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Design and Development of Drivetrain for Rear Independent Drive Electric Four-Wheeler

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ABSTRACT:

This study presents the intricacies of designing and developing a drivetrain tailored specifically for a rear independent drive electric four-wheeler. The project addresses the challenges of achieving equitable power distribution to the drive wheels without a conventional differential unit. Through meticulous selection of components, CAD modeling, simulation, and analysis, the drivetrain's performance characteristics are thoroughly examined. A chain drive system with mid shafts is proposed as a solution, promising seamless power transmission while considering factors such as cost, complexity, and performance. This research contributes to advancing electric vehicle technology by providing insights into drivetrain optimization for rear independent drive configurations.

The development journey begins with a meticulous analysis of drivetrain requirements, encompassing factors such as vehicle weight, cost considerations, and complexity. By carefully balancing these requirements, a design framework is established to guide component selection and system integration. The chosen drivetrain architecture incorporates a chain drive system with mid shafts, strategically positioned to facilitate seamless power transfer from the electric motor to the individual drive wheels. Central to the design process is the utilization of CAD modeling techniques, which provide a detailed visualization of the drivetrain components and their spatial relationships. CAD models serve as a virtual blueprint, enabling engineers to iterate rapidly and refine the design iteratively. Through simulation and analysis using MATLAB/Simulink, the performance characteristics of the drivetrain are evaluated under various operating conditions. This includes assessing torque distribution, efficiency, thermal management, and dynamic response to dynamic loads and driving scenarios. The adoption of a rear independent drive configuration introduces complexities in power distribution, necessitating

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innovative control strategies to ensure optimal performance. Furthermore, consideration is given to the integration of regenerative braking systems to maximize energy efficiency and extend the vehicle's range. By leveraging innovative design methodologies, advanced simulation techniques, and collaborative interdisciplinary efforts, this project aims to push the boundaries of drivetrain technology and accelerate the adoption of electric vehicles in the automotive industry.

Keywords: Powertrain, Drivetrain, Electric four-wheeler, CAD, MATLAB, CAE

I INTRODUCTION: The electrification of vehicles, particularly in the four-wheeler segment, has gained significant momentum in recent years due to the growing concerns about environmental sustainability and the need to reduce reliance on traditional internal combustion engines. The drivetrain is a critical component of an electric four-wheeler, influencing its performance, efficiency, and overall driving experience.

As sustainability and environmental concerns become more pressing, the automotive industry strives to develop greener solutions. Enhancing the aerodynamic performance of SUVs can significantly contribute to the reduction of greenhouse gas emissions, promoting an eco-friendlier transportation sector. The implications of aerodynamic improvements are not limited to fuel efficiency and performance gains alone. By reducing drag and lift forces, manufacturers can achieve quieter cabins, lower wind noise, and an overall reduction in road noise, contributing to a more comfortable and pleasant driving environment.

Need for the study: The existing electric vehicle drivetrain configurations are shown below and the need for rear independent drive electric four-wheeler drivetrain is discussed in detail.

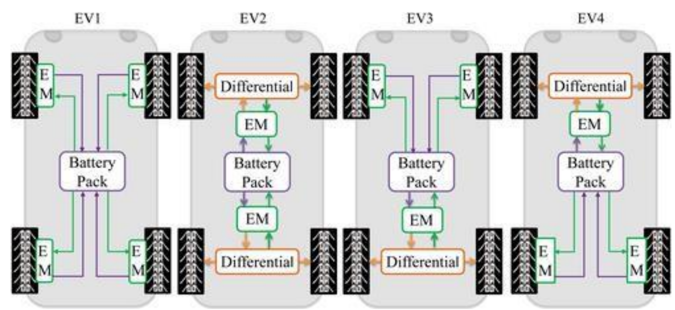

Fig.1 Conventional Drivetrain Configurations

The need for developing an RID drivetrain for electric four-wheelers stems from several factors:

- Improved Manoeuvrability: RID enables individual control of rear wheels, leading to tighter turning circles, superior handling, and enhanced stability, especially at low speeds and challenging terrains. This is crucial for urban driving and off-road applications.

- Regenerative Braking: Each wheel motor can recover energy independently, potentially increasing overall braking efficiency and extending range, a significant concern for EVs.

- Simplified Design: Eliminating the driveshaft and differential can potentially reduce weight and complexity, making the overall design more efficient and cost-effective.

Difficulties in RID:

Implementing a rear independent drive system can increase the complexity of the overall drivetrain, leading to higher manufacturing and maintenance costs compared to a conventional drivetrain. The additional components in a rear independent drive system, such as multiple motors and associated control systems, may introduce more points of failure, potentially leading to increased maintenance requirements and costs. The additional components needed for a rear independent drive system, including extra motors and control electronics, may contribute to a weight increase in the vehicle. This could potentially impact energy efficiency and overall performance.

II POWERTRAIN CALCULATIONS:

The calculations required for the development of the drivetrain has been initiated. For the selection of motor and battery, power and torque requirements, various vehicle considerations are collected by referring to central motor vehicle rules. The required battery capacity and range calculations were also calculated analytically. Motor selection: In-wheel motors offer compact integration but pose thermal management challenges, while inboard motors provide more flexibility for cooling but require additional drivetrain components. The project needs to carefully consider motor type, power, and efficiency based on target vehicle performance and cost requirements.

III CIRCUIT MODELING AND SIMULATION:

The circuit modeling and simulation of the drivetrain for a rear independent drive electric four-wheeler using MATLAB/Simulink involves several steps to accurately represent the electrical and mechanical components of the system.

By identifying the key components of the drivetrain, including the electric motor, power electronics (inverters, converters), battery pack, and any additional components such as sensors or controllers. Developed mathematical models for each component based on their electrical and mechanical characteristics. For example:

- Electric Motor: Model the motor using equations that describe its torque-speed characteristics, electrical parameters, and efficiency.
- Power Electronics: Model inverters and converters to simulate power conversion processes, considering switching dynamics, losses, and control strategies.
- Battery Pack: Model the battery using equivalent circuit models to represent its voltage, internal resistance, and state of charge.
- Interconnection: Connect the modeled components in Simulink to represent the physical connections within the drivetrain. Ensure proper interfacing and signal flow between components.

V CAD MODELING AND CAE:

CAD modeling for mechanical assembly of drivetrain systems like motor, controller, battery, and electrical components. The increasing demand for electric vehicles (EVs) necessitates efficient drivetrain designs. Computer-aided design (CAD) plays a crucial role in this process, enabling the creation of accurate 3D models for drivetrain components, facilitating assembly analysis and optimization. This project investigates the utilization of CAD software for modeling and assembling the mechanical components of an EV drivetrain system, encompassing the motor, controller, battery, and associated electrical components.

VI PROTOTYPE DEVELOPMENT:

The assembly of an electric vehicle drivetrain involves integrating several key components into a cohesive system using CAD (Computer-Aided Design) modeling software. Here's a brief overview of the typical components and their assembly process:

Electric Motor: Begin by placing the electric motor in the designated location within the vehicle chassis. Ensure proper alignment with the drivetrain layout and mounting points.

- Transmission or Gearbox: Position the transmission or gearbox adjacent to the electric motor, connecting them via appropriate couplings or shafts. Align the gearing system to facilitate power transmission from the motor to the wheels.
- Driveshafts and Axles: Connect the driveshafts from the differential to each wheel axle. Ensure proper length and alignment to accommodate suspension travel and steering angles.
- Battery Pack: Position the battery pack within the vehicle chassis, typically located beneath the cabin or in the rear for optimal weight distribution. Connect the battery terminals to the electric motor and other electrical components.

VII COMPONENTS:

Motor and Controller: The vehicle consists of two motors with 2000W 48V rated voltage A motor converts supplied electrical energy into mechanical energy. Various types of motors are in common use. Among these, brushless DC motors (BLDC) feature high efficiency and excellent controllability and are widely used in many applications. The BLDC motor has power-saving advantages relative to other motor types.

An electric vehicle's motor controller (48V 2000W each) is a combination of power electronics and embedded microcomputers that effectively converts the energy stored in the batteries into motion. A simplified block schematic of a typical electric three-wheeler vehicle can be seen on the cover. As one can see, the main element that regulates the energy supply to the motor is the motor controller. The Motor controller receives commands from interfaces such as the Throttle, Brake, or Forward/Reverse control switches. The Motor controller processes these commands and very precisely controls the speed, torque, direction, and consequent horsepower of a motor in the vehicle. The use of a separate motor controller for the motors not to divide the current among them.

Fig.2 Motor

Fig.3 Controller

Battery pack with BMS: A lithium-ion or Li-ion battery of 48V 25 AH is a type of rechargeable battery which uses the reversible reduction of lithium ions to store energy. The anode (negative electrode) of a conventional lithium-ion cell is typically graphite made from carbon. The cathode (positive electrode) is typically a metal oxide. The electrolyte is typically a lithium salt in an organic solvent. It is the predominant battery type used in portable consumer electronics and electric vehicles. It also sees significant use for grid-scale energy storage and military and aerospace applications. Compared to other rechargeable battery technologies, Li-ion batteries have high energy densities, low self- discharge, and no memory effect. And advanced battery technology that uses lithium ions as a key component of its electrochemistry.

Electrical Components: A DC-to-DC converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another (48V to 12V). It is a type of electric power converter. DC-to-DC converters convert one DC voltage level to another, which may be higher or lower, by storing the input energy temporarily and then releasing that energy to the output at a different voltage. The storage may be in either magnetic field storage components (inductors, transformers) or electric field storage components(capacitors). This conversion method can increase or decrease voltage.

Low voltage components which include instrument cluster, real light, taillight which consumes low voltage. We need to buck the voltage for the components, so the DC-DC converter is used.

Pedal throttle controls effective motor voltage by applying high frequency 0-100% PWM, so you could say that it indirectly affects commutation timing because motor speed is proportional to applied voltage. However, motor speed is also affected by loading, which may vary independently of throttle level.

VIII RESULTS:

The outcome of the Project will provide insights into whether the development of a drivetrain for a rear independent drive electric four-wheeler is practical and viable. It helps in making informed decisions about whether to proceed with the project, refine certain aspects, or reconsider the approach based on identified challenges and opportunities.

The Regeneration of energy due to braking / deceleration would be increased, as two motors will act as a generator during downhill. So, this drivetrain acquires more regeneration energy and decreases the required capacity of the battery to have long range. This regeneration will provide us with extended range with respect to driving.

As the battery capacity decreases the overall cost will also decrease. The only difficulty faced while driving would be larger turning radius, because of the two rear independently driven motors, the wheels would receive the same acceleration input to the Motor Controller Unit, so both inner and outer wheels while cornering would receive the same power and rotates at the same rpm. Our non-endlessly optimized drivetrain models are acted in both Circuit Simulation and CAE and the eventual outcomes are thought about and assessed in other diary papers, to demonstrate the rear independent drivetrain. It brings about the financial benefits of extended range and Electrical expenses for EV Vehicles.

CIRCUIT SIMULATION: Analyzed the simulation results to assess the performance characteristics of the powertrain. Evaluated metrics such as efficiency, range, acceleration, and energy consumption to optimize the design. The input drive cycle source is shown in the following figure, it is represented in velocity vs time where the max speed of 35 m/s is reached at 33.3 seconds.

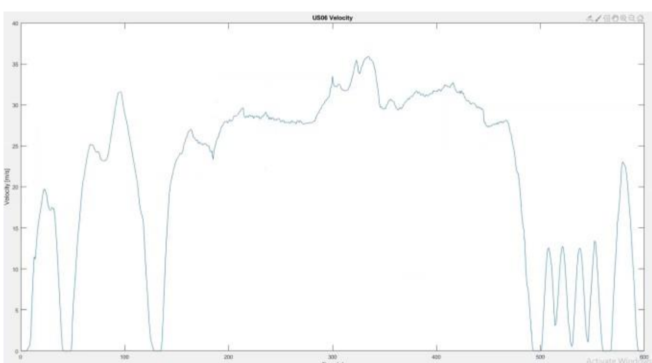

Fig.4 Drive cycle source Input

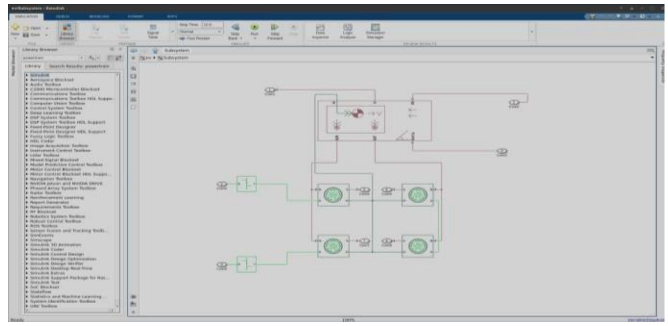

Fig.5 Vehicle Model

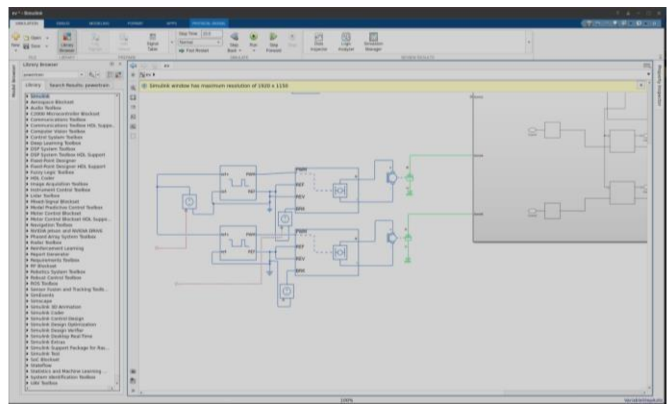

Fig.6 Powertrain Model

CAD MODEL DEVELOPMENT: Autodesk Fusion 360 CAD software is utilized to make the computer aided design model of our venture to play out the CAE and Prototype Development. The existing vehicle chassis systems like suspension, steering and brakes are utilized to integrate the drivetrain with the vehicle. The Brackets/Mounts required to assemble the drivetrain components in vehicle chassis are designed by considering the wiring harness and fastening methods.

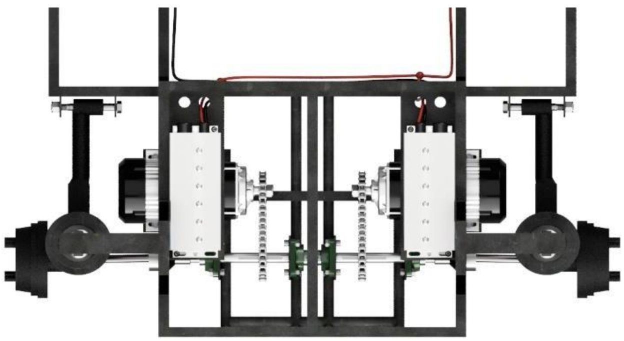

Fig.7 CAD model Top view

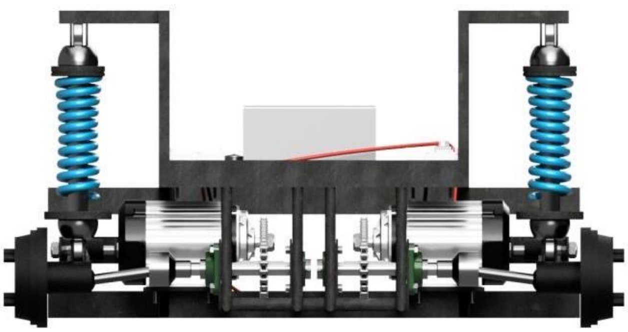

Fig.8 CAD model Front view

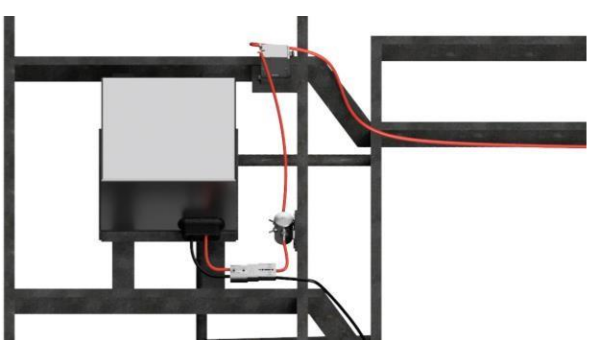

Fig.9 Location of Battery pack

ANALYSIS OF DRIVETRAIN: A comprehensive analysis was conducted to assess the stresses incurred by the brackets and mounts under dynamic vehicle conditions. Special attention was given to evaluating the structural integrity and performance of these components to ensure reliability and safety during operation. Of particular concern was the mounting of the battery pack, necessitating careful consideration of its placement to mitigate the impact of vibrations experienced while the vehicle is in motion. The objective was to secure the battery pack in a manner that shields it from excessive vibrations, safeguarding its functionality and longevity. Additionally, the motor brackets were subjected to rigorous scrutiny, particularly in relation to the twisting moments.

generated during the initial peak torque exerted by the motor. It was imperative to design these brackets to withstand these forces, ensuring optimal support and stability for the motor assembly. Through meticulous analysis and design refinement, the brackets and mounts were engineered to meet the demanding requirements of the drivetrain system, thereby contributing to the overall performance and durability of the electric four-wheeler.

PROTOTYPE DEVELOPMENT: As per the

planned design the brackets were fabricated to assemble drivetrain components. To minimize the cost of the drivetrain system we assembled the mid shaft concentric to the other using pillow blocks. As we designed the vehicle with independent suspension, CV joints were used to connect the mid shaft and drive shaft.

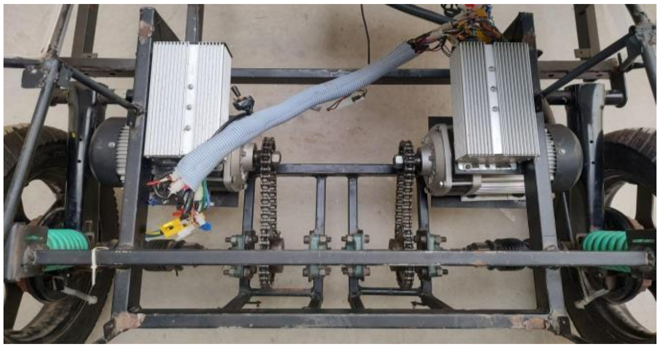

Fig.10 Prototype development Top view

Fig.11 Prototype development Front view

COST COMPARISON:

3 KW BLDC Mid drive motor	33510	1.5+1.5 KW BLDC Motor	11523 + 11523
Controllers and converters	11448	Controllers and Convertors	6500 + 6500
Battery Pack (25 Ah)	24000	Battery Pack (25 Ah)	24000
Differential with drive axle	11500	Drivetrain components	8500
Total	**80458 /-**	**Total**	**68546 /-**

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