vehicles, such as race cars and off-road trucks, use limited-slip differentials.

#### **Advantages of Limited-slip Differential**

Tire wear is reduced in comparison to a locked differential.

It also enables the tire to transmit torque while maintaining greater traction.

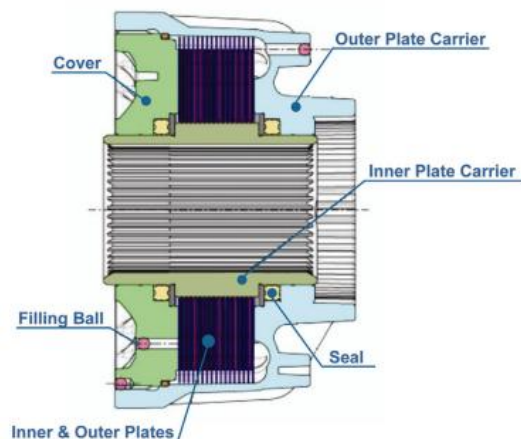
It has a very smooth functioning and lacks the low-speed clunkiness that other LSD kinds that transverse a tight space are known for.

#### **Disadvantages of Limited-slip Differential**

The device requires a speed difference between the two sides to transfer torque, therefore it can't entirely lock.

LSD's effect is diminished when it is used too frequently.

### Viscous Limited-slip Differential

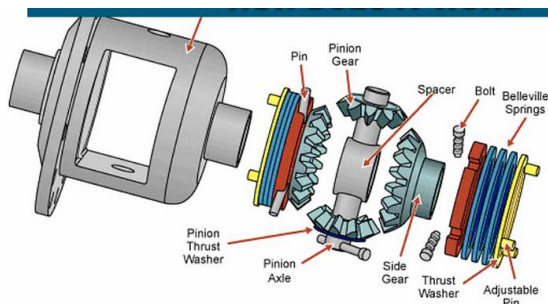


#### Viscous Limited-type Differential

It's a sort of limited-slip differential that employs a thick liquid to provide the necessary resistance to convert the differential's behavior from open to closed. It has fewer parts than a mechanical LSD, which is a plus.

When a wheel turns, the viscous fluid heats up, adding to the resistance. As a result, the spinning wheel slows down and the torque is diverted to the wheel with grip. VLSDs can deliver more torque to the wheel with the most traction

### Mechanical Limited-slip Differential



#### Limited-slip Differential (Mechanical)

The mechanical limited-slip differential resists the free movement of the wheels, shifting the differential's impact from open to locked and providing better traction. One-way, This style allows for 1.5-way, two-way, and even electronic communication.

### Active Differential



Active Differential

The active differential makes use of a specific mechanism to offer the necessary resistance for torque transmission from one side to the other. Instead of relying on mechanical force, these are powered by electricity.

It has the ability to adjust the mechanical forces of the system utilizing electronics by changing driving conditions, thus making them programmable and further controllable. A computer can autonomously recognize which drive wheels need power and when by using a series of sensors throughout the vehicle.

It has more agility, better handling, and excellent traction. It compensates for the rear wheels' variable rotational speeds, especially on curves.

### Locking Differential



Locking Differential

These differentials employ a clutch and springs to operate the lock, which distributes the same amount of power to each wheel regardless of traction. It basically acts as a solid axle.

Because the whole amount of torque is always accessible to one wheel and is not limited by the lesser traction of a single wheel, the locking differential has the advantage of being able to achieve more traction.

This is a disadvantage at greater speeds, but it is a huge advantage while off-roading or climbing. Many ATVs and certain high-performance automobiles have them.

### Advantages of Locking Differential

This can supply torque to the wheel, allowing for increased traction. This will allow the majority of the torque to reach the ground in varied designs, regardless of the surface condition.

Robust, simple, and very effective.

It provides a solution for drifting circumstances when maintaining a consistent wheel speed on the axle is desirable.

### Disadvantages of Locking Differential

The locking differential has the disadvantage of preventing wheel speed differences between the right and left wheels. As a result, there will be more tire wear and clogging of the drivetrain.

### Torque-vectoring Differential



Torque vectoring Differential

A series of sensors and electronics gather input from numerous sources (road surface, throttle position, steering system, etc.) to engage an electronically operated clutch and a controller in this sort of differential.

They run as efficiently as possible, resulting in a really dynamic, high-performance driving experience. In high-performance rear-wheel drive and all-wheel drive cars, there is a torque-vectoring difference.

#### **Advantages of Torque-vectoring Differential**

As the outer wheel approaches the bend, it is able to send additional torque.

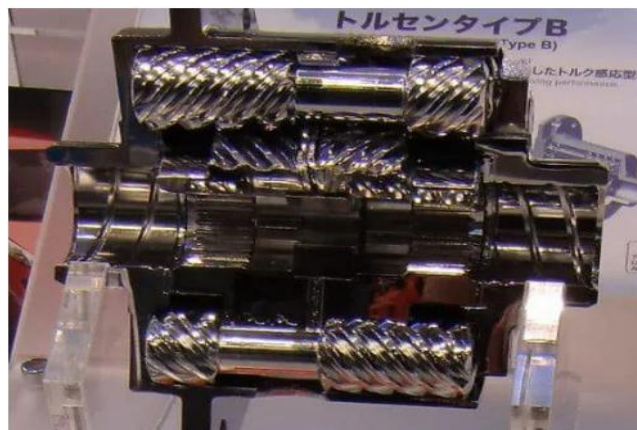
It gives the designer ultimate control; rather than being reactive, the system can determine when the vehicle sends greater torque to any one wheel.

It has the ability to send up to 100% of the available torque to a wheel.

#### **Disadvantages of Torque-vectoring Differential**

It does not have any disadvantages, but it does have two drawbacks: expense and complexity.

#### **Torsen Differential**



Torsen Differential

Torque-sensing is what Torsen stands for. These are limited-slip differentials that use accelerated gearing instead of a clutch or fluid resistance to make an impact.

This can be accomplished by adding a set of worm gears to an open differential's traditional gear configuration. On each axle, these worm gears offer the necessary resistance for torque transfer.

This is accomplished by having the worm gears mesh with each other in a continuous mesh through linked spur gears. The continuous mesh between the differential's two sides has the advantage of delivering rapid torque and making it sensitive to varying road and driving circumstances.

#### **Advantages of Torsen Differential**

It starts providing additional torque to the slower wheel as long as there is a speed gap between them. It also reacts much faster than LSD.

Because differential motion is based on friction across the gear, these systems do not require frequent maintenance.

#### **Disadvantages of Torsen Differential**

A Torsen differential works similarly to an open differential when a wheel is in the air, transferring very little torque to the driving axle. This is fine for road use, but that can be a problem on the track with more purpose-built vehicles.



### Welded or Spool differential



A spool differential is a form of locking differential. An open gap permanently welds it to a fixed axis. This is frequently done when the features of a locked differential make it easier for both wheels to spin at the same time. This is generally not recommended because the heat from welding can hazard the component's strength and increase the risk of part failure.

## II. APPLICATIONS AND USE CASES

Differential systems in electric vehicles have various applications:

- **Improvement of Handling:** Properly designed differentials enhance handling during turns, making the vehicle safer and easier to drive.
- **Enhanced Stability in Various Conditions:** Limited-slip and torque vectoring differentials provide better traction on slippery or uneven surfaces, offering a safer ride in poor weather.
- **Efficiency in Power Distribution:** With advances in electronic differentials, electric vehicles can more effectively distribute power to each wheel, optimizing performance and energy use.

## III. KEY FACTORS FOR EV DIFFERENTIALS

- **Regenerative Braking:** Many EVs use regenerative braking, which recovers energy when slowing down. Differentials must work seamlessly with this system to avoid mechanical resistance while maintaining stability.
- **Efficiency:** EV differentials are designed with an emphasis on reducing mechanical losses and improving energy efficiency. This is especially important as EVs typically focus on maximizing range and performance while minimizing energy consumption.
- **Weight and Complexity:** EVs tend to have a simpler and lighter drivetrain than traditional ICE vehicles, which can impact the design of the differential. The emphasis is on reducing weight while maintaining or improving performance.

## IV. CHALLENGES AND LIMITATIONS

Despite their advantages, integrating differential systems into electric vehicles comes with challenges:

- **Complexity in Design:** Creating a differential system that works with electric motors can be technically complex, requiring innovative engineering solutions.
- **Weight Considerations:** As EVs strive for efficiency and longer range, adding traditional differential systems could increase weight, negatively impacting performance.
- **Cost:** Advanced differential systems, such as electronic and torque vectoring types, can be costly to implement, which may increase the overall price of electric vehicles.
- **Limited Awareness:** There is also a need for more education and understanding among consumers regarding how differential systems impact EV performance.

## V. COMPARING WITH RELATED CONCEPTS

Understanding differentials in electric vehicles also involves comparing them to traditional systems in combustion engine vehicles. Traditional differentials are mainly mechanical systems, while modern EVs increasingly rely on

electronic controls that simplify the design and improve responsiveness. The capabilities of torque vectoring offer advantages that typical vehicles cannot match, providing an edge in performance.

While conventional differentials focus on mechanical efficiency, electric differentials prioritize adaptability, allowing for real-time adjustments based on driving conditions. This transition reflects a broader shift in automotive engineering practices towards greater integration of electronic systems.

## **VI. CONCLUSION**

In conclusion, the differential system in electric vehicles (EVs) plays a critical role in ensuring smooth power delivery to the wheels while maintaining efficiency and performance. While the traditional differential used in internal combustion engine (ICE) vehicles remains largely similar, electric drivetrains present unique challenges and opportunities. The use of one or more electric motors with varying torque distribution allows for different approaches to differential systems, such as the use of electronically controlled differentials or torque-vectoring technologies.

Electric vehicles, with their instant torque delivery and the ability to independently control each motor's power output, are redefining how power is distributed across the wheels. This leads to greater flexibility in vehicle design and the potential for improved handling, efficiency, and traction under various driving conditions. Moreover, as EV technology continues to evolve, innovations in differential systems are likely to further enhance performance, contributing to the overall growth of electric mobility.

The ongoing research and development in differential systems for electric vehicles promise a more sustainable and high-performance future for the automotive industry. Understanding and optimizing these systems will be crucial as the shift toward electric transportation accelerates. Thus, advancements in the differential design of EVs will not only affect vehicle dynamics but also contribute to greater energy efficiency and the reduction of environmental impact, underscoring their importance in the future of automotive engineering.

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