Hybrid Electric Vehicle -Curriculum

1. Introduction to Electric Vehicle

1.1 History

Early Innovations

- Ferdinand Porsche built one of the first hybrid cars, the Lohner-Porsche Mixte, in the early 1900s.

Oil Crisis Revival

- Interest in hybrids reemerged during the 1970s oil crisis due to the demand for fuel efficiency.

Prius Launch

- Toyota introduced the Prius in the 1990s, the first mass-produced hybrid, proving mainstream viability.

Modern Expansion

- Hybrid technology grew in popularity, leading to diverse models like plug-in hybrids and eco-friendly options across vehicle lines.

1.2 Classification of Electric vehicles

Battery Electric Vehicles (BEVs)

- Fully electric, powered solely by rechargeable batteries, with zero emissions.

Hybrid Electric Vehicles (HEVs)

- Combine an internal combustion engine with an electric motor, recharging through regenerative braking.

Plug-in Hybrid Electric Vehicles (PHEVs)

- Use both a battery-powered motor and combustion engine; batteries can be recharged via an external power source.

Fuel Cell Electric Vehicles (FCEVs)

- Generate electricity through hydrogen fuel cells, emitting only water vapor as a byproduct.

1.3 Career opportunities

Automotive Engineering

- Design and development of HEV components like electric motors, batteries, and control systems.

Battery Technology

- Research and innovation in battery chemistry, energy storage, and battery management for enhanced HEV performance.

Manufacturing and Assembly

- Production roles in hybrid vehicle assembly, including specialized HEV components and quality control.

2. Design of Electric bike/Scooter

2.1 Forces effecting the motion

Aerodynamic Drag

- Resistance from air as the vehicle moves, affecting energy efficiency at higher speeds.

Rolling Resistance

- Friction between tires and the road surface, impacting fuel and battery consumption

Inertial Force

- Resistance to changes in speed, requiring energy from the HEV's powertrain to accelerate or decelerate.

Gravitational Force

- Affects HEVs on inclines, requiring more power when climbing and enabling energy recovery when descending.

Hybrid Electric Vehicle -Curriculum

2.2 **Power calculations**

2.3 **Motor and Battery selections**

3. Motor

3.1 Principle

Electromagnetic Induction

- HEV motors use electromagnetic fields to convert electrical energy into mechanical motion.

Torque Generation

- Electric current flows through coils, creating magnetic forces that generate rotational torque on the motor shaft.

Regenerative Braking

- HEV motors can operate in reverse to convert kinetic energy back into electrical energy, recharging the battery during braking.

Control Systems

- Motor speed and torque are managed by controllers that adjust current flow to match driving conditions and efficiency needs.

3.2 Types of Motor

Aleternatice Current Motor (AC Motor)

- Electirc Motor that operates by converting alternating current (AC) electrical energy into mechanical motion
- AC motors rely on the interaction between a rotating magnetic field generated by the AC supply and magnetic fields within the motor's rotor, producing torque that causes the rotor to spin
- Types - Synchronous Motors & Asynchronous Motoros

Direct Current Motor (DC Motor)

- Electirc Motor that converts direct current electrical energy into mechanical motion.
- DC motors operates based on the principles of electromagnetism, where a magnetic field is created by electric current flowing through coils, generating torque that turns the motor's rotor.
- Types - Brushed Motors, & Brushless Motoros

3.3 DC Motor

- Rotor Coils
- Commutator
- Shaft
- Brushes
- Stator Magnets

Hybrid Electric Vehicle -Curriculum

3.4 Brushed DC Motor

- **Introduction** - A brushed DC motor uses brushes and a commutator to transmit current, creating rotational motion with simple control but requiring more maintenance due to brush wear.
- **Types** - DC Shunt Motor, Series DC Motor
- **Components** - Stator, Commutator, Brush Assembly, Armature, Bearings, Shaft, End Bracket, Yoke

3.5 Brushless DC Motor (BLDC)

- **Introduction** - A brushless DC motor (BLDC) uses electronic control instead of brushes and a commutator, offering higher efficiency, reliability, and low maintenance.
- **Types** - Inner Rotor BLDC Motors, Outer Rotor BLDC Motors
- **Components** - Bearings, Shaft, Rotor, Front End Cap, Stator, Fram Cover, Rear End Cap, Hall IC Sensors, Stator Winding, Permanent Magnet

4. Battery

4.1 Principle

Electrochemical Storage

- HEV batteries store energy through chemical reactions, which release electricity to power the motor.

Energy Conversion

- During discharge, stored chemical energy is converted into electrical energy for propulsion.

Regenerative Recharging

- Kinetic energy from braking is converted back into electrical energy to recharge the battery, improving efficiency.

Cycle Durability

- HEV batteries are engineered to withstand frequent charging and discharging cycles, ensuring a long operational life.

4.2 Components in a Battery System

- Cathode
- Anode
- Electrolyte
- Separator
- Container

4.3 Cell Reaction in a Battery System

- Anode Reaction - Is a oxidation reaction which releases electrons (Anode is the -ve electron in the EC Cell)
- Cathode Reaction - Is a reduction reaction which consumes electrons (Anode is the +ve electron in the EC Cell)

4.4 Classification of Battery

- Primay Battery - For One-Time usage or for Single usage
- Secondary Battery - For Multiple usage or for repititive usage

Hybrid Electric Vehicle -Curriculum

4.5 Electric Vehicle Battery (EVB)

- An EVB also known as Traction Battery can be either Primary battery or a Secondary battery used for the propulsion of HEV's
- EVB's differ from Starting, Lighting and Ignition (SLI) batteries because they are designed to give power over sustained period of time

4.6 EV Battery Requirements

- High Energy Density
- Fast Charging Capability
- Long Cycle Life
- Safety and Stability

4.7 EV Battery Types

- Lead-Acid Batteries
- Nickel-Metal Hydride (NiMH) Batteries
- Lithium-Ion (Li-ion) Batteries

5. Chassis

5.1 Introduction

Structural Framework

- The chassis serves as the vehicle's foundational structure, It provides the necessary strength and rigidity to withstand forces during operation while also serving as the foundation for the vehicle's overall design

Weight Distribution and Handling

- An optimized chassis design enhances weight distribution and handling characteristics, contributing to overall vehicle performance and driving experience.
- It plays a crucial role in vehicle dynamics, influencing handling, stability, and safety.

Components

- Engine, Brakes, Steering System, Transmission, Suspension, Wheel mounted on the frame

5.2 Principle Function

- To safely carry the maximum load
- Holding all Components together while driving
- Accomodate twisting on even road surface
- Endure Shock Loading
- It must absorb engine and driveline troque

5.3 Materials Used for Chassis Manufacturing

- Steel, Aluminium
- Magnesium, Plastic Composites
- Fibre Reinforced Composites, Carbon Fibre Epoxy Composites
- Glass Fibre Composites

Hybrid Electric Vehicle -Curriculum

5.5 Frame

- An EVB also known as Traction Battery can be either Primary battery or a Secondary battery used for the propulsion of HEV's
- EVB's differ from Starting, Lighting and Ignition (SLI) batteries because they are designed to give power over sustained period of time

5.6 Components and Sections of Frames

Crossmembers

- Horizontal supports that provide strength and rigidity to the frame, helping to distribute loads and resist bending forces.

Longitudinals

- Long, vertical beams running along the length of the frame, which bear the weight of the vehicle and provide structural integrity.

Suspension Mounts

- Attachment points for the suspension system, designed to absorb and manage forces during driving while maintaining wheel alignment.

Reinforcement Plates

- Additional metal plates welded or bolted to the frame in high-stress areas to enhance strength and durability, especially in off-road or heavy-duty applications.

Channel Section

- A channel section is a structural beam with a C-shaped profile, providing high strength-to-weight ratios and used in chassis frames for efficient load distribution and support.

Box Section

- A box section is a hollow rectangular or square structural beam that offers excellent rigidity and resistance to torsional forces, commonly used in chassis frames for enhanced strength and stability.

Tubular Section

- A tubular section is a cylindrical or hollow structural beam that provides high strength and lightweight characteristics, ideal for chassis frames where flexibility and resilience are required.

6. ANSYS WORK BENCH

6.1 Introduction

- ANSYS software is a powerful simulation tool for engineering analysis, including structural, thermal, and fluid dynamics.

6.2 Ansys Interface

- Working with Cells
- Menu Bar

6.3 Engineering design

Simulation Setup

- Ansys Workbench provides tools to create and set up engineering simulations, allowing for analysis of stress, thermal, fluid, and other physical properties.

Hybrid Electric Vehicle -Curriculum

Finite Element Analysis (FEA)

- Engineers can use FEA within Ansys to break down complex designs into smaller elements, analyzing how each part behaves under various conditions.

Optimization Tools

- Ansys Workbench offers optimization features to enhance design performance, reduce weight, and ensure structural integrity.

Integrated Workflow

- Workbench streamlines the design process by linking CAD models, simulation results, and post-processing, simplifying modifications and analysis.

6.4 Design modeler

6.5 Solution

8. Design and analysis of frame/chassis

8.1 Model importing

CAD Model Import

- Ansys Workbench allows importing of CAD models from various software, ensuring compatibility and preserving design accuracy for chassis analysis.

Geometry Simplification

- Imported models can be simplified by removing non-essential features, reducing complexity and improving analysis efficiency.

Material Assignment

- Materials can be assigned to different chassis components, allowing for accurate simulation of real-world physical properties.

Mesh Generation

- After import, the model is meshed into smaller elements to prepare for finite element analysis, ensuring detailed and precise simulation results.

8.2 Structural Analysis

Load Application

- Structural analysis involves applying various loads, such as weight, forces, and vibrations, to evaluate the chassis's strength under operating conditions.

Stress and Deformation Analysis

- The analysis identifies areas of high stress and potential deformation, ensuring the frame can withstand real-world forces without failure.

Factor of Safety (FOS)

- Structural analysis calculates the FOS to confirm that the design meets safety standards, protecting against overloading.

Optimization for Weight Reduction

- Analysis results can be used to optimize the chassis design, reducing weight while maintaining structural integrity and performance.

Hybrid Electric Vehicle -Curriculum

8. Brakes

8.1 Introduction

Energy Conversion

- Brakes slow down the vehicle by converting kinetic energy into heat through friction, either in disc or drum systems.

Safety and Control

- Effective braking systems are essential for vehicle safety, providing precise control during deceleration and stopping.

8.2 Types

- Drum Brakes
- Disc Brakes
- Electronic Brakes

8.3 Drum Brakes

Overview

- Drum brakes use brake shoes pressing against a rotating drum to create friction, effectively slowing or stopping the vehicle.

Types

- Mechanical Brakes
- Hydrolic Brakes
- Pneumatic Assisted Brakes

Components

- Braking Plate, Brake Drum,
- Wheel Cylinder, Brake Shoe
- Automatic Adjuster, Return Springs

8.4 Disc Brakes

Overview

- The fluid from the master cylinder is forced into a caliper where it presses against a piston
- The piston inturn squeezes two brake pads against the disc (rotor), which is attached to wheel, forcing it to slow down or stop

Types

- Ventilated Disc Brakes, Slotted Disc Brakes
- Drilled Disc Brakes, Solid (Non-Ventilated) Disc Brakes
- Carbon-Carbon Disc Brakes, Composite Disc Brakes

Components

- Caliper, Piston, Brake Pads
- Rotor, Mounting Bracket, Hub Stator
- Pistons, Threaded Studs, Hydraulic Lines and Fluid

Hybrid Electric Vehicle -Curriculum

8.5 Actuating systems

- Mechanical Actuating Systems
- Utilize physical linkages, such as cables or rods, to transfer force from the brake pedal to the brake components, providing simple and direct control.

Hydraulic Actuating Systems

- Use brake fluid to transmit force from the brake pedal to the calipers, offering smooth and effective braking with the advantage of increased force multiplication.

Pneumatic Actuating Systems

- Employ compressed air to actuate brakes, commonly used in larger vehicles like trucks and buses for reliable performance in heavy-duty applications.

Electronic Actuating Systems

- Integrate sensors and electronic controls to optimize braking performance, often seen in advanced systems like anti-lock brakes (ABS) and brake-by-wire technologies.

8.5 • Regenerative Braking

Overview

- Regenerative braking captures kinetic energy during deceleration and converts it back into electrical energy, which is stored in the vehicle's battery for future use.
- This technology enhances overall energy efficiency in electric and hybrid vehicles, reducing reliance on conventional braking systems and improving driving range.

Types

- Electric Regenerative Braking System
- Hydraulic Regenerative Braking System
- Antilock Braking System

Hybrid Electric Vehicle -Curriculum

9. MATLAB

9.1 Introduction

- MATLAB is a high-level programming language and interactive environment used for numerical computation, data analysis, and algorithm development across various engineering and scientific fields.
- It offers extensive toolboxes for specialized applications, including control systems, signal processing, and machine learning, facilitating complex mathematical modeling and simulation tasks.

9.2 MATLAB Script

Script Basics

- MATLAB scripts are plain text files containing a sequence of MATLAB commands that can be executed as a single program, streamlining repetitive tasks.

Variable Management

- Scripts allow for the creation and manipulation of variables, enabling users to store and process data efficiently within a single execution environment.

Function Integration

- Users can define and call custom functions within scripts, enhancing code reusability and organization for complex projects.

9.3 Interactive Development

- Scripts can be tested and modified in real-time, allowing for immediate feedback and iterative development during the programming process.

9.4 Motor Power calculation using MATLAB

- Input Parameter
- Motor power calculation in MATLAB requires input parameters such as voltage, current, efficiency, and speed to determine the motor's performance.

Power Equations

- The calculation typically involves using formulas like $P=V\times I\times$ ■ for electrical power, where P is power, V is voltage, I is current, and ■ is efficiency.

Data Visualization

- MATLAB can plot the results of motor power calculations, providing visual insights into performance trends and efficiency across different operating conditions.

Simulation Capabilities

- Advanced simulations can be performed using MATLAB's toolboxes, allowing users to analyze motor behavior under various loads and speeds for more accurate predictions.

Hybrid Electric Vehicle -Curriculum

CAPSTONE PROJECTS

1 **Modeling the Acceleration of Small Electric Car (GM EV1 battery electric car) using MATLAB**
- Analyze the vehicle's acceleration characteristics under various driving conditions and load scenarios.
- Analyze how the vehicle's mass, power train characteristics, and road conditions affect acceleration.
- Calculate the forces acting on the vehicle during acceleration, including aerodynamic drag, rolling resistance, and gravitational forces

2 **Velocity and Distance Calculation of Electric Vehicle from Motor Torque using SimulinkModel**
- Analyze the relationship between motor torque, power output, and vehicle acceleration to establish a clear understanding of how torque influences performance.
- Using Simulink's visualization capabilities to present results, including velocity vs. time graphs and distance traveled, for better analysis.
- Integrate the velocity to determine the distance traveled over time, enabling distance tracking during various driving scenarios.

3 **MATLAB Script development for EV Motor efficiency plots**
- Define key motor characteristics such as rated power, torque, speed, voltage, and current, which are essential for calculating efficiency under different conditions.
- Implement the efficiency formula, dividing motor output power by input power, and ensure all units are consistent to yield accurate results across simulations.
- Use loops to simulate motor behavior over a range of speeds and torques, calculating efficiency at each point and storing results for further analysis.
- Generate 2D or 3D plots in MATLAB to visualize the efficiency as a function of speed and torque.

LIVE PROJECT

1 **Modeling of DC Motor**
- Mathematical Representation: The modeling of a DC motor involves creating equations that represent its electrical and mechanical dynamics, typically incorporating parameters like resistance, inductance, back EMF, torque, and inertia.
- State-Space Representation: DC motor models can be expressed in state-space form, allowing for a comprehensive analysis of system behavior and the design of control strategies.
- Simulink Integration: MATLAB's Simulink environment enables the graphical modeling of DC motors, allowing users to simulate and visualize dynamic responses to different inputs and control actions.
- Parameter Estimation: Accurate modeling requires the estimation of motor parameters through experimental data, ensuring that the simulation closely reflects real-world performance and behavior.