Mojomotor App - Motor Wiz Guide

Contents

Motor Log Page

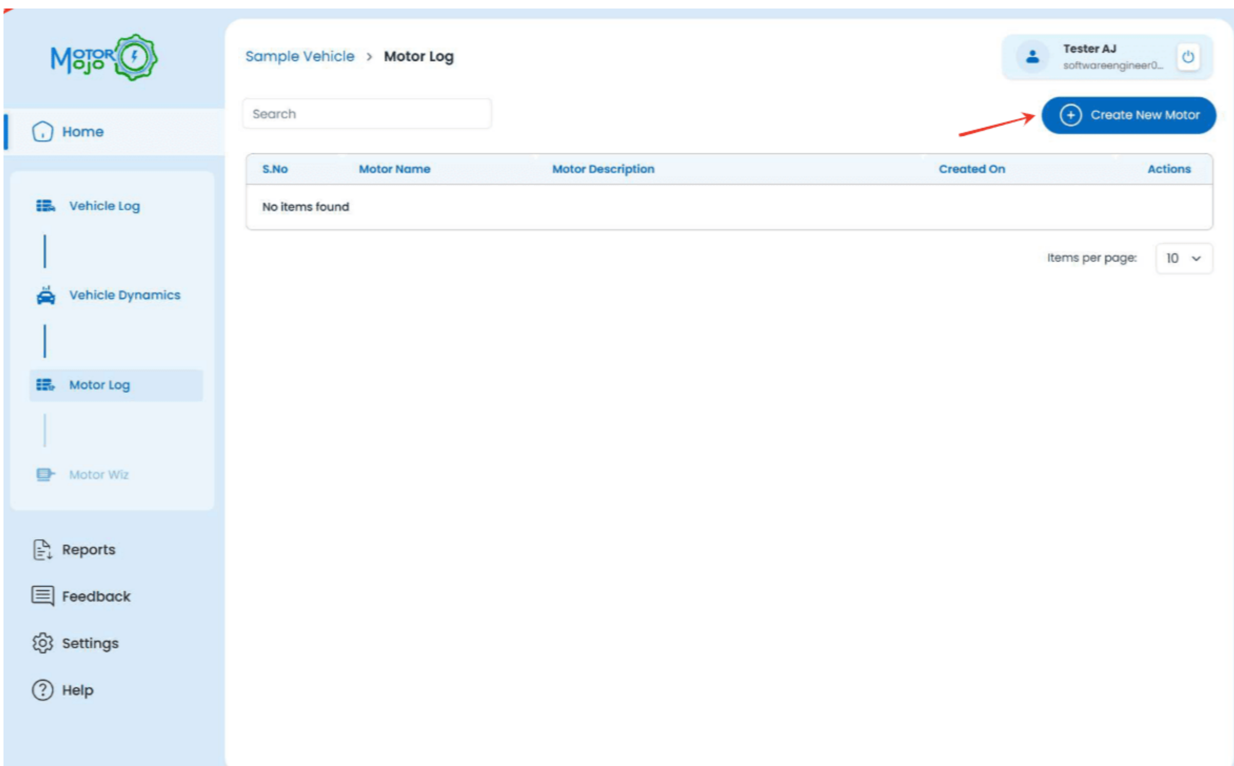
The **Motor Log Page** allows users to manage their motors. The motor log records multiple motors linked to a single vehicle, capturing their specifications, parameters, and performance data for detailed analysis.

"A motor cannot be created unless a vehicle has been created first. Users should not be able to proceed to the MotorLogTable without an existing vehicle."

Creating a New Motor

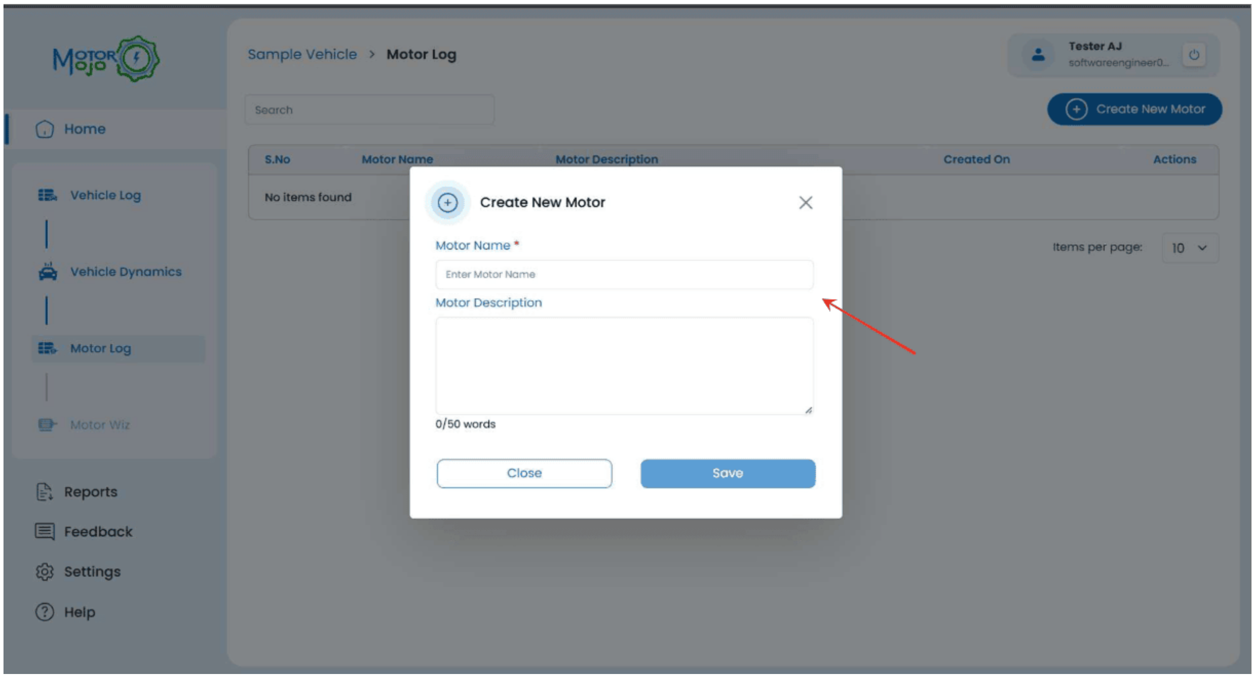
To create a new motor:

1. Click on the **Create New Motor** button on the right side.



2. A modal will appear with the following text fields:
   - **Motor Name**
   - **Motor Description**

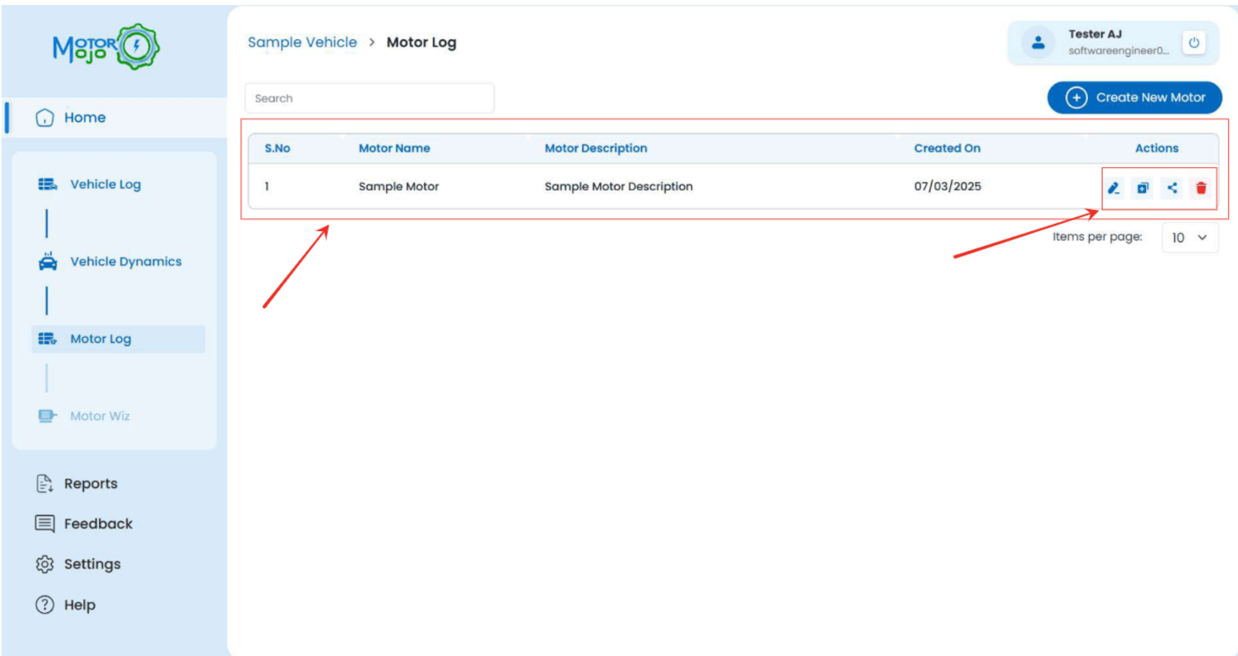
3. Enter the details and proceed to **Save**.



4. The newly created motor will be listed in the **Motor Log Table** with its **Created Date** and **Actions**.

Motor Log Table

The **Motor Log Table** displays all created motors along with their details. The following actions are available:



Actions

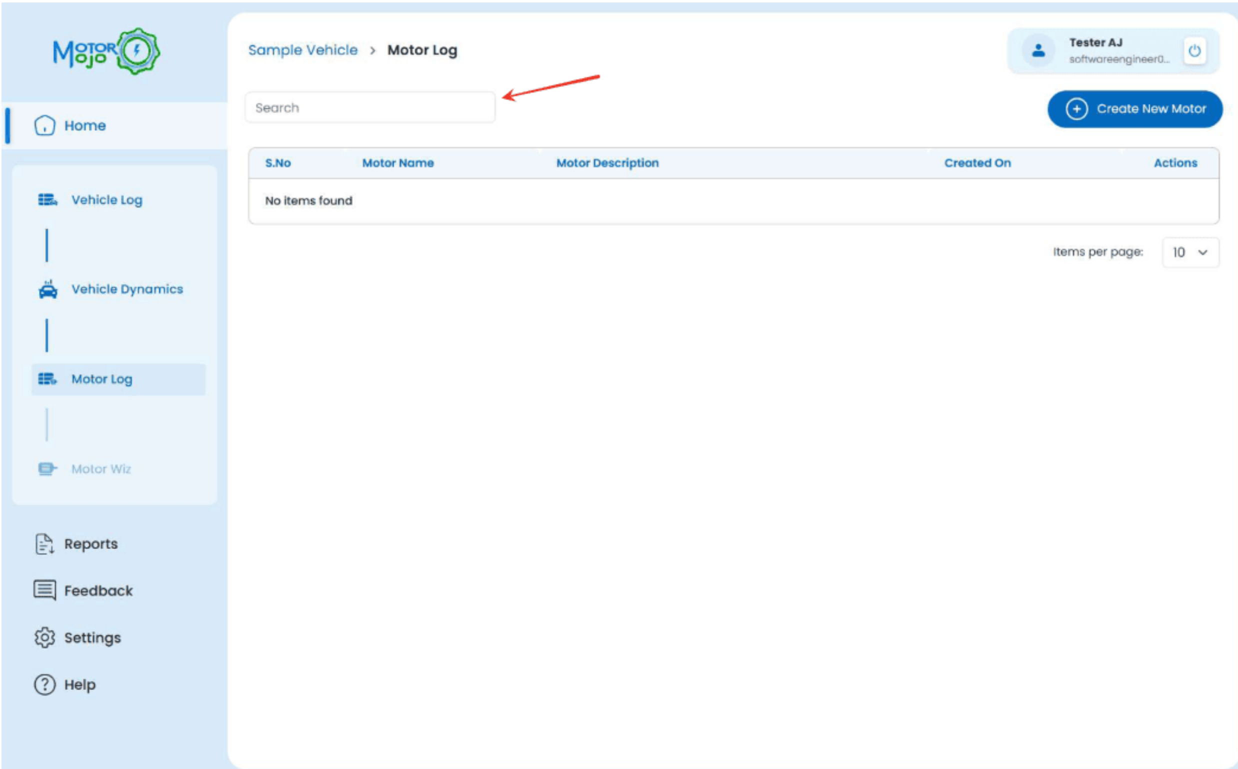
- **Edit:** Modify the motor name & description.
- **Create Version:** Duplicate the existing motor.
- **Share:** Share the motor internally with other Mojomotor users.
- **Delete:** Soft delete the motor from the list.

(Note)

- ✓ The motor-related actions follow the same structure and workflow as the vehicle actions, including functionalities such as creation, deletion, versioning, and sharing.
- ✓ **Motor Sharing:** When a motor is shared with a user, the corresponding vehicle

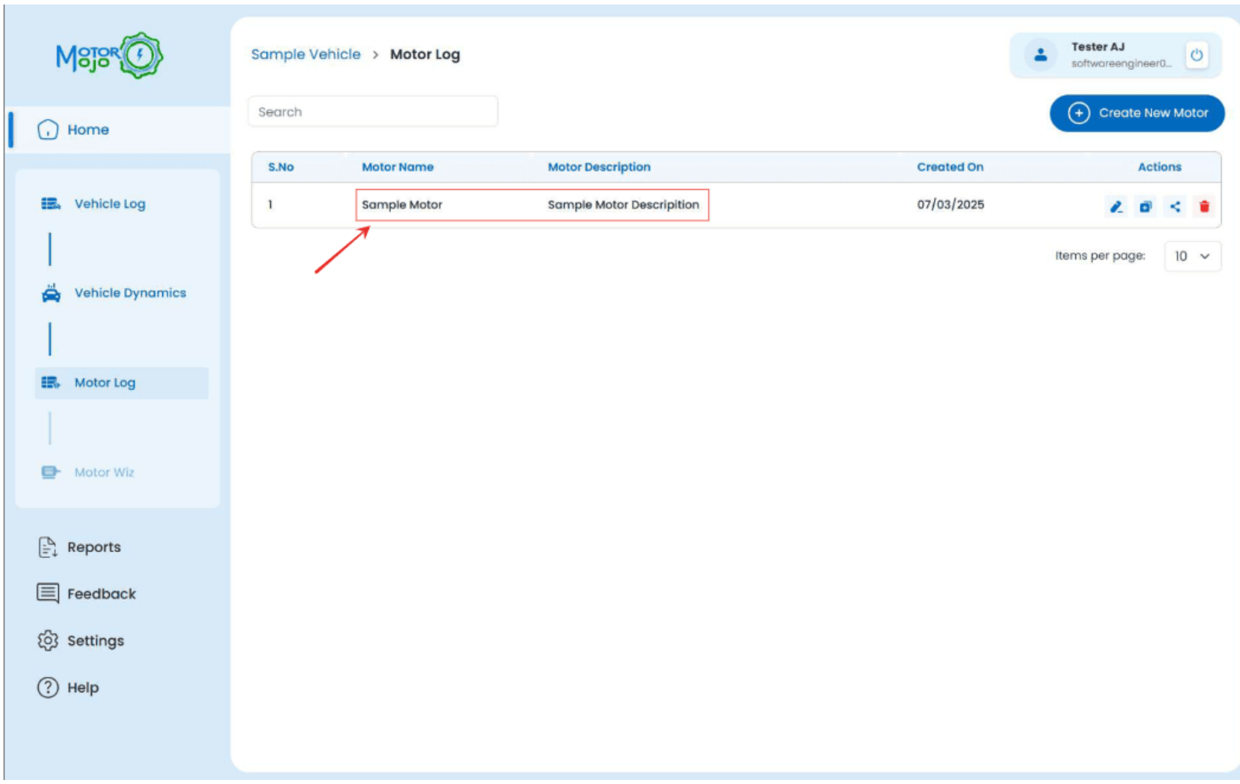
will also be shared with that user to ensure proper access and association.

Search Bar



- A **Search Bar** is located at the **top-left** of the page. It allows users to search for specific motors efficiently.

Navigating to Motor Wiz Page



- Clicking on a **Motor Name** or **Motor Description** in the **Motor Log Table** will take you to the **Motor Wiz Page**.

Motor Wiz Overview

What is Motor Wiz?

Motor Wiz is an advanced motor design and analysis tool integrated into the **MojoMotor** web application. It helps engineers and researchers **design, simulate, and optimize** electric vehicle (EV) motors efficiently. The tool provides a structured workflow for defining motor topology, materials, geometry, thermal properties, and performance characteristics, making it a crucial component in EV powertrain development.

Motor Wiz assists in achieving an optimal balance between **efficiency, performance, cost, and manufacturability** by providing real-time insights into motor parameters. It also enables quick iterations, making it ideal for **rapid prototyping and design validation**.

Key Aspects of Motor Wiz

Motor Wiz is built around several **core functionalities** that guide the motor design process. These include:

1. Motor Topology Definition

- Selection of **motor type** (e.g., IPMSM, SPMSM)
- Defining the **number of poles and slots**

2. Material Selection

- Wire material (Copper, Aluminum)
- Insulation type and fill factor
- Magnet material (NdFeB, SmCo, Ferrite)

- Steel grade for the stator and rotor core

3. Geometry & Dimensions

- Aspect ratio of the motor
- Stator and rotor diameter
- Air gap dimensions
- Magnet placement and length
- Tooth depth and back iron thickness

4. Thermal Properties & Cooling

- Slot insulation thickness
- Housing and yoke heat transfer coefficients
- Cooling techniques (natural convection, liquid cooling, forced air cooling)
- Operating temperature limits

5. Performance & Simulation

- Torque-speed characteristics
- Efficiency maps
- Winding temperature simulation
- Loss analysis (copper loss, core loss, mechanical loss)
- Maximum torque per ampere (MTPA) strategies

6. Cost & Weight Estimation

- Estimating material costs based on selection
- Predicting weight based on motor topology and geometry
- Optimization for cost-effective manufacturing

Importance of Motor Wiz in EVs

Motor Wiz plays a **critical role** in the development of **electric vehicle motors**, ensuring that they meet performance, efficiency, and cost requirements. Some key contributions include:

1. Enhanced Efficiency & Range Optimization

- Helps in selecting optimal motor parameters that **minimize energy losses**
- Ensures **higher efficiency**, leading to **longer EV range**

2. Faster Development & Prototyping

- Provides a **systematic approach** to motor design
- Reduces **trial-and-error iterations** through simulations

3. Performance Bench-marking

- Allows engineers to compare motor designs under **different drive conditions**
- Helps **refine motor control strategies** for improved acceleration and power delivery

4. Thermal Management & Reliability

- Predicts **heat dissipation** and helps in designing better cooling strategies
- Prevents **overheating issues**, increasing motor lifespan

5. Cost-Effective Design

- Assists in **material selection and weight optimization**
- Ensures **cost-efficient manufacturing** without compromising performance

Key Challenges in Motor Wiz

Despite its capabilities, Motor Wiz faces several challenges in the **motor design and validation process**:

1. Complex Trade-Offs in Design

- Balancing **power output, efficiency, and cost** is challenging
- Conflicting design goals require **multi-objective optimization**

2. Accurate Material Data & Simulation

- Reliable thermal conductivity and loss data for different materials are crucial
- **Real-world validation** of simulation results is necessary

3. Handling High-Speed Performance

- Ensuring rotor stability at **high RPMs**
- Managing **vibrations and mechanical stresses**

4. Integration with Vehicle-Level Simulations

- Synchronizing motor simulation results with **EV drive cycle analysis**
- Predicting **real-world energy consumption** based on motor characteristics

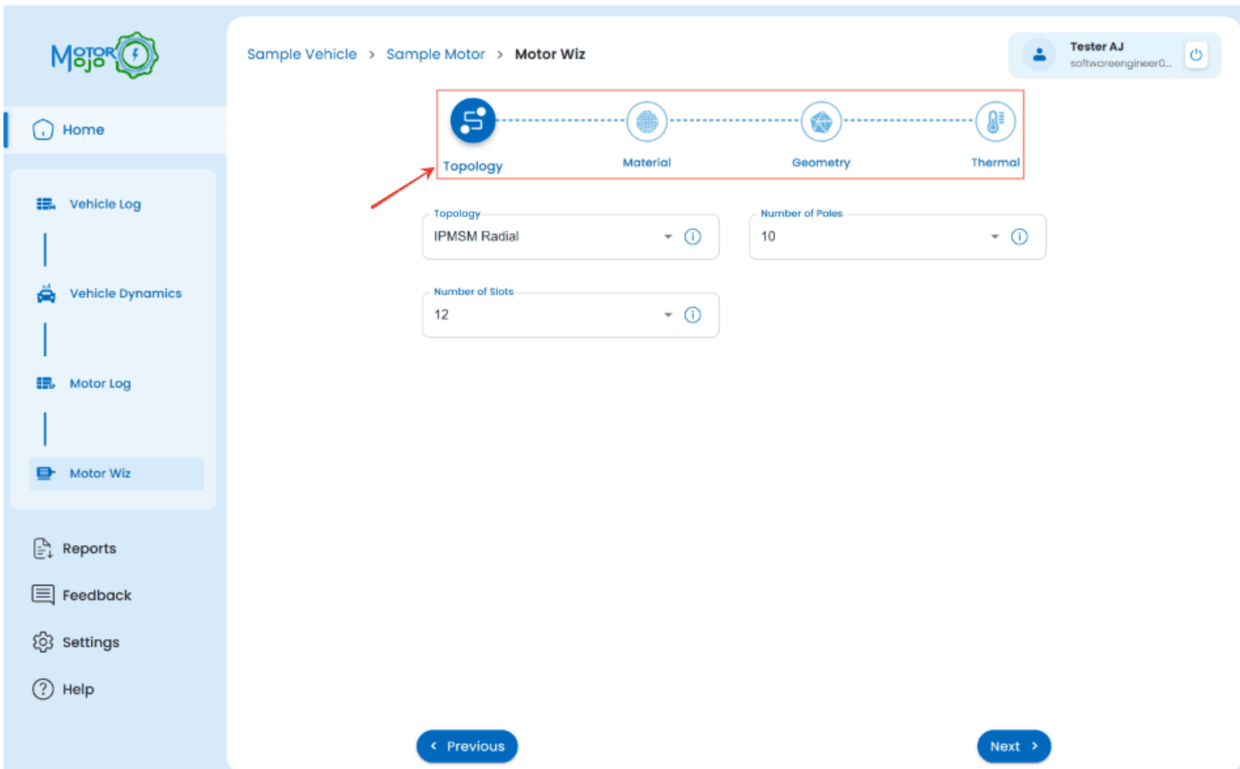
5. Scalability & Manufacturing Constraints

- Ensuring that the designed motor can be **mass-produced efficiently**
- Handling **manufacturing tolerances and variations**

Motor Wiz Page

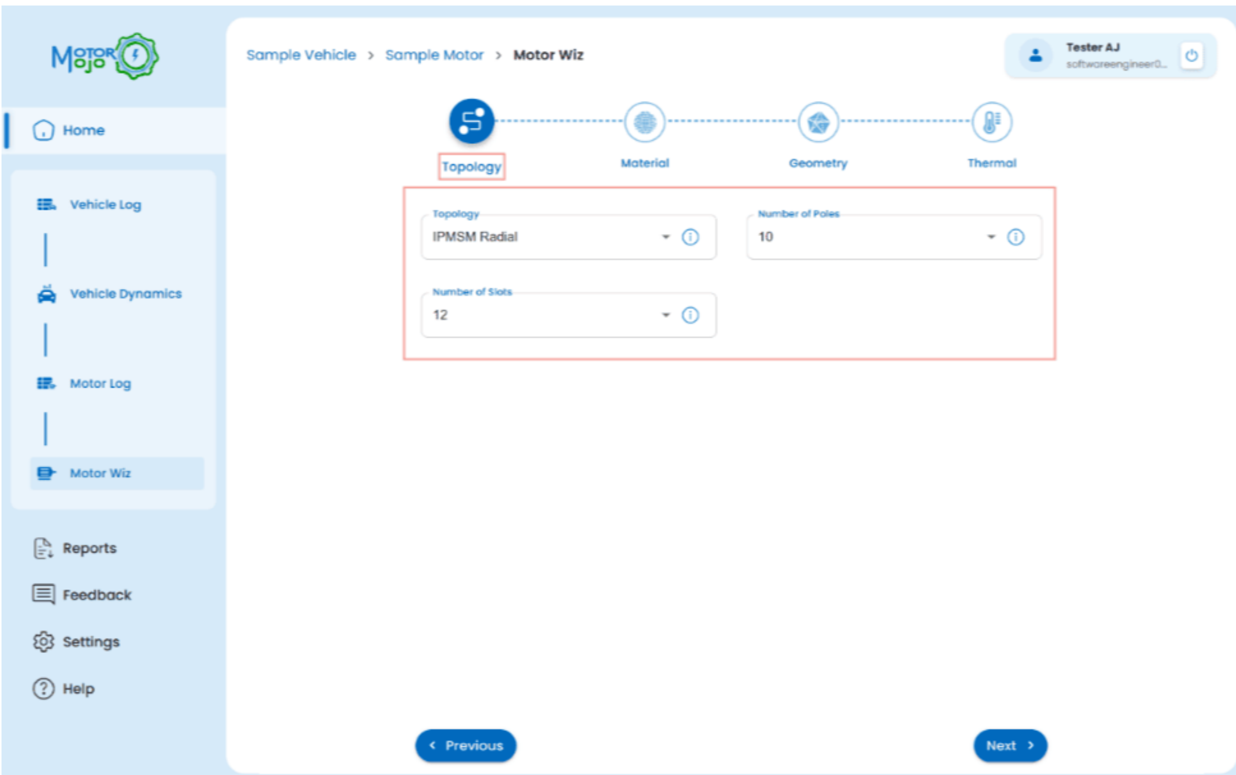
The **Motor Wiz Page** consists of four sections:

a. **Topology**
b. **Material**
c. **Geometry**
d. **Thermal**



Topology

The **Topology** section in **Motor Wiz** defines key parameters for motor design, including **Topology Type**, **Number of Poles**, and **Number of Slots**. These parameters determine the motor's electromagnetic configuration and significantly impact its performance.



Topology Type

The user can select one of the following motor topologies:

- **IPMSM (Interior Permanent Magnet Synchronous Motor)**
- **SPMSM (Surface Permanent Magnet Synchronous Motor)**

Number of Poles

The number of poles in a motor influences its speed, torque characteristics, and overall efficiency. The available options for the **Number of Poles** are:

- ✓ **8 Poles**
- ✓ **10 Poles**
- ✓ **12 Poles**

Number of Slots

The number of slots affects the motor's winding configuration, magnetic field distribution, and cogging torque. The user can choose from the following **Number of Slots** options:

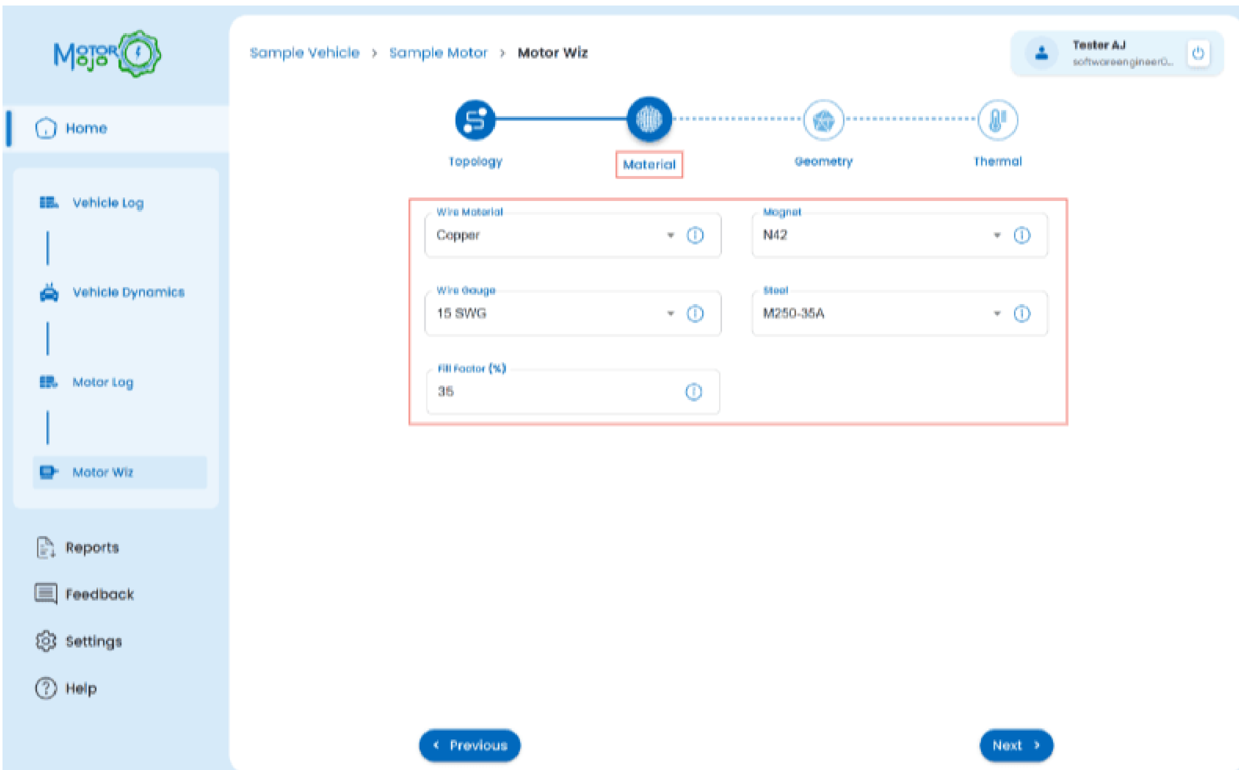
- ✓ **9 Slots**
- ✓ **12 Slots**
- ✓ **15 Slots**

Summary:

The **Topology** section in **Motor Wiz** allows users to configure key motor parameters: **Topology Type (IPMSM/SPMSM), Number of Poles (8, 10, 12), and Number of Slots (9, 12, 15)**. A dependency exists between these values—if **12 Poles** is selected, the **Number of Slots** is restricted to **9**. This constraint ensures proper winding configuration and optimal motor performance.

Material

The **Material Section** in the Motor Wiz provides options for selecting essential materials used in motor design and testing. These materials influence the performance, efficiency, and durability of the motor. Below are the key parameters available in this section:



Wire Material

Options: Copper, Aluminum

The wire material refers to the conductive material used in motor windings.

- **Copper:** Offers higher electrical conductivity, lower resistance, and better efficiency compared to aluminum. It is preferred for high-performance motors.
- **Aluminum:** Lightweight and cost-effective, but has higher resistance than copper, leading to increased energy losses. It is used in applications where weight and

cost are primary concerns.

Magnet Type

Option: N42

- N42 is a grade of **Neodymium (NdFeB) magnet**, which is known for its high magnetic strength and efficiency.
- It provides strong magnetic fields, making it suitable for high-torque and high-speed applications.
- Used in permanent magnet synchronous motors (PMSM) and brushless DC (BLDC) motors.

Wire Gauge

Range: 15 to 30 SWG (Standard Wire Gauge)

- Wire gauge determines the thickness of the winding wire, which impacts resistance, current-carrying capacity, and efficiency.
- **Lower SWG (e.g., 15)** means a thicker wire, allowing more current flow with lower resistance, improving efficiency but requiring more space.
- **Higher SWG (e.g., 30)** means a thinner wire, increasing resistance and reducing current capacity but allowing more turns in the winding.

Steel Type

Option: M250-35A

- **M250-35A** is a silicon steel grade commonly used in electrical machines.
- It offers low core loss and high permeability, reducing energy losses due to eddy currents.
- Enhances motor efficiency and performance in high-speed applications.

🧬 Fill Factor (%)

Range: 1 to 100

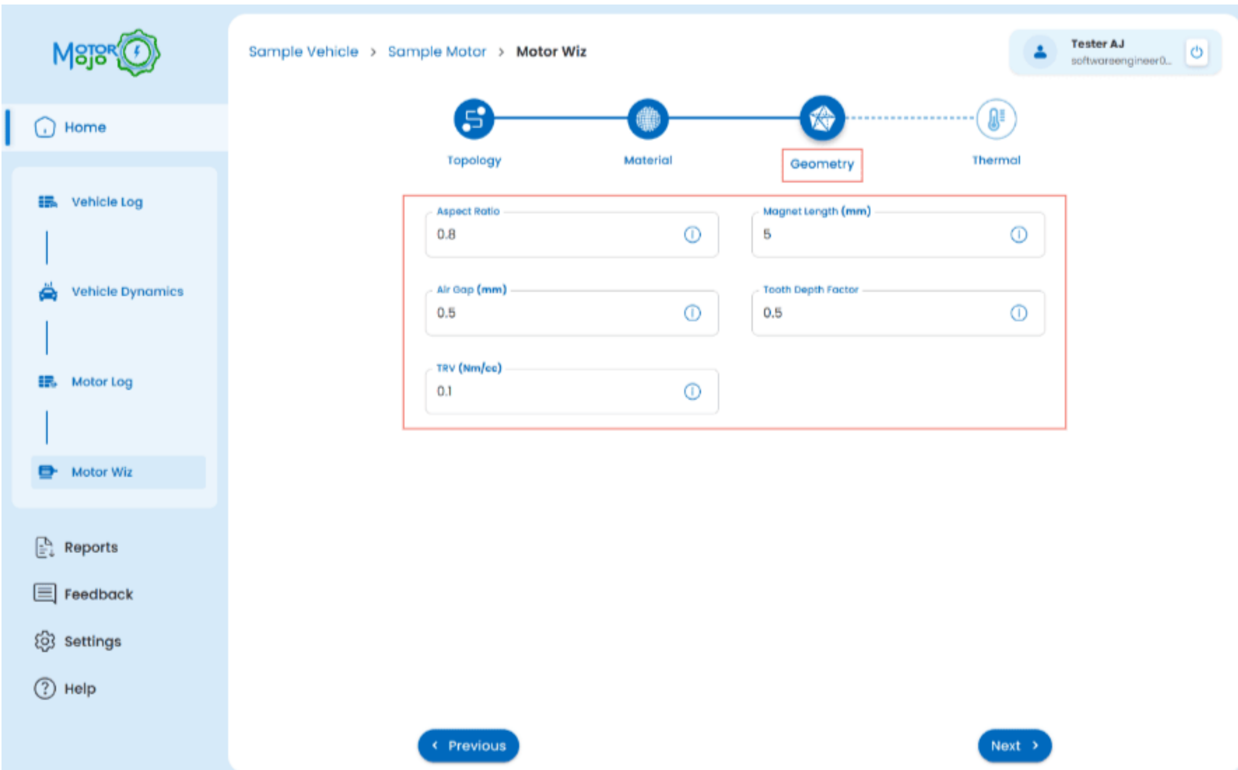
- Fill factor represents the percentage of the slot area occupied by copper (or aluminum) conductors.
- Higher fill factors (closer to 100%) mean more conductor material is used, leading to better electrical performance and reduced losses.
- Lower fill factors indicate a looser winding, which may be necessary for thermal management or manufacturing constraints.

Summary:

The material choices in the **Motor Wiz** significantly impact the performance, efficiency, and cost of motor designs. The selection of **wire material (Copper or Aluminum), wire gauge (15-30 SWG), magnet type (N42), steel type (M250-35A), and fill factor (1-100%)** are crucial in motor optimization. These materials are primarily used in **electromagnetic performance analysis, thermal studies, efficiency calculations, and durability tests** to ensure optimal motor performance.

Geometry

The **Geometry Section** in Motor Wiz defines the physical design parameters of the motor. These parameters impact the motor's efficiency, magnetic properties, and mechanical robustness.



Aspect Ratio

Range: 0.25 to 1

- The aspect ratio is the ratio of the rotor's axial length to its diameter.
- Lower aspect ratios (closer to 0.25) result in a shorter and wider rotor, which can impact torque production.
- Higher aspect ratios (closer to 1) create a longer and narrower rotor, affecting the motor's speed and efficiency.
- **Usage in Testing:**

- ✓ Torque-speed optimization
- ✓ Mechanical stress analysis
- ✓ Efficiency evaluation

Air Gap

Range: 0.3 to 1.5 mm

- The air gap is the small space between the rotor and the stator.
- A **smaller air gap (closer to 0.3 mm)** improves magnetic coupling, increasing efficiency but requiring precise manufacturing.
- A **larger air gap (closer to 1.5 mm)** reduces eddy current losses but decreases magnetic interaction.
- **Usage in Testing:**
  - ✓ Electromagnetic field distribution analysis
  - ✓ Core loss and efficiency testing
  - ✓ Thermal performance assessment

TRV (Tooth-Root Ventilation Ratio)

Range: 0.01 to 0.11

- TRV is the ratio of the stator tooth root width to the slot width, influencing heat dissipation and mechanical stability.
- **Lower TRV values** allow for better cooling and lower material usage.
- **Higher TRV values** improve mechanical robustness but may increase heat buildup.
- **Usage in Testing:**

✓ Thermal dissipation analysis

✓ Structural integrity assessment

✓ Vibration and noise testing

Magnet Length

Range: 3 to 7 mm

- Magnet length determines the extent of the magnetic field in the rotor.
- **Shorter magnet lengths (closer to 3 mm)** reduce material costs but may lower torque output.
- **Longer magnet lengths (closer to 7 mm)** enhance torque but increase weight and cost.
- **Usage in Testing:**
  - ✓ Torque-speed performance evaluation
  - ✓ Back EMF measurement
  - ✓ Magnetic flux density analysis

Tooth Depth Factor

Range: 0.3 to 0.8

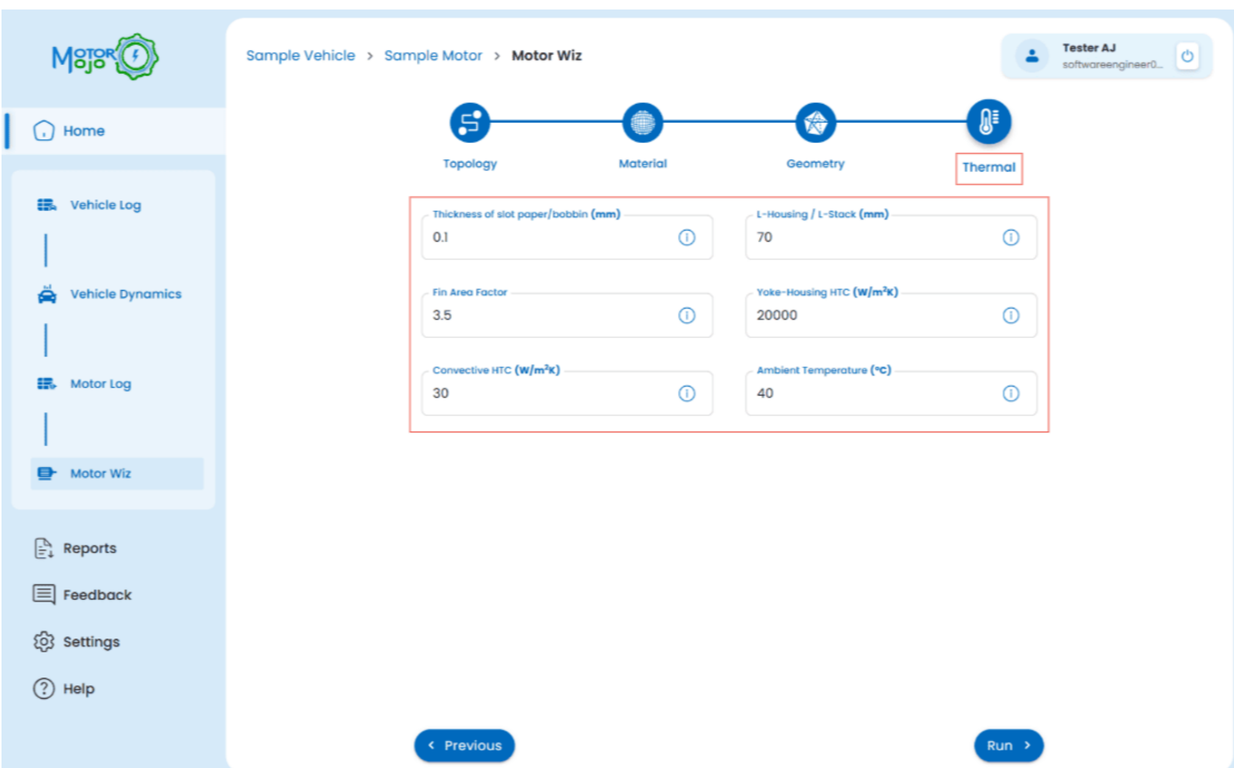
- The tooth depth factor represents the depth of the stator teeth relative to the total core height.
- **Lower values (closer to 0.3)** result in shallower teeth, reducing material use but possibly affecting flux distribution.
- **Higher values (closer to 0.8)** allow for better flux control but may increase core losses.
- **Usage in Testing:**
  - ✓ Magnetic saturation analysis
  - ✓ Efficiency calculations
  - ✓ Noise and vibration testing

Summary

The **Material Section** in Motor Wiz defines the key materials used in motor construction, including wire material, magnet type, wire gauge, steel type, and fill factor, all of which impact electrical and thermal performance.

The **Geometry Section** focuses on the physical dimensions of the motor, including aspect ratio, air gap, TRV, magnet length, and tooth depth factor, which influence mechanical integrity, thermal properties, and electromagnetic efficiency. These parameters are crucial in various motor tests, such as **torque-speed evaluation, electromagnetic analysis, thermal assessment, and structural integrity testing** to ensure optimal motor performance.

Thermal



Thickness of Slot Paper Bobbin

Range: 0 to 3 mm

- **Description:** This parameter defines the insulation thickness of the slot paper or bobbin used in the motor. Slot paper is typically used to insulate the stator windings from the stator core to prevent electrical short circuits.
- **Impact:** A thicker slot paper improves insulation but may reduce the available slot space for windings, affecting performance.

Fin Area Factor

Range: 1 to 4

- **Description:** This factor represents the effectiveness of cooling fins in dissipating heat. Fins increase the surface area for heat exchange, improving thermal performance.
- **Impact:** A higher fin area factor enhances heat dissipation but increases material usage and weight.

Convective Heat Transfer Coefficient (HTC)

Range: 10 to 10,000 W/m^2K

- **Description:** This coefficient quantifies the heat transfer efficiency between the motor surfaces and the surrounding medium (air or liquid). It depends on factors such as airflow, cooling system efficiency, and fluid properties.
- **Impact:** Higher HTC values indicate better cooling efficiency, reducing thermal stress on motor components.

L-Housing/L-Stack Ratio

Range: 40 to 150

- **Description:** This ratio represents the relationship between the length of the housing (L-Housing) and the length of the stator stack (L-Stack). It affects thermal performance and mechanical stability.
- **Impact:** A well-balanced ratio ensures effective heat dissipation and structural integrity while optimizing motor size and weight.

Yoke-Housing Heat Transfer Coefficient (HTC)

Range: 400 to 25,000 W/m²K

- **Description:** This parameter measures the heat transfer efficiency between the motor yoke and the housing. The yoke is a crucial thermal path, and efficient heat dissipation through the housing prevents overheating.
- **Impact:** Higher HTC values enhance heat flow from the yoke to the housing, reducing thermal buildup and increasing motor reliability

Ambient Temperature

Range: -5°C to 80°C

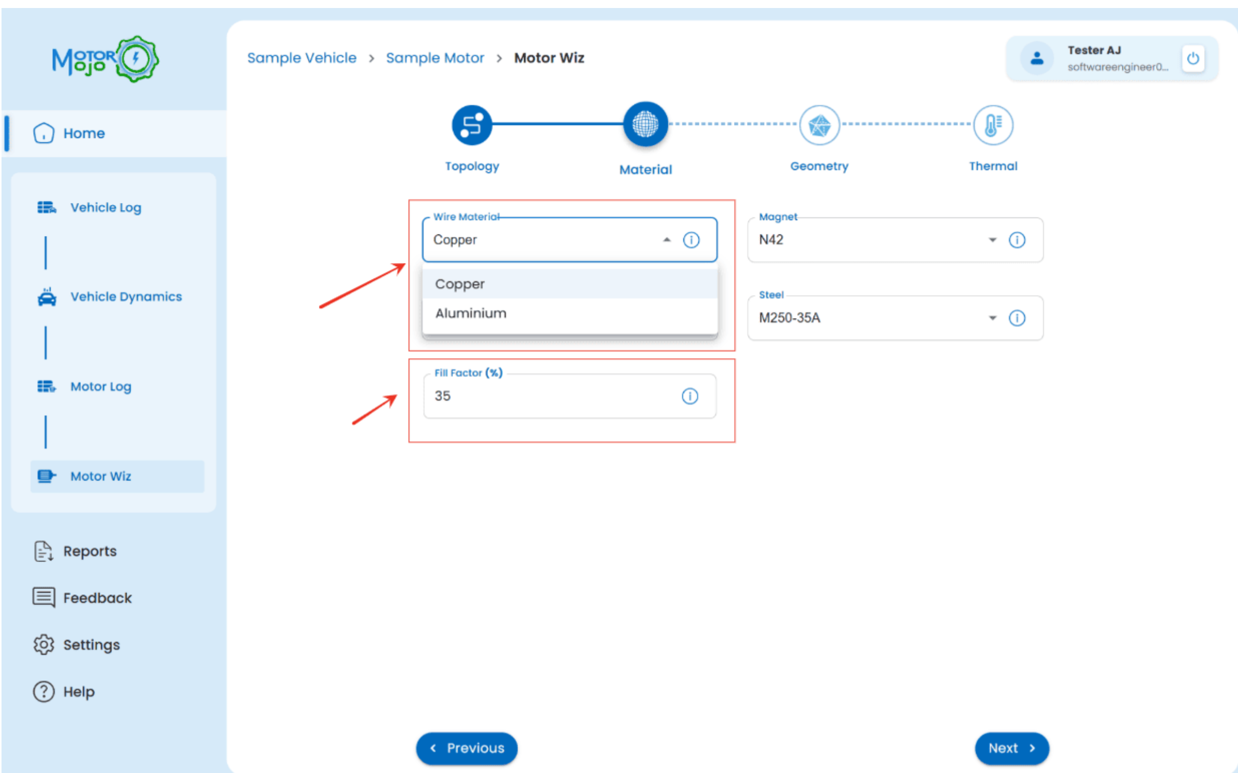
- **Description:** The surrounding environmental temperature in which the motor operates. External temperature variations affect motor cooling efficiency and thermal performance.
- **Impact:** Higher ambient temperatures can reduce cooling efficiency, leading to overheating, while lower temperatures improve heat dissipation but may introduce material contraction effects.

Summary

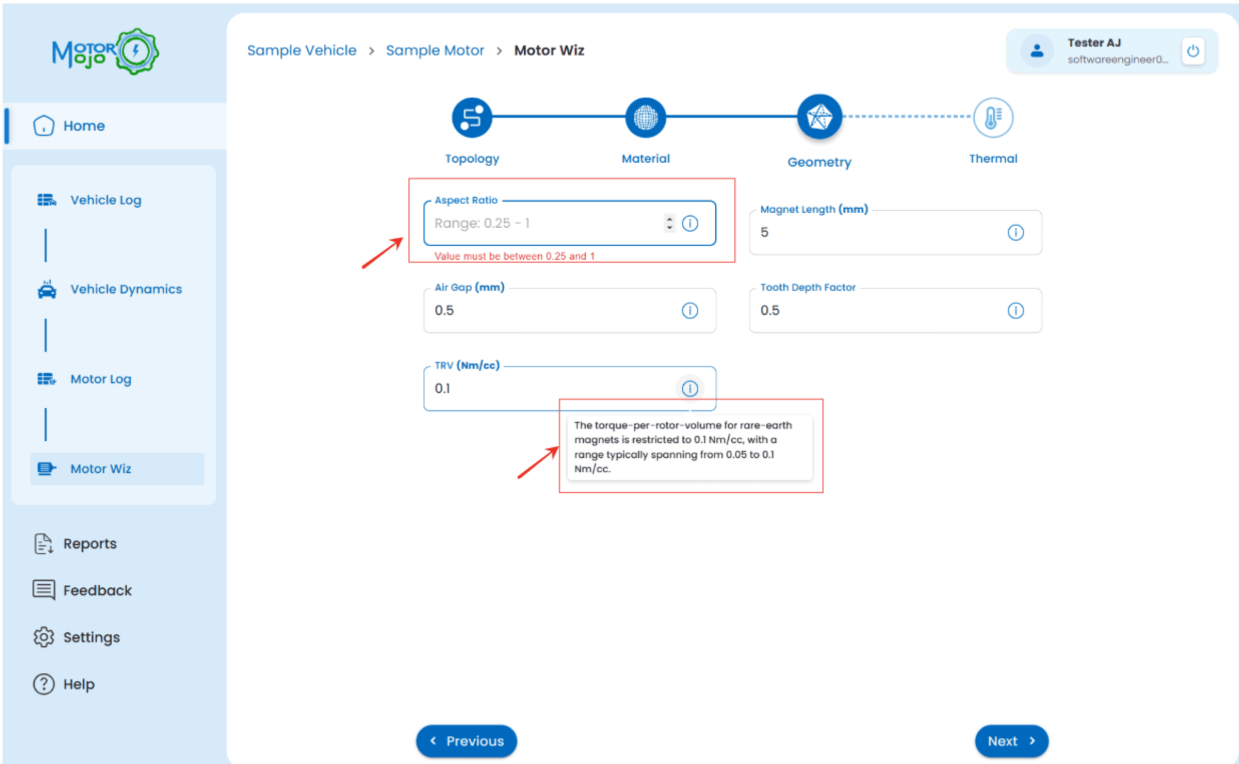
The **thermal section parameters in Motor Wiz** play a critical role in the heat management of an electric motor. These parameters influence the efficiency, reliability, and longevity of the motor by controlling heat dissipation, insulation, and cooling effectiveness. Proper selection and optimization of these values ensure that the motor operates within safe thermal limits, preventing overheating and performance degradation.

(Note)

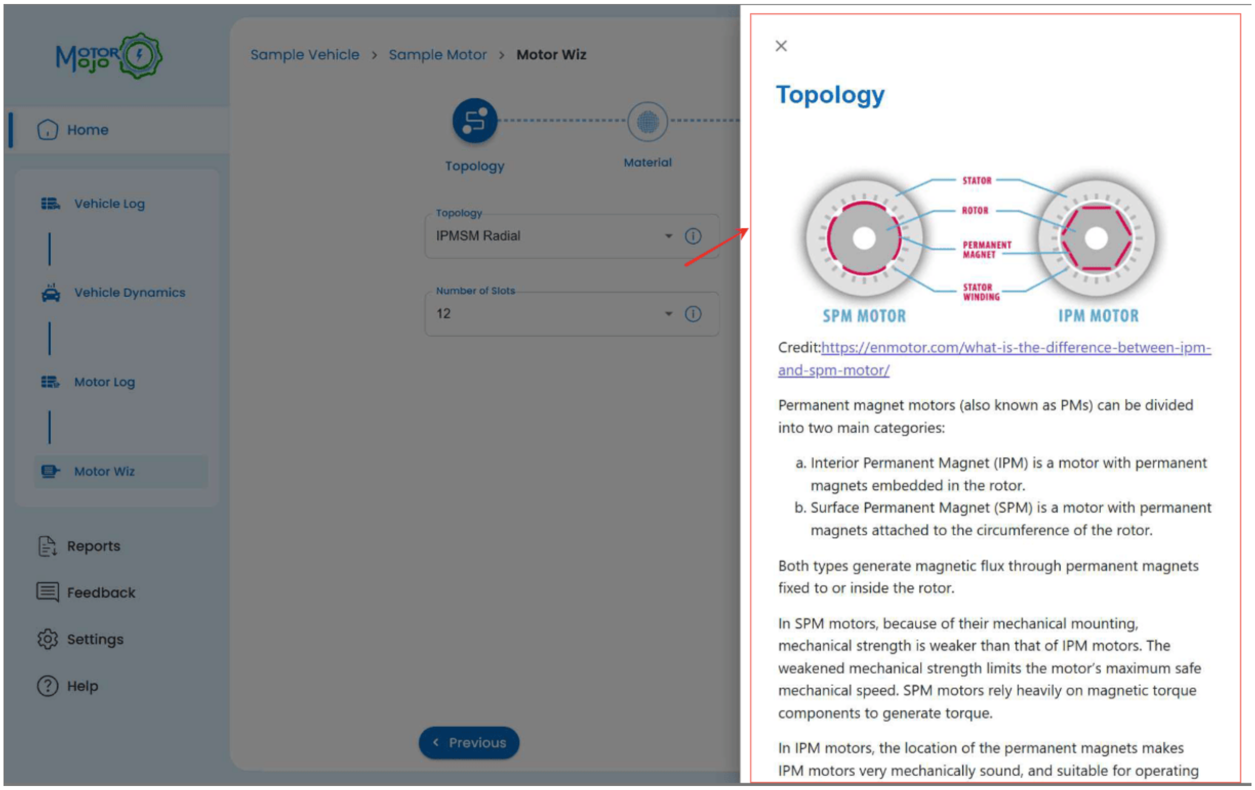
- Each parameter includes **dropdown options** and **text fields** based on its specific use.



- Each section contains a set of parameters with defined **minimum and maximum value ranges**.
- An **info button** is available next to each parameter, which provides a **tooltip** with brief information.



- Clicking on the **info button** will display a **slider** with detailed explanations and adjustable values.



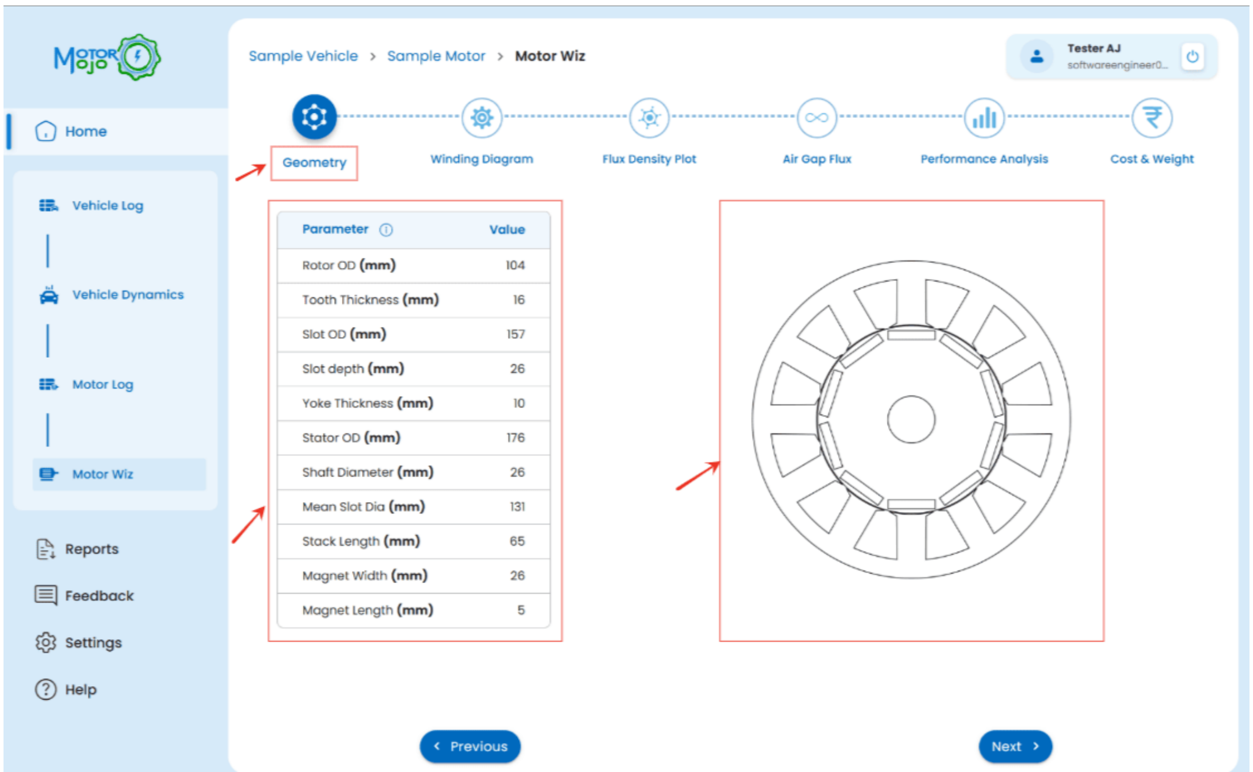
Running Motor Wiz Simulation

After entering the required values:

a. Click the **Run** button to start the **Motor Wiz Simulation**.

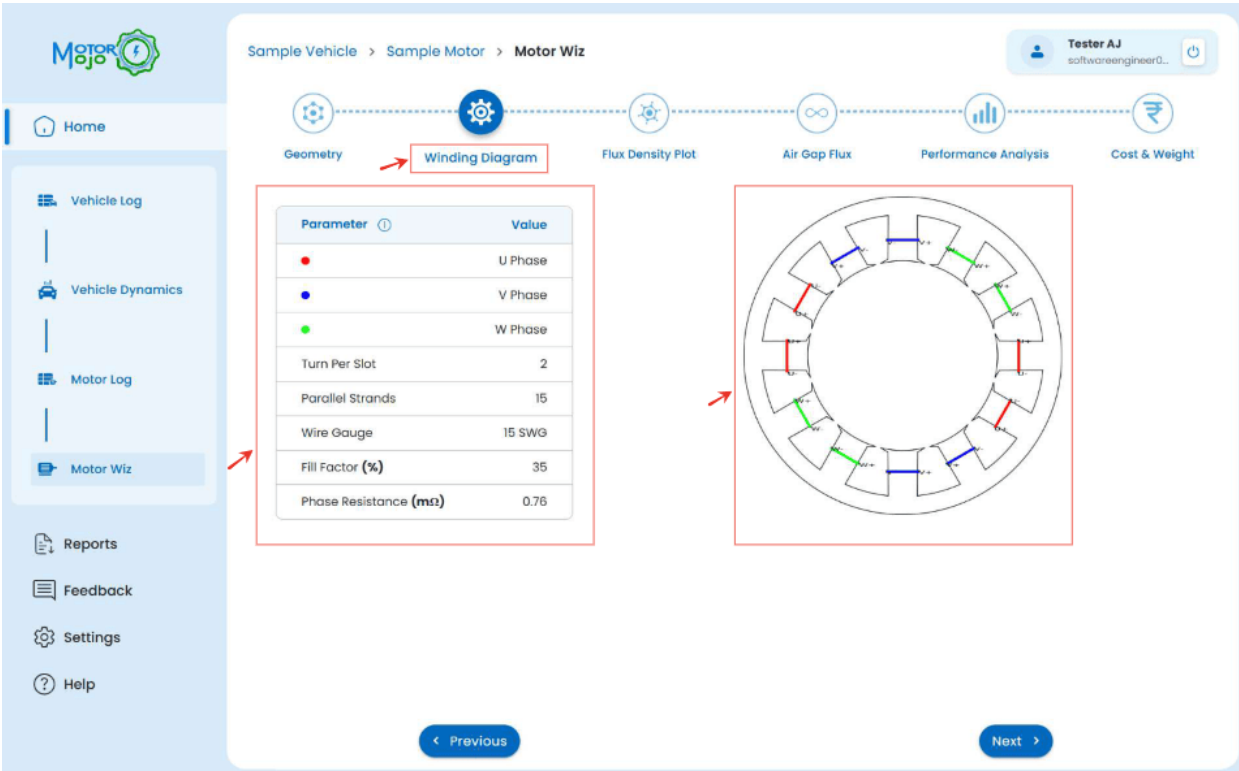
b. The output includes:

Geometry



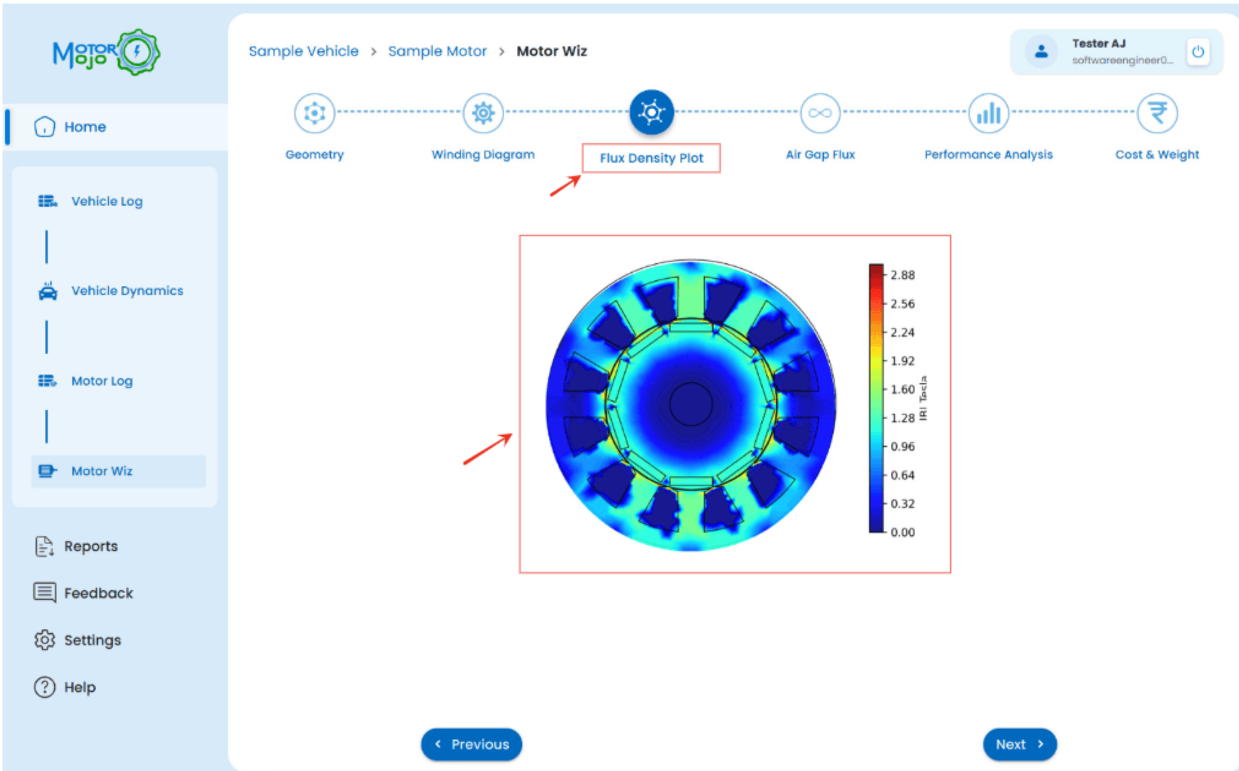
- The motor geometry consists of a table with the following parameters and its values: **Rotor Outer Diameter (OD)**, **Tooth Thickness**, **Slot Outer Diameter (OD)**, **Slot Depth**, **Yoke Thickness**, **Stator Outer Diameter (OD)**, **Shaft Diameter**, **Mean Slot Diameter**, **Stack Length**, **Magnet Width**, and **Magnet Length**.
- **DXF drawing** represents these geometric parameters visually.

Winding Diagram



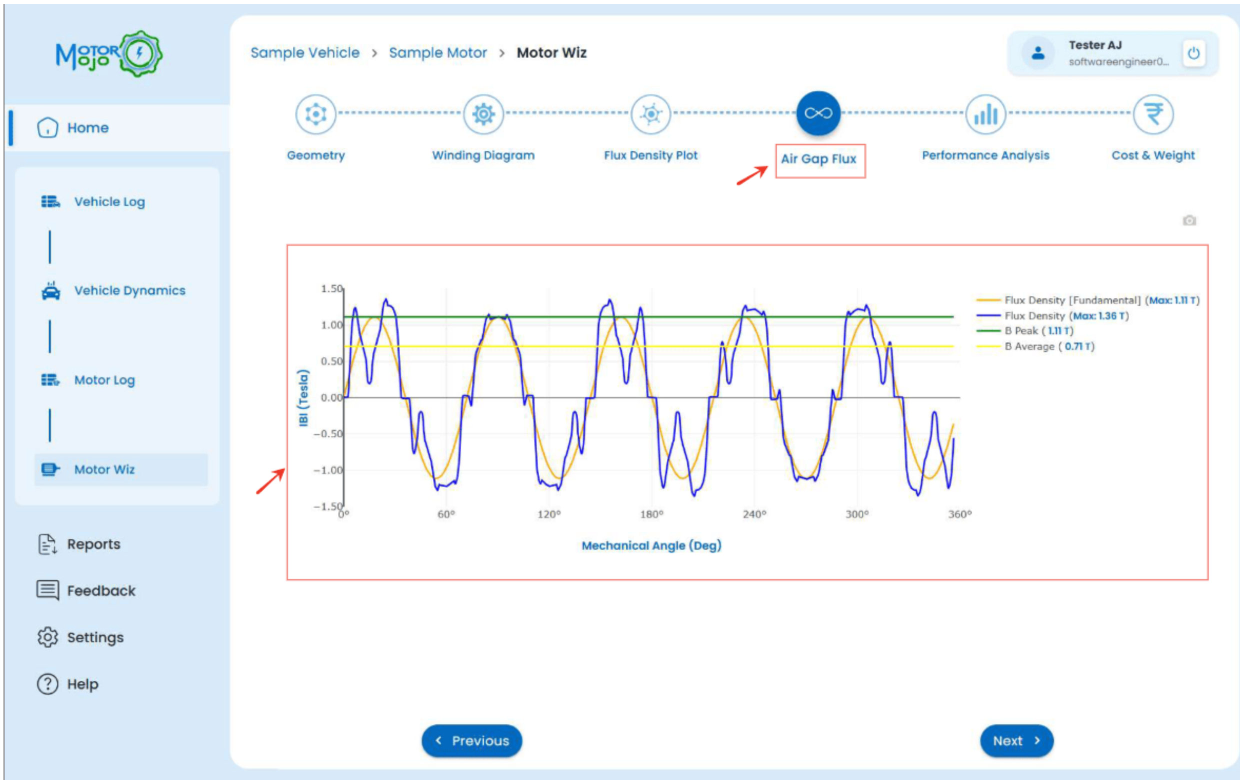
- **Winding Diagram of the Motor** consists of a table including U Phase, V Phase, W Phase, Turns Per Slot, Parallel Strands, Wire Gauge, Fill Factor (%), and Phase Resistance (mΩ).
- **DXF Drawing** with winding details of U, V, and W phases.

Flux Density Plot



- The **Flux Density Plot** represents the distribution of **magnetic flux density (B-field)** inside the motor components, such as the **stator, rotor, and air gap**.
- It helps in understanding how effectively the magnetic field is utilized and whether any regions experience **saturation** (where the material cannot handle more magnetic flux).
- The plot typically uses a **color gradient (e.g., blue to red)** to indicate varying flux densities.
- **Dark blue/green areas** indicate low flux density, while **red/yellow areas** indicate high flux density or possible saturation.
- Engineers use this plot to **optimize motor design**, ensuring that critical components do not exceed the material's **saturation limit**, leading to performance losses or inefficiencies.

Air Gap Flux



- The **flux density waveform** typically appears as a periodic curve, fluctuating over time based on rotor position.
- **Fundamental flux density** is a smooth sinusoidal waveform derived from the main component, while **actual flux density** may contain distortions due to harmonics.
- The **B Peak value** should remain within the material's saturation limits to prevent excessive core losses and inefficiencies.
- The **B Average** is useful for assessing motor performance, as lower average flux densities generally reduce core losses and improve efficiency.

Performance Analysis

The **Performance Analysis** section contains the following outputs:

(Clicking these buttons will display corresponding output graphs and tables.)

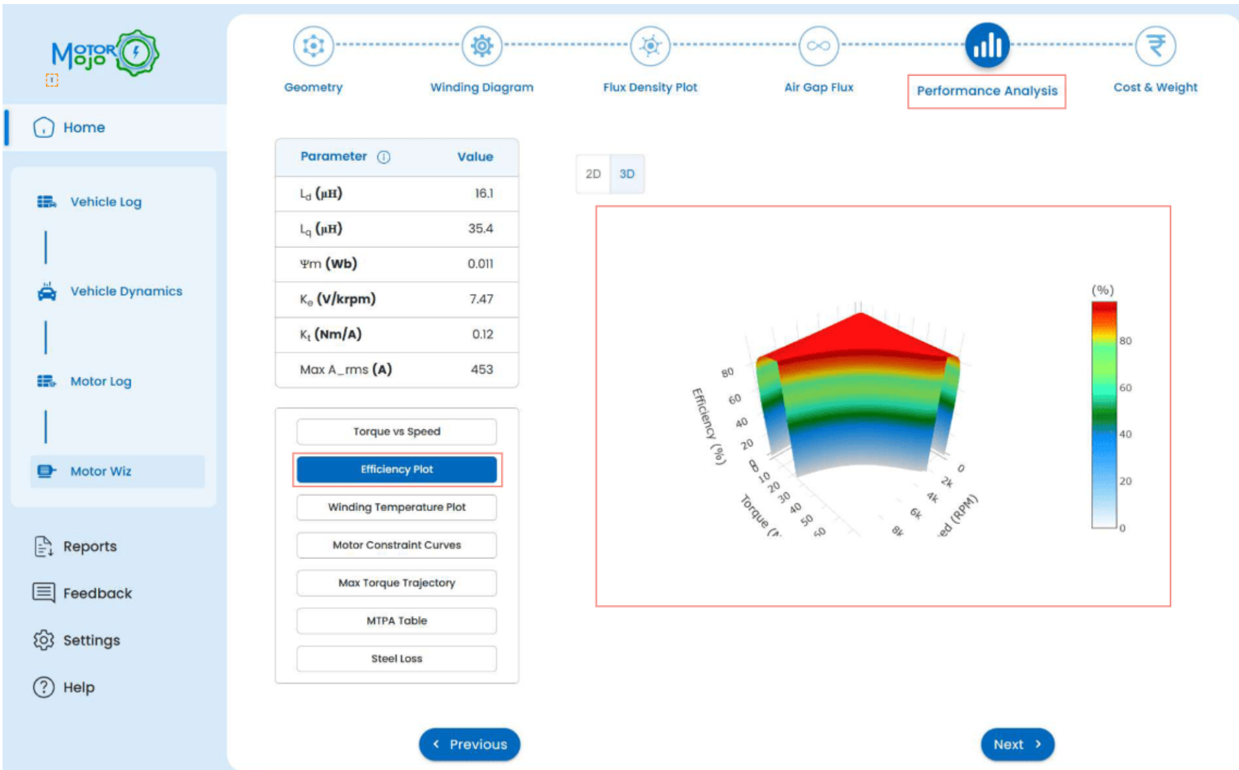
Torque vs Speed Graph

- **Torque vs Speed Graph** in MojoMotor provides a detailed visualization of motor performance across different speed ranges.
- It helps in analyzing the motor's torque characteristics, efficiency, and operational limits for various applications.
- The graph is essential for optimizing motor control strategies, ensuring maximum performance and efficiency.
- Engineers use this data for design validation, performance tuning, and selecting the ideal motor specifications.

Efficiency Plot 2D & 3D Graph

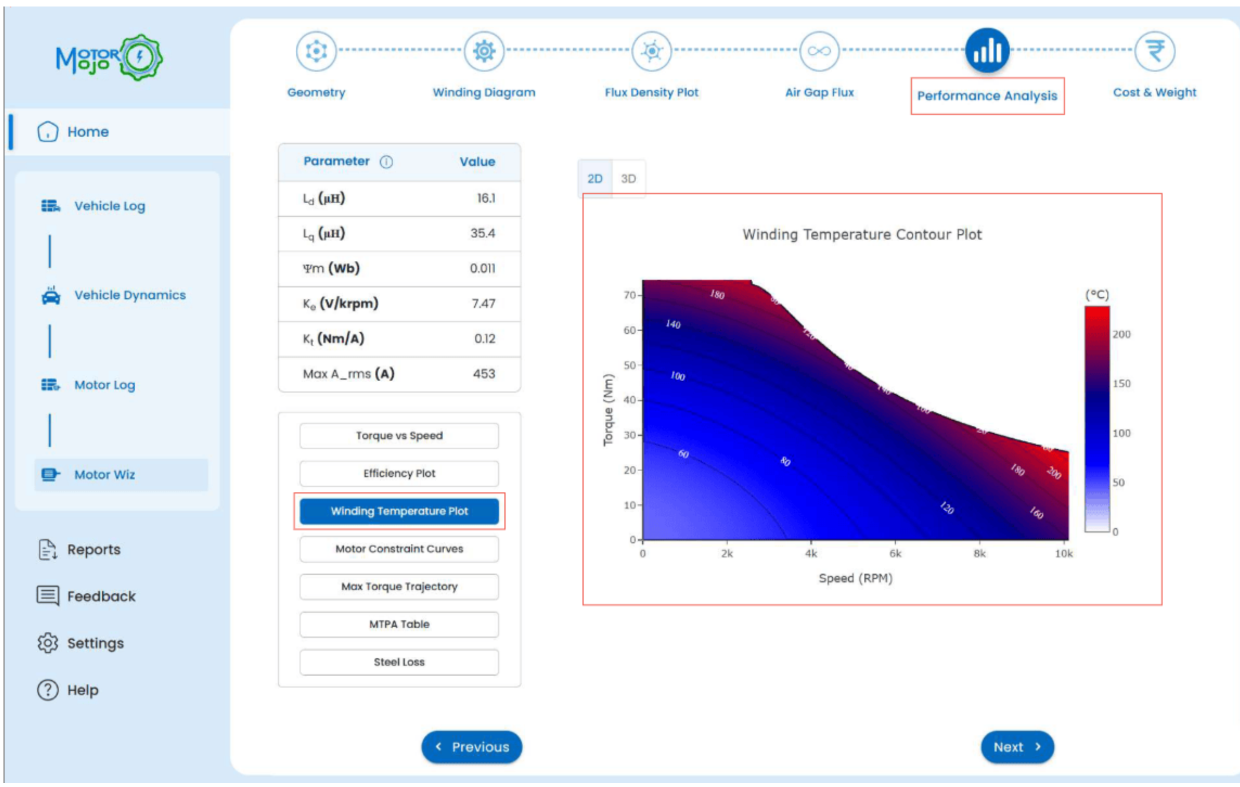
- **Efficiency Plot Graph** in MojoMotor provides a comprehensive visualization of motor efficiency across various operating conditions.
- **2D Plot:** Displays efficiency contours against speed and torque, offering clear insights into performance zones.

- **3D Plot:** Provides a detailed perspective on efficiency variations, enhancing analysis with depth and clarity.
- Designed for professional-grade motor analysis, aiding engineers in optimizing motor performance efficiently.



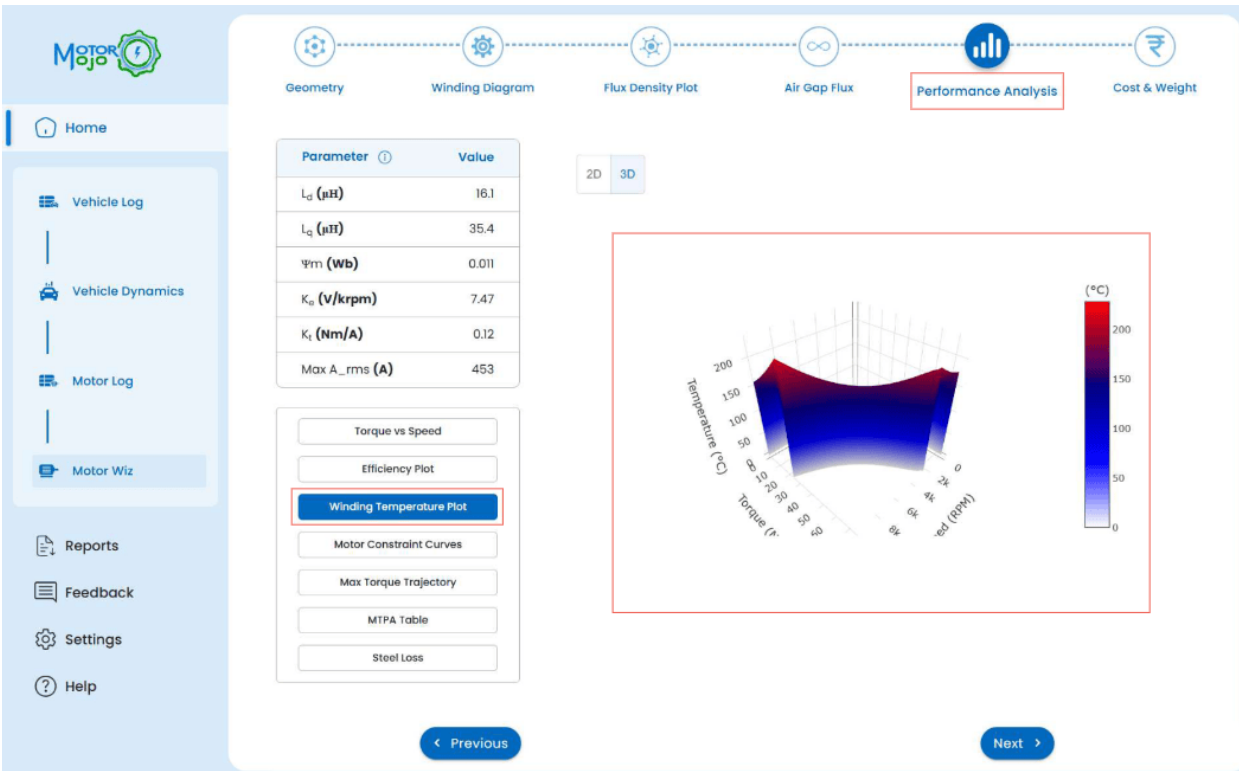
Winding Temperature Plot 2D & 3D Graph

- The **Winding Temperature Plot Graph** in MojoMotor provides insights into the thermal behavior of motor windings.
- It is available in both **2D and 3D** views, allowing for detailed visualization of temperature distribution.

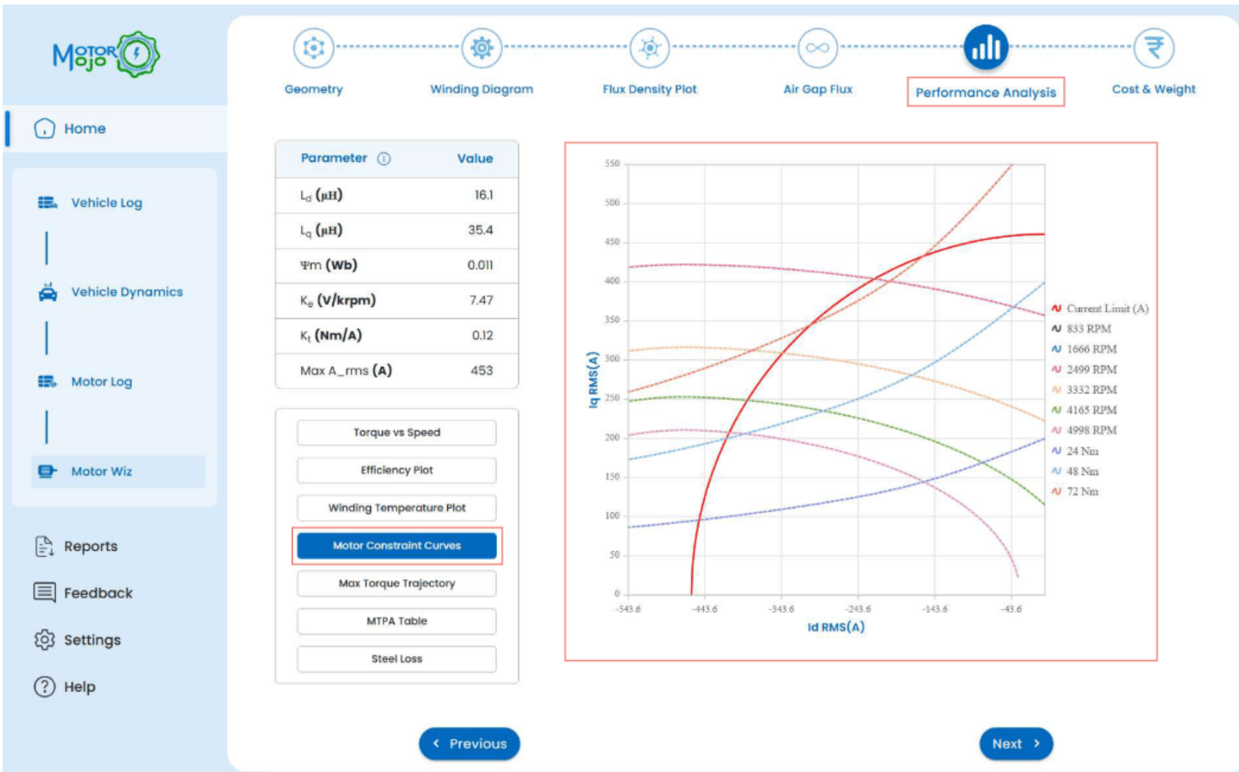


✓ The **2D plot** presents a clear temperature variation over time, aiding in performance analysis.

✓ The **3D plot** offers a spatial representation of heat dissipation, crucial for optimizing thermal management.

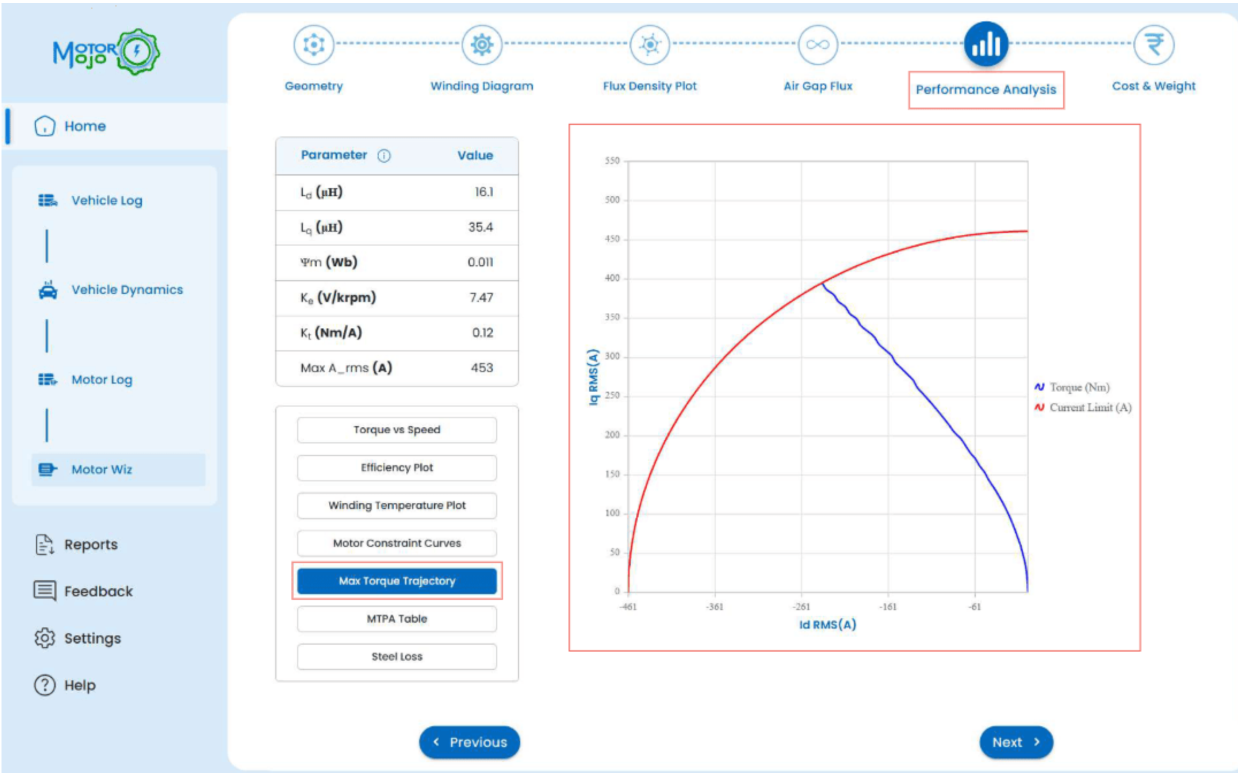


Motor Constraint Curves



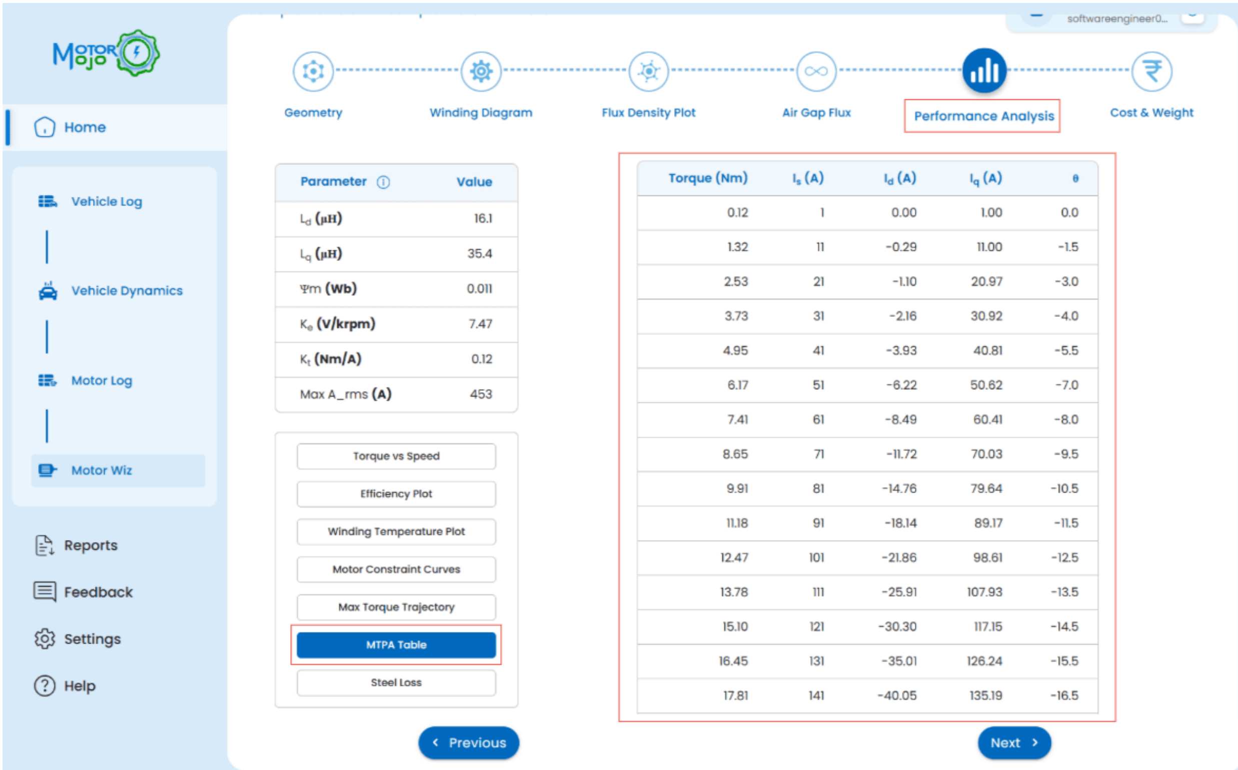
- ✓ The **Motor Constraint Curve Graph** in MojoMotor visually represents the operational limits of the motor, including torque, speed, and power constraints.
- ✓ It helps engineers analyze the feasibility of motor performance under different load conditions and thermal limits.
- ✓ The graph assists in optimizing motor design by identifying safe operating regions and potential performance bottlenecks.
- ✓ It is crucial for ensuring reliability, efficiency, and compliance with design specifications in electric vehicle applications.

Max Torque Trajectory



- ✓ The **Max Torque Trajectory** graph in MojoMotor visualizes the maximum torque achievable across different speed ranges.
- ✓ It helps in analyzing motor performance, ensuring optimal torque delivery for various operating conditions.
- ✓ The graph aids in designing efficient motor control strategies by identifying peak torque capabilities.
- ✓ Engineers use this data to optimize motor efficiency, thermal performance, and overall drivability.

MTPA Table

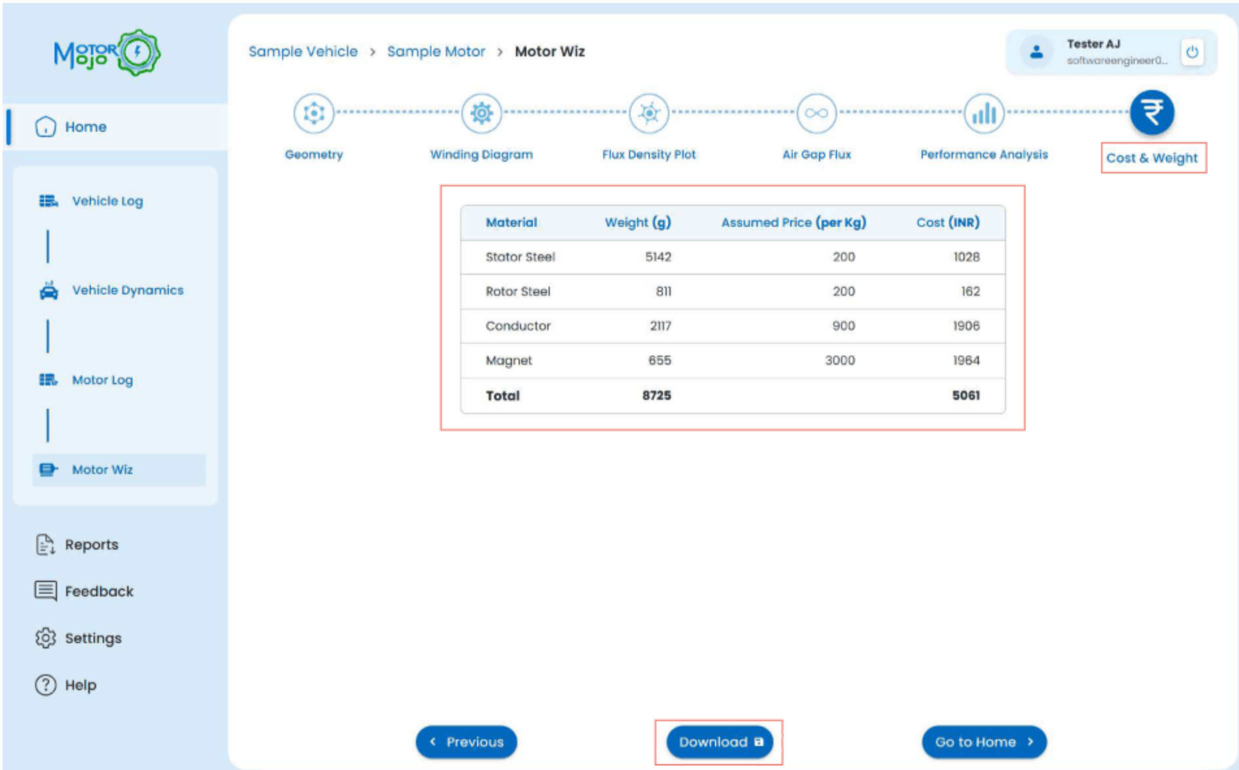


- ✓ **Definition**: The **Maximum Torque Per Ampere (MTPA) Table** in MojoMotor provides optimal current vector control data to achieve maximum torque efficiency.
- ✓ **Purpose**: It helps in minimizing current consumption while maximizing torque output, improving motor performance and energy efficiency.
- ✓ Usage: The table is used for motor control strategies, aiding in precise torque management for various load conditions.
- ✓ It contains data points for current, torque, and efficiency mapping for different operating conditions.

Steel Loss

- **Steel Loss Graph** in MojoMotor visualizes core losses in the motor, including hysteresis and eddy current losses.
- It provides insights into energy dissipation within the stator and rotor, aiding in efficiency optimization.
- The graph helps engineers analyze the impact of frequency, flux density, and material selection on losses.
- By interpreting the graph, designers can refine motor performance and reduce thermal effects for improved reliability.

Cost & Weight



Cost & Weight Table

The table displayed in the **Cost & Weight** section of **Motor Wiz** provides a breakdown of the materials used in the motor, along with their respective weights, assumed price per kilogram, and the total cost in INR.

Breakdown of Table Columns:

a. **Material** – Lists the key materials used in the motor construction.
b. **Weight (g)** – Specifies the weight of each material in grams.
c. **Assumed Price (per Kg)** – The estimated price per kilogram for each material.
d. **Cost (INR)** – The calculated cost of each material in Indian Rupees (INR), based on its weight and assumed price per kg.

Interpretation of Data:

- **Stator Steel** and **Rotor Steel** have the same price per kg (₹200), but since the **stator is significantly heavier** than the rotor, it contributes more to the total cost.
- **Conductor material** is one of the major cost contributors due to its high assumed price of ₹900 per kg.
- **Magnet** has the highest price per kg, making it the most expensive component in terms of cost contribution despite being lighter (0.655 kg).

Downloading Files in the Cost & Weight Page

In the Cost & Weight page, users can download several important files related to the motor design. The Download button is located at the center of the Cost & Weight page. Clicking this button allows users to obtain the following files:

Available Downloadable Files in Zip:

- ✓ **Motor.femm** – This file contains the motor geometry and properties for FEMM (Finite Element Method Magnetics) simulations. It can be opened using the FEMM application.
- ✓ **Motor.ans** – An analysis file that includes results from simulations, useful for evaluating motor performance.
- ✓ **Motorfull.dxf** – A comprehensive DXF file containing the entire motor design, including both the rotor and stator. It should be opened in CAD software.(ex: FreeCad, etc..,)
- ✓ **Stator.dxf** – A DXF file that includes only the stator design, used for manufacturing and analysis. Open this file in CAD software. (ex: FreeCad, etc..,)
- ✓ **Rotor.dxf** – A DXF file that includes only the rotor design, useful for further modifications or simulations. Open this file in CAD software. (ex: FreeCad, etc..,)
- ✓ **MTPA Table CSV** – A CSV file containing Maximum Torque Per Ampere (MTPA)

data, essential for motor control strategies.

Steps to Download the Files:

a. Navigate to the Cost & Weight page in Motor Wiz.
b. Locate the Download button in the center of the Cost & Weight page.
c. Click on the Download button.
d. The files will be downloaded and saved to your default download folder.

Conclusion

This guide serves as a structured reference for navigating and utilizing the motor wiz features within the **Mojomotor** app.

Additionally, details regarding the **Other feature** section will be provided in an upcoming specific document.